AN

INTRODUCTION TO GEOLOGY:

INTENDED TO CONVEY A

PRACTICAL KNOWLEDGE OF THE SCIENCE,

AND CO

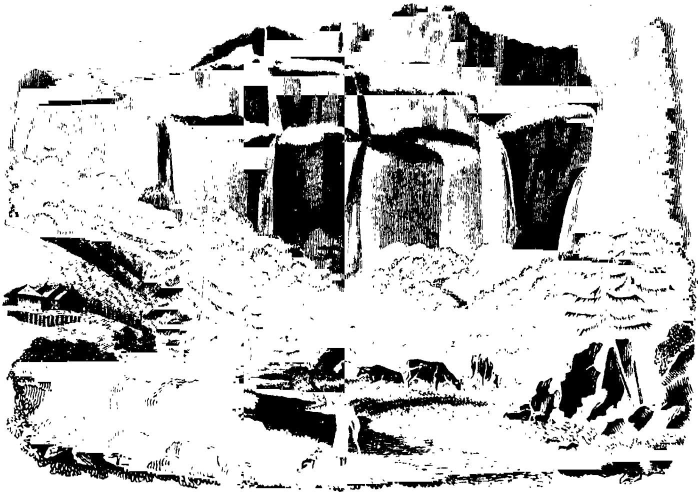
THE MOST IMPORTANT RECENT DISCOVERIES;

WITH EXPLANATIONS OF THE

FACTS AND PHENOMENA

WHICH SERVE TO CONFIRM OR INVALIDATE VARIOUS GEOLOGICAL THEORIES.

By ROBERT BAKEWELL.



VALLEY OF SIXT, IN SAVOY.

THE FOURTH EDITION, GREATLY ENLARGED.

LONDON:
LONGMAN, REES, ORME, BROWN, GREEN, & LONGMAN.
1833.

LONDON:
Printed by A. & R. Spottiswoode,
New-Street-Square.

PREFACE

TO

THE FOURTH EDITION.

THE present Volume contains above one fourth more letterpress than the Third Edition: being printed closer, and in a fuller page, in order to comprise numerous additional facts, and the important discoveries recently made in Geology. There are five entirely new chapters, beside considerable additions to most of the former chapters. The new chapters in this Edition are:—Chap. XVI. On the Formation of Secondary Limestone and Sandstone, and on the progressive Developement of Organic Life. Chap. XVII. On the Quaternary Strata. Chap. XX. On Subterranean Currents, and on Caverns. Chap. XXII. On the Elevation of Mountain Ranges and Continents. Chap. XXIV. On the Temperature of the Earth; on Central Heat; and on Astronomical Causes illustrative of Geological Theories. Beside two new plates, the present Volume contains also numerous wood-cuts.

Since the publication of the Third Edition, the Author has revisited several of the localities which were the scenes of his earliest investigations; he has also examined certain parts of England, of which the geology was dubious; and has inserted in this work such alterations as were deemed necessary. These, however, bear a small proportion to the valuable labours of foreign and English geologists, during the last five years, of which an account is given in different parts of the volume. In a preliminary dissertation on certain living species of animals that elucidate fossil conchology, and also in the work itself, the author has endeavoured to direct the attention of geological students to a subject hitherto much neglected. Great importance is attached to the study of fossil shells; but the character of the animals that inhabited them, or the power they might possess of modifying the form of the shell under various circumstances, has scarcely been thought of. Some French conchologists are endeavouring to establish the doctrine that fossil conchology, independent of the succession and stratification of rocks, is the only true basis of geology; and a trifling difference in the form of a shell, is deemed sufficient to constitute a new species, and to warrant the most important conclusions respecting the age of rock formations. Cato, when the Roman Haruspices were gravely examining the entrails of the sacred victims, to ascertain the future revolutions of empires by the convolutions of the intestines, said, that he much wondered how they could refrain from laughing, whenever they looked each other in the face. Surely we might say the same to fossil conchologists, when they gravely attempt to ascertain the past revolutions of the globe, by the convolutions of a shell.

If the same conchologists were interrogated respecting the power which the ancient inhabitant of the shell might possess of changing its structure when placed in different circumstances, they would be compelled to confess their ignorance. A knowledge of fossil shells is highly useful to the geologist in cases where the superposition of strata cannot be ascertained; but fossil shells alone, give us less positive information respecting the ancient condition of the globe, than the organic remains of other classes of animals, or of vegetables; because, for any thing we know to the contrary, all the species of molluscous animals that inhabited these shells, *may have been capable* of living in the same medium, and under the same conditions. But different species of vertebrated animals, and plants, must have existed under very different conditions, on land, or in water. M. Boué, an enlightened and indefatigable continental geologist, to whose labours the science is greatly indebted, is meritoriously endeavouring to resist the absurd attempt, to force Fossil Conchology into the chair of Geology. I trust his example will be followed by English geologists. Indeed, I am convinced that many of the frivolous distinctions introduced by conchologists will soon pass away, as those of mineralogy have already passed*; and that these two branches of natural history, will take their proper stations as auxiliaries subservient to geology.

It will be seen, by the titles to the new chapters in the present volume, that they comprise various subjects connected with important enquiries relating to the Theory of the Earth. The opinions of the author have not been rashly advanced, to oppose or

---

* See the end of the Preface to the first edition. Some of the distinctions in Mineralogy, on which most important conclusions have been founded respecting the formation of rocks, are now known to be erroneous: magnesian minerals were all stated to be of aqueous origin. Pyroxene (Augit) was considered as an unerring criterion of igneous products, and to be an entirely distinct species from Amphibole (Hornblende): they are now proved to be identical minerals, convertible into each other, according to the degree of temperature under which they are crystallised. Observations on the true value of Fossil Conchology will be found in Chapter XVII.

maintain the systems of other geologists: they are the result of long-continued reflection, on what appeared to him the most probable explanations of geological phenomena. The author says *probable*, because he considers that the words truth and certainty cannot yet be introduced with advantage into geological theories.

The author requests the experienced geologist, who may honour this volume with the perusal, to refer to Chap. XXII., in which he will find that the doctrine of the elevation of mountain ranges, at different epochs, was distinctly announced, and was published by him in the year 1823, supported by the same principles, as what have been recently advanced by M. Elie de Beaumont. He has farther *proved*, that the elevation of large islands and continents, was long posterior to the elevation of mountain ranges.

The Third Edition of this work was republished in America, in 1829, by Professor Silliman of Yale College, Connecticut, the distinguished editor of the *American Journal of Science.* It was commenced without any previous communication or acquaintance with the author. The reasons for the republication were stated in the Professor's preface, an extract from which is subjoined. The author will be satisfied if the present work should be thought deserving of the commendation given by the American editor, of being "a comprehensive Treatise on Geology, which the student will be willing to read, and able to understand."

Hampstead, near London,
April 18. 1833.

Part of Professor Silliman's Preface to the American reprint of the Third Edition.

The Editor believes that he is performing a service to his country, by encouraging the republication of a work conspicuous for attractiveness—for perspicuity—for a style generally vigorous and correct—often eloquent and beautiful; and for an independence of spirit, which carries the Author straight forward to his object, certainly without any servile regard to previous systems. While bestowing this merited commendation, we do not mean to say that we fully adopt all the Author's theoretical views, although most of them appear to be philosophical and just, and some of them are peculiarly happy.

Speaking in the character of a public instructor of youth, I beg leave to add, that my immediate motive for recommending the republication was, that I might place in the hands of my own classes, a comprehensive treatise on geology, which they would be willing to read and able to understand.

CAUTION.—*In* 1829 *a book was published in duodecimo, entitled " An Introduction to the Study of Mineralogy, by J. R. Bakewell." Several friends of the Author of the present volume have informed him, that they were induced, by the name, to purchase the book; he therefore thinks it necessary to state, that he has no connection with the writer of that book, and he has reason to believe that the name was assumed to mislead the public.*

PREFACE

TO

THE THIRD EDITION.

THE First and Second Editions of the *Introduction to Geology* were favourably received, and sold off, soon after their publication. The work has since been translated and published in Germany, by Mr. Frederick Muller of Friburg; but it has been long out of print in this country. The causes which have retarded the publication of a Third Edition it is unnecessary to mention: the delay has, I trust, been favourable to its appearance in a very improved state; as I have been collecting materials for it, during several years, having visited almost every situation of much geological interest in our own island, from the Land's End in Cornwall, to the Grampian Mountains in Scotland; and passed part of three years in examining the geology of Savoy, Switzerland, and France. There is scarcely a rock formation described in the present volume, that I have not examined in its native situation, and compared with the descriptions of former geologists. I have also had opportunities of examining the collections, and of profiting by the communications, of some of the most eminent geologists on the Continent.

While engaged in these pursuits, I have not been inattentive to the labours of other observers. So numerous and interesting are the discoveries made in geology during the last ten years, that in order to present a concise view of the science in its present advanced state, the *Introduction to Geology* has been recomposed, and all the Chapters are greatly enlarged.

The following new Chapters have been added:— Chap. II. On Fossil Organic Remains. Chap. IV. On the Principles of Stratification. Chap. X. A Retrospective View of Geological Facts. Chap. XVIII. On the Destruction of Mountains; and on the Bones of Land Quadrupeds, found in Diluvial Depositions and in Caverns. Chap. XIX. On the Formation of Valleys; and on Deluges and Denudations.—The Plates are new, except Plate IV. and part of Plate VII.

The Outline Map of the Geology of England and Wales, was I believe, when published in the First Edition of 1813, the only geological map of England that had then appeared. It presents in one view the grand geological divisions of the country, without delineating the different strata in each division. Mr. William Smith has since published a map of the Geology of England, which possesses extraordinary merit,—when it is considered as the unaided attempt of one person, to trace the course of each rock formation through England and Wales. Mr. Greenough, and other members of the Geological Society of London, have subsequently published a geological map of England and Wales. This map, from the great variety of its useful details, and its general correctness, may be regarded as the best approximation to a complete exhibition of the geology of an extensive country, that has yet appeared. It was thought, however, that the publication of my Map in its original form, (or nearly so,) would be acceptable to those who wished to gain a general knowledge of the geology of their own country, without entering into geological details; and that it would also serve as a useful introduction to the study of the above-mentioned maps.

In the course of the present work, I have frequently attempted to elucidate the geology of England, by comparisons with situations I have examined on the Continent, in order to connect the geology of our own island, with that of France, Switzerland, and Savoy.

By comprising the numerous facts and observations contained in the present volume, within the limits of an elementary work, from the desire to be concise, I may have run the risk of becoming obscure: this I have studiously endeavoured to avoid; my chief aim being to present the reader with a system of Geology, which shall describe and explain geological phenomena in a clear and intelligible manner, and as free from technical obscurity as the nature of the subject would admit. In order that the price may not exceed that of the last Edition, this work is printed in a smaller type. For any errors into which I may have inadvertently fallen, I would claim the candid indulgence of the reader, in the last words of that distinguished geologist Horace Benedict de Saussure, "*On peut être utile, sans atteindre à la perfection.*"

PREFACES

TO

THE FIRST AND SECOND EDITIONS,

ABRIDGED.

In tracing the progress of knowledge, we may frequently observe that the cultivation of particular branches of science, at certain periods, was determined by causes which had little connection with their intrinsic utility. Fashion, caprice, and the authority of eminent names, govern mankind in philosophy, as well as on all other subjects. But, independently of accidental causes, there are leading objects in the universe, which, as nations advance in civilisation, seem naturally to direct their attention to certain sciences in succession. The brilliancy of the sun, moon, and planets, their various motions, and connection with the changing seasons, would first arrest the attention of the rude philosopher; nor need we wonder that he soon began to regard them as endowed with life and intelligence, and attributed to them a mysterious power over human affairs: thus the heavenly orbs became the objects of religious adoration; and curiosity, hope, and fear, lent their aid to the early cultivation of astronomy.

Mathematics and mechanical philosophy are so intimately connected with astronomy and the most useful arts, that they naturally claimed the second place among the early sciences.

The branches of philosophy which comprise a knowledge of the physical qualities of matter, or such as are perceptible by the senses, follow next; and at a later period, chemical philosophy, or that science which endeavours to ascertain the elementary substances, of which all material objects are composed. In the order of succession, mineralogy and geology are the last of the natural sciences; for though an acquaintance with the earth is more important to man, than a knowledge of the distant parts of the universe, yet, previously to the cultivation of the other sciences, and of chemistry in particular, our knowledge of the mineral kingdom could not extend much beyond that of the rudest periods. Thus we find, that notwithstanding the precious metals, and many of the mineral treasures which the earth contains, have been the objects of insatiable cupidity in every age, yet, till the present day, almost all that was known of mineralogy was confined to uneducated working miners.

In looking over the pages of history we may observe, that the most polished nations of antiquity had scarcely advanced beyond a limited acquaintance with astronomy, geometry, and mechanical philosophy. In modern Europe, all the natural sciences, geology and mineralogy excepted, have been successfully cultivated, and their progress has been astonishingly rapid; but till about the middle of the last century, the structure of the earth had scarcely engaged the attention of philosophers. Near that time, Lehman, the German, first observed that there are certain rocks which occupy the lowest relative situation in different countries, and that these rocks contain no organic remains: hence he gave them the name of primary, and established a division between them and the rocks by which they are covered, in which the remains of animals or vegetables frequently occur: the latter he called secondary. In our own country, the Reverend J. Michell was the first person who appears to have had any clear views respecting the structure of the external parts of the earth: they were made public in a valuable paper on the cause of earthquakes, in the Philosophical Transactions, 1759. About twenty years afterwards, Mr. John Whitehurst published his "Inquiry into the original State and Formation of the Earth." His observations were principally confined to the rocks and strata of Derbyshire. Independently of its speculative opinions, this work was highly valuable as an attempt to describe the geology of a district, from actual examination. The great variety of original information it contained, and its general accuracy, will remain a lasting monument of the writer's industry and ability. Mr. Whitehurst, however, fell into the same error with the celebrated Werner in Saxony, an error to which the first cultivators of geology were particularly exposed, — that of drawing general conclusions from local observations, and forming universal theories from a limited number of facts.

Though Mr. Whitehurst's book was favourably received, yet till the beginning of the present century geological pursuits made little progress in England. On the continent, the researches of Saussure, Pallas, Werner, St. Fond, Dolomieu, and others, had before this time produced a powerful interest, and brought into the field many active and enlightened enquirers. The first general impulse given to the public taste, for geological investigations in this country, was produced by Professor Playfair's luminous and eloquent illustrations of the Huttonian theory. The leading feature of this theory, that all rocks or strata have been either formed or consolidated by central subterranean fire, was very warmly opposed; and much personal animosity and many adventitious circumstances were associated with the contest, not highly honourable to philosophy, but well calculated to keep alive the attention of the disputants to those appearances in nature which favoured or opposed their different theories.

He who attempts to make a scientific subject familiar, runs the risk, in this country, of being deemed superficial: a plentiful share of dullness, combined with a certain degree of technical precision, are regarded as essential proofs of profundity. By prescriptive right, long established in these realms, dullness and pedantry guard the portals of the temple of Science, and command those who enter, to avert their eyes from whatever can elevate the imagination, or warm the heart, and to look at nature through a sheet of ice. In compliance with their authority, writers of introductory treatises have generally thought it necessary to avoid that felicity in the familiar illustration of scientific subjects, so conspicuous in some of the elementary works of our neighbours. Without venturing to depart too far from established usage, I have endeavoured to render geology more intelligible, by avoiding as much as possible theoretical and technical language, and by introducing a simple arrangement, suited to the present state of our knowledge. The local illustrations from various parts of our island, with the drawings, sections, and map in the present volume, will, I trust, facilitate the study of geology, and prove particularly acceptable to those who are entering on these enquiries: at the same time, I flatter myself with the hope, that the original information this work contains, respecting the geology and natural history of England, will secure it a candid reception.—*Edition of* 1813.

Several have been deterred from the study of geology by the supposed difficulty of learning its attendant science, mineralogy; but an acquaintance with the nice distinctions made by many modern mineralogists, is not necessary to gain a knowledge of the structure and arrangement of the great masses of matter that environ the globe, nor of the substances of which they are composed. He who would gain a useful knowledge of geology, would do well to provide himself with specimens of common rocks, and the simple minerals of which they are composed, and examine their external characters and physical properties, comparing them with the descriptions given by the best mineralogical writers. Fortunately these substances are not very numerous, and he may (without present inconvenience) omit the more rare crystallisations and varieties, so much valued by cabinet philosophers; for here, as in many other instances, the received value is in an inverse ratio of the utility. The pedantic nomenclature, and frivolous distinctions recently introduced into mineralogy, may gratify vanity with a parade of knowledge; but they are unconnected with objects of real utility, or with any enlarged views of nature.

On hearing the various names which mineralogists give to the same substance, and observing the avidity with which each new name is seized, as if it conveyed a hidden charm, the uninitiated might suppose that he was "journeying in the land of Shinar," and had fallen in company with a set of masons fresh from the tower of Babel, each one calling the same stone by a different name, and glorying in his absurdity. Such frivolities disgust men of sense with the study of an important and interesting science; a science that has for its immediate object the structure of the planet which the Author of nature has destined for our abode, and an acquaintance with the situation of its various mineral productions, subservient to the wants or enjoyments of man in civilised society.

The advice of Cicero to the cultivators of moral science, applies with peculiar force to the geologists and mineralogists of the present day. "In these natural and laudable pursuits, two errors are particularly to be avoided: the first, not to confound those things of which we are ignorant with those we know, or rashly to yield our assent without due investigation; the second, not to bestow too much labour and study on obscure, intricate, and unprofitable subjects."—"In hoc genere et naturali et honesto duo vitia vitanda sunt: unum, ne incognita pro cognitis habeamus, *hisque temere assentiamur* (quod vitium effugere qui volet, adhibebit ad considerandas res et tempus et diligentiam.) Alterum est vitium, quod quidam nimis magnum studium multamque operam in res obscuras atque difficiles conferunt, easdemque non necessarias." — *Cic. Offic.* i. 6.

CONTENTS.

CHAPTER I.

CHAP. II.

ON PETRIFACTIONS, OR FOSSIL, ANIMAL AND VEGETABLE REMAINS.

CHAP. III.

ON THE MINERAL SUBSTANCES THAT COMPOSE THE CRUST OF THE GLOBE; AND ON THE STRUCTURE OF ROCKS.

CHAP. IV.

ON STRATIFICATION, AND THE RELATIVE POSITION OF ROCKS.

CHAP. V.

ON ROCKS DENOMINATED PRIMARY, AND THE CHANGES TO WHICH THEY HAVE BEEN SUBJECTED.

CHAP. VI.

ON GNEISS AND MICA-SLATE, AND THE ROCKS WHICH ARE ASSOCIATED WITH THEM.

CHAP. VII.

ON INTERMEDIATE OR TRANSITION ROCKS.

CHAP. VIII.

ON THE LOWER OR GREAT COAL FORMATION.

CHAP. IX.

ON UNCONFORMABLE TRAP ROCKS AND BASALTIC DYKES.

Different Positions of Trap Rocks, as overlying, imbedded, or intersecting other Rocks.—Varieties of Trap Rocks.— Porphyry, Porphyritic Trap, Sienite, Greenstone, Clinkstone, Basalt, Amygdaloid, and Wacke.— Passage by Gradation into each other, and into Volcanic and Granitic Rocks.— Remarkable Instance of this Passage at Christiania in Norway.— Mountains of Porphyritic Trap and Clinkstone with deep Craters.— High Stile, Cumberland; Cader Idris, Monmouthshire.—Basaltic Dykes: Extent of the Cleveland Basalt Dyke.— Isolated Caps of Basalt.— On interstratified Basalt.— Remarks of Professor Sedgwick on the Protrusion of Basalt between regular Strata.— On columnar Ranges of Basalt.— Organic Remains enveloped in Basalt.— Remarkable Basaltic Districts in Europe and America. — Experiments on Basalt.— Theory of Werner.— On the relative Age of Trap Rocks - - - - Page 185

CHAP. X.

A RETROSPECTIVE VIEW OF CERTAIN GEOLOGICAL FACTS AND INFERENCES.— RELATIVE AGES OF MOUNTAIN RANGES.— PRELIMINARY OBSERVATIONS ON THE SECONDARY STRATA

CHAP. XI.

TABULAR ARRANGEMENT OF SECONDARY STRATA.— RED SANDSTONE.— MAGNESIAN LIMESTONE.— ROCK SALT AND GYPSUM.

Relative Geological Position of the Secondary Class of Rocks.— Their Mineral and Zoological Characters.— Tabular Arrangement.— New Red Sandstone and Red Marl.— Upper, Middle, and Lower Beds, chiefly formed of the Fragments of more ancient Rocks, broken by some great Convulsion.— Lowest Red Sandstone, or Roth-todte Liegende of the German Geologists.— Separated from the Middle Beds, by Beds of Magnesian Limestone.— Middle and Upper Beds of Red Sandstone and Marl; their Accordance with those of France and Germany.— Muschel Kalk wanting in England, but probably exists in Ireland, as the Lily Encrinite has recently been discovered there. — Magnesian Limestone of the Northern Counties.— English Red Marl and Sandstone formed of more ancient Rocks, particularly of Porphyry and Trap.— Gypsum accompanying Rock Salt originally Anhydrous.— Rock Salt Deposits, in different Formations - - - - - - - - 230

CHAP. XII.

ON THE LIAS AND OOLITIC SERIES.

Geological Position of Lias Clay and Limestone. — Their Mineral Characters. — Alum-Slate in Lias. — Remarkable Organic Remains and Characteristic Fossils. — Extent of the Lias Formation in England. — Interesting Junctions of Lias and Red Marl. — Lias of France and the Alps. — Oolite or Roestone, the Jura Limestone of Foreign Geologists. — Mineral Characters, and remarkable Organic Remains. — Lower Oolite. — Oxford or Clunch Clay. — Middle Oolites. — Kimmeridge Clay. — Upper or Portland Oolites. — Stonesfield Slate with Organic Remains of Insects, Birds, Flying Reptiles, and small Land Quadrupeds. — Extent of the Oolite Formation in England, and its abrupt Termination. — Sections of the Oolitic Series of Beds in Yorkshire and the West of England, compared with a Section of the Secondary Strata in Germany - Page 261

CHAP. XIII.

ON THE SUSSEX BEDS, OR WEALDEN, CONTAINING REMAINS OF LAND PLANTS, AND AMPHIBIOUS AND FRESH-WATER ANIMALS.

Extent of the Sussex Beds. — Their Geological Position and Mineral Characters. — Remarkable Organic Remains of enormous Lizards and Plants, analogous to those of Tropical Climates found in the Sussex Beds. — Supposed Appearance of the Country when these Animals flourished. — Petworth Limestone. — Hastings' Sand and Weald Clay. — The Wealden Beds formerly furnished the greatest Part of the Iron manufactured in England. — Mr. Mantell's Enumeration of the Species of Terrestrial and Freshwater Fossil Remains in the Wealden Beds. — Observations on the Wealden Beds, and the Change from Marine to Freshwater Formations - - - 280

CHAP. XIV.

ON CHALK, AND THE SUBJACENT BEDS OF GREEN SAND.

Extent of the Chalk Formation. — Green Sand divided into lower and upper Green Sand by a Bed of Clay called Galt. — Chalk Marl. — Chalk; its Mineral Characters. — Change of Character in the Alps. — Flints in the upper Chalk. — On the Formation of Flints. — Remarkable Organic Remains in Chalk. — Recent Discovery of Beds belonging to the Chalk Formation, in the United States of America. — On the Scaglia of the Alps supposed to represent Chalk - - - - 292

CHAP. XV.

ON THE FORMATION OF SECONDARY LIMESTONE AND SANDSTONE, AND ON THE PROGRESSIVE DEVELOPEMENT OF ORGANIC LIFE.

CHAP. XVI.

ON THE LOWER OR MORE ANCIENT TERTIARY STRATA.

CHAP. XVII.

ON THE RECENT TERTIARY STRATA, OR WHAT ARE CALLED BY SOME GEOLOGISTS QUATERNARY.

CHAP. XXI.

ON THE DESTRUCTION OF MOUNTAINS, AND THE FORMATION OF SOILS; AND ON ALLUVIAL AND DILUVIAL DEPOSITIONS.

CHAP. XXII.

ON THE ELEVATION OF MOUNTAINS AND CONTINENTS.

CHAP. XXIII.

CHAP. XXIV.

SUPPLEMENT TO CHAP. VIII.

APPENDIX.

DESCRIPTION OF THE PLATES.

THE FRONTISPIECE is a bird's-eye view of the river that descends from the Falls of Niagara to where it issues from the channel which it has excavated, into the plain at Queen Town. The distant country extending to Lake Erie is introduced, to represent the physical structure of the country. See pp. 315—317.

PLATE I.

Figs. 1, 2, 3, 4, 5, 6. Illustrations of plane and curved stratification. (See Chap. IV.)

PLATE II.

Fig. 1. Overlapping strata with straight edges.

Fig. 5. Overlapping strata with curved edges.

Fig. 2. Structure of a part of the Alps, representing the beds, nearly vertical, that approach the central range, and the bended stratification of the outer ranges. The dotted lines represent the supposed extension of the beds at the period of their elevation; *d d*, granite and mica-slate; *c c*, beds of soft slate; *b a*, *b a a*, beds of secondary limestone, sandstone, and conglomerate; *x y z* represent the arched stratification of the outer ranges.

Fig. 4. A section representing the arrangement of the rocks and strata at Charnwood Forest, in Leicestershire, from the manor of Whitwick, to near Barrow-on-Soar. In this section the proportions of distance are disregarded, in order to bring the different rock formations within the space of the plate. *a a a*, stratified red sandstone; *b b*, rocks of granite, sienite, and porphyry; *c c*, slate-rocks of Swithland quarry, the beds much elevated; *d d*, coal strata, rising towards the granitic and slate-rocks; *e*, lias, covering the red marl at Barrow: the elevated strata out of the line of section on the left hand side of the plate, represent limestone rocks of Clouds Hill and Breedon. It is obvious from this arrangement, that the strata of sandstone *a a a* were deposited upon the slate-rocks and granite, after the beds had been raised into their present position: whereas in fig. 2. the beds *a a* have evidently been deposited before the beds of granite in the Alps were elevated; and as these beds *a a*, *b a b*, are of more recent formation than the sandstone *a a* in fig. 4., their position proves decidedly, that the beds of granite

in the Alps were elevated after the beds of granite and slate in Leicestershire. (See 491, 492.)

Fig. 3. A granite vein in slate.

Fig. 6. The remaining portion of a thick bed of limestone, forming an isolated mass *b* on a mountain in Savoy. *a a*, the former extent of the bed; *c c*, a bed of soft sandstone.

PLATE III.

Fig. 1. The conformable position of rocks. *a*, granite; *b*, gneiss; *c*, mica-slate; *d d*, slate; *x x*, a subordinate bed of limestone in slate; 2, a bed of conglomerate; *e e*, transition limestone and greywacke; F F, coal strata.

Fig. 2. A, unconformable massive rocks; a thick bed of porphyry or basalt c c, covering the transition rocks 1, 2, 3, and dykes of porphyry or basalt intersecting transition rocks. — N.B. The porphyry at Christiania, in Norway, occurs in this position; the lower part of it is amygdaloidal basalt; the middle part is porphyritic, which passes in the upper to beautiful sienite and common granite. (See page 191.) The rocks B, on the right, represent the three modes of basalt: a columnar bed *d*, with a vertical dyke of basalt, and beds of interposed basalt; *b* is an isolated cap of columnar basalt.

Fig. 3. Unconformable strata of sandstone, covering coal strata on the side of the dip B, and on the side of the rise D. (See page 179.)

Fig. 4. A section of the strata near Dudley, Staffordshire. A, Wren's Nest Hill; the two beds of limestone are folded round the hill, as represented in the small compartment B, which is an horizontal section of the two beds of limestone *a*, *b*; the thirty feet bed of Staffordshire coal c is seen cropping out near the foot of Wren's Nest Hill; B, the arrangement of the limestone strata at Dudley Castle Hill; D, a hill capped with basalt. In this section the proportion of distance has been disregarded, for the same reason as in Plate II. fig. 4.

PLATE IV.

Fig. 1. Arrangement of the strata from Sheffield, in Yorkshire, to Castleton, in Derbyshire. (See page 72.)

Fig. 2. Coal strata, arranged in basin-shaped concavities, and intersected by a fault. (See page 153.)

Fig. 3. Coal strata thrown up by a broad dyke. (See Chap. VIII.)

Fig. 4. Metallic veins. *a a*, a vein divided by the vein *b b*; *c c*, a pipe vein.

Fig. 5. Metallic veins in limestone, cut through by toadstone.

PLATE V.

The gigantic Trilobite, and two smaller species.

PLATE VI.

Map of the geology of England and Wales, and a section of the Vale of Thames.

PLATE VII.

A section of England through Durham and Cumberland; a group of columnar trap rocks, Cader Idris; sections of ground plans of metallic veins, &c.

PLATE VIII.

Living illustrations of fossil conchology:—
Fig. 1. Cuttle-fish, or Sepia.
2. Beak of a Sepia.
3. The Nautilus Pompilius and its shell.
4. A Scaphite.
5. A Hamite.
6. Cornu Ammonis, or ammonite.
7. Indented partitions of an ammonite.
8. Baculite.
9. Belemnite.
10. Turrilite.
11. Spirula.
12. Orthoceratite.
13. Nummulite.
14. Hippurite.
15. The animal and shell of a Buccinum.
16. Animal and shell of a Bucardium.
17. A living Pentacrinus.
18. The mouth and excretory organ of the Pentacrinus.

WOOD-CUTS.

PRELIMINARY OBSERVATIONS

ON THE OBJECTS CONTAINED IN PLATE VIII., ENTITLED "LIVING ILLUSTRATIONS OF FOSSIL CONCHOLOGY," ETC.

MAN, when he becomes the historian of the animal kingdom, generally considers his own structure as a type of the most perfect organisation; and regards those animals that depart the most from this type, and have the smallest number of organs and senses, as the least perfect. Strictly speaking, every animal is perfect, that is, so organised as to answer the purposes for which it was created: yet with reference to ourselves, we may, without much impropriety of language, call those animals which have the smallest number of organs and senses, the most imperfect. The very earliest inhabitants of the ancient world appear chiefly to have belonged to those orders of imperfect animals, that had little power of locomotion, and few organs of sense: many of them were without heads or eyes, and were, like the oyster, confined in shells, which they could merely open and close. Of these there were such immense multitudes, that calcareous mountains of vast magnitude and extent, are sometimes chiefly composed of their remains.

From what we see of the present animal creation, we have reason to believe, that creatures of every species, when free, and provided with the aliment they require, derive pleasure from the very action of their organs, and from existence itself. Of the kind or extent of the happiness enjoyed by a creature enveloped in darkness, and without head, heart, or eyes, or the power of removing its habitation, we can, however, form no idea; yet for any thing we know to the contrary, the inhabitant of a bivalve shell, may be far happier, than the monk immured in his stony cell, or than other individuals of the highest order —Man — who, however perfect their physical organisation, make but little use of the intellectual and moral organs, figuratively called the head and the heart.

Dr. Paley, in his "Natural Theology," has some beautiful reflections on the apparent happiness enjoyed by shoals of young shrimps, that were bounding into the air from the shallow margin of the water, or from wet sand. He observes: "If any motion of a mute animal could express delight, it was this." We cannot take cognisance of the actions of creatures enclosed in bivalve shells; but a distinguished philosopher was so fully convinced of the happiness enjoyed by testaceous animals, that he calls calcareous mountains, filled with their remains, "monuments of the felicity of past ages."

It is with a view to excite the curiosity of the geological student, and to direct his attention to something beside the external form of shells, that I offer the following observations, and not with the design to teach fossil conchology, which the limits of the present volume would not admit of.

The reader who is entirely unacquainted with conchology may form some general idea of a shell, if he be told that it is univalve, like a snail or a perriwinkle; or bivalve, like the muscle or cockle.

There are, however, numerous fossil bodies classed with shells, of which the general reader can form no notion whatever from the names;—such are the orthoceratite, the scaphite, &c. These are called chambered shells, from their being divided by partitions into numerous narrow cells or chambers. A tube, called a siphunculus, passes through the series of chambers. In all probability, this tube enabled the animal to rise from great depths of the ocean to the surface, by exhausting the water from the chambers, and filling them with air.

Till within the last few years, these chambered shells have been considered as the habitation of marine animals, like the bivalve and univalve shells; but a little reflection may convince us, that the chambers were much too small to contain the animal, nor could the animal possibly pass from one chamber to another. There is, however, one living species, in which the outward cell or chamber is so much larger than the rest, that there is sufficient space to contain a great part of the animal. This is the nautilus pompilius, an inhabitant of the Indian Ocean. (See Plate VIII., fig. 3., which represents the animal collapsed in the last, or open chamber of the shell.)

The animals belonging to the different chambered shells were molluscous. (See Chap. II.) They are called by Cuvier Cephalopodes, because the organs of motion are placed round the head, and they walk with their heads downwards. The living species of cephalopodes are for the most part without any external shell; but some have an internal hard substance without chambers, of which the cuttle-fish bone affords a familiar example. This is taken out of the body or sac of the animal — the sepia officinalis, which is common on our coasts.

The general character of the cephalopodes, as given by Cuvier in his *Règne Animal*, tom. iii., is, "that the mantle or cloak is united under the body of the animal, and forms a muscular sac, which envelopes all the viscera. The head projects from the opening of the sac; it is round, and has two large eyes, and is surrounded (*couronnée*) by fleshy arms or feet, which are conical, and vary in length in different species. These arms bend in every direction, and are exceedingly powerful. On the surface of these arms are numerous suckers, by which the animal fixes itself strongly to the bodies that it seizes and enfolds. These arms serve the animal both to seize its prey, to walk, or to swim. It walks in every direction, having the head below, and the body above. At the base of the arms is the mouth, which is provided with two strong jaws resembling the beak of a parrot, and also with a fleshy gizzard like that of a bird.

"Most of these animals, when pursued, excrete a particular black liquor, which darkens the water, and conceals them from their enemies. There is a fleshy funnel placed near the neck, which serves the animal for its excretions, and also to eject the water that it absorbs for the purpose of respiration. They are of two sexes, and are voracious and cruel: as they have great agility in seizing their prey, they destroy multitudes of fish and crustaceous animals." The fleshy funnel, or excreting organ, is not seen in fig. 1., being placed on the under side; but in fig. 3., the projecting organ below the tentacula is the funnel. The sepia has the power of contracting its arms; and in some species the arms are much shorter than represented in the plate, fig. 1., but these have, besides, two extremely long arms or feelers. If the accounts of voyagers could be relied upon, there are sepia in the Indian Ocean with arms nine fathoms in length, and so large that their sac would contain the body of an elephant. The flesh of the sepia was esteemed a great luxury by the ancients. In Plate VIII., fig. 1. is the sepia octopedia, an inhabitant of the British seas. Fig. 2. is the beak of a species of sepia, the calmar; these are found fossil, and are called Rhyncolites. Fig. 3. is the nautilus pompilius or pearly nautilus. Great uncertainty prevailed respecting the true character of the nautilus, which has been removed by a scientific examination of the body of one of these animals caught by George Bennet, Esq., and of which an interesting account has been recently published by Mr. Richard Owen, illustrated by beautiful engravings. It should appear from Mr. Owen's account, that the organisation of this animal is in many respects less perfect than that of several species of sepia that have no external cell: it had ninety-two arms or tentaculæ. Fig. 3. is taken from Mr. Owen's first plate, but greatly reduced; it is chiefly intended to show the position of the animal in the shell. It is a section representing the interior of the shell divided into chambers, and the siphunculus passing through them. The nautilus pompilius is not uncommon as a fossil shell. It may be seen both recent and fossil in most museums. We shall now proceed to notice the principal genera of chambered shells, not in the numerical order of the plate, but as they approach the nearest to the form of the nautilus.*

The SPIRULA (fig. 11.) is both a recent and a fossil shell: the turns or whorls of the shell do not touch. The spirula is an inhabitant of tropical seas; the animal resembles that species of sepia called the seiche or common sepia. The shell is almost entirely inclosed in the sac. Indeed, it appears from its structure, that the animal could not be contained within the outer cell.

The AMMONITE (fig. 6.) of which there are numerous species, differs greatly from the chambered nautilus, the whorls or turns being all distinct, and in the same plane, and the cells are very small. The siphunculus is placed near the outer edge of the shell. In many species, the cells are divided by indented partitions, as represented in fig. 7.: in other species the cells are undulated. Some ammonites in the vicinity of Bath are eighteen inches or more in diameter. The shell must have been internal, and the animal that contained it very large. Ammonites, though so abundant in the secondary strata, have not been found in a recent state, except the account can be relied upon, of their having been discovered in the Pacific Ocean.

The SCAPHITE resembles an ammonite partly unrolled. A very remarkable specimen of one recently discovered in France is represented fig. 4. It is not improbable, that many internal shells were composed rather of a corneous substance than of shell, and were capable of being coiled or folded by the will of the animal.

Fig. 8. is a straight chambered shell called a BACULITE.

---

* The animal that inhabits the thin open shell called the paper nautilus, but more properly the argonota, is also a species of sepia: it is common in the Mediterranean. It is very rarely found fossil.

Fig. 12., the ORTHOCERATITE, is a straight chambered shell resembling ammonites unrolled, but the cells are divided by concave partitions, as in the nautilus. Some orthoceratites are two or more feet in length: the animal that contained them must have been of vast size. Orthoceratites are the most ancient of fossil chambered shells, and are chiefly found in transition limestone.

Fig. 9. The Belemnite is a taper straight shell, with an internal chambered cone. In some species there is no chambered cone. This unchambered internal shell may have performed the same office as the internal bone of the sepia officinalis, or cuttle-fish. It is deserving notice, that the coat of the belemnite, when slightly burnt, yields the odour of burnt horn, which tends to confirm the supposition that internal shells were corneous substances.

Fig. 13. The Nummulite, (so called from its resemblance to a small Roman coin) has nearly a flat or lenticular form. It has within it a cavity, divided by partitions into numerous small cells, but without a syphon or siphunculus; part of the outside of the shell is removed in the figure, to show the internal chambered structure. Whether the animal belonged to the genus Sepia is not known.

This little fossil forms entire calcareous hills and immense beds of building stone in some countries. "It is of stone composed of these shells that the Pyramids of Egypt are constructed." Cuvier, *Règne Animal.*

All the above genera of chambered shells, with the exception of the Nautilus and Spirula, are fossil.

We come now to other orders of molluscous animals, whose organisation is less complex, and their powers of motion more limited, than in the cephalopodes. These are the inhabitants of bivalve and univalve shells. The first are called by Cuvier Acephalous, being without heads. Of these the oyster offers the most familiar example. Most of the species are permanently attached to rocks, and have no member to protrude beyond the shell. Those species of the oyster family that are not attached permanently, can only move by driving out the water, as they suddenly shut the valves of the shell. Species of other genera of bivalves, though without heads, possess the power of locomotion.

Fig. 16. represents the animal and shell of a Bucardium.

This animal puts out a triangular body, formed of two pipes or tubes, separated and flat, but which become round as the water enters by the lower tube, and goes out at the upper one. The tubes are surrounded with hairs. When the animal is disturbed, or hears a noise, it throws out water to the distance of a foot. When it wishes to change its quarters it protrudes a long foot, and seeks, with the further end of it, some object or point of support, to which it fixes it; the animal then draws back its shell about two inches at a time, till it has attained or reached the spot where it desires to abide. Cuvier regards one of the tubes as suited for respiration by the absorption of water, and the other for its excretions. He further states, that bivalves which have these tubes live buried in mud or sand.

The animals inhabiting univalve shells are chiefly classed by Cuvier as Gasteropodes, from their moving in their stomachs like snails. In most species of univalves, the animal has a head with two eyes, and a trunk resembling the trunk of an elephant; with this trunk it seizes its food; and in some species the trunk is used for piercing other shells. The animal crawls upon a fleshy foot, near the end of which there is a horny substance called an operculum, that serves as a door to close the shell, when the animal withdraws into it. In many species of univalves, the animal can fold the mantle so as to form a tube which protrudes into the water, while the head and foot remain in the shell. Some species of univalves are carnivorous, others are herbivorous, and the nature of their food determines their residence either near the shore or in deep water.

Fig. 15. represents the shell and animal of a species of *Buccinum*, which agrees with the above description of the inhabitants of univalve shells. The foot on which it crawls is on the left hand, with the oval operculum near the end of it. On the right hand of the figure, at the top, the mantle is represented folded, to form a tube, as above described.

In some species, both of bivalve and univalve shells, the animals depart considerably from the general character of the class to which they belong. There are some bivalves which have the cavities of the shells divided by partitions, the uses of which are not known; and some univalves have an apparatus for swimming on the surface of the water.

The Hippurite, a remarkable fossil bivalve, with a deep conical under shell, and a flat lid, is represented fig. 14. It is classed by Cuvier with the oyster family; and, by Parkinson, with chambered shells. The nature of the animal is unknown. The shell is divided by transverse septa, or partitions, on which account Mr. Parkinson places it among other species of chambered fossils. The existence of a lid seems to prove, that it was not an internal shell, but the habitation of the animal. A fossil hippurite has recently been found in the chalk hills of Sussex, by Mr. Mantell.

The Janthina is a beautiful purple-coloured univalve shell, nearly resembling in form the snail; Lamarck discovered, that it could not crawl on its foot, but that the foot is covered with air bladders, which enable the animal to rise and swim on the surface of the water. The janthina is common in the Mediterranean; when touched, it excretes a deep purple liquor, which tinges the surrounding water. (Cuvier, *R. A.* tom. iii.) There are other animals occupying univalve shells, that have the power of swimming. The Lymnea stagnalis, an inhabitant of ponds, swims on the surface of the water in a reversed position. It descends by compressing itself within the shell, and expelling the air, and thus sinks immediately to the bottom. Mr. Parkinson rightly conjectures, that the shells resembling the Helix, or snail, in the older strata, were constituted for swimming, like the janthina: they could scarcely have used a foot for crawling, at the bottom of a deep and agitated ocean.

We come now to another division of the animal kingdom, called by Cuvier *Radiated.* See Chap. II. Some of the animals comprised in this division have left abundant remains in the fossil state, particularly the encrinite and the pentacrinite. These animals had a stem, composed of numerous plates, and terminating in branches surrounding the mouth, resembling the stem and branches of a vegetable. Both these species were supposed to be extinct; but a living pentacrinus has been discovered in the West Indies, and a smaller species, more recently, in the Cove of Cork. This has been described by Mr. J. V. Thompson, of Cork. A drawing of this animal, taken by Mr. Thompson, is given (Plate VIII. fig. 17.) A cut of a remarkable species of fossil encrinite is given, p. 240.: it is named the Lily Encrinite, because the arms, when folded, resemble the head of the lily. Indeed, the whole class of encrinites and pentacrinites are called *crinoidea,* from *krinon,* the lily, by Mr. Millar, in his valuable work on these fossils. The arms of part of a Briarean pentacrinite are represented, p. 264.

In the encrinite, the stem is composed of numerous round plates, or vertebræ; the branches are also composed of numerous smaller, but similar plates, as may be seen by referring to fig. 17. and the cuts. The pentacrinite differed from the encrinite by the plates, or vertebræ, of the stem and branches being pentagonal. The stems of both were attached to rocks. They appear, like various polipi, to have increased by throwing out lateral stems (see the above fig.). The calcareous vertebræ that formed the stem and branches, were enveloped by a thin coat of animal matter, which must have possessed great muscular power, to have enabled the animal to move its arms with great facility, when seizing its prey.

In fig. 17. the expanded arms of the upper head of the pentacrinus expose the pentagonal aperture or mouth in the centre; and a little above this is a round tube or aperture, which serves for the excretion of the fæces. In fig. 18., which is a head with the arms removed, it will be seen, that the excreting tube projects a little above the mouth. One head of the pentacrinus is represented as folded, and another as partly collapsed. As these animals were enveloped in a thin fleshy covering, their calcareous remains may be regarded as portions of the skeleton. Some beds of mountain limestone, in Derbyshire, are almost entirely composed of broken stems and branches of encrinites, not uncommonly called entrochites. In a part of this work it was stated, on the authority of a letter sent to the Author, that the Lily Encrinite had been discovered in Ireland; but the cut subsequently given of it in Mr. Loudon's *Magazine of Natural History*, makes it doubtful, whether it is the true Lily Encrinite, or a species nearly resembling it.

The Author cannot conclude these remarks, without expressing a wish, that scientific voyagers, and medical gentlemen, who visit tropical seas, would carefully examine the different species of sepia that may be caught. It is probable, that there are living species, with internal chambered shells, resembling more or less the figures in plate VIII. Cuvier says, that a little change in the structure of the oval internal shell of the cuttle fish, would convert it into the internal chambered shell of the spirula. It was with a view to excite the curiosity of voyagers, when near the coast of North America, that the Author has suggested the possibility of the ichthyosaurus visiting those seas, p. 312. Cuvier too hastily conjectured that no new living species of large terrestrial quadrupeds remained to be discovered. The gigantic tapir and new species of elephants have since been discovered in India. The Author considers it far from improbable, that the great mastodon may exist in some of the unexplored recesses on the western side of North America; and he would particularly recommend comparative anatomists to examine the structure of the Grisly bear, and compare it with the skeleton of the cavern bear, (ursus spelæus.) When Cuvier published the last edition of his *Règne Animal*, in 1829, he does not appear to have known anything respecting the Grisly bear.

INTRODUCTION TO GEOLOGY.

CHAPTER I.

Objects of the

ERRATUM.

Page 61. lines 14, 15. for "The chalk without flints, the lower chalk with flints," read "The chalk with flints, the lower chalk without flints."

In this Chapter the author has endeavoured to give such an outline of the science, and its practical application to the knowledge of the Geology of England, as may be clearly and easily understood by the general reader, and prepare him for the perusal of the succeeding Chapters.

There are perhaps few persons possessed of much curiosity in early life, to whom the following question has not frequently presented itself—*What is the world made of?* Now this question, with certain conditions, comprises the most important objects of geological research; namely, *What are the substances of which the Earth is composed? What is the order in which they are arranged? What are the changes they appear to have undergone?*—But how are satisfactory answers to these inquiries to be obtained?

When we examine the terrestrial globe, where the solid parts are uncovered and exposed to our view, we observe vast masses of rock or stone lying in apparent confusion on each other; or, should we perceive some regularity in their position and arrangement, we soon lose sight of it again by the intervention of other rocks. In this department of nature all seems vast, unshapen, and chaotic; but let us not be discouraged, for we may recollect that the grandest objects in the material universe, seldom present to the hasty view of the superficial observer, immediate proofs of order or design.

The shepherd who first discovered that the planets were not fixed in the heavens, and noticed their apparently intricate wanderings among the stars, could not possibly anticipate the regularity and harmonious simplicity of their movements, which subsequent observations have demonstrated.

Let us then endeavour to ascertain by what means we may become acquainted with the structure of the solid covering of our globe. Were these means bounded by the power of man to penetrate below the surface, our knowledge must ever remain very limited and imperfect; but natural operations have greatly facilitated our inquiries, and have broken the rocky pavement of the globe, and raised up or laid bare the mineral substances of which it is composed. By an attentive examination of the situations where the rocks and strata are thus exposed to our research, we lay the foundation of the science denominated Geology.

Geology is derived from two Greek words, *ge* "the earth," and *logos* "reason," and signifies the Science of the Earth. Werner and his disciples, and also some of the French geologists, have changed the term into *Geognosy;* but for this change no sufficient reason can be assigned, and it is contrary to established analogies of language.* Philosophers, in former ages,

---

* Nothing can be more unmeaning than the apologies that have been offered for substituting (*gnosis*) "knowledge," for (*logos*) "reason." By the same rule we ought to change meteorology, physiology, &c. into meteorognosy, physiognosy, &c.

neglected the examination of the earth, and contented themselves with vain speculations respecting its formation; whereas the only proper answer to the question, *How was the world made?* is briefly this—"By the almighty power of its Creator." We may however be permitted, and indeed we are almost irresistibly impelled, to inquire into the nature of the secondary causes, that have been operative in reducing the surface of our globe to its present state. This inquiry comprises what may properly be denominated Speculative Geology. Nor is this, as some assert, entirely useless: the advocates of particular systems have engaged in an active examination of nature to support their opinions, and have "compassed sea and land to gain proselytes:" thus numerous facts have been discovered, with which we should not have been acquainted had they remained idle in their studies.

The earth is now well known to be one of those globular bodies called planets, that revolve round the sun in orbits nearly circular, and in stated periods of time, which bear a certain ratio to their respective distances from it. They turn round their axes with different degrees of velocity; and this motion appears to have had considerable influence on their external shape, by enlarging their equatorial diameters; they are not perfect spheres, but are more or less flattened at their poles.

In the planet Jupiter, the velocity of the equatorial parts is more than four hundred miles per minute, whilst in the same time the equatorial parts of the Earth have moved only seventeen miles. A difference between the polar and equatorial diameter of Jupiter is perceptible with a telescope that has a distinct magnifying power of a hundred times, and it is ascertained to be as 12 to 13. The equatorial diameter of the earth exceeds its polar about twenty-seven miles; the length of the equatorial diameter being 7927, that of the polar 7900 miles.

The relative density of the sun, the earth, and of the other planets, is estimated by the attractive force which they exert on each other, as they move round their common centre of gravity. The absolute density or the quantity of matter contained in the earth, compared with an equal bulk of any known substance, may be nearly determined by the attractive force which any given mass of matter exerts upon a plummet (when suspended in its vicinity) to draw it from a vertical line. This will be proportional to the absolute quantity of matter in that mass compared with that of the earth. By this method, it has been found that the mean density of the earth is about five times greater than that of water, or nearly twice the average density of the rocks and stones on the surface.

Hence it has been inferred that the interior part of the earth is solid; or, if it be cavernous, that the solid matter must possess great density. It is not improbable that iron, nearly in a metallic state, may be one of the constituent parts of the central mass, and to this it may owe its magnetic polarity.

Dr. Halley supposed that the earth is a hollow sphere, containing within it a central magnetic globe, and that the revolutions of this globe on its axis, occasioned the variations of the magnetic needle. Laplace, the celebrated French astronomer, asserts, that the nutation of the earth's axis, and experiments on the vibration of the pendulum, indicate an increase of density of the mineral beds, as they approach nearer to its centre, at least to a certain depth from the surface. The rapid transition of motion to very distant parts of the earth during violent earthquakes, renders it probable that there are cavities filled with fluid or gaseous matter, which extend to different parts of the globe, at great depths under the surface.

An opinion has long been entertained, that our planet contains within it a mass of igneous matter, the source of central heat, which is supposed to be an important agent in maintaining the present temperature of the globe, nor are facts wanting to lend support to this opinion. The occurrence of numerous active volcanoes in both hemispheres, and in every degree of latitude; the existence of extinct ancient volcanoes, and of rocks of igneous origin in almost every country; and the numerous hot and warm springs that preserve an unvarying temperature for centuries, — all indicate the existence of a source of heat deeply seated beneath the surface. It seems also to be proved by observations made for the purpose in deep mines, that the temperature of the earth increases as we descend; though at a small distance from the surface, the temperature of the ground and of wells is the same in every season, but it varies in different latitudes. The animals and vegetables whose remains in a fossil state are found in northern climates, are for the most part analogous in structure to the animals and vegetables of tropical climates; hence it has been inferred by some geologists, that the central mass of heat is gradually refrigerating. It is, however, the crust of the globe that offers proper occupation to the geologist. The greatest depth to which he can extend his observations from the uppermost strata, to the very lowest beds that have been raised up or laid bare by these natural operations which have formed mountains or valleys, is less than eight miles; a thickness which, compared with the bulk of the earth itself, does not exceed that of a coat of varnish upon an artificial terrestrial globe. Were we to bear this sufficiently in mind, the mighty catastrophes which have changed the surface of the globe in former periods, and have left traces of their action, appalling to the imagination, would cease to exceed the sober measure of belief.

The superficies of our planet is calculated to contain about one hundred and ninety millions of square miles; but could we be raised to a sufficient height above the earth, so as to have its whole enlightened hemisphere for our horizon, we might perceive as it revolved under our feet, how small a portion is fitted for the habitation of man. More than three fifths of the earth's surface are covered by the ocean; and if from the remaining part we deduct the space occupied by polar ice and eternal snow, by sandy deserts, steril mountains, marshes, rivers and lakes, the habitable portion will scarcely exceed one fifth of the whole of the globe. Nor have we reason to believe that at any former period the dominion of man over the earth was more extensive than at present. The remaining four fifths of our globe, though untenanted by mankind, are for the most part abundantly stocked with animated beings, that exult in the pleasure of existence, independent of human control, and no way subservient to the necessities or caprices of man. Such is and has been for several thousand years the actual condition of our planet; nor is the consideration foreign to our subject, for hence we may feel less reluctance in admitting the prolonged ages or days of creation, when numerous tribes of the lower orders of aquatic animals lived and flourished, and left their remains imbedded in the strata that compose the outer crust of our planet.

The ocean has been an important agent in effecting vast changes on the surface of our globe, which will be afterwards considered. The average depth of the sea has been differently estimated. According to Laplace, this depth cannot be less than ten miles, to account for the height of the tides by the laws of gravitation; but it is more generally admitted that the average depth does not exceed five miles. No admeasurement by soundings has exceeded the depth of one mile and a quarter.

The ocean has not always occupied its present bed, for rocks almost entirely composed of the shells or remains of marine animals, are found in almost every country that has yet been explored; and these remains occur near the summits of the highest mountains, in the old and new continents, some of which rise more than two miles above the present level of the sea.

It is well known that the water of the sea contains a considerable portion of common salt, and a small portion of other saline ingredients.* The average amount of salt in the ocean may be estimated at 2½ per cent. of common salt, and ½ per cent. of other saline compounds.

The atmosphere which surrounds the earth does not come under the attention of the geologist, except as an agent in wearing down the solid surface, by the precipitation of rain, and by change of temperature. The inequalities of the earth's surface formed by mountains and valleys afford frequent opportunities for observing that the mineral substances of which it is composed are of different kinds: in some situations, we observe strata of chalk; in others, of sandstone, or compact limestone, or beds of slate, granite, &c. It was long known to working miners, that the different beds of mineral matter lay over each other in a regular order in certain districts, and that certain beds were always found under, and never above, other particular beds.

The first observations which may be said to have laid the foundation for a correct classification of rocks were made by the German Lehman, about the middle of the last century. He found that the lower rocks, in some of the mining districts, were distinguished from the upper rocks by their great hardness, and by their structure, which was, for the most part, either crystalline or slaty; they were also dis-

---

* The inquiry has often been made,—Whence did the sea derive its saline contents? It has been supposed by some writers that the salt in the sea has been gradually augmented by saline particles brought into it by rivers; but this cause is totally inadequate to explain the immense quantity of salt existing in the whole mass of the ocean. If the average depth of the sea be five miles, and it contain 2½ per cent. of salt,—were the water entirely evaporated, the saline residue would form a stratum of salt more than five hundred feet in thickness covering three fifths of the surface of the globe.

tinguished by the absence of shells and other organic remains, and by the absence of fragments of other rocks, which occur so frequently in the upper rocks or strata. He further observed, that many of the upper strata, besides containing organic remains, appeared to have been formed of fragments of the lower rocks, broken down and agglutinated together; and hence he inferred, that the lower rocks were formed prior to the creation of animals, and he gave them the name of *Primitive* or *Primary*, and distinguished the upper by the name of *Secondary*. This grand division, though too hastily formed, was of use in the infancy of the science, and induced naturalists to examine more attentively the nature and position of the rocks in different countries: and, as their observations became more extended and accurate, a more extended arrangement and classification was found necessary. Many of the earlier geologists maintained that each bed or stratum of rock is spread universally over the globe, and that a series of beds, in regular succession, environs our planet, like the coats of an onion. This position is, however, much too general, as many beds of rock which are common in one country, are entirely wanting in another: but, taken as an illustration of the structure of the crust of our globe over a certain extent, the successive coats of an onion, if they were of different colours, might not unaptly represent the different strata that cover certain districts.

It may here also be proper to observe, that the different strata which occur under each other, are not arranged in the order of their density or specific gravity. Coal strata, for instance, are often covered with strata of iron-stone, the specific gravity of which is more than twice that of coal.

I shall now proceed to enumerate the different classes of rocks generally admitted by geologists, and briefly describe the principal characters of each class; and, in order to direct the attention of the reader more forcibly to the subject, I shall trace on an outline map the principal situations in our own island, where rocks of each class occur, except the recent volcanic.

All the different rocks and strata that cover the earth's surface may be arranged under the following classes: —

1. Primary.
2. Intermediate, or Transition.
3. Secondary; comprising
    - *a.* The Lower Secondary Series, and
    - *b.* The Upper Secondary Series.*
4. Tertiary.
5. Basaltic and Volcanic.
6. Diluvial and Alluvial Ground.

This arrangement is substantially followed by most geologists of the present day, though with some modification of the names. Several of the French geologists class the lower secondary, including the coal strata, with the intermediate or transition rocks: some urgent reasons may be advanced for this, which we shall subsequently notice. Objections have been made to the terms primary, secondary, &c., that they do not strictly conform to the present state of geology; but a change of names, which are in general use and well understood, would be attended with no adequate advantage, and would be ill suited to promote the knowledge of the science in an introductory work. It is greatly to be regretted, that a morbid desire to obtain celebrity by inventing new nomenclatures, should so much prevail among some of the cultivators of natural science. The author is of opinion, that a more simple arrangement of rocks might be made without any material change of the present names, and he is persuaded that such an arrangement will take place in a more advanced state of the science, (see Chap. V.)

---

* By some geologists these secondary strata are called "the older" and "the younger series," terms which are equally clear andintelligible.

That primary rocks environ the whole globe will not admit of direct proof; but, from their frequent occurrence in mountainous districts in the most distant parts of the world that have been examined, we may infer that some of the rocks of this class constitute the foundation rock of every country. We have no means of ascertaining that the similar rocks of distant districts were formed at the same time, nor can we be certain that the rocks called Primary, have not once contained organic remains, that were destroyed during the process by which they acquired their present crystalline structure. We may however, with apparent probability, infer that their formation was prior to the existence of animals or vegetables on our planet in its present state, because the rocks which immediately cover them contain almost exclusively the organic remains of the lowest class of animals, which are considered as forming the first link in the chain of animated beings. On this account these rocks have been called by the German geologists *transition* rocks, from the supposition that they were formed when the world was passing from an uninhabitable to a habitable state.

Transition or *intermediate rocks* are generally less crystalline than the primary; they contain occasionally organic remains of the lower classes of animals, and also fragments of rocks of the primary class. They are frequently interposed between rocks of the primary class, and those more generally called secondary, and often partake of the character belonging to both. The prevailing rocks in the transition series are limestone, slate, called clayslate, and coarse slate, passing sometimes into sandstone, and conglomerate; this has been called by the Germans grau waccé, or grey wacke. The rocks of the primary and transition class are the principal repositories of metallic ores, but in Europe they contain few saline or inflammable minerals.* In South America, according to Humboldt, sulphur and bitumen exist in considerable quantities in rocks denominated primary.

Rocks of the transition class are not universally interposed between the primary and secondary rocks, for in some situations the transition series are entirely wanting. Thus in passing from Lyons to Clermont, in the centre of France, I observed the regular coal strata resting upon beds of sand, clay, and rounded stones which immediately cover granite.

Secondary Rocks.—The lower series are almost all distinctly stratified; they consist chiefly of sandstone, soft argillaceous slate called shale, and beds of coal and iron-stone. Many of the secondary strata of this class abound exclusively in the fossil remains of vegetables, analogous to ferns, palms, and reeds;

---

* Except we comprise the regular coal formation in the transition series.

while the rocks in the former or transition class, contain almost exclusively the remains of marine animals. This change in the nature of the fossil remains in the two classes of rocks, indicate an important change in the condition of the globe, prior to the deposition of the lower series of secondary strata. The transition rocks were evidently formed under the sea, some of the beds being almost entirely composed of the exuviæ of madrepores and encrini, but the terrestrial plants whose remains abound in the lower secondary strata, must have grown on land, from which the ancient ocean had retired, and the strata which contain them were probably deposited at the bottom of rivers or fresh water lakes, as marine organic remains seldom, if ever, occur in them. The upper series of secondary strata again indicate another important change of the surface of the globe. The prevailing beds in this series are stratified limestone with beds of clay shale and sandstone interposed. The limestone has generally an earthy texture, and very rarely partakes the hard and crystalline character of the lower limestones. The fossil remains in the upper secondary strata are, with some exceptions, those of marine animals, but of different genera or species from those in the strata below them. It is in the upper secondary strata that we first meet with remains of saurian or lizard-shaped animals, some of which were of immense size. The co-existence of dry land, at the period when most of the upper secondary strata were deposited, is, however, proved, by the occasional occurrence of terrestrial fossil plants, and the bones of fresh-water and amphibious reptiles, such as the crocodile and tortoise.

Another important fact respecting the upper series of secondary strata is, that they appear to have been formed, not only under different circumstances from the lower, but after a long interval, during which the surface of the globe had been much fractured and displaced; for the upper series do not lie parallel with the lower, but they cover the edges of the lower strata unconformably.

To make this better understood, suppose a number of books to be laid regularly upon each other, and the lowest volume to be tilted up so as to give an inclined position to the whole, if we then take other books and place them horizontally, or nearly so, on the upper edges of the inclined volumes, we may then form a distinct idea of the unconformable position of the upper series of secondary strata over the lower series. This position is represented Plate 1. fig. 3.; it will be more fully described in the 4th chapter.* The last of the upper secondary strata is chalk, a rock well known in the south and south-east parts of England, though entirely wanting in the north-west and in Scotland.

Tertiary Strata comprise all the regular beds that have been deposited subsequently to the chalk strata, on which they frequently repose. It was formerly supposed that tertiary strata were very limited in extent, and were confined to a few districts in Europe; recent observations, however, prove that strata of this class cover considerable portions of the surface in various countries, though there are other countries in which they are entirely wanting. Tertiary strata are the most recent or uppermost of all the regular rock formations. They consist chiefly of clay, marle, limestone, and friable sandstone: the lower series of these strata contain numerous marine shells, while some of the middle and upper strata contain shells resembling those found in our present rivers, or in fresh water lakes. The most remarkable fact respecting the tertiary strata is, that some of them contain numerous bones of large terrestrial quadrupeds of the class Mammalia, but these for the

---

* There are some situations in which the lower strata have not been subjected to any great dislocations prior to the deposition of the upper strata upon them, for the latter occur in a position parallel with that of the lower strata.

most part belong to genera or species which no longer exist upon the earth.

Volcanic and Basaltic Rocks have been either ejected from volcanoes, or poured out in a state of fusion from rents and openings on the earth's surface. They cover in an irregular manner the rocks of the preceding classes. In some situations the melted mineral matter has taken a columnar form in cooling; in other situations it fills vast fissures, called by miners *dykes*. Basaltic rocks are very common in the northern part of our island. Volcanic and basaltic rocks are of different ages: the most ancient approach in their nature to rocks of the primary class, and appear to be chiefly formed of the same mineral substances, more or less softened by subterraneous heat, and protruded through the crust of the globe.

Diluvial and Alluvial.—Considerable portions of the surface of the ground are in many countries covered with thick beds of gravel, sand, or clay, and fragments of rock and loose stones, more or less rounded by attrition. In some situations these have evidently been transported from a vast distance, for frequently no rock similar to the fragments occurs within a hundred miles or more of the place where they are deposited. They indicate the action of torrents and inundations, which have swept over the face of our present continents. The French have given to these depositions the name of *terreins de transport*, a name which defines them precisely, and involves no theory; for it comprises both deposits formed suddenly by mighty irruptions of the ocean, and alluvial deposits formed by the gradual deposition of sediment at the mouths of rivers or in lakes.

The classes of rocks above enumerated have their appropriate mineral productions, and, with the exception of rocks of the first and fifth classes, their appropriate organic remains; and it would be as useless to search for regular beds of common coal in the primary rocks, as it would be to search for metallic veins, or statuary marble, in the tertiary strata.

It has been before stated, that we cannot be absolutely certain that rocks of the same class and of a similar kind in distant countries were formed at the same time. This is more especially the case with rocks that contain no organic remains, such as granite, porphyry, and volcanic rocks, as it is only from their relative position that we can obtain evidence respecting their geological antiquity. Those rocks which generally serve as the foundation for the other classes are inferred to be the most ancient. Strata in the same class, that contain similar species of organic remains, are admitted to belong to the same geological epoch, and to have been deposited under the same condition of the globe ; yet admitting that certain distant strata were of coeval formation, it may be proved, that portions of the same series of strata have emerged from the ocean at different intervals of time, and that certain parts of the present continents have become dry land at very distant and remote epochs. The period when rocks or strata were first deposited has no necessary connection with the period of their elevation, as will be afterwards more fully stated.

I shall proceed to elucidate the situation of the different classes of rocks in England, by a reference to the outline map, Plate 6.

The waving line A A A, extending from the south-west of Dorsetshire to the county of Durham, forms a striking geological division of England : all the land on the east of this line is composed of the upper secondary and tertiary strata, in which neither metallic veins nor regular beds of mineral coal are found. The tertiary strata lie over the upper secondary, within the parts bounded by the letters *o o o o*. On part of the eastern coast of Yorkshire and Lincolnshire, there is a submarine forest about seventeen feet under the present highwater level. This forest appears to have extended eastward, as stumps of trees and roots may be seen at low-water at a considerable distance from the coast.

West of the line A A A there is an important change in the mineral productions; from thence to the line C C C the lower secondary strata appear, and most of the principal coal districts in England occur between the lines A A A and C C C. It is remarkable, that few if any regular metallic veins are found in this division. The lower secondary strata are also continued west of the line C C C, through the midland and northern counties, but rocks of the transition series occasionally appear in this part of our island. A very extensive coal district occurs in that part of South Wales bordering the Bristol Channel. On the east of the line C C C it may be remarked, that the strata geneally incline or dip to the south-east; west of this line they are more irregular, and dip in various directions.

West of the part composed of the lower secondary strata, and coloured green, we meet with rocks of the primary and transition classes, in which metallic ores are found; they constitute the alpine parts of England, passing through Cornwall and Devonshire, into North Wales, and the north-west parts of Yorkshire and Lancashire, and through Westmoreland and Cumberland, into Scotland. This part is coloured red; rocks of the primary class chiefly occur in the parts distinguished by dark lines.

Near the centre of England, at Charnwood Forest in Leicestershire, and at the Malvern Hills in Worcestershire and Herefordshire, the primary rocks pierce through the secondary strata, and compose two small districts of primitive country surrounded by secondary strata. Also in the counties of Derbyshire and in the West Riding of Yorkshire, and part of Cumberland and Westmoreland, rocks of transition or mountain limestone rise to a considerable elevation from beneath the secondary strata, which occur east and west of them; some of these limestone mountains are rich in metallic ores. Along the line E E beds of rock-salt and the principal springs of brine are situated.

It must be kept in mind when observing this map, that the tertiary strata lie upon the secondary, and the secondary upon the transition and primary rocks. Now, if the tertiary and secondary strata had both extended to the western counties, it is obvious that we could have had no knowledge of the existence of the lower series but by boring or sinking through the upper series; and the aggregate thickness of these exceeds the power of the miner to pierce through. The tertiary strata, however, only cover a part of the secondary, and the secondary do not cover the whole of the lower series; so that in travelling westward, we come immediately upon the lower strata in succession, as they rise from underneath each other; for, as I before observed, the general inclination or dip of the beds is towards the south-east. The action of the sea upon our coasts and cliffs, has exposed to view the succession of the different rocks and strata in many parts of our island, and has enabled us to obtain a correct knowledge of their thickness and direction, and of the organic remains peculiar to each series.

Before concluding the present chapter, let us take a view of some of the more striking appearances, which afford demonstrative evidence, that great changes have taken place in the relative level of the present continents, and that the ocean has in former ages rolled its waves over what are now the most elevated parts of the earth. Many proofs of this exist in our own island, and in various parts of the world.

The calcareous or limestone mountains in Derbyshire, and Craven in Yorkshire, rise to the height of about two thousand feet above the present level of the sea. They contain through their whole extent, fossil remains of zoophytes and marine animals, but more abundantly in some parts than in others. Particular species occupy almost exclusively distinct beds, and in some situations the whole mass appears a compact congeries of mineralised organic remains. Over these vast beds of ancient limestone occur a series of sandstone strata and shale, containing almost exclusively remains of terrestrial vegetables associated with beds of coal. Above this series we meet with other calcareous strata, containing remains of fish and enormous reptiles of the saurian or lizard tribe, intermixed with numerous species of bivalve and univalve shells, but of different genera or species from those living in the present seas. Again, in the uppermost or tertiary strata, we meet with bones and teeth of land quadrupeds of the class Mammalia, some of which belong to unknown genera, and nearly all to unknown species. Among these are the bones of large animals, as the mastodon, the elephant, the rhinoceros, the hippopotamus, and the gigantic tapir. These large animal remains occur chiefly in beds of clay or gravel, or in caves. In the latter situation they are abundantly mixed with bones of smaller quadrupeds, of which the species no longer exist in England.

The calcareous mountains of the Jura, and the outer range of the Alps, contain beds filled with the remains of marine animals, many of which I have examined, and found to be similar to those in the secondary strata in England. In the Alps they occur at the height of from six to eight thousand feet. Similar phænomena are observed in the calcareous mountains of the Pyrenees; and according to Humboldt, organic remains occur in the Andes, at the height of fourteen thousand feet. The distinct characters of the animals found in the upper and lower beds in these mountains, as well as in those of our own country, prove that they were not brought into their present situation by any sudden inundations, which would have mixed different orders of animals together. The beds which contain exclusively the remains of animals of the same species, must have remained for ages under the ocean; for these animal remains often compose nearly the whole substance of a bed of limestone of great thickness, as is the case with the beds of encrinal limestone in Derbyshire, and the limestone called coral-ragg at Steeple Ashton.

The fossil remains of animals not now in existence, entombed and preserved in solid rocks, present us with durable monuments of the great revolutions which our planet has undergone in former ages. We are carried back to a period when the waters of the ocean have covered the summits of our highest mountains, and are irresistibly compelled to admit one of two conclusions, — either that the sea has retired and sunk far below its former level, or that some power operating from beneath, has lifted up the islands and continents, with their hills and mountains, from the watery abyss, to their present elevation above its surface.

These organic remains present also undeniable proofs of another fact equally interesting. Every regular stratum in which they are disseminated was once the uppermost rock, however deep it may be below the present surface, or with whatever rocks it may now be covered. This inference is not the less conclusive, whether we suppose that the animals lived and died where their remains occur, or whether they were aggregated and carried by marine currents into their present situation. Hence we learn that the secondary strata were formed in succession over each other, and thus these fossil remains preserve the records of the ancient condition of our planet, and the natural history of its earliest inhabitants. The unknown causes by which zoophytes and different genera and species of testaceous animals, of reptiles, vegetables, and mammiferous quadrupeds were buried in different strata, have operated in succession at distant intervals of time; for we do not find the remains of different classes confusedly intermixed together, except in beds of clay or gravel, near the surface, or in fragments of various rocks which have been broken down and subsequently united. Bones of vertebrated animals, or such as had a brain and spinal marrow, have never been found in the lower strata, except of a few species of fish; nor have the bones of large mammiferous quadrupeds ever been discovered below the chalk. Hence we acquire a perfect certainty, that the different beds which form the crust of our planet were deposited in distant epochs, and under different conditions of the globe. The animal remains in some of the strata are so delicate, and so regularly deposited, that we can have but little doubt that the animals lived and died tranquilly where their remains are now found: in other strata the remains are dispersed and broken, and the animals appear to have perished by some sudden convulsion.

If the bones of man, or of mammiferous quadrupeds resembling existing species, have casually been found with fossil remains peculiar to the lower or more ancient strata, I believe a careful examination of all the circumstances, would generally explain the apparent anomaly. I shall state a remarkable fact of this kind, which came to my knowledge when engaged in a mineralogical examination for the Earl of Moira, in the vicinity of Ashby-de-la-Zouch, in Leicestershire: it will evince how cautious we ought to be in drawing general conclusions in geology, from single facts. A thick bed of coal belonging to his lordship, at a place called Ashby Wolds, is worked at the depth of two hundred and twenty-five yards; it is covered with various strata of iron-stone, coal, and solid sandstone. On an estate adjoining to his lordship's manor, in the same bed of coal (which is ninety-seven yards below the surface), the entire skeleton of a man was found imbedded. No appearance existed of any former sinking for coal; but the proprietor ordered passages to be cut in different directions, until the indication of a former pit was discovered, though the coal had not been worked. Into this pit the body must have fallen, and been pressed and consolidated in the loose coal by an incumbent column of water, previously to the falling in of the sides of the pit.

The imperfect skeleton of a woman, imbedded in a kind of calcareous sandstone, brought from Guadaloupe, and exhibited in the British Museum, may appear to invalidate what was asserted in the first edition of this work, that no instances have been known of human bones being found in regular stratified rocks, nor even in undisturbed alluvial ground, where the remains of extinct species of quadrupeds are not unfrequently met with.* Due attention to all the circumstances, will reconcile that assertion with the present fact. The skeleton from Guadaloupe is described as having been found on the shore below the high-water mark, among calcareous rocks formed of madrepores, and not far from the volcano called the Souffriere. The bones are not petrified, but preserve the usual constituents of fresh bone, and were rather soft when first exposed to the air. Specimens of the stone which I have in my possession, that were chipped from the same block, present, when examined with a lens, the appearance of smooth grains, consisting of rounded fragments of shells and coral, aggregated and united without any visible cement.

We have an example of a similar formation of calcareous sandstone on the north coast of Cornwall,

---

* Since the publication of the first and second editions of this work, I have seen in the possession of a gentleman at Plymouth, one of two human skulls that were found in digging a stream work, forty or fifty feet below the level of the river at Carnon in Cornwall. Nuts, and the horns of some animal allied to the stag, were discovered in the same situation. — In a note I made at the time, 1816, it is stated that the forehead was remarkably low and narrow, and the part of the skull which contained the cerebellum unusually prominent. That these skulls were ancient there can be little doubt, but there is no sufficient data to enable us to approximate to the period of their deposition.

The bone was not mineralised, though very hard. The absence or extreme rarity of human bones in these beds of gravel and clay, or in caves that contain the remains of large land quadrupeds, is far more extraordinary than their non-occurrence in the regular strata that cover our present continents.

composed entirely of minute fragments of shells. In the Arundel papers, there is mention of an inundation of sand, which covered a great part of the coast near St. Ives in the twelfth century: it is also known by oral tradition, that whole farms have been overwhelmed at a period not very remote; and at this very day, upon the shifting of the sands by high winds, the tops of houses may occasionally be seen. In several parts of the coast, this sand is seen passing into the state of compact rock, very difficult to break; and it is even used for building-stone. Entire shells of land snails and fragments of slate occasionally occur in it.* When I was in the county I examined numerous specimens of the rock with a lens, and compared them with a specimen of the Guadaloupe sandstone that I had with me, and they appeared closely to resemble each other. Dr. Paris, in an interesting paper read to the Geological Society of Cornwall, ascribes the consolidation of the sandstone to the infiltration of water containing iron, from the decomposing slate-rocks in the vicinity. Instances of the consolidation of beds of loose sand are common on the coast of Sicily. It cannot therefore excite surprise, that in a volcanic island like Guadaloupe, subject to violent convulsions from earthquakes, inundations, and impetuous hurricanes, human bodies should occasionally be discovered, that have been enveloped in driving sands, which have subsequently become indurated. The situation of this skeleton near the sea-shore, the state of the bones, and the nature of the stone in which they are imbedded, take away the probability of their high antiquity.

In the Institutes of Menu, which according to Sir William Jones are nearly as ancient as the writings of Moses, the account of the six days of creation so closely resembles that given in Genesis†, that it is

---

* See Guide to Mount's Bay and the Land's End.

† The discoveries in astronomy which proved the diurnal and annual motions of the earth, were for some time warmly opposed,

scarcely possible to doubt its being derived from the same patriarchal communication. There is, however, a particular definition given of the word *day* as applied to the creation, and it is expressly stated to be a period of several thousand years. If this interpretation be admitted, it will remove the difficulty that some have felt in reconciling the epochs of creation with the six days mentioned by Moses. The six days in which Creative Energy renovated the globe and called into existence different classes of animals, will imply six successive epochs of indefinite duration. The absence of human bones in stratified rocks or in undisturbed beds of gravel or clay, indicate that man, the most perfect of terrestrial beings, was not created till after those great revolutions which buried many different orders and entire genera of animals deep under the present surface of the earth. That man is the latest tenant of the globe, is confirmed by the oldest records or traditions that exist of the origin of the human race.

The great convulsions which have at distant periods changed the ancient surface of the globe, and reduced it from a chaotic to its present habitable state, were not, it is reasonable to believe, effected by the blind fury of tumultuous and conflicting elements, but were the result of determined laws, directed by the same wisdom which regulates every part of the external universe. Compared with the ephemeral existence of man on the earth, the epochs of these changes may appear of almost inconceivable duration; but we are expressly told, "that with the Creator a thousand years are as one day, and one day as a thousand years."

---

as being at variance with the motion of the sun and moon, and the motionless stability of the earth which the sacred writings describe. We should not, however, admire the judgment of the writer, who in the present day should publish a *scriptural astronomy*, in opposition to the Copernican system. The sacred writers describe natural objects as they appear to the senses, and do not teach systems of philosophy.

CHAP. II.

ON PETRIFACTIONS, OR FOSSIL, ANIMAL, AND VEGETABLE REMAINS.

Opinions of early Naturalists respecting Petrifactions. — On the Process called Petrifaction. — Experiment of Dr. Jenner on the Petrifaction of recent Bones. — Living Reptiles occasionally found in solid Stone. — Remarkable Difference in the Condition of Fossil Remains in adjacent Strata; Instance of this at Westbury Cliff, Gloucestershire. — The four grand Divisions of the Animal Kingdom. — Distribution of the Remains of certain Classes and Orders of Animals in each Division through the different Rock Formations. — Fossil Elephant proved to have been an Inhabitant of cold Climates. — Remains of Monkeys hitherto undiscovered in a Fossil State. — On Vegetable Petrifactions in the Transition, Secondary, and Tertiary Strata, supposed to prove the former high Temperature of the Globe in Northern Latitudes. — Observations on Fossil Organic Remains, as serving to identify Strata in distant Countries.

If it had been predicted a century ago, that a volume would be discovered, containing the natural history of the earliest inhabitants of the globe, who flourished and perished before the creation of man, with distinct impressions of the forms of genera of animals no longer existing on the earth, — what curiosity would have been excited to see this wonderful volume; how anxiously would Philosophers have waited for the discovery! But this volume is now discovered; it is the volume of Nature, rich with the spoils of primeval ages, unfolded to the view of the attentive observer, in the strata that compose the crust of the globe. The numerous and varied forms of organic beings, whose remains are there distinctly preserved, sometimes differ so much in structure from any known genera of animals, that we can scarcely hazard any probable conjectures respecting their modes of existence. Nor is it merely the forms of unknown animals that we discover in the different strata, we also learn the order of succession in which they first appeared on the globe.

It is only within a comparatively short period, that these fossil organic remains have engaged the attention of naturalists. It is true that in remote times, the occasional discovery of shells and bones of large animals imbedded in rocks, did not escape the attention of philosophers; but the shells were supposed to belong to species now living, and the bones to a gigantic race of men, that perished during some great inundation, or had been buried by earthquakes. Other hypotheses, equally remote from truth, serve to show how little attention had been bestowed on this department of Natural History. The celebrated botanist, Tournefort, from the regularity of form in many fossil remains, was induced to believe that they were stones that grew and vegetated from seeds. "How could the *Cornu Ammonis*," he observes, "which is constantly in the figure of a volute, be formed without a seed containing the same structure in the small, as in the larger forms? Who moulded it so artfully, and where are the moulds?"

As fossil organic remains, particularly shells and zoophytes, are found many hundred and even thousand feet below the present surface of the earth, the first enquiry that naturally suggests itself is, how did they come there? It is impossible that the animals when living, or their exuviæ when dead, could pass through such vast depths of solid rock. A few of them might fall into vertical fissures, and remain there*, but they could never in this way enter into

---

* Instances of reptiles found living in the midst of solid stone sometimes occur. At the colliery on Rothwell Haigh near Leeds, a living lizard or newt was found in a bed of coal at the depth of 180 yards from the surface. I saw it in the year 1819 soon after its discovery; it was preserved in spirits, and was about five inches in length. I could not perceive that it differed from the living species. The animal had probably crept into the mine along one of the levels that drain off the water, or down the sides of the shaft. The specimen is now in the possession of the Rev. A. Sharp, Vicar of Wakefield. In all instances where toads have been

strata almost entirely composed of organic remains. Beside, the strata now deep under the dry ground are chiefly filled with the remains of marine animals; nor do we generally find these animal remains confusedly aggregated; different genera or species occupy particular strata, or are associated with certain genera or species of the same class, and never with others. It is therefore evident that they were not brought into their present situations by vast inundations, and buried under the earthy matter which a subsequent inundation cast over them. Neither could zoophytes, fish, or large reptiles, or the inhabitants of bivalve or univalve shells, have lived and flourished in the midst of solid stone. We are therefore led to the conclusion, that each stratum which contains these organic remains was once the uppermost covering of the globe, and that the animals for the most part lived and died near where their bones or shells are now found, and were covered by successive

found in solid stone, it is reasonable to believe that they entered through fissures that have been subsequently closed. That these animals will live without food for a great number of years, is proved by the following circumstance.

The late Sir Thomas Blacket, of Britton Hall in Yorkshire, had one cellar which was only opened once a year, as it contained some particularly choice wine which was never brought to table but on the annual celebration of his birthday, which was on the 21st of December, or St. Thomas's day. The butler when taking out the wine, observed a small toad crawling along the stone floor. He placed the toad under a wine bottle, and thought no more of it till he went into the cellar the following year, when on removing the bottle he was much surprised to see the toad immediately leap. This circumstance he mentioned to Sir Thomas, who descended with his visiters into the cellar to look at the toad, after which the bottle was replaced, and the poor animal was kept a close prisoner till the succeeding year, when he was again uncovered, and found alive as before. The same annual experiment was continued for more than twenty-five years, when the wine was exhausted, the cellar cleared, and the toad, who was still living, was thrown out of doors. Having heard of this circumstance from a person who had lived in the family part of the time, I questioned the old butler respecting it, and he fully confirmed the truth of the story.

depositions of strata, on which following races of living beings flourished, and in like manner left their remains.

Animal or vegetable substances found imbedded in rocks, are more or less impregnated with mineral matter, and hence have been called petrifactions. The process of petrification consists in the infiltration of mineral matter into the pores of bone or vegetables. In some instances the animal or vegetable matter has been almost entirely dissolved or removed, and the mineral matter so gradually substituted, as to assume the perfect form of the internal structure either of the plant or animal.

The process of petrification may be more rapidly effected than has generally been supposed. In the year 1817, I paid a visit to the celebrated Dr. Jenner, at Berkley, who informed me that he had made several experiments upon recent bones, by burying them in the dark mud from the lias clay: in less than twelve months the bones became black throughout, and when dry, they were harder, heavier, and more brittle than recent bone, and the surface was shining. The specimens which he showed me, presented the same appearance as the fossil bones in the lias clay. The effect was probably produced so speedily by the presence of the sulphate of iron, and other saline ingredients with which that stratum abounds. As this stratum is the most remarkable of all the secondary series, for the large animal remains which it contains, particularly of the saurian or lizard order, and as the bones are frequently covered with crystals or incrustations of pyrites, I will venture to hazard a conjecture respecting the manner in which these crystals, or incrustations of pyrites, or sulphuret of iron, are formed. The stratum before mentioned, contains much sulphate of iron or green copperas in solution. I suppose that the carbon in the animal matter had decomposed the sulphuric acid and the oxide of iron, and that the sulphur and iron in their nascent state had united, and formed the sulphuret of iron or pyrites. I was led to this conclusion by reading an account by Mr. Pepys, of some mice having by accident been immersed in a jar containing a solution of sulphate of iron: how long they had lain there was unknown, but the remains were partly covered with small crystals of pyrites, which could only have been formed in the manner above suggested. The stone surrounding the organic remains in the lias, I have observed to be considerably harder than the other parts of the same stratum. The organic remains of zoophytes and shells in limestone strata are also generally harder than the stone in which they are imbedded; and on this account, when the stone has been exposed to the atmosphere a long time, the organic remains rise above the surface.

Organic remains are generally coloured by the strata in which they are imbedded; in roe-stone, chalk, and the upper fresh-water limestones, they approach to a yellowish or brownish white: in lias, bituminous shale, and dark limestone, they incline to black; and the shells in bituminous shale are sometimes filled with bitumen in a fluid state. In the strata above chalk, the bones and shells retain their original constituent parts very little changed; in chalk, and all the strata under chalk, the organic remains are more or less completely impregnated with mineral matter. The outer crust or shell of many chalk fossils is calcareous, and the internal part filled with flint. In some cases we meet with an internal cast formed in the cavity of a crustaceous animal, and the external covering has disappeared: in other instances, the shell or crust of the animal has formed a mould in the stone, into which mineral matter has been subsequently infiltered, and has thus made an external cast.

It is particularly deserving attention, that some animal remains contain the most delicate fibres and spines, perfect and unbroken: this proves that the mineral matter in which they are imbedded was deposited in a finely comminuted state, and in a tranquil sea. In some instances the most delicate shells are regularly arranged in the same position in which the animals lived and died, while the animal remains in the strata above or below them, are broken and confusedly aggregated together. The most remarkable instance of this kind I have ever observed, occurs at Westbury Cliff, on the northern bank of the river Severn, about seven miles below Gloucester. It is a low cliff, nearly perpendicular; the lower part is composed of what is generally called red marle, over which are the lower beds of dark argillaceous limestone and clay, called lias. A few yards above the junction of the lias and red marle, there is a thin stratum of dark micaceous sandstone, entirely filled with bones, and the teeth of the shark, and animals of the saurian or lizard tribe, broken and intermixed in the greatest imaginable disorder. Near the upper part of the cliff, not many feet above the stratum filled with bones, there is a thin stratum of whitish argillaceous limestone, called white lias, which is filled with the most delicate minute bivalve shells, all arranged in the same position, without any intermixture with shells of other species.

It is facts like these that are particularly deserving the attention of the geologist, as they mark in a striking manner the convulsions which the surface of the globe has at different periods undergone.

The stratum with aggregated bones of saurian animals appears again, on the other side of the Severn, at Aust Passage, where the junction of the lias and red ground may be also observed; but I could not discover there any trace of the white lias bed with the bivalves, similar to those at Westbury Cliff.

Some of the more delicately constructed animals, and the fish whose bodies are found entire, imbedded in stone, appear to have been instantaneously destroyed and enveloped in mineral matter, before the putrefactive process could commence.* The process of petrifaction must also, in some instances, have commenced almost immediately after the death of the animal. In some specimens of fossil fish from chalk, in the museum of Mr. Mantell of Lewes, the air bladder is uncompressed, and filled with mineral matter.

In tracing the different animal remains that occur in the lower, the middle, and the upper strata, the circumstance most worthy of notice, is the first appearance of any of the different divisions and classes of animals, and of the orders, genera, or species belonging to each division. In the luminous arrangement of Baron Cuvier, in his *Règne Animal*, all animals are distributed, according to their organisation, into four grand divisions—*Vertebrated*, *Moluscous*, *Articulated*, and *Radiated*.

1st, *Vertebrated.* — Animals which have a skull, containing the brain, and a spine or back bone, containing the principal trunk of the nervous system, commonly called the spinal marrow: they have red blood. This division comprises the mammalia (or animals that suckle their young), birds, reptiles, and fishes.

2d, *Moluscous.* — Animals in this division have no internal skeleton: the muscles are attached to the skin, which, in many species, is covered with a shell. The nervous system and viscera are composed of detached masses, united by nervous filaments: they possess only the senses of feeling, taste, and sight; but many species want the latter. They have a complete system of circulation, and particular organs for respiration. Animals with bivalve, univalve, or

---

* In the Museum at the *Jardin de Plantes* in Paris, there is a large specimen of two fossil fish, which are supposed to have been destroyed and covered with mineral matter, when one of them was in the very act of swallowing the other; but an inspection of the specimen inclined me to infer, that the two heads had been pressed together, by the incumbent weight of stone deposited upon them.

with chambered shells, belong to this division; but many moluscous animals have no shell.

3d, *Articulated.* — To this division belong worms, crustaceous animals, and insects: their nervous system consists of two long chords, ranging along the body, and swelling out in different parts into ganglions and knots. Worms having their bodies composed of rings, are called annelides; they have red blood: some species inhabit a calcareous tube, supposed to be formed by exudation.

4th, *Radiated* — comprises all the animals which were by former naturalists called zoophytes, or animal plants, as the corallines, &c. which were long mistaken for marine vegetables. In animals of this division, the organs of sense and motion are disposed circularly around a centre or axis. They have no distinctly marked nervous system, and the traces of circulation in many species can scarcely be discerned. Many of the animals in this division have no power of locomotion, as madrepores and encrinites. Others, as the echinus, possess a very complex organisation, and the power of moving from place to place on their spines, which serve them for feet.

In describing the order in which the organic remains belonging to each of these grand divisions are distributed through the different classes of rocks, it will be more convenient to begin with the lowest.

Radiated Animals, such as encrini and madrepores, have left their remains abundantly dispersed through rocks of the transition series: many of the strata appear almost entirely composed of their mineralised exuviæ, but generally in a broken state. The chain coral occurs occasionally in transition limestone. Other genera of radiated animals occur in the more recent formations of limestone, but seldom in sufficient abundance to compose nearly the whole mass of a stratum. This is the more remarkable, as coralline animals are forming extensive calcareous rocks in our present seas. Some genera and species of radiated animals which abound in transition rocks, have not left their remains in any of the upper strata; hence it might be inferred that they had long been extinct. In some instances the inference is not correct; the *Madrepora stylina*, so common in transition limestone, is entirely wanting in the secondary and tertiary strata; but a living animal of this species has recently been discovered in the South Seas. The pentacrinus, which is chiefly distinguished from the encrinus by its pentagonal stem and branches, makes its first distinct appearance in the lias, but is not frequently met with in the upper strata, and disappears entirely in the uppermost formations: hence it was long supposed that the species was extinct. A living pentacrinus has lately been discovered in the West Indies, and its stem and branches in a perfect state have been sent to this country; and still more recently a living pentacrinus was found in the Cove of Cork.

The genus echinus makes its first appearance in the midst of the secondary strata, and various species are continued into chalk, which abounds with remains of this animal in high preservation. It may be remarked, that scarcely any calcareous stratum abounding in marine organic remains has been examined, in which remains of some species of radiated animals may not be found.

Articulated Animals. — Some species of worms (annelides) inhabiting tubes, have left their remains in the upper secondary, and tertiary strata: remains of crustaceous animals (crabs, &c.), are not numerous in the upper secondary strata, where they first occur; but they are more common in chalk and the tertiary beds of clay covering chalk. One of the very first inhabitants of the globe appears to have been a crustaceous aquatic animal, called in England the Dudley fossil, from its being first noticed in the transition limestone near that town. Its more appropriate name is the *Trilobite*, from the three parallel lobes or divisions of the body, with ranges of transverse ventral fins, somewhat similar to those under the tail of a lobster. The largest species are found in the slate quarries at Angers, in France. A specimen in my possession, from that place, measures seven inches in length: the body has taken the flat form common to almost all fossils found in slate, (See Plate 5.) it scarcely rises more than one third of an inch above the surface of the slate; the upper slate contains the impression or mould of the animal. To this species Guettard has given the name of *Ogyges*, from its occurrence among the most ancient rock formations, that contain vestiges of organic life.

The remains of winged insects have sometimes been found in the upper secondary strata in England, particularly in the calcareous slate of Stonesfield, Oxfordshire, where numerous impressions of the elytra, or hard cases which cover the wings, of coleopterous insects occur. Professor Buckland very ingeniously conjectures that these winged insects might serve as food for the flying lizards (Pterodactyli) that are found in the same strata, and were cotemporaneous with them. Of all the four grand divisions of the animal kingdom, the *Articulated* has supplied the smallest number of fossil organic remains.

Molluscous Animals. — Shells of these animals, chiefly bivalves, occur in the limestones of the transition series; but the number of the species is comparatively small. Some chambered shells, particularly orthoceratites, are found in transition limestone.

In the secondary strata that cover the transition series, shells of molluscous animals, both bivalves and univalves, are more abundant, and the number of the species is greatly increased.

It is in the lower strata of this series that chambered shells, such as nautilites and ammonites, first become numerous: some species are continued into the chalk strata, but no ammonites are found in the strata above chalk. Trochiform or top-shaped spiral univalve shells first appear in the lower part of the secondary series, but become more numerous in the upper part of this series. In the tertiary strata above chalk, the species of univalve shells greatly exceed that of the bivalves: in the lower strata the reverse is the case. We may further remark, that, as the tertiary strata are the most recent of regular rock formations, so the organic remains which they contain, bear a closer resemblance to the shells of molluscous animals living in our present seas, than what are found in the more ancient strata. Some of the shells in the upper part of the tertiary strata appear, indeed, to be identical with those of existing species.

The different classes and orders of molluscous animals that have left their remains in the lower and the upper strata, doubtless possessed each the peculiar organisation that best enabled them to exist and multiply under the peculiar condition of our planet, that was cotemporaneous with the epoch of their creation. When this condition was changed, their numbers were diminished, or they disappeared entirely, and were succeeded by different races, with an organisation adapted to other modes of existence, and to the new circumstances in which they were placed. Such are the legitimate inductions we appear justified in making, from the organic remains in the different strata. The further consideration of this interesting enquiry will be resumed in the succeeding chapters.

Vertebrated Animals are arranged under four classes: — fishes, reptiles, birds, and mammiferous animals. Remains of fishes are exceedingly rare in transition rocks; but they appear decidedly in the lower secondary strata. The entire bodies are sometimes well preserved; and the bones, scales, teeth, and vertebræ are met with occasionally in almost all the strata that contain fossil shells, whether secondary or tertiary. Many of the species bear a close resemblance to species at present existing, either in the ocean or in rivers.

The bones and entire skeletons of reptiles allied to the saurian or lizard class occur in the lower part of the secondary strata, and are very abundant in a dark argillaceous limestone called lias, and in the beds of clay that are over it. These animals are many of them different from any known existing genera: they were inhabitants of the ocean, and furnished with paddles instead of feet.* In the upper secondary strata, between the lias and chalk, the remains of other saurian animals, closely allied to living species of crocodiles and lizards, are fully developed: they had feet, and were evidently amphibious. Of the saurian animals in this series, that called the iguanodon, discovered by Mr. Mantell, near Cuckfield, in Sussex, is the most remarkable for its size; the length exceeding eighty feet, and the thickness of the body being equal to that of the elephant. It is supposed to have been herbivorous. It closely resembles in structure the iguana, a native of America and the West Indies.

The fossil remains of birds are so rare, that their occurrence in any of the regular strata was long considered doubtful. The bones recently discovered in some of the English secondary strata, supposed at first to be those of birds, belong to species of flying lizards. Bones of birds are, however, found in some of the tertiary strata, particularly in the gypsum near Paris.

---

* The ichthyosaurus, or fish lizard, had an organisation intermediate between that of a lizard and a fish: its paddles were long, broad, and flat, to enable it to move rapidly through the water: the orbits of the eyes are enormously large. Four species have been ascertained; some are of immense size. The Plesiosaurus, another genus more nearly approaching the organisation of the lizard, is distinguished from all oviparous quadrupeds by the form of its neck, which is longer than its body, and is composed of no less than thirty vertebræ, exceeding in number those in the neck of the swan. This animal is supposed to have swam on the water, with its neck arched to dart on its prey. The *Testudo ferox*, living in the rivers in Florida, is somewhat similarly constructed: it hides itself in reeds, and darts out its head suddenly, to seize birds and other animals. There are five species of the Plesiosaurus, some of them were more than twenty feet long. Remains of flying lizards have been discovered in a fossil state in Germany, and very recently in Oxfordshire and Dorsetshire.

Vertebrated animals of the highest class, the mammalia, occur in the tertiary strata, and in ancient beds of gravel and clay. Cetaceous animals, allied to the whale and seal, have been found in some of the tertiary strata; but they are by no means common. The bones of herbivorous land quadrupeds occur in the upper part of the tertiary beds, or what may be regarded as the latest geological formations: they are more frequently found in beds of clay and gravel than in the solid strata. Cuvier has ascertained the existence of fossil bones belonging to about seventy species of mammiferous quadrupeds, in the tertiary strata near Paris. Nearly forty of these are of extinct species, and several of them belong to extinct genera. A very considerable number of the large fossil bones belong to the different genera and species of the order named by Cuvier *Pachydermata*, or thick-skinned non-ruminant animals; as the elephant, the mastodon, the tapir, the hippopotamus, the rhinoceros, and the palæotherium. As these bones are very abundantly found in many countries in northern Europe, the fact proves either that the animals were natives of cold and temperate climes, or that the temperature of the earth has decreased. The entire body of an elephant embedded in ice, in Siberia, was found in the year 1799. Its skin was covered with two kinds of coarse hair and a soft fur beneath, which affords almost certain proof that the animal was an inhabitant of a cold climate, or at least of one in which the winters were severe. A similar defence against cold is provided for terrestrial quadrupeds that inhabit cold countries, but is never observed in tropical climates, except in mountainous regions that have a low temperature. The author's attention was directed to this subject many years since; and in his "*Observations on the Effect of Soil and Climate on Wool,*" he has stated instances of English long-woolled sheep casting their fleece in hot climates, and being clothed with short coarse hair like bristles. Bishop Heber, in his travels in the Himalayan mountains, mentions a species of elephant which he saw there, not larger than an ox, and "as shaggy as a poodle." He further states, "that English dogs, brought to those mountains, in a winter or two acquire the same short fine shawl wool, mixed with their own hair, which distinguishes the indigenous animals of the country: the same is in a considerable degree the case with horses." The fossil elephant that was once a native of Europe, according to Cuvier, differed as much from the Asiatic or the African elephant, as the horse differs from the ass. Bones and teeth of extinct species of carnivorous quadrupeds most frequent are found in caverns, intermixed with bones of herbivorous animals, in a broken state. Since the time that these bones have been examined by naturalists who have attended to comparative anatomy, no vestiges of human remains have been discovered; nor have any of the bones of the animals which approach nearest to man in structure, the *Quadrumanes* or monkeys, been yet found with those of the more ancient inhabitants of the globe. The vast diluvial beds of gravel and clay, and the upper strata in Asia*, have, however, not yet been scientifically explored; and both sacred and profane writers agree in regarding the temperate regions of that continent, as the cradle of the human race.†

Vegetable Petrifactions.—The remains of vegetables found in different strata afford interesting information respecting the ancient condition of our planet,

---

* In the diluvium near the river Irrawaddy, in Ava, Mr. Crawford has recently discovered numerous bones and teeth of two new species of mastodon, intermixed with bones of the rhinoceros and hippopotamus. The bones are penetrated with iron.

† It has been conjectured, that the bones of man are more fragile and perishable than those of land quadrupeds; but this is contrary to experience: for it has been well observed by Cuvier, that the bones of men, left on the field of battle with those of horses, are as well preserved as the latter, making allowance for the difference of size. Neither is there any essential difference in the chemical constituent parts of human bone from those of other

which we could not have obtained from animal remains alone. The animal remains found in the transition rocks are almost exclusively marine; hence we could not have inferred, from these remains alone, that any portion of the globe was dry land when these rocks were deposited. In some of the slate rocks, however, a few remains of terrestrial plants, analogous to ferns, occasionally occur, which indicate the existence of islands or tracts of land at that remote epoch. In the strata of sandstone and shale, which alternate with coal and cover transition rocks of marine origin, the remains of terrestrial vegetables are abundantly distributed, and those of marine animals disappear entirely in most of the beds: the part formerly covered by the sea had, therefore, become dry land, with rivers, lakes, and marshes, on which the plants had grown, or were deposited. Again, at a subsequent period, the dry land and its vegetation became buried under a deep ocean, that deposited numerous calcareous beds, filled with shells and remains of marine animals, but occasionally containing a few broken fossil stems of terrestrial plants, which had probably been carried into the ocean by the rivers of distant countries. In the upper strata, the alternation of marine and fresh water formations are distinct and frequent.

Now it appears that a progression from simple to more complex, or, in other words, from less perfect to more perfect forms, takes place in the vegetable as

animals of the class mammalia. Dry bones, according to Berzelius, contain as under: —

	Human Bones.	Human Teeth.	Ox Bones.	Ox Teeth.
Cartilage - - - -	33	—	33	3·5
Phosphate of lime -	51	85·3	55	81
Carbonate of lime -	11·5	8	9	7
Fluate of lime - -	2	3·2	3	4
Phosphate of magnesia -	1·2	1·5	2	3
Soda and muriate of soda	1·3	2	2	2

well as in the animal kingdom, as we ascend from the lower to the upper or more recent strata.

I will endeavour to state this intelligibly to the geological student, who may at present be unacquainted with vegetable physiology, avoiding technical expressions as much as the subject will admit of.

Vegetables of all kinds may be arranged under two grand divisions — *Cellular* and *Vascular*.

Cellular — without regular vessels, but composed of fibres, which sometimes cross and interlace. Confervæ lichens, fungi, algæ, or sea-weed, and mosses belong to this division. In some of these families there are no apparent organs of fructification.

Vascular—with vessels which form organs of nutrition and reproduction. According to the arrangement of these organs, and their number or complexity, vascular plants may be divided into the following classes, and each class contains distinct families: —

1. Without perfect flowers, the organs of fructification concealed (*cryptogamia*). To this class belong in the fossil state gigantic ferns, equisetum (*horse tail*), and other plants allied to ferns.
2. With flowers, the seeds naked or without capsules. To this class belong the family of cycas and coniferæ or firs. This class is denominated phanerogamia gymnospermous.
3. Flowering plants with one cotyledon: phanerogamia monocotyledonous. It comprises water-lilies, palms, lilies, and canes.
4. Flowering plants with two cotyledons; this comprises all forest trees and shrubs: Phanerogamia dicotyledonous.

None of the families of plants but those in the last class have the true woody structure, or produce perfect wood, except the coniferæ or firs, &c.; but the wood of these differs from true dicotyledonous wood.

In tracing the distribution of vegetables through the different classes of rock, we shall find only the lowest or simplest forms of organisation, in the most ancient formation.

1. Transition slate contains occasionally impressions of algæ or sea weed; but, considering the frail texture of the cellular plants, we cannot expect the forms to be well or abundantly preserved in rocks, which have probably been subjected to heat and various disturbing agents. A few fronds or leaves of ferns have been found in some rocks of this class.
2. Coal-measures abound in vegetable remains of the first or lowest class of vascular plants. Gigantic ferns, large equisetums (horse tail), and lycopodia are of frequent occurrence. Palms and canes are more rare.
3 The secondary strata are principally marine formations; but the beds of sandstone and clay frequently contain vegetable remains of plants of the second class (ferns and lycopodia, &c.), but of different species to those found in the regular coal measures. In part of this series occur fossil remains of the third class, coniferæ and cycas. In the marine strata are occasionally found broken fossil stems, but the vegetable fossil remains appropriate to them are of algæ or sea weed. Plants of the fourth class sometimes occur in the upper secondary strata.
4. Tertiary strata contain fossil plants of the more perfect classes, which are rarely if ever found in the secondary strata. Some of the most recent tertiary beds contain remains of trees analogous to what now flourish in Europe.

The above brief outline may be taken as a near approximation to the distribution of the different classes of fossil vegetables. The instances of trees or plants of the highest class found in coal are doubtful; for stems of large lycopodia divided into two branches at the top, have not unfrequently been mistaken for trees that have the true woody structure.

The progressive developement and succession of more perfect forms, as we ascend from the ancient to the most recent strata, appears confirmed by the fossil remains both of animals and vegetables. These remains afford a mass of positive concurrent evidence that cannot be refuted by negative arguments. We are told that the bed of the sea has not been dredged, to discover what species of animals have existed in former ages. The geologist can have no need of such an operation. If the bottom of the sea has not been dredged it has been laid bare, and is now exposed over an extent equal to that of the habitable globe. For every island and continent has formed part of an ancient bed of the ocean, and that not only once, but repeatedly and at distant epochs. This extended surface of the bed of the ancient ocean, is exposed to the examination of thousands of observers in every degree of latitude, not covered by polar snows. These examinations have hitherto confirmed the position (taken with certain limitations) that a progressive developement of more perfect organic forms, both in the animal and the vegetable kingdoms, may be traced from the most ancient rocks in which these remains appear, through the different classes of rock, until we ascend to the most recent, which contain remains of animals analogous to existing species. All or nearly all the instances that have been cited of animals of the higher classes being found in ancient strata have proved, on further examination, to be fallacious; yet when we consider what disturbing causes have acted on the crust of the globe, it need not appear surprising if recent species of animals should sometimes be found buried in the lower rocks: this, however, would not affect the present question. The subject will be referred to in a subsequent chapter.

In fossil vegetables, the original vegetable matter is often so completely removed, that no trace of it is visible, and the stem appears converted into ironstone, sandstone, or chert. In some instances the surface of the stem is black and carbonaceous, and all the inner part is mineralised. Sometimes, even when the stem is completely silicified, the vegetable organisation is still perceptible, and some traces of the vegetable principles may be obtained by distillation.

As most of the vegetable remains found both in the secondary and tertiary strata are analogous to the plants of tropical climates, it has been inferred that the temperatnre of the globe was once considerably higher than at present. It cannot be denied that there are many geological phenomena which strongly favour this conclusion: there are, however, some striking facts which seem opposed to it. The consideration of this question will, therefore, be resumed in another part of the present volume.

OBSERVATIONS.

The author has attempted, in this chapter, to give a succinct account of the geological distribution of fossil organic remains belonging to the animal and vegetable kingdoms. This, he conceives, will interest the learner, for whose use it was chiefly intended, more than a detailed enumeration of the genera or species supposed to be peculiar to different rock formations. With respect to fossil conchology, he is inclined to believe, that the attempt to identify the strata of distant countries by the isolated occurrence of any particular species of shell, has been carried farther than a sound induction from facts or analogy would warrant. His opinion on this subject, given in the second edition of this work, he will here insert: — "It may be doubted whether the occurrence of similar organic remains is sufficient to identify strata in distant parts of the globe; for could we admit that strata are universal formations, and extended from the frozen to the torrid zone, it seems more than probable, that the animals which lived on any one particular stratum would be of very different species in different latitudes." — We know so little respecting the forms or habits of the animals classed by the conchologist, that we are far from certain whether many shells which he regards as belonging to different species, or even genera, are not mere varieties of form, occasioned by difference of age or situation. Such a change is ascertained to take place by age in shells of the genus *Cypræa.*

In animals like the mollusca, which have no internal skeleton to determine their form, the construction of the external shell may probably admit of considerable variation under a change of circumstances. Few conchologists, excepting M. D'Avilla, have made accurate observations on the living animals inhabiting oceanic shells. His interesting work, entitled "*L'Histoire Naturelle éclaircie dans une de ses parties principales, la Conchologie; et augmentée de la Zoomorphose, ou Répresentation des Animaux à coquilles, avec leurs Explications,*" — presents us with some truly extraordinary forms of molluscous animals, of which we could not have had a remote notion from the mere study of the shell.

In strata belonging to one formation, and in adjacent districts, the existence of certain shells, whether we regard them as distinct species or as varieties, may be of use in identifying any particular bed: — and in distant countries where we find the same remarkable species of shell associated with any other remarkable species in considerable numbers, it may serve to indentify a particular rock formation, where the mineral character of the rock may be very different from that in which the observer has been accustomed to meet with them. The occurrence of a considerable number of gryphææ, the *Gryphæa arcuata*, in a bed of blue clay in the mountains round the Lake of Annecy, in Savoy, served the author as a key to discover to what formation the calcareous strata belonged, when their mineral characters would have indicated a more ancient series.

Vegetable organic remains have not till recently been studied with the attention they deserve and require. — These remains are never found entire, as is frequently the case with the skeletons and exuviæ of animals: they cannot, therefore, be satisfactorily studied in cabinet collections. Were any botanist well acquainted with vegetable physiology to devote some time to exploring the vegetable remains, as they are abundantly brought up by our coal-miners, they might have the opportunity of re-constructing many entire species from the fragments; but, in order to form a geological classification of fossil plants, a practical acquaintance with all the secondary strata is further required. The attempt of M. Adolphe Brongniart to give a geological classification of the families of plants peculiar to each principal formation, is entitled to high commendation, as the nearest approximation to a correct arrangement of fossil plants that has yet been made. See his "*Histoire des Végétaux fossiles,*" and his "*Prodome* d'un Histoire des Végétaux fossiles."

CHAP. III.

ON THE MINERAL SUBSTANCES THAT COMPOSE THE CRUST OF THE GLOBE; AND ON THE STRUCTURE OF ROCKS.

The constituent Elements of the simple Minerals that compose Rocks. — The physical Characters of simple Minerals composing Rocks. — Explanation of the Terms employed in describing the internal Structure of Rocks, and the external Structure of Mountain Masses. — Sedimentary Depositions.

The most careless observer can scarcely fail to notice, that the mineral substances which occur on the surface of the globe differ from each other in density, hardness, colour, and other sensible qualities. Indeed, the different varieties of stone appear at first so numerous, as to render it difficult to become acquainted with them: but, however numerous these varieties may be thought, the simple minerals which compose rocks or strata are very few, and the elementary substances of which each of these minerals is formed are still fewer.*

The elementary substances of which the solid matter of our globe is composed, are the *Earths*, —

---

* The mineralogist and the geologist consider those minerals as simple and homogeneous, which present no difference of qualities to our senses throughout the mass, although the chemist may discover that such minerals are composed of two or more elementary substances. Thus, limestone or marble is regarded as a simple substance, though chemistry has discovered that it contains, in every 100 parts, lime 57 parts, and carbonic acid 43. It is the latter which is expelled from it by burning; a process which is well known to make the stone lighter, and to render it caustic; in which state it is called quicklime. Nor do the researches of the chemist end here: the two substances, quicklime or pure lime, and carbonic acid, are themselves compounds: the former, lime, is a compound of a metallic substance called calcium, united with oxygen; the latter, or carbonic acid, is composed of oxygen and carbon or charcoal.

silex, alumine, lime and *magnesia.* The *Metals,*—*iron* and *manganese.* The *Inflammable Principles,*—*carbon* and *sulphur;* and the *Alkalies,*—*potash* and *soda.*—*Muriatic* and *Phosphoric Acid* occur also in the mineral kingdom. The newly discovered earths and alkalies, and metallic ores cannot be regarded as forming essential constituent parts of rocks: they chiefly occur in veins. The four earths above enumerated, together with iron, compose nineteen parts in twenty of the known solid matter of the globe. The Earths, when pure, are infusible, except at an intense heat; they are nearly insoluble in water at the common temperature: when pure, they are white or colourless. Though the earths are infusible when pure, if they are combined in certain proportions, they may be fused with facility at a comparatively low temperature.

Silex, or *Siliceous Earth,* exists nearly pure in large masses, forming minerals, and even entire rocks, as rock crystal, quartz rock, and flint: it communicates a great degree of hardness to all rocks or stones in which it enters in a large proportion. Such stones are denominated Siliceous: they resist the point of a knife, or scratch glass. In its combinations with other earths, Silex appears to act as an acid. More than one half of the crust of the globe is composed of siliceous earth either pure or combined. In some thermal waters, siliceous earth occurs either in a state of minute division or in solution; and the waters of the boiling springs, or geysers, in Iceland, deposit siliceous incrustations of considerable thickness.

Alumine, pure argillaceous Earth, (Lat. *argilla,* Fr. *argille,*) is a substance which in a mixed state is well known, but pure unmixed clay is one of the rarest substances in the mineral kingdom. This earth is soft, smooth, and unctuous to the touch; it strongly absorbs water; where it exists in the proportion of thirty per cent, it communicates in some degree these properties: such rocks are called argil-

Magnesia has rarely been found pure in a native state. It enters into the composition of some of the primary rocks, to which it generally communicates a soapy feel, a striated or striped texture, and sometimes a greenish colour. It occurs also in various limestones in different proportions.

Iron appears to be more abundant than magnesian earth: it forms a constituent part of numerous rocks and stones; to it they most frequently owe their colour: the earths, when pure, are white. Iron, when in combination with the earths, is, like them, an oxide, or a metal united with oxygen. To the presence of iron the increase of specific gravity in all stones or earthy minerals may be attributed, if it much exceed 2·5, or approach 3: in other words, if they are

---

* Though alumine or pure clay communicates a soft quality to most stones of which it forms a principal constituent part, a very remarkable exception to this is offered in adamantine spar and the sapphire, which nearly equal the diamond in hardness. Klaproth, one of the most laborious and eminent chemists of the present age, has analysed these stones: the former contains 90 parts in the 100 of pure clay; the latter 95 parts in the same quantity. "What a high degree of cohesive power (he observes) must nature command, to be able to transform such a common substance as clay (aluminous earth) into a body so eminently distinguished and ennobled as the sapphire by its hardness, brilliancy, and its resistance to the action of fire, of acids, or the effects of all-destroying time!" —*Klaproth's Essays.*

nearly three times heavier than an equal bulk of water. Gems and the earths barytes and strontian are exceptions; but these never form entire rocks. The presence of iron not only increases the weight, and darkens the colour of numerous rocks and stones, but is one principal means of their decomposition, for iron exists in stones in two states of oxygenation, as the black or the red oxide; and when the former is exposed to air and moisture, it absorbs a greater portion of oxygen, and is converted into a brown ochrey incrustation, which peels off, and exposes a fresh surface of the stone to a similar process.

Manganese, in a state of oxide, occurs in a few rocks, to which it generally communicates a dull reddish colour inclining to purple, and a peculiarly dry and burnt-like appearance.

Sulphur, though found in considerable masses, cannot by itself be regarded as a constituent part of rocks; but when it is combined with oxygen forming sulphuric acid, it unites with lime, and forms the well-known mineral gypsum or plaster stone.

Carbon, or *Charcoal*, enters as a constituent part into many of the slate rocks, to which it generally communicates a dark colour: it forms also regular beds of considerable thickness, being the principal constituent part of coal. Carbon, combined with oxygen, forms carbonic acid or fixed air, which is combined and solidified in all limestone rocks in a proportion exceeding two fifths of the whole weight. As carbon exists in such a large proportion in even the oldest limestones, we may regard it as a constituent element, and not as a substance derived from the vegetable kingdom. For whence did the vegetables themselves derive their carbon?

Potass and *Soda*. — These alkalies occur in minerals which compose parts both of primary and volcanic rocks; but the proportion is so small, that they would scarcely deserve the attention of the geologist, did not the latter alkali, soda, exist in such abundance in the waters of the ocean and in rock salt. Pure sea salt, or rock salt, contains nearly 53½ parts of soda, 46½ muriatic acid or chlorine.

Muriatic acid, combined with soda, is the only state in which this acid forms a constituent part of any rocks we are yet acquainted with; except in some volcanic rocks, where it may be regarded as accidental.

Phosphoric Acid, combined with calcareous earth, is a principal constituent of animal bones: it occurs also in a few limestone beds, which are supposed to have derived phosphoric acid from the decomposition of animal matter. This acid is of very rare occurrence in the mineral kingdom.

The above elementary substances, either separately or combined, form all the simple minerals of which rocks are composed. A knowledge of these minerals, and their different intermixtures and combinations, can only be learned by an examintion of specimens: they are, however, far from being numerous; and a short description of each is necessary in an introductory treatise.

The most important simple minerals composing rocks are quartz, felspar, mica, talc, chlorite, hornblende, serpentine, limestone, and slate.

Quartz is one of the hardest minerals of which mountain masses are composed: it gives plentiful sparks with steel; it breaks with a smart stroke of the hammer; the surface of the fracture in crystallised quartz is conchoidal, in uncrystallised splintery: the lustre is vitreous. Crystals of quartz, or rock crystals, as they are commonly denominated, have different degrees of transparency: the blue varieties are amethysts. The most common forms of the crystals are six-sided prisms terminated by six-sided pyramids; or, two six-sided pyramids united, forming a dodecahedron, whose faces are isosceles triangles. Uncrystallised quartz is seldom transparent, most frequently translucent, but sometimes opaque. Its colours are various shades of white, grey, brown, yellow, red, and green. It yields a phosphorescent light and peculiar odour when rubbed. Quartz is composed of siliceous earth, combined with a very small portion of alumine. It is infusible when unmixed, but with alkalies it melts easily, and forms the well-known substance called glass. It is not acted upon by any acid except the fluoric. Quartz exists in veins intersecting mountains, and it sometimes forms large beds, and even entire mountains, which are composed of this mineral in grains united without a cement, called granular quartz. Fragments or crystals of quartz are common in compound rocks. Grains of quartz form a principal constituent part of most sandstones. The milkwhite pebbles in gravel are composed of quartz. Flint, chert or hornstone, opal, chalcedony, and agate, are different modifications of siliceous earth, which in their chemical composition differ little from quartz. Combined with a large portion of alumine and iron, quartz loses its translucency and passes into jasper, which forms beds in primitive mountains, and is said to compose the substance of entire ranges of mountains in Asia.

Felspar or *feld-spar* (a name received from the Germans) is a constituent part of numerous rocks. It is hard in a somewhat less degree than quartz, and is more easily broken. It is laminar, or composed of thin laminæ or plates, by which it may be generally distinguished from quartz. The crystals are most commonly four-sided or six-sided prisms, whose length is greater than the breadth. It has a shining lustre. The colours are white, grey, milkwhite, yellowish or reddish white, sometimes inclining to green. The red passes through various shades, from a pale to a deep red. Crystallised felspar is translucent. It may be melted without the admixture of alkalies, and forms a glass more or less transparent, which quality it derives from the limes or alkali that compose part of its constituent ingredients; but different specimens of this mineral vary, according to the analyses of the same chemist.

Silex - - -	63 —	74
Alumine - -	17 —	14
Potash - - -	13 —	
Lime - - -	3 —	6
Oxide of iron	1 —	
Loss - - -	3 —	6

Others give the proportion of silex 46, alumine 24, lime 6.

The existence of potash, or the vegetable alkali, in felspar, is a fact deserving particular attention.* It may be owing to this circumstance that felspar is so frequently observed in a soft or decomposing state, although its hardness is little inferior to that of quartz when undecayed. Those felspars which are durable are probably free from potash. Felspar occurs in many rocks in a compact form; constitutes the principal part of most porphyries, and of the lighter-coloured lavas. Compact felspar differs from hornstone, the latter being infusible without the addition of alkalies.

Mica derives its name from the Latin *micans*, glittering. It is known as the substance called Muscovy glass, and has a splendid lustre. It consists of very thin leaves or laminæ, which may be easily separated with a knife. The plates are elastic, by which it may be distinguished from the mineral called talc. The thin plates are transparent. The colours of the thick plates are yellow, grey, blackish green, white, and brown. The surface may be scratched with a knife: it melts into an enamel with the blowpipe: it is sometimes crystallised in six-sided risms.

Talc nearly resembles mica in appearance. The

---

* It has recently been discovered, that, in some of the felspathic rocks, soda occupies the place of potash, and gives a slight change to the crystalline form: this variety some mineralogists are desirous of making a new species, and have proposed to give it the name of Cleavelandite; but geology and mineralogy are already too much burdened with unmeaning terms, and if a new name must be introduced, that of felsparite would be more appropriate, and convey an idea of its approximation to felspar.

plates are flexible, but not elastic: it is much softer than mica, and is infusible; its colours generally incline towards green, but it is sometimes a silver white: it has a soapy feel. *Chlorite*, which is nearly allied to talc, derives its name from *chloros*, the Greek word signifying green. Talc and chlorite pass by insensible gradations into each other, and in this state they supply the place of mica in most of the granitic rocks that I have examined in the vicinity of Mont Blanc. Chlorite is of a darkish dull green colour; it has a glistening lustre; its structure is minutely foliated; it is soft, and rather unctuous. The constituents of these three minerals are, —

	Mica.	Talc.	Chlorite.
Silex - - - -	50	62	41
Alumine - - -	35	2	6
Lime - - - -	1		1
Magnesia - - -	2	27	40
Oxide of Iron - -	6	3	10
Water and loss -	6	6	2;

but these proportions vary in different specimens.

Hornblende, to which the French give the name of *amphibole*, forms a constituent part of many rocks, and appears to connect the primary with those which are of volcanic origin. It is of a black or dark green colour: it is heavier, but less hard, than quartz or felspar: it may be scratched with a knife, and the colour of the streak is a light green: it yields a bitter smell when breathed upon, and melts easily into a black glass. Common hornblende is often confusedly crystallised: it sometimes forms entire mountains, or slaty beds in mountains, and is very commonly met with in granular pieces as an ingredient in compound rocks: when it becomes more abundantly and minutely disseminated in them, it forms what are denominated trap rocks, whose origin has greatly divided the opinions of geologists. Hornblende and the rocks to which it is most nearly allied contain as under: —

	Hornblende.	Basalt.	Obsidian, or volcanic glass.	Lava.
Silex	42	44	72	49
Alumine	8	16	12	35
Magnesia	16	2		
Lime	9	9	sometimes	4
Oxide of iron	23	20	2 with manganese.	12
Soda		4	6 with potash.	
Manganese	1			
Water and loss				

Another mineral substance, called *serpentine*, from its spotted colours resembling the serpent's skin, will afterwards be described as forming entire rocks: it differs in composition from hornblende by having a larger portion of magnesia and less iron; it may perhaps be regarded as an intimate combination of hornblende with talc or chlorite. Its component parts, as given by different chemists, are as under:—

Silex	45	29	45
Alumine	18	23	
Magnesia	23	34	33
Iron	3	4	14 with a trace of alumine.
Lime			6
Water and loss	11	10	8

From these analyses it is evident that the specimens vary in their component parts; in some, the proportions are almost the same as in hornblende; in others, they more nearly agree with talc and chlorite.

The intimate connection between hornblende and serpentine is now completely established; for hornblende is observed to be changed into serpentine by contact with limestone in various situations. Serpentine sometimes occurs crystallised, and has received the name of diallage.

Limestone (*Carbonate of Lime*), however various in external appearance it may be, is, if pure, essentially composed of 57 parts of lime, and 43 carbonic acid; but in some rocks the limestone is intermixed with magnesia, alumine, silex, or iron. The specific gravity of limestone varies from 2·50 to 2·80. All limestones may be scraped with a knife. They are infusible; but when impure by an intermixture with a portion of other earths, they vitrify in burning. All limestones effervesce when a drop of strong acid is applied on the surface; and they dissolve entirely in nitric or muriatic acid. The specific gravity, hardness, and effervescence with acids, taken collectively, distinguish limestone from all other minerals.

Crystallised Carbonate of Lime (*Calcareous Spar*) occurs crystallised in a great variety of forms; the crystals break easily with the stroke of a hammer, and the fragments are always rhomboidal.

Vast mountains and extensive strata of limestone cover a large portion of many countries. The varieties of limestone will be described, as the rocks occur in the primary or secondary series. The different appearance of statuary marble and chalk is well known to every one. They are only different modifications of limestone, and are chemically the same. Magnesian limestone, sometimes called Dolomite, possesses most of the physical characters of common limestone, but contains various proportions of magnesia.

Gypsum, or *Sulphate of Lime*, is far less abundant than carbonate of lime; but it forms, in some situations, beds of considerable thickness and extent. Gypsum is generally of a colour inclining to white, and is sometimes snow-white. Common gypsum has a laminated or granular structure, and is sometimes compact. It is much softer than common limestone, and may be scratched with the nail: it does not effervesce with acids. Crystallised gypsum has the properties of common gypsum; it is frequently called selenite. The constituent parts of gypsum are lime 32·7, sulphuric acid 46·3, and water 21. A variety of gypsum which has no water in its composition, and hence called anhydrous, occurs in beds in the Savoy Alps; it is there combined with siliceous earth. It is much harder than common gypsum, and even than common limestone. The specific gravity of common gypsum varies from 2·16 to 2·28; that of anhydrous gypsum is from 2·80 to 2·90. Gypsum, under the name of plaster stone, is a mineral generally known.

Slate, improperly called by some geologists clay-slate, and by the old geologists argillaceous schistus, is well known, — at least the common variety used as roofing slate, which may be regarded as the purest form of this mineral.

The prevailing colours of slate are bluish or greenish grey: it has a silky lustre. Slate rocks have frequently a distinct slaty structure, and may even be split in two directions, which have an acute angle with each other; but some slate rocks have a compact structure, and will not admit of splitting. Slate yields to the knife: it is fusible into a black slag. The composition of slate is various: indeed, by many geologists it is not regarded as an homogeneous rock. Its composition has been given as under: — Silex 48, alumine 23, manganese 1·6, oxide of iron 11·3, oxide of manganese 0·5, potass 4·7, carbon 0·3, water 7·6. The quantity of carbon increases in the upper formations of slate, and it passes by a greater admixture of carbon into a soft, dark, slaty bed, denominated shale by the English miners. Slate is a very extensive formation, composing entire mountains in many alpine districts.

Basalt and compact lavas are classed by some mineralogists with simple minerals, but they are composed of three or more simple minerals closely united: — they will be afterwards described.

Some of the minerals here enumerated compose entire rocks; other rocks are composed of an intermixture of two or more simple minerals, either cemented together by another mineral substance, or the minerals are crystallised and united without a cement. The different modes in which simple minerals are found united together in rocks have given rise to the following terms: —

Granitic, composed of grains or crystals united without a cement, as in granites, and some sandstones.

Porphyritic, composed of a compact homogeneous rock, in which distinct crystals or grains are imbedded. The compact stone is called the base, and sometimes the paste. The base of some porphyritic rocks is granitic; in this case some of the crystals are much larger than the rest.

Amygdaloidal, containing rounded or kernel-shaped cavities filled with mineral matter of a different kind.

Breccia is composed of angular fragments of rocks cemented together.

Pudding-stone consists of rounded stones imbedded in a paste.*

Fragments of stone broken from *simple rocks* display the structure of the internal parts. The face of the broken part is called the fracture. This internal structure may be denominated the mineral structure, and is either

Compact, without any distinguishable parts or divisions; or

Earthy, composed of minute parts resembling dried earth.

Granular, composed of grains.

Fibrous, composed of long and minute fibres.

Radiated, when the fibres are broader and flattish, and diverging.

Lamellar or *Foliated*, composed of minute plates laid over each other.

Porous, penetrated by pores.

Cellular, or *Vesicular*, when the pores swell into rounded cavities, like bladders, as in some lavas.

Slaty, or *Laminar*, composed of straight parallel thin plates, or laminæ.

The structure of *compound rocks* may also be *Slaty*.

The external structure of rocks *en masse*, or considered as mountain masses, is as distinct from their

---

* When fragments of stone, whether angular or rounded, are large, and are imbedded in strata of indurated clay, sand, or sandstone, they are called *Conglomerates*.

internal mineral structure, as the shape of a building from that of the bricks or stones of which it is composed; though this distinction has been generally overlooked. The external structure of rocks, as forming mountain masses, may be

Stratified, or stratiform.

Tabular, or in large plates.

Columnar.

Globular, or in spherical masses.

Massive, or *Indeterminate*, which includes all unstratified rocks that have no determinate shape.

Stratified mountains or rocks are those which are composed of layers of stone, laid over each other, and divided by parallel seams like the leaves of a closed book. In these seams or partings, which divide the strata, there are frequently thin laminæ of soft earthy matter; but sometimes the surfaces of the upper and lower stratum are so closely joined, that it requires a considerable force to separate them. These layers are denominated strata: they extend through the whole mountain or mass, their length and breadth being much greater than their thickness. If the thickness of any stratum exceed two or three yards, it is more usually denominated a bed; and if it lie between beds of stone of a different kind, it is said to be imbedded. Strata almost always decline, or dip down to some point of the horizon, and of course rise towards the opposite point. A line drawn through these points is called the line of their dip: another line drawn at right angles to this, marks the course along which the strata stretch out to the greatest extent: — it is called the line of bearing. If a book be raised in an inclined position, with the back resting lengthwise upon the table, the leaves may be supposed to represent different strata; then a line descending from the upper edges to the table will be the line of dip, and their direction lengthwise will be the line of bearing; and the angle they make with the table will be the angle of inclination. Strata are, however, sometimes curved or bent in both directions, and are frequently broken; which makes it difficult to ascertain their true position.

Stratified rocks of sandstone, and beds of clay and marl, are generally admitted to have been deposited by the turbid waters of the sea, or of large rivers or lakes. These sedimentary depositions are arranged over each other in regular layers; the particles or fragments of which they are composed vary in size, and indicate the different states of agitation or repose of the waters from which they were deposited. It is proper to notice, that certain rocks are disposed to divide in parallel seams, in a different direction from that of the regular stratification: this results from the crystalline structure of the rock. Some strata appear to have been formed by chemical precipitation; and not unfrequently chemical precipitation and sedimentary deposition have taken place at the same time, and produced rocks of a mixed character.

The *Tabular structure* consists of parallel plates of rock, separated by regular seams. This structure has often been confounded with stratification: it appears to be the result of crystallisation, and is closely allied to the columnar structure.

The *Columnar* or *Prismatic structure* is peculiar to certain rocks, but chiefly occurs in the basaltic and volcanic class. Thick beds are divided into columns or prisms, which are most generally pentagonal. They sometimes form vast ranges of natural columns, as at Staffa, the Giant's Causeway in Ireland, and in many volcanic countries. Sometimes the prismatic structure may be observed forming detached groups of columns and prisms, as represented in the group of columns on Cader Idris. (Plate VII.) A group of basaltic columns, of similar form, and equally perfect, was observed by the author on the side of the volcanic mountain called Gravenaire, in Auvergne, at a small distance from the crater.

The *Globular structure* consists of globular masses, either detached or imbedded in rocks of the same kind: they are frequently composed of concentric layers.

The terms *Massive* or *Indeterminate*, may be applied to all unstratified rocks that have no regular divisions. Many of the primary rocks, such as granite, porphyry, and serpentine, occur in masses of enormous thickness, which are broken by irregular fissures in every direction. Thick currents of lava, which have filled up hollows or valleys, are also indeterminate, as might be expected from their mode of formation. Sometimes rocks of granite and porphyry, and also of compact lava, present either a tabular or a columnar structure; but the structure is seldom so regular as in basaltic rocks.

CHAP. IV.

ON STRATIFICATION, AND THE RELATIVE POSITION OF ROCKS.

Strata and Geological Formations explained. — Various Appearances presented by plane Strata. — Appearances presented by curved Strata, and Errors respecting them. — Distinction between Strata Seams and Natural Fissures or Cleavages. — On the conformable and unconformable Positions of stratified and unstratified Rocks. — The Continuity of stratified Rocks broken by Valleys. — Longitudinal Valleys. — Transverse Valleys. — Lateral Valleys. — Denudations. — On the Elevation of Mountains and Mountain Chains. — On the Direction of Mountain Chains in the new and old Continents. — On vertical Beds in Mountains. — On the apparent Devastation in Alpine Districts. — On the Passages in the Alps called Cols; and Observations respecting their Formation. — Different Ages of Mountain Ranges.

WHEN we have ascertained what are the most common or prevailing rocks in a part of any country, and observed that any one stratum or rock which attracts our attention is in that part of the country invariably covered by a peculiar rock or stratum of a different kind, or invariably covers any particular stratum; we hence learn that there is a certain order of superposition, and we naturally feel desirous to know whether the same order is observable in every country where similar rocks occur. Thus, in the vale of Thames round London, there is, at the depth of a few feet under the surface, a dark-coloured clay, called London Clay, much intermixed, in the lower part, with beds of sand. If we bore through this clay, we shall find its average thickness to be nearly 300 feet. When we have pierced through this, we invariably come to chalk*; and were we to continue to bore in the

---

* The lower clay is by some geologists denominated plastic clay. See Chap. XIV.

chalk, after piercing through many hundred feet of that rock, we should come to a stratum of sand or sandstone filled with green particles, and hence called Green Sand.

The observer who had confined his researches to this part of the country only, would form a very erroneous conclusion, were he to infer that the outer crust of the globe was invariably composed of London clay, chalk, and green sand. But wherever similar beds occur together, they lie in the same order of superposition over each other. Thus the London clay is never found under the chalk or the green sand.

But it is not always necessary to bore through the upper beds to ascertain this order; for the different strata scarcely ever occur in a flat or horizontal position: they generally rise in a certain direction, and come to the surface, as represented in *Plate I. fig. 1.* Now, by travelling over the strata from A to B, we come upon the outer edges 1, 2, 3, and may trace their order of succession as they rise from under each other. In ravines and the escarpments of mountains, and in the cliffs on the sea-coast, we are also enabled to trace the position and order of succession of rocks. But to do this with tolerable correctness, we must have an accurate knowledge of stratification in all its various possible forms. However simple the principles of stratification may at first appear, this knowledge, when applied to practice, is not of such easy attainment as some may imagine; and for want of it, geologists of considerable eminence have fallen into the most egregious errors. A knowledge of stratification is indeed of far greater importance to the practical geologist, than an acquaintance with the minutiæ of mineralogy or conchology.

Though the word Stratum, in its original language, and by general acceptation in speaking of rocks, denotes a bed, it is convenient to restrict the term bed to a stratum of considerable thickness; for such beds are often subdivided into several distinct minor strata, and we cannot well describe a stratified stratum.

When a series of strata of a similar rock are arranged with occasional strata intervening of rocks of another kind, which recur in different parts of the series, they are regarded as having been all formed nearly at the same epoch, and under similar circumstances; and such series are called by geologists *Formations.* Thus, the strata of shale, sandstone, and ironstone that accompany beds of coal are called the *Coal formation.* Strata of different kinds, in which a gradation is observed into each other, and which contain similar species of organic remains, also constitute a *geological Formation.* The chalk without flints, the lower chalk with flints, the chalk-marl and the green sand under the chalk, are regarded as members of what is denominated the *Chalk formation.* The student, however, must be careful to distinguish the different meaning of a *rock formation,* as here described, and the formation of a rock: the latter term implies the mode of formation, or the agent by which the rock was formed or consolidated; whether by igneous fusion, as beds of lava; by deposition from water, as beds of clay and sandstone; or by animal secretion, as beds of coral.

In order to obtain a distinct idea of stratification in its simplest form, let the young geologist take a piece of pasteboard or thin wood, say 12 inches square: let him divide it in the middle into two equal planes, each 12 inches in length and 6 in breadth. Place one of these planes flat on a table with the ends facing the north and south; the sides will of course be at right angles, and face the east and west. Now, if one of the sides be tilted up, — say the western side, — we may suppose the pasteboard plane to represent a stratum rising to the west and dipping eastward. The lengthwise direction of the plane is called the *line of bearing;* and the declining direction is called the *line of dip,* which is at right angles to the line of bearing. The angle at which the stratum rises above the horizontal line or level is called the *Inclination.* Suppose the western edge of the pasteboard plane is raised above the table, forming with it an angle of thirty degrees; then we say the direction of the stratum is north and south, its dip east, its rise of course west, and its angle of inclination thirty degrees. Simple as this appears, geologists of considerable eminence have made the most palpable mistakes in defining stratification. It has been said correctly, that, the line of dip being always at right angles to the direction or line of bearing, when the dip is given, the direction is known: but when it is further said, that, if the direction is given, the line of dip is given also, the assertion is erroneous; for let the above plane of pasteboard be again laid flat upon the table in the same direction, due north and south; and instead of tilting up the western edge, if we tilt up the eastern, we shall then have the same line of bearing as in the first instance, but the dip will be west instead of east.

It sometimes happens that a stratum, without varying its direction, may be so bent as to dip two ways in the same mountain, like the sloping sides of the roof of a church, or the letter V reversed (Λ). (See Plate I. fig. 2. stratum 4. and 5.) Place the two planes of pasteboard in a north and south direction, and raise them so as to make the upper edges meet; we shall then have the line of bearing north and south as before, and the dip east on one side and west on the other. The limestone strata at Dudley Castle Hill dip on each side of the hill as above described. (See Plate III. fig. 4. B.) When strata are bent on each side of a mountain, without being broken at the top, they are called saddle-shaped. A line traced on the surface of a country, to designate where the strata dip in opposite directions, has been called the *anticlinal* line, and should be introduced in all geological maps, when it can be conveniently ascertained.

Whatever may be the inclination of a stratum, its true thickness is measured by a line perpendicular to the upper and under surface.

If we take a number of similar planes of pasteboard of different colours, and lay the undermost a little inclined, and place another plane upon it, with the upper edge about an inch or more distant from that of the under stratum, and again lay the others in succession in the same manner; the uncovered ends of the planes will rise from under each other like a number of slices of bread and butter laid on a plate. These uncovered edges will represent the outcrop or crop of the strata, and it will be perceived how we may obtain a knowledge of an under stratum without sinking or boring, merely by crossing a country in the line of the rise or dip of the strata. When strata are arranged in this manner, they are said to be in a conformable position. (Plate I. fig. 1.) It will naturally be enquired whether the strata absolutely terminate where we find their outcrop? In some instances this is the case; but frequently the strata are bent or broken in the line of their rise, and the same stratum may crop out in one place, and appear again farther on in the line of its rise, as represented Plate I. fig. 2. We must be particularly attentive to this circumstance, otherwise we may commit the most egregious errors in describing a country which we have travelled over, where there is no opportunity of seeing a section of the strata. Thus, in fig. 2., after passing over the beds 1, 2, 3, 4, and having no easy method of ascertaining the dip, we may, without great care, mistake the beds 4, 3, 2, 1, as different and lower beds in the series. Ebel and many flying geologists have made this mistake. In some instances we come suddenly to the termination of a whole series of strata, as in descending the Cotswold Hills into the Vale of Severn; the limestone called Roe-stone, of which they are principally composed, is not found on the other side of the valley, nor in any part of England to the north-west of it. Has this limestone ever extended farther westward?

and if it have extended farther, by what cause has it been removed? These enquiries will be adverted to in a following chapter.

To return to our pasteboard planes, arranged as before described, with the edges rising from under each other in the conformable position. If we take another series of planes, and lay them flat over the outcropping edges of the conformable series, we shall then have the unconformable position represented, Plate I. fig. 3. Now, the strata that cover the lower stratified class in England occur in this position; and the following important inference may be drawn from it, namely, that the under stratified rocks had been formed, and their strata broken and raised up, at a period which must have preceded the formation of the upper series by a considerable interval; for the lower series were evidently solidified, and afterwards in many instances broken, and the fractured edges of the strata levelled, before the upper strata were deposited upon them.

The most common error which persons commencing the study of geology are liable to make, is in mistaking the apparent for the real inclination of the strata. Plate I. fig. 4. will render this more intelligible than any description. It represents a portion of a stratified mountain, of which the strata have a considerable dip to the east. If the escarpment or section be made in the line of bearing, *c d*, the strata will appear to range from north to south, without any rise or dip, and would be described by a young observer as being horizontal. But if an opening or section be made on the side parallel to the line of dip, as at *c c*, the true inclination will be seen. Any section made in an oblique direction to the line of dip will cause the inclination to appear less than the true one, and the line of dip will appear to vary from the true dip. The chances, therefore, are very great against the natural section made in a mountain presenting the true dip and inclination of the strata. Another error which a person who does not attend to the dip and direction of the strata may fall into is, mistaking an under for an upper stratum. Suppose a hill to be covered with vegetable soil, and a quarry or pit was made in it near the bottom, as at *a*, Plate I. fig. 1., and the stone was discovered to be sandstone: if another pit was sunk near the summit at *b*, which cut into limestone; it might be supposed, because the limestone is met with at a higher level, that it lies over the sandstone stratum, when it is in reality below it. The young observer, who has not a clear notion of this, may be said not yet to have passed the *pons asinorum* of the geologist.

In calcareous mountains of vast magnitude, as those in the Swiss and Savoy Alps, the enormous beds of limestone are often intersected by regular seams, which cut through the whole bed in a direction nearly perpendicular to that of the true strata seams, or make very oblique angles with them. These partings or seams are sometimes nearly vertical, when the strata are almost horizontal. The cliffs and escarpments of these mountains being lofty, and much exposed to the action of the atmosphere, the vertical seams enlarge, and are often more conspicuous than the strata seams; hence, without great attention, the observer may describe the strata of a mountain as being perpendicular, when in reality they are nearly horizontal. To add to the difficulty, it very frequently happens that a calcareous deposition, like a coat of plaster, covers the face of a rock: this has been formed by moisture running over the surface, and depositing calcareous particles upon it. This deposition sometimes conceals the partings or seams of the stratification as completely as a coat of plaster covers the rows of brick in a building. The vertical seams or partings are also sometimes open, and sometimes form parallel ridges, which efface the appearance of the strata seams in one part of a rock, but not in the other; and in such instances we have a mountain mass in which the strata are apparently partly horizontal and partly vertical. See Plate I. fig. 5. Inattention to this circumstance, I am convinced, has sometimes deceived the eye of M. Saussure, one of the most diligent and accurate of observers.

The regular partings or cleavages in many slate rocks which intersect the beds, nearly at right angles to their dip or inclination (See Plate III. fig. 1. *d d*), have often been mistaken for strata seams, and have led geologists of some eminence to draw very erroneous inferences. The thick beds of transition or mountain limestone which compose a great part of Ingleborough, and other adjacent mountains in the district called Craven, in Yorkshire, generally dip at a moderate inclination towards the south-east; the lower beds rest on coarse slate, which has in reality the same inclination as the limestone, but as the under part of the slate is often concealed, the vertical partings are mistaken for strata seams. This limestone is described by Professor Playfair as resting on vertical beds of slate; and he draws several important conclusions respecting the elevation of the beds of slate, and its action on the superincumbent beds of limestone; whereas a more extended survey of the district would have shown him, that the slate rocks rest on other beds, which have the same inclination as the limestone above them, and that the slate and limestone are conformable.

The modes of stratification we have been considering are those of plane strata; but in many situations, particularly in the Alps and the Jura chain, the strata are curved and bent round the mountains, encircling them like a mantle. The ravines and escarpments, according to the position in which the sections have been made, present the most varied forms of stratification in the same mountain. In one part, the strata will seem to rise almost vertically; in another, to be nearly horizontal; and in a third, to be deeply curved: and this will depend much on the relative position of the observer, whether he be placed on one side, or in face of the escarpment. Suppose a transverse section be made through a mountain in the direction *a b*, (Plate I. fig. 6.) it would show the true position of the arched strata: but if we suppose a section to be made only on the side *c d*, an observer would see the face or escarpment on that side, with the edges of the strata lying horizontally, and might describe them as horizontally stratified, were he to view no other part of the mountain. In some situations the fracture made in the arched stratification is much broken, and we have on the side of the same mountain, the appearance both of horizontal and greatly inclined stratification. An instance of this occurs near the Lake of Bourget in Savoy. Plate II. fig. 1. represents the appearance of strata on the side of a mountain, which has the arched stratification before described; but the outermost strata, instead of enfolding the whole mountain, only cover the southern side, and are broken off at the summit in a line nearly parallel with it, and their edges present the appearance of horizontal strata, *a a a*. Lower down the mountain, part of the under strata have fallen off in a sloping direction, and their projecting edges present at a distance the appearance of highly inclined strata. This may be further illustrated by taking a half cylinder, or, for want of that, a thick book, and opening it a little; place it with the edges upon the table, and the back uppermost; cover the book or half cylinder with a number of folds of paper of different colours, — these will represent arched strata. Cut across the outermost folds along the back, and take away the other half; the edges of the paper will represent those of the upper strata, and their position will appear to be horizontal. Cut away the corners of the under sheets a little behind each other, so that the edges of each coloured sheet may be visible, and these will represent the appearance of highly inclined strata, and have frequently been mistaken for such. The young geologist may greatly facilitate the study of stratification, by laying coloured planes of any soft and yielding substance over each other, and inclining them in various positions; then let him make sections in different directions with a knife, and also carve out hollows representing valleys, cutting through inclined strata at various angles with the line of dip and line of bearing: by this means he may gain a more correct idea of the varied phenomena of stratification, both in mountains and valleys, than the most elaborate descriptions can convey.

The appearance of *contorted stratification* in the calcareous mountains of the Alps is frequently an optical illusion. Strata which have originally enfolded a mountain like the coats of an onion, have fallen off in curved lines, leaving waving edges, overlapping each other, as represented Plate II. fig. 5.. Suppose indented sections were made in the side of an onion, the edges of the different indented rinds would present similar contortions.

Inequalities in the general curvature of the beds may have occasioned them to break off in this manner. The *Montagne de Tuille*, near Montmelian, in Savoy, of which a plate is given in the third volume of Saussure's *Voyages dans les Alps*, offers an instance of this apparent contortion, which Saussure considers as almost inexplicable. I examined this mountain from various stations with much attention, and am convinced that the contortions are only illusory, and are not like the real contortions, which the lower beds of transition limestone, in this country, frequently present on a small scale. In certain situations in the Alps, however, the strata have evidently been raised by some violent convulsion, and have been bent by the resistance which they have offered to the moving cause. Of this a remarkable instance may be seen in the Baltenberg mountain, at the head of the lake of Brientz, of which I have given a description and drawing in the second volume of my Travels in the Tarentaise.

The strata of secondary rocks belonging to the same formation, frequently preserve nearly the same thickness for a considerable extent, and are arranged conformably over each other, except in situations where their regularity has been disturbed by rents or fractures. In these secondary conformable strata, the order in which they succeed each other indicates their relative ages; but this rule cannot be extended to all classes of rocks.

No inference can at first appear more legitimate than this: — "The rock which supports another must be older than that which rests upon it, if their original position has not been changed." But this conclusion, when examined with attention, will fairly admit of doubt, with respect to those rocks which are crystalline like the primary. These were either formed by chemical affinity from a state of solution, or by crystallisation from a state of fusion: — if by the latter mode, all the different beds may have been arranged at the same time, and the upper and lower rocks may have a contemporaneous origin. If a mass of melted matter from a furnace cool slowly, the internal and external parts will vary both in their physical and chemical properties; but it cannot, on this account, be said that the lower part is older than the upper. But strata deposited by water were evidently formed after the rocks on which they rest. Even were we to admit the subsequent fusion of granite, it existed in another form as a substratum of the upper rocks, as these must always have had a foundation. It has been before observed, that those rocks which contain different species of organic remains, separated by strata in which no such remains occur, must have been formed in succession over each other, and probably at very distant intervals of time. This inference appears conclusive, nor can it be invalidated by the crystalline arrangement and cleavage of some of those rocks.*

---

* We have reason to believe that many rocks which present no indications of stratification, were originally arranged in regular strata. In some limestone rocks, where the stratification is extremely well defined by distinct partings, there occur spaces in which different strata are blended into one mass. These masses

Rocks of the primary class frequently cover each other in an order which, viewed on a grand scale, may be said to be conformable; but the different rocks in each class are generally of such vast and irregular thickness, that their order of succession is often not easy to trace: beside, some of these rocks pass by a change of structure into each other, and their line of junction or separation can seldom be observed. Viewed, however, as composing mountain chains, the more general arrangement is represented Plate III. fig. 1. Granite, or the foundation rock, *a;* gneiss, *b;* mica slate, *c*; common slate (called clay slate); *d d.* The transition series, *c c.* The lower strata with coal, F F. A bed of limestone, or any other rock, in a slate mountain, is represented, *x x:* in this position it is said to be *imbedded;* and if a number of these beds occur at different intervals, they are said to be subordinate. A bed of conglomerate, composed of bolders and fragments of the lower rocks, as at G, is frequently interposed between slate rocks and transition limestone.

The unconformable position of unstratified rocks is represented Plate III. fig. 2., where a mass of porphyry A, ranging from C to C, covers the rocks 1, 2, 3, without any conformity to the inclination or form of the lower beds. The lower beds are, however, cut through by veins of porphyry, which indicate that the porphyry had been erupted in a melted state through these veins, and poured over the surface of the lower rocks. A similar arrangement of porphyry, which occurs in Norway, will be described in Chap. IX.

Basalt, either massive or columnar, frequently covers rocks in an unconformable position. See Plate III. fig. 2. B, *d*, and *b*.

The superincumbent rocks in this situation are evidently of more recent origin than those which

are called by the quarrymen knobs, and are more hard and difficult to work than the stratified limestone, but are equally good in quality.

they cover: the lower must have been hard and unyielding when the upper were thrown upon them. If a thick stream of lava, as frequently happens, were to flow over a range of conformable rocks, filling up the cavities and inequalities of the surface, — when it became hard by cooling, it would form a bed of superincumbent unconformable rock. Such instances are common in volcanic countries. Very extensive ranges of rocks and mountains occur in this position in various parts of the world, not only covering the primary, but the secondary rocks. These will hereafter be described under the name of porphyry, sienite, and basalt. They frequently assume the columnar structure, and sometimes form vast ranges of natural pillars; as at Staffa one of the Hebrides, on the north coast of Ireland, in Iceland, Sicily, and many volcanic countries.

Having described the position of both stratified and unstratified unconformable rocks, it may be proper to state, that the latter rocks occur, covering both primary, transition, secondary, and tertiary strata: many of those which cover the secondary and tertiary seem evidently to have been the products of subterranean fire; and even those which cover the primary and transition rocks bear a close affinity to volcanic rocks. If we admit that our loftiest ranges of mountains were elevated by the expansive force of central fires, this power acting upon an extensive portion of the globe might be ages in upheaving the incumbent surface, which would continue to rise until vast fissures were made, through which the subterranean melted matter would be thrown over the mountains and plains then existing, and form the superincumbent rocks of basalt, porphyry, and sienite, that seem to be so nearly allied to volcanic products. While one part of the surface was rising, another part would sink, and form a new bed, into which the waters of the ocean would gradually retire.

According to Humboldt, the extraordinary eruptions by which new islands have been formed since the period of authentic history, have been preceded by a swelling of the softened crust of the globe. At Kamenoi, the new island made its appearance above the sea twenty-six days before the smoke was visible. "Every thing indicates that the physical changes of which tradition has preserved the remembrance, exhibit but a feeble image of those gigantic catastrophes which have given mountains their present form, changed the position of the rocky strata, and buried sea-shells on the summit of the higher Alps. It was undoubtedly in those remote times which preceded the existence of the human race, that the raised crust of the globe produced those domes of trappean porphyry, those hills of isolated basalt in vast elevated plains, those solid nuclei covered with the modern lavas of the Peak of Teneriffe, of Etna, and Cotopaxi."—*Humboldt.*

To these great catastrophes, and to vast inundations, and in some cases to submarine currents, must we ascribe many inequalities of the earth's surface, the fracture of strata, and the transport of the broken masses and fragments into distant countries. The formation of valleys constitutes an important subject of geological research: it will be reserved for a subsequent part of the volume; but it may be useful to state to the geological student, that all stratified mountains are only parts of extended strata, with which they were once united.

This will be more distinctly understood by consulting Plate IV. fig. 1., which is intended to represent the general rise of the strata from Sheffield in Yorkshire to Castleton in Derbyshire, intersected by the valley through which the river Derwent flows.

The town of Sheffield, fig. 1., is built over coal strata, which rise towards the west, and disappear in that direction about five miles from Sheffield (2). Here the under rock makes it appearance (3), which is a bed of coarse gritstone, more than one hundred and twenty yards in thickness, forming the summits of all the mountains as you advance to the vale of

Derwent (4). The grit-rock rests upon a thicker bed, of a different kind, chiefly composed of slaty sandstone, represented (5). On the western side of the valley, the grit-rock (3) exists only as a cap or covering on Whin-Hill, a lofty mountain, marked (6). Two miles farther west the grit-rock disappears, and the slaty sandstone, which is the base of Whin-Hill, forms the summit of the celebrated Mam Tor, or the Shivering Mountain. The mountain limestone (7) here makes its appearance as the base of Mam Tor, and farther west the same limestone forms entire mountains. The difference observable in the rocks east and west of the Derwent, is owing to the general rise of the strata in the latter direction.

It is here obvious, that Whin-Hill, though it appears an isolated mountain, is only a portion of the thick beds of gritstone, and slaty sandstone, on the other side of the valley.

It deserves notice, that isolated caps, like that on the top of Whin-Hill, fig. 6., often occur where we can trace no similar rocks in the vicinity: they are sometimes the only remaining relics of a stratum that has been destroyed, and removed by some of the great catastrophes that have changed the surface of the globe.

When valleys take the same direction as that of a range of mountains, they are called *longitudinal valleys;* when they cut through a range of mountains, they are called *transversal valleys:* in the latter case, the strata on each side of the valley are generally the same.

The small valleys which open into a larger valley nearly at right angles to it are called *lateral valleys.* In some rare instances, a valley is formed by the bending of the strata, which make a trough as represented Plate I. fig. 2. *c.*

When considerable tracts of the upper strata are wanting, as between A, B, Plate I. fig. 2., it is supposed that the lower strata have been laid bare by some convulsion that has torn off and carried away the strata by which they were once covered: this constitutes what is called a denudation. Instances of such denudations are of frequent occurrence.

Mountains, except those formed by volcanos, are seldom isolated masses rising from a plain, but they form groups, or are ranged together in a certain direction, and compose long and lofty ridges, denominated mountain chains. Lower ranges of mountains, running in the same direction as the principal range, and separated by valleys of greater or less width, may be observed accompanying almost all very lofty mountain chains. This fact appears to indicate the operation of a powerful elevating force, acting in one direction along a certain line, and decreasing in intensity as the distance from each side of this line increases; but this action does not appear to extend with equal force on both sides of the line, for the smaller chains parallel to the great chain are seldom so numerous on one side of it as on the other. The principal mountain chain, if very large, has its sides furrowed by small lateral valleys, and has not been unaptly compared to a back-bone or spine, with diverging ribs.

The shape of many countries and islands is evidently determined by the direction of the grand mountain chains that run through them.

The principal mountains in Europe and Asia, when viewed on a large scale, may be considered as forming a mountain chain composed of numerous mountain groups, and extending in an easterly direction from Cape Finisterre in Spain, to the most eastern extremity of Asia. Various parts of this chain receive different denominations in the different countries through which they pass. The Pyrenees, the Alps, Mount Taurus, Mount Caucasus, the Altaic, and the Himmaleh mountains, and the Yablonnoy mountains of Tartary, which extend nearly to Behring's Straits, may be regarded as forming together one immense mountain chain, and dividing the northern from the southern dry land, both in Europe and Asia.

In North and South America one unbroken chain of mountains runs in a northerly and southerly direction for eight thousand miles, near the western side of that vast continent, and, with some minor diverging chains, has evidently determined the general outline of both countries.

A remarkable similarity occurs in the position of the escarpments or steep sides of mountains in the same mountain range. Various opinions have been formed respecting the law which the position of the escarpments appears to follow, but I believe the rule I submitted to the attention of geologists in the first edition of this work, will be found to approximate to the truth.

Mountain chains or ranges present the steepest declivities on the sides nearest to the sea. This is remarkably the case in the long chain of the Alleghany mountains on the eastern side of America, which are steep towards the Atlantic. On the contrary, the Stony Mountains, which run near the north-west coast, and the Andes, near the southern Pacific Ocean, are steepest on their western side. In ranges of mountains that form the boundaries of lakes or of extensive vales, through which large rivers flow, the mountains nearest to the rivers have the steepest declivities. The largest rivers have their origin from the sides of mountains which are most inclined to the horizon, and most remote from the sea.

The beds or strata of very lofty mountains are generally much inclined, and are sometimes nearly vertical. Among these highly inclined beds, we not unfrequently observe beds of limestone containing marine shells, which must have been originally deposited at the bottom of the ocean. In some instances we meet with vertical strata, containing rounded pebbles and water-worn fragments of other rocks; these must also have been originally deposited on a surface nearly horizontal: we are therefore certain, that the present vertical position of these strata is not their original one, and we hence also learn, that all the strata associated with them in the same mountain, and having the same inclination, were raised together. We have further proof that, before the epoch when this great revolution was effected, all these beds were covered by the seas then existing, and it was under the ocean that the change of position took place.

No person who reflects on the appearances presented in a mountainous district can believe that the broken and elevated beds, the peaked summits, the impending cliffs, and the immense fragments of rock scattered in the valleys and adjacent countries, were originally created and placed as we now observe them.

The traveller who, in crossing an extended desert, should meet with the remains of some unknown temple, could not for a moment doubt that the broken and prostrate columns, the mutilated arches, the scattered capitals and inscriptions, had been removed by some devastating cause from their original position; nor is the proof less certain, that the rocky pavement of our globe has been broken, and its parts, which were once united, widely separated from each other. Some of the phenomena we observe in mountains were produced by the disturbing force which first elevated them; others have been subsequently effected either by vast inundations, or by torrents that have torn away considerable portions of the softer beds, or by the more gradual decomposition and disintegration produced by atmospheric influence; by the latter cause, the lofty and exposed peaks and escarpments of rocks are constantly wearing down.

During the two summers I passed in the Alps, I was much struck with the circumstance, that all the great openings or passages over these mountains, called *Cols*, were made by excavations in beds of soft slate; and the fact I think admits of an easy explanation, but I do not know that it has been before remarked by geologists.

If we suppose a portion of the Alps to be represented, Plate II. fig. 2., the dotted lines above the present surface will mark the supposed original prolongation of the different beds, at the period when they were raised. As the ocean, from whence these beds were raised, must have been agitated with inconceivable violence, the retiring waters would scoop out deep excavations in the softer beds of schist, and also tear off many of the vertical plates of the hardest rocks, and form the rudiments of these pyramidal peaks and aiguilles, which rise like the spires of a Gothic cathedral. Mountain torrents, caused by thunder-storms or the sudden melting of alpine snow, may have subsequently torn away large portions both of the harder and softer beds: the disintegration of the granitic aiguilles which are exposed to the influence of atmospheric agency is daily taking place, and their ruins are every day falling on the surface of the glaciers, and are carried down into the valleys: their peculiar forms are derived from their laminated structure, which disposes them to split in a vertical direction.*

It is important to observe, that different groups and ranges of mountains have been elevated at different and remote epochs, and the birth of different parts of the same continent was not coeval: the more lofty parts constituted separate islands, before the whole surface emerged from the ocean. Satisfactory evidence of this will be adduced in a subsequent part of this work: it is sufficient to the present purpose to state, that the ocean has covered all that is now dry land, but not at the same epoch.

---

* Plate II. fig. 2. represents the general position of the beds near the Col de Balme and Mont Blanc; *a a a*, alternating beds of sandstone and limestone; *b b*, elevated beds of puddingstone, containing rounded stones and fragments of the lower rocks; *c c*, soft slate, in which a passage or col is formed; *d d d*, vertical granitic beds rising in pyramidal forms, called Aiguilles or Needles.

CHAP. V.

ON ROCKS DENOMINATED PRIMARY, AND THE CHANGES TO WHICH THEY HAVE BEEN SUBJECTED.

The Origin of Rocks called Primary believed by many Geologists to be igneous. — A Classification founded on this View. — A Classification independent of Theory. — Constituent Minerals of Granite. — Varieties of Granite. — Structure and Appearance of Granitic Mountains. — Mont Blanc, and the Aiguilles in its Vicinity. — Localities of Granite. — Granite Veins. — Passage of Granite into Porphyry and Sienite. — Minerals found in Granite. — On Granite as the Foundation Rock on which other Rocks are laid. — The relative Antiquity of different Granitic Mountain Ranges. — Granite pierced through by Porphyry and Currents of Lava. — Granite sometimes protruded among the upper Strata.

In describing the different classes of rock, we may either commence with the lowest or most ancient, or with the uppermost or most recent; but I am persuaded that the student will find it most convenient to begin with the lowest, and proceed in an ascending series to the uppermost. The rocks called primary have distinctly marked mineral characters, and contain few, if any, organic remains. As the student proceeds, he may trace the first indications of organic existence, and in ascending to the upper rocks, he will observe the gradual increase of genera and species that have left their remains in the different beds; in some cases indicating great changes in the condition of parts of the globe, as from sea to land, or from salt water to fresh, or from deep to shallow seas. If the student begin with the more recent or uppermost strata, he will find them difficult to recognise by fixed mineral characters, and he will be confused by the variety of organic species presented to his notice, but from which he can derive little instruction, until he be able to compare them with the fossil remains in the lower strata. In the geological description of a particular country or district, it may often be more convenient to commence with the beds nearest the surface, and proceed in a descending series, but then the reader is supposed to be already acquainted with the science.

IF any rocks can with propriety be denominated primary or primitive, they are those which are most widely spread over the globe in the lowest relative situation, and which contain no remains of organic existence. Primary rocks are supposed by geologists to constitute the foundation on which rocks of all the other classes are laid; and if we take an enlarged view of the structure of the globe, we may admit this to be the fact,—but the admission requires certain limitations. The same causes that have produced granite and the other primary rocks in immense masses below all other rocks, have in some situations reproduced them in smaller masses, covering rocks belonging to the transition or secondary classes.

Granite, for instance, which has been regarded as the most ancient of all known rocks, has been sometimes found covering secondary rocks, and sometimes obtruded between them. Facts of this kind are rare, and can only be explained by admitting that granite, like volcanic rocks, has once been in a state of fusion, and was protruded in this state through the upper rocks. Similar facts are observed with respect to other primary rocks, which are believed to be of igneous formation.

Indeed, if the science were sufficiently advanced to enable us to pronounce with absolute certainty on the agents by which rocks were formed, a more intelligible arrangement might be substituted, than one founded on their relative ages; it might be comprised in three great divisions:—

CLASS I. *Rocks of igneous Formation.*
CLASS II. *Rocks of aqueous Formation.*
CLASS III. *Conglomerates, and mechanical Formations.*

These would admit of distinct subdivisions:—

CLASS I. *a.* Rocks that have been fused and consolidated without ever having flowed as lavas.
b. Rocks that have been fused and protruded through the solid covering of the globe.
c. Rocks that have been greatly modified

by heat, but which were originally aqueous depositions.

CLASS II. *a.* Marine formations.
b. Freshwater formations.
CLASS III. *a.* Ancient conglomerates.
b. Recent conglomerates.

Each of these divisions would comprise rocks of different relative ages; that of rocks of the first class would be determined by their position; those of the second and third classes by their order of succession, and the organic remains in each.*

I shall now proceed to describe the rocks denominated primary, without any reference to theory; and shall propose an arrangement of them that will, I trust, be found conformable to the present state of the science.

Primary rocks are chiefly composed of the hard minerals, quartz, felspar, and hornblende; the minerals, mica and talc, are disseminated in smaller proportions, and limestone and serpentine occur in beds or masses, but less frequently than the above-named minerals. If we refer the slate rocks to the transition class, the few simple minerals here enumerated constitute nearly the whole of the mountains denominated primary.

---

* Such an arrangement might be objected to, as resting too much on theory; and the fate of the Wernerian system ought to caution us against founding systems of classification on theoretical views respecting the formation of rocks. The following rocks, according to the evidence at present obtained, might be referred to the different divisions of the first class; and it may be useful to bear this in mind, without yielding implicit assent to the theory that they are all igneous formations; yet it must be allowed, that such a mode of formation will satisfactorily account for many positions in which these rocks occur, that appear inexplicable by any other theory.

Supposed igneous Rocks. — All varieties of granite, gneiss, and mica slate; — all varieties of porphyry and felspar rocks; — all varieties of hornblende rocks and serpentine; — all basaltic or trap rocks; — all ancient and recent lavas.

In subdivision *c*, slate rocks, clay-slate, and crystalline limestone, imbedded in igneous rocks.

The structure of primary rocks is crystalline; they form the central parts of the most elevated mountain chains, and they occur also at the lowest depths that have yet been explored, and are hence believed to be the most ancient of rock formations.

Werner has enumerated fourteen primary rocks; but as some of these have only been found hitherto in one place, it appears improper to consider them as distinct orders, unless we arrange every variety of rock in the same manner, and increase the number of orders indefinitely.

The following arrangement of primary rocks includes only three principal rocks as primary — granite, gneiss, and mica slate, which are nearly allied to granite, and form an incrustation over it: these never contain organic remains, and they have rarely been observed lying over other rocks in which such remains are found. It comprises also the rocks which are sometimes found imbedded in granite, gneiss, and mica slate, and are regarded as subordinate formations.

Class I.

Principal Rocks denominated Primary.

1. Granite, comprising all the varieties of this rock, and small-grained granite passing into porphyry, the Eurite, of the French geologists, primitive porphyry of the Germans.
2. Gneiss or slaty granite.
3. Mica slate.

Subordinate Rocks which occur among Primary.

Hornblende rock.
Serpentine.
Crystalline limestone.
Quartz rock.

Some of these subordinate rocks occur also among rocks of the transition class.

The three principal rocks of the primary class, — granite, gneiss, and mica slate, — might, with propriety, be regarded as belonging to one formation. They are essentially composed of the same minerals varying in different proportions, and are rather modes of the same rock than different species. They pass by gradation into each other, as one or other of their constituent minerals become more or less abundant; they alternate with each other in various situations, and may be regarded as contemporaneous. It may, however, for the convenience of description, be proper to treat of each separately.

Rocks of the first Class.

Granite is considered as the foundation rock, on which slate rocks and all secondary rocks are laid. From its great relative depth, granite is not frequently met with, except in alpine situations, where it appears to have been forced through the more superficial covering of the globe. Where granite rises above the surface, the beds of other rocks in the same district generally rise towards it, and their angles of elevation increase as they approach nearer to it.* Granite is composed of the three minerals described in the third chapter, — quartz, felspar, and mica, — which are more or less perfectly crystallised, and closely united together.

The three minerals of which granite is composed vary much in their proportions in different granitic rocks, and often in specimens from the same rock the crystals are large, or small, or equally intermixed, in one part, and in another part, quartz or felspar greatly predominates. Some granites are composed of small grains, and have large crystals of felspar interspersed; these are denominated porphyritic granites. Stones

---

* Some writers derive the name from *geranites*, a word used by Pliny to denote a particular kind of stone; others, with more probability, suppose that the name originated from its granular structure, or the grains of which it is composed.

of this kind are common in the foot-pavements of London.*

Felspar constitutes by far the largest part of granite: the more common colours are white and red; it is sometimes in a soft or decomposing state, and appears earthy. In some granites the crystals of felspar are distinctly formed. Quartz generally occurs in small irregular shaped grains, which have a vitreous lustre. The mica in granite occurs most commonly in small shining scales, which are generally either black, or whitish and silvery. It sometimes occurs in large hexagonal plates; but this is more commonly the case in the granite that forms veins in granitic mountains; such veins, with large plates of mica, are frequent near Aberdeen, in Scotland. Mica readily separates or divides into thin transparent laminæ; and where the plates are very large, as in the Siberian granite, it is used instead of glass for windows. This variety is improperly called Muscovy talc. Talc resembles mica, but is much softer. When the grains of felspar and other minerals are very minute in granite, it can scarcely be distinguished from sandstone.

Beside the three minerals, quartz, felspar, and mica, which were formerly considered as the essential constituent parts of all true granite, whoever has attentively examined various granitic districts, must have frequently observed, that other minerals occupy the place of mica, either in part or entirely. Thus near the summit of Mont Blanc, the granite is composed of felspar, quartz, and talc or chlorite, the

---

* Specimens of Cornish and Scotch granites are not difficult to procure in London, as they are commonly used for paving-stones In the former the felspar is white ; the mica appears like glistening scales which have a tarnished semi-metallic lustre. The quartz has a vitreous appearance, and is of a light grey colour. In Scotch granite the felspar has more commonly a reddish-brown colour. The mica is not unfrequently black and splendent, and may be divided into thin scales by the point of a penknife: this distinguishes it from hornblende, which is sometimes intermixed with this granite.

latter mineral supplying the place of mica. To this variety of granite the name of protogine has improperly been given, whereas *talcy* or *chloritic granite* would at once convey a distinct idea of its nature. In some instances, hornblende supplies the place of mica, or is intermixed with it. To this rock the name of sienite was given, because a granitic rock of this kind from Sienna, in Upper Egypt, was much used by the ancients for obelisks.

The following varieties of granite are often associated in the same granitic mountains, and may be regarded as contemporaneous with it, being essentially the same rock, accidentally modified by an admixture with other simple minerals.

Common Granite.—The felspar, white or red, composed of quartz, felspar, and mica.

Porphyritic Granite, in which large crystals of felspar occur in a small-grained granite. The granite near Shap, in Westmoreland, offers an excellent type of this.

Sienite or *Sienitic Granite*, in which hornblende, either wholly or in part, supplies the place of mica. The granite of Malvern, and the Charnwood Forest hills afford specimens of this granite.

Talcy or *Chloritic Granite.*—Quartz, felspar, and talc or chlorite. Many of the granitic mountains in Savoy are composed of this granite; and loose blocks of it are scattered over the valleys and on the sides and summits of the calcareous mountains, in the countries to the north and north-west of the Alps. This granite is by some writers called protogine.

Felspathic Granite, in which the felspar is the principal ingredient, and the quartz, and particularly the mica, very rare; larger crystals of felspar occur in it. It is frequently nearly white. To this variety Werner has given the name of white stone, and the French, eurite. It occurs in beds in common granite in Cornwall. In its most compact form, it becomes a porphyry, and is closely allied to volcanic rocks in Auvergne. Indeed the common granite of

Auvergne I observed to be chiefly composed of felspar and quartz without mica; in some parts, the mica was replaced by the mineral called pinite.

Granite occurs in masses of vast thickness, which are commonly divided by fissures into blocks, that approach to rhomboidal or pretty regular polyhedral forms. Sometimes a columnar structure may be observed in granitic mountains; in other instances, where the quantity of mica is considerable, granite divides into parallel layers or plates, that have been mistaken for strata. Granite is occasionally found in globular masses, which are composed of concentric spherical layers, separated by granite of a less compact kind, and enclosing a hard or central nucleus. These globular masses are often three or four yards or more in diameter, and are either detached or imbedded in granite of a softer kind; this structure is not peculiar to granite.

The aspect of granitic mountains is extremely various: where the beds are nearly horizontal, or where the granite is soft and disintegrating, the summits are rounded, heavy, and unpicturesque. Where hard and soft granite are intermixed in the same mountain, the softer granite is disintegrated and falls away, and the harder blocks remain piled in confusion on each other like an immense mass of ruins. Where the granite is hard, and the beds are nearly vertical, and have a laminar structure, it forms lofty pyramidal peaks or aiguilles, that rise in enormous spires; such are the aiguilles in the vicinity of Mont Blanc, which are far more interesting, both to the picturesque traveller or the geologist, than Mont Blanc itself. The Aiguille de Dru is, perhaps, the most remarkable granitic mountain at present known; the upper part, or spire, rises above its base nearly to a point in one solid shaft more than four thousand feet; the summit is eleven thousand feet above the level of the sea.*

---

* A short description of this mountain, with a plate, is given in the 2d volume of "Travels" by the author.

It has been observed in so many situations, that it may perhaps be regarded as a general law, — where-ever granite rises high above the surface of the earth, the strata of limestone or other rocks in its vicinity rise towards it. Numerous instances of this occur in the Swiss Alps. In the higher part of the valley of Lanterbrun, in the Canton of Berne, I have seen a bed of limestone in immediate junction with granite, in a perfectly vertical position, like a wall built up against it; but both rocks were cemented together without any perceptible line of parting. The limestone was extremely hard, but the parts in immediate contact with the granite did not differ in appearance from the other parts of the bed.

In many of the highest mountains in the northern or Swiss Alps, granite is only seen near their bases; the summits are composed of immense beds of limestone, and secondary stratified rocks. In the southern chain, or the Savoy Alps, the highest summits are granite; indeed the highest known point at which granite has been observed in any part of the world is Mont Blanc in Savoy, the loftiest mountain in Europe, rising fifteen thousand six hundred and eighty feet above the level of the sea, or nearly five times higher than any mountain in England or Wales. It was first ascended by Dr. Pacard in 1786, and afterwards by Saussure, who has published a very interesting account of his ascent. Several persons have since ascended this mountain, but Saussure is the only traveller who has given us any information respecting its structure. I shall therefore insert a brief account of his observations; they are highly interesting. He set out from the priory of Chamouni, from whence the distance to the summit of the mountain, in a direct line, is not more than two French leagues and a quarter: but owing to the difficulty of the ascent, it requires eighteen hours' continued labour, exclusively of the time necessary for repose and refreshment. The first day's journey was comparatively easy, the route being over soil covered with vegetation, or bare rocks. The ascent on the second day was over snow and ice, and more difficult: at four o'clock in the afternoon of the same day, Saussure and his attendants pitched their tent on the second of the three great plains of snow which they had to traverse. Here they passed the night, fourteen hundred and fifty-five toises (or three thousand one hundred yards) above the level of the sea, and ninety toises higher than the Peak of Teneriffe. The barometer stood at seventeen inches. The next morning they proceeded with much difficulty and fatigue, arising principally from the extreme rarity of the atmosphere, which affected their respiration. The upper parts of Mont Blanc are above the limits of perpetual snow, and it is only on the sides of the nearly perpendicular peaks and escarpments that the bare rock is visible. They gained the summit by eleven o'clock A.M. "From this elevated observatory," says Saussure, "I could take in at one view, without changing my place, the whole of the grand phænomenon of these mountains; namely, the position and arrangement of the beds of which they are composed. Wherever I turned my eyes, the beds of rock in the chains of secondary mountains, and even in the primary mountains of the second order, rise toward Mont Blanc and the lofty summits in its neighbourhood: the escarpments of these beds of rock were all facing Mont Blanc, but beyond these chains were others whose escarpments were turned in a contrary direction. Notwithstanding the irregularity in the forms and distribution of the great masses that surround Mont Blanc, and those which constitute the mountain itself, I could trace some features of resemblance not less certain than important. All the masses which I could see were composed of vertical plates (*feuillets*), and the greater part of these plates were ranged in the same direction, from north-east to south-west. I had particular pleasure in observing the same structure in the lofty peak of granite called the *Col du Midi*, which I had formerly endeavoured, but in vain, to approach, being prevented by inaccessible walls of granite. After the second day's ascent, this lofty pinnacle was beneath me; and I fully convinced myself that it is entirely composed of magnificent plates (*lames*) of granite, perpendicular to the horizon, and ranging from east to west. I had formerly been induced to believe that these plates were folded round the peak, like the leaves of an artichoke, but this was an optical illusion, when seen imperfectly from below: here, where the eye could as it were dart down into the interior structure of the mountain, the plates of rock appeared regularly parallel in a direct line. I was also," says Saussure, "particularly desirous of ascertaining whether the vertical beds were composed of the same substances at their summits as at their bases, where I had so frequently inspected them; and, I am perfectly satisfied, from actual examination, that they preserve the same nature through their whole extent, and are the same at the summit as below." * *Voyages dans les Alpes*, tom. iv.

The inference drawn by Saussure, respecting the vertical position of the beds of granite that compose a principal part of Mont Blanc and the adjoining mountains, is, that they were originally horizontal, and have been subsequently elevated by some tremendous convulsion of nature. The summit of Mont Blanc, he says, must at one time have been more than two leagues under the surface. To the same convulsion he also attributes the position of the escarpments or steep sides of the rocks which face Mont Blanc for a considerable extent, and then turn

---

* The extreme fatigue and exhaustion which Saussure experienced during the ascent of Mont Blanc, is supposed to have abridged the life of this active and intelligent philosopher. It may amuse the reader to be told, that Saussure, during his excursions in the Alps, wore a full-dressed scarlet coat and gold-laced hat. He informs us, that when he was seated on Mont Breven, the lace of his hat attracted the electric fluid from a passing cloud, and occasioned a hissing sound. *Tempora mutantur, et nos*, &c.

from it in an opposite direction. This would be the case had the surface of the globe been broken and elevated in the manner he supposes. There is a circumstance stated by Saussure, which tends strongly to confirm, if not absolutely to prove, the truth of his hypothesis. Some of the vertical beds of rock adjacent to the granite contain round pebbles, boulders, and water-worn pieces of the lower rocks. See observations on these beds, Chap. IV. It is impossible to conceive that those rounded fragments could have been placed in a vertical position; for, if they be really pebbles and boulders, the beds on which they occur must originally have been nearly horizontal. Now as these beds are at present placed between others which are also vertical, and in the same range, it follows, that the whole have been overturned and thrown up, at a period subsequent to their formation.*

The Himmaleh Mountains in the centre of Asia, rise ten thousand feet higher than any mountains in the Alps, but where their summits are uncovered by snow, they are believed to be composed of secondary strata.

Many of the mountains in the extensive range of the Andés in South America also rise much higher than Mont Blanc; but granite has not been found there in a greater elevation than eleven thousand five hundred feet, an elevation exceeded by many of the granite mountains in Europe. The range of the Andés is the seat of active volcanic fires, which appear to have covered the primary mountains with an immense mass of matter, ejected by ancient and recent eruptions. In Mexico and New Spain also, the granite appears to be nearly covered by basalt, porphyry, and lava, ejected from the numerous volcanoes which now exist, or have existed, in those countries.

---

* Saussure says expressly, that the boulders in the rocks near Mont Blanc are precisely similar to the boulders on the shores of the lake of Geneva.

To this accumulation of volcanic matter the mountains in South America owe their superior elevation. Chimborasso and Cayambo are nearly the highest mountains in the Andés, — the former rises twenty-one thousand four hundred and forty feet, — but their summits are vast cones, composed of volcanic productions covered with snow. Chimborasso is one mile and one hundred and sixty yards higher than Mont Blanc. The general arrangement of the Andés consists, according to Humboldt, of granite, gneiss, mica, and clay-slate, as in the Alps; but on these are frequently laid porphyry and basalt, "arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky."

In the eastern parts of the United States, and in Canada, granite is seen near the surface uncovered by other rocks, and does not rise to any great elevation. The constant occurrence of granite at a lower level in America than in Europe, is a remarkable geological fact. In Europe the central part of the principal mountain ranges are granite; as in Scandinavia, the Alps, the Pyrenees, and the Carpathian mountains. In Asia, granite forms a considerable part of the Uralian and Altaic range of mountains, and it appears to compose the principal mountains that have been examined in Africa.

The parts of England and Wales where granite and granitic rocks occur are Cornwall, Devonshire, North Wales, Anglesea, the Malvern Hills in Worcestershire, Charnwood Forest in Leicestershire, and in Cumberland and Westmoreland. Granite rises near the bottom of Skiddaw in Cumberland. The granite near Shap in Westmoreland is porphyritic, containing large crystals of red felspar. There are rolled masses of granite on the banks of Ulswater resembling the granite of some parts of Cornwall, and of the Wicklow Mountains in Ireland, but more highly crystalline than the latter. The felspar is in large white and reddish-white crystals. The mica is a blackish-green, and on the outer parts decomposed. I am inclined to believe that the same formation of granite, which just makes its appearance on the western side of England and Wales, is continued under the Irish Channel; or if broken there, it rises again in the Isle of Man, and in the counties of Dublin and Wicklow in Ireland. Blocks of granite are found in the beds of some of the rivers in the northwest part of Yorkshire, and in clay-pits in Lancashire and Cheshire, at a great distance from any granite mountains. Most of the granitic rocks on Charnwood Forest are of that kind denominated sienite.* Among the English localities of granite, I have recently ascertained, that both granite and imperfect gneiss rise to the surface near Bedworth in Warwickshire, evidently a continuation of the Charnwood granite.

Granite sometimes forms veins shooting up into the superincumbent rocks. This is a fact of some geological importance, as it seems to indicate, either that the granite has been in a state of fusion, the heat of which has softened and rent the upper rocks, and forced up the granite in a melted state into these fissures; or else that the granite and the rocks resting immediately upon it were both in a fluid state at the same time, and are contemporaneous. A remarkable instance of granitic veins in argillaceous schistus at Mousehole in Cornwall is described in Dr. Thomson's Annals of Philosophy, May, 1814. "The schistus is of a greyish colour, rather hard, but breaks in large fragments in the direction of the strata. The granite is of a fine grain, and the fel-

---

* According to Brongniart, granite, sienite, and prophyry, are frequently observed graduating into each other in some parts of France; and he forms this conclusion:—"En étudiant les granites d'un grand nombre de pays pour tâcher de distinguer clairement les anciens granites des nouveaux, on trouve presque peu de pays granitiques, qu'on puisse rapporter avec certitude à cette ancienne et primitive formation des granites." *Journal des Mines, Mars,* 1814.

spar is of a light flesh colour, and contains but a small portion of mica. At the junction, numerous veins of granite may be traced from the rock of granite into the schist. Some of these veins may be observed upwards of fifty yards, till they are lost in the sea, and in point of size, vary from a foot and a half to less than an inch. It may deserve notice, that, as the felspar is of a flesh colour, it is impossible for any observer to consider them as quartz veins: one of these large veins is dislocated, and heaved several feet by a cross course. Quartz and fragments of schistus having the appearance of veins are found in the granite veins. At one place there is a very curious and satisfactory phænomenon. One of these veins of granite, after proceeding vertically some distance, suddenly forms an angle, and continues in a direction nearly horizontal for several feet, with schistus both above and below it. This appearance most completely destroys one of the theories suggested for the explanation of similar veins at St. Michael's Mount, viz. that a ridge of projecting granite had been left, and schistus deposited afterwards on its sides."

In 1816 I visited the place, which is close by the sea-side, at low water, and observed some appearances which I believe have not hitherto been noticed. The junction of the granite rock and the schist may be distinctly seen: they form together a sloping beach uncovered by any fragments: the line of junction is waving from the coast into the sea, as represented Plate II. fig. 3., G. the Granite, S. the Schist.

It is truly worthy of notice, that the veins of granite may be distinctly seen penetrating both the schist and the granite; for the granite in the veins is finer-grained than the granite rock, and may as easily be distinguished in the granite as in the schist. The granite rock itself is smaller-grained near the line of junction of the two rocks, than it is a little distance from it, where it contains large white crystals of felspar in a smaller-grained reddish granite. What is further remarkable, the largest granite vein, in passing into the schist, cuts through a vein of quartz thicker than itself; and a few yards nearer the sea, a small quartz vein cuts through the same granite vein: see Plate II. fig. 3. What is called the schist or killas in Cornwall, in the places where I have observed it in immediate junction with granite, is highly indurated and of a dark colour, and appears to have been changed by the junction: it has no appearance of slate; —indeed the change, in the size of the grain of granite, as the latter approaches the killas at Mousehole, would indicate that the two rocks were passing into each other. Perhaps the best designation of the killas rock on this situation is, that of a minutely grained and highly indurated gneiss, that had lost its schistose character.*

Granite veins of large size traverse rocks of small-grained granite and gneiss in the vicinity of Aberdeen: in these veins both the felspar and mica occur in crystalline plates and laminæ of considerable magnitude, accompanied with tourmaline. At Glentilt in Scotland, a singular intermixture of granite in veins and amorphous masses occurs with slate and limestone, and has been described by Dr. MacCulloch in the Geological Transactions, vol. i. page 145. It seems impossible to conceive how masses of granite could be intermixed with, or imbedded in limestone, without admitting that the two substances have been both in a fluid or semi-fluid state at the same time; and we are not acquainted with any cause which could effect a simultaneous fusion of both rocks, except heat combined with pressure.

Some geologists describe the granite under gneiss and the granite over gneiss as different formations; but as gneiss is itself a schistose granite, it would be more correct to state, that the massive and schistose

---

* In the Phil. Mag. March, 1829, there is a full description of the granite veins in killas, by two German geologists, but no new or important facts are communicated.

granite sometimes occur alternating with each other. When the mica becomes abundant, the granite passes to the state of gneiss; when the felspar and quartz predominate, it becomes again massive or common granite.

What has been said respecting the alternation of gneiss and granite, will apply to the alternation of granite and mica-slate. In the latter, the felspar is wanting; but if it re-appear, it becomes either granite or gneiss. Mica-slate also passes by such insensible gradations into slate, that the occasional occurrence of granite in some ancient slate-rocks, may admit of a similar explanation. We shall thus sweep away the secondary granites, which have so much bewildered the systems of many geologists: indeed nothing can appear more puerile and trifling than the labour of making distinctions, where nature has made none. Of this we have an instance in the distinctive characters which have been given of primary and secondary granite.

Primary Granite.	Secondary Granite.
1. Sometimes red.	1. Felspar commonly a deep red.
2. Contains garnets.	2. Contains garnets.
3. Is sometimes porphyritic.	3. Not porphyritic; but, according to Professor Jamieson, is sometimes porphyritic.

Again, M. D'Aubuisson tells us, that the colour of primary granite is almost always white.

What has been advanced may be sufficient to prove that the attempts to distinguish primary from secondary granite by their mineral characters, are worse than useless; as they waste the time of the learner, and tend to disgust him with a science already too heavily burdened with unmeaning terms and frivolous distinctions.

There is a particular form of granite, in which the constituent parts are so minute and so intimately mixed, that it appears very minutely granular or even compact: to this variety the French geologists have given the name of *Eurite;* it has generally been described by English geologists as *Compact felspar*, into which it passes by insensible gradations. This rock frequently contains imbedded crystals of felspar, and forms what has been denominated felspar-porphyry. In Cornwall it occurs in beds in common granite; but instead of being regarded as a different rock, it may be more properly classed by the geologist with granite, being only a variety in which felspar greatly predominates. This rock occurs also in an unconformable position, and is generally described as porphyry, and appears to form a connecting link between common granite and the compact varieties of volcanic porphyry, with a base of felspar called by the French *Trachyte*.

Sienitic granite, in which the mica is partly or entirely replaced by hornblende, in some situations occurs with common granite in the same bed, and therefore must be regarded as a variety of granite. Instances of this change from granite to sienite in the same rock, I have frequently observed in the granite of Charnwood Forest. The same change may also be noticed in the granite of the Malvern Hills. That able and accurate observer Dr. MacCulloch maintains the identity of granite and sienite, from their frequent passage into each other in the same rocks in Scotland. When the hornblende becomes abundant, and is closely intermixed with felspar, it forms a dark finely granular rock, which has been denominated trap or greenstone: it nearly resembles basalt. In the Charnwood Forest hills, and at Shap in Westmoreland, well defined granite may be seen passing into a dark coloured trap-rock nearly compact. I have even broken off hand specimens in which one part was granite and the other trap, and the passage from one to the other might be distinctly observed.

The crystallised earthy minerals which occur most frequently in granite, are schorl or tourmaline, and pinite, a mineral nearly allied to mica,—the emerald, corindon, axinite, and topaz, are also found occasionally in granite. Sometimes the tourmaline is so abundantly disseminated, as to form a constituent part of the rock.

Common granite, or massive granite, contains few beds of any other rock, nor is it rich in metallic ores. Tin ore, however, chiefly occurs in granite, either in veins accompanying quartz, or disseminated through the rock at a distance from the veins. Ores of other metals, as copper, iron, wolfram, bismuth, and silver, are also occasionally found in granite.

Granite supplies durable materials for architecture, but it varies much in hardness, and care is required in its selection. I was told, when in Cornwall, that granite got from a considerable depth in the quarry is so soft when it is first raised, that it can be easily sawed into blocks, but it soon acquires great hardness by exposure to the air. In the mountains of Auvergne, the granite is extremely soft, and the felspar appears earthy; this is probably the original state of the stone. I believe it is the soft earthy granite from this district, which supplies the kaolin used in the porcelain manufacture at Sevres. Mons. Brongniart, who obligingly accompanied me through the works, showed me a specimen of their best kaolin: it contained crystals of pinite. I had recently arrived from Auvergne, and I thought I recognised its locality.

Granite is regarded as the foundation rock on which all other rock formations rest, and has hence been called the most ancient formation; but if the age of a rock is to be dated from the period in which it became consolidated, the inference respecting its relative antiquity would not be conclusive. According to the Huttonian theory, granite is made of the melted crust of a former world, and the fusion may have taken place after this ancient crust was covered with the upper rocks; but, admitting that it has been fused under pressure, the matter that now constitutes granite must have existed in some mode or other, and have served as the foundation for the rocks that are upon it. If we date the age of granite from the period of the elevation of granite mountains, we must admit that some granite mountains are comparatively recent, for they have been elevated since the deposition of the secondary strata. I have shown this to be the case with the granite of the Bernese and Savoy Alps, in my Travels in the Tarentaise, &c. published in 1823. In the third edition of the present work in 1828, I have also shown, by a description and sections, that the elevation of the granite of Savoy is more recent than that of the central part of England. M. Elie de Beaumont has since adopted the same views, and has extended them to other mountain ranges. Prof^{r}. Sedgwick and Mr. Murchison have further proved, that a great part of the Tyrolean and Bavarian Alps was elevated since the deposition of tertiary strata; for these strata are lifted up with them to the height of several thousand feet.

Here, however, we must also admit that the material which formed granite is more ancient than the strata that rest upon it.

Whether granite ever formed at one time the stony pavement of the whole globe, or whether it was elevated in a solid state *bodily*, or whether different parts of the surface were fused at different epochs, are legitimate objects of geological enquiry, and may perhaps admit of a satisfactory solution by extended series of observations. In whatever state granite forms, or has formed, the ancient crust of the globe, it has been since pierced through by ancient and recent igneous rocks. Thus porphyry cuts through, and in some parts covers granite, on the west side of Scotland from Inverary to Ben Nevis. Volcanic rocks, and streams of lava, of a recent geological epoch, pierce through and have poured over the granite of Auvergne, and a large part of central France.

Some of the currents of lava appear as fresh as the recent currents from Etna or Vesuvius. In other parts of Auvergne the granite appears to have been acted upon by subterranean fire *in situ*, and in some mountains, as in the Puy de Chopine near Riom, granite and volcanic rocks are intermixed, one part being true granite and the other volcanic porphyry (trachyte).*

These volcanoes have long been dormant; and the only remaining proofs of the existence of subterranean fires under that district, are the hot springs that rise in the vicinity of the ancient volcanoes. According to Humboldt, in the Canary Islands, as well as in the Andes of Quito, in Greece, and various parts of the world, subterranean fires have pierced through the primary rocks; and he adduces the great number of warm springs which he has seen issuing from granite, gneiss, and mica-slate, as a proof of this opinion. Indeed, in the Andes, numerous volcanoes are in present activity, from Cape Horn to Mexico; and it is probable that those mountains owe their elevation to subterranean fire; for we have a recent instance of the mighty power of this agent to upheave the crust of the globe. During the earthquake in Chili in November 1822, the whole line of coast, running north and south from Valparaiso, to the distance of one hundred miles, was raised above its former level, the bottom of the sea was laid dry, and shells were discovered sticking to the rocks, some of which were not before known in those seas. It is stated by an observer, that the whole country, from the coast to the feet of the Andes, and even far out to sea, was permanently raised by the earthquake: the greatest rise was about two miles from the shore. The granite which forms the foundation rock was rent in parallel fissures. The earthquake is estimated to have extended over an area of one hundred thousand miles. The average rise of the land upon the coast was from two to five feet; at the distance of a mile from the shore inland the elevation was seven feet.

During my residence in Savoy and Switzerland, in

---

* See "Travels in the Tarentaise and Auvergne," vol. ii. p. 367.

the years 1820, 1821, and 1822, I was desirous to ascertain whether there were any vestiges of the action of subterranean fires in the Alps. In the part of the great southern chain, extending from near the source of the Rhone to the Little St. Bernard, there do not occur in the numerous situations which I examined, or from which I have seen specimens, any minerals of a volcanic character, with the doubtful exception of some rocks in the valley of Saass and in the Valorsine.

Though I could observe no indications of volcanic fire in the rocks themselves, I was greatly surprised with a circumstance that, as far as I know, had escaped the attention of geologists. Along the whole line of Alps before mentioned, which extends for one hundred and twenty miles, numerous hot springs are gushing out at the feet of the primary mountains near the junction of the lowest secondary limestone, with schistose rocks passing into mica and talcous slate. It was known that a few thermal waters existed in the Valois and in Savoy, but they were regarded as isolated phænomena, and their geological position had not been attended to. Since Saussure visited the Alps, thermal waters have been discovered in various situations; and since I left Savoy, another considerable warm spring has been opened in the vicinity of the village of Chamouni, near the foot of a glacier.

There is also further reason to believe that thermal waters would be found in all the deep valleys of the Alps near the junction of the primary and secondary rocks, were they not covered by *éboulements* under heaps of loose stones (as was the case with the warm baths in the valley of Bagnes in the Bas Valois); or were not the temperature of the warm springs reduced by admixture with torrents from the glaciers.

In vol. i. ch. 8. of my "Travels in Savoy," I have described the geological position of nine of the principal known thermal waters of the Alps; their temperature varies from 94° to 126° Fahrenheit.

The quantity of water which issues from these springs is very considerable; and the thawing of the bottom of the glaciers during intense frost may, I believe, be attributed to the action of thermal waters. On the Italian side of the same range of Alps, particularly at St. Didier, near the steep southern escarpment of Mont Blanc, there are several thermal waters; and further west than the hot springs at Aix in Savoy, other hot springs have been recently discovered near Grenoble. It thus seems probable that there still exists, under this range of the Alps, one common source of heat, to the agency of which, in remote ages, the mountains originally owed their elevation; for we can scarcely doubt that the hot springs in the Alps, like those in Auvergne, in Italy, or Iceland, derive their great temperature from subterranean fire. This inference is farther supported by the well authenticated fact, that the districts in which the hot springs are situated have been subject to great and frequent convulsions. In the year 1755 the ground in the vicinity of the hot springs of Leuk and Naters, in the Upper Valois, was agitated with earthquakes every day from the 1st of November to the 27th of February. Churches were thrown down, the springs were dried up, and the waters of the Rhone were observed to boil in several places. The mountain above the warm spring at Naters is said to have opened and discharged a quantity of hot water.

The hot springs at the feet of the Pyrenees probably derive their temperature from the same source as those of the Pennine Alps. Hot springs also occur in Dauphiny and Provence which have probably a similar source of heat.

What has been here advanced may be sufficient to show the high probability that the elevation of the vertical beds in the Alps has been effected by subterranean heat, — an agent which we have direct proof has in our own times elevated considerable portions of the crust of the globe; and it were contrary to the rules of sound philosophy to seek for other causes than those which are now existing, when such causes are adequate to the production of the phænomena we observe.

Two cases are mentioned by M. Elie de Beaumont, in the " Mémoires de la Société d'Histoire Naturelle," tom. v., of granite cutting through and covering secondary rocks; such cases, however, demand the strictest scrutiny before the fact can be regarded as well established. In the " Bulletin de la Société Géologique de France," tom. ii., a section is given of the Jungfrau Mountain, in the canton of Berne, representing two cone-shaped masses of limestone penetrating the granite near the summit. I spent some weeks almost close to the mountain, and studied its structure with particular attention, and I have no hesitation in expressing a decided opinion that the section is fallacious. The part represented as penetrated by the limestone is concealed by a covering of eternal snow. The granite which the author improperly calls gneiss is small grained: near the foot of the Jungfrau, in the upper part of the valley of Lauterbrun, I observed a vertical junction of limestone and granite. If cone-shaped, protruding masses of limestone are observed in any part of the mountain, they are, I am persuaded, mere spurs from the limestone on the north side, and cover the granite, but do not penetrate into it. The penetration of granite into limestone represented in fig. 2. of the same plate, is far more probable and intelligible.

CHAP. VI.

ON GNEISS AND MICA-SLATE, AND THE ROCKS WHICH ARE ASSOCIATED WITH THEM.

On the Passage of Granite into Gneiss. — Gneiss and Granit veiné. — Mica-Slate. — Formation of Gneiss and Mica-Slate. — Talcous Slate, and Chlorite Slate. — Crystalline Limestone denominated Primary, occurs both in Primary and Secondary Mountains. — Formation of Limestone and Coral Islands by Animal Secretion. — Dolomite, or Alpine Magnesian Limestone. — Serpentine and Ollite, or Potstone. — Euphotide or Saussurite the hardest and heaviest of Rocks. — Trap Rocks changed to Serpentine. — Eurite or White Stone. — Primary Porphyry a Mode of Granite. — Recurrence of the same Rocks in Rock Formations of different Epochs.

The principal primary rocks enumerated with granite in the preceding chapter, were Gneiss and Mica-slate. With these, certain rocks are frequently associated, and are therefore regarded as primary; for where one rock occurs imbedded in another, it is evident that the enclosed rock must be as ancient as the rock which enfolds it, unless the imbedded rock has been subsequently protruded within more ancient rocks, as is the case with some volcanic or trap rocks.

Gneiss received its name from the German miners; according to Mr. Jameson, the decomposed stone on the sides of some metallic veins was first so called; but Werner designated by this term a schistose or slaty granite, abounding in mica. Granite frequently passes into gneiss by an almost imperceptible gradation: where the quantity of felspar decreases, and the crystals or grains become smaller, if the mica increases in quantity, and is arranged in layers, the rock loses the massive structure, and becomes schistose; we have then a true gneiss. By the reverse of this process, if the quantity of felspar increases, and the mica diminishes, the rock loses the schistose structure and becomes massive, and we have granite again. Some geologists call this secondary granite; but the upper and lower granite, and the gneiss, are in this instance, but different modes of the same rock.

The granite of the Alps, which Saussure calls *granit veiné*, is properly an incipient state of gneiss: the mica is arranged in thin parallel laminæ varying in distance from each other; when they approach very near, they form what in hand specimens is called true gneiss. When the parallel layers of mica are at some distance from each other, they give a striped appearance to the rock. Laminæ of quartz of considerable thickness sometimes separate the felspar from the mica, and occasionally, masses of quartz are imbedded in gneiss. When the mica becomes very abundant, and the other constituent parts are small in size and quantity, gneiss passes into mica-slate; — gneiss has often a waved form. This rock has been represented as stratified, I conceive, by a mistake, in confounding the stratified with the slaty structure: the latter is occasioned by the quantity of mica, and sometimes of talc which it contains, and is the effect of crystallisation.*

Beds of crystalline limestone, and of hornblende rock, occur in gneiss. It contains most of the metallic ores both in veins and beds. Crystals of garnets are frequently interspersed in gneiss, but are more common in micaceous schist, which is nearly allied to this rock.

The declivities of granite mountains are covered by rocks of gneiss in many parts of the world. Gneiss constitutes the principal rock-formation in a considerable part of Sweden. It occurs in Scotland and Ireland, but is scarcely known in any part of

---

* The partings or divisions in rocks, which may properly be denominated rents, are distinct from those which are the effect of crystallisation, and may be distinguished by their irregularity, roughness, and the indeterminate manner in which they intersect the stone. Some partings have evidently been the result of mechanical causes.

England or Wales. Very well characterised gneiss occurs in the vicinity of Aberdeen. An imperfectly formed gneiss is found on the Malvern Hills. I have also seen gneiss brought from the lower part of Skiddaw in Cumberland. Mountains of gneiss are not so steep and broken as those of granite, and the summits are generally rounded.

Mica-slate, or *Micaceous Schistus*, is frequently incumbent on gneiss, or granite, and covered by common slate: it passes by gradation into both these rocks — the coarser grained resembling gneiss, and the finer kind, by insensible transition, becoming clay-slate.

Mica-slate is essentially composed of mica and quartz intimately combined; the felspar, which is a principal constituent part of granite and gneiss, occurs only occasionally in irregular masses in this rock. The colour of mica-slate is generally a silvery or pearly white, inclining to a bluish grey or a light green; it sometimes is nearly black, and, when weathered, is generally yellow. I have a specimen of mica-slate from North America, which has the purple colour of the amethyst; but such deviations from the common colours are rare.

Crystals of garnet are frequently disseminated in mica-slate: it contains occasionally crystals of other minerals. It has a slaty structure, and is often waved and contorted, and divided by thin laminæ of quartz. It sometimes contains beds and laminæ of crystalline limestone, or is intermixed with serpentine. Mica-slate also frequently contains beds and veins of metallic ores. The gradation of mica-slate into gneiss and clay-slate, and the transition from granite to mica-slate, may be distinctly seen in some of the rocks near Bray, in the county of Wicklow in Ireland, where I observed that the beds of mica-slate adjoining the granite, are traversed by numerous and large seams of quartz, running parallel with the slaty structure of the rock, and increasing in size as they approach the granite. The quartz has a greasy aspect, and is evidently of contemporaneous formation with the mica-slate and granite.

Mica-slate has a near affinity to clay-slate; and as I have arranged the latter with rocks of the second class, it may perhaps be doubted whether mica-slate should not also have been transferred to the same class. No well characterised rocks of mica-slate of any extent occur in England. I noticed a micaceous rock, which may be considered as an imperfect kind of mica-slate, near the granitic rocks of Mount Soar Hill; but it was covered by wood, which concealed its junction with other rocks. On the western side of Anglesea, near Holyhead, there are numerous rocks of an intermediate kind between mica-slate and talcous slate. The laminæ are separated by very thin seams of quartz; and I observed some of them bent and contorted in various directions, as is not unfrequently the case with mica-slate in other districts.

The mica-slate on the opposite coast of Ireland, near Bray, I am inclined to consider as of the same formation with that in Anglesea. Probably this rock stretches under the Irish Channel, of which it may form the bed in that parallel of latitude. The structure of both rocks is the same, presenting the same divisions by thin laminæ of quartz, but the mica of Anglesea is more combined with talc. Mica-slate abounds in the Highlands of Scotland, and in many alpine districts in Europe, particularly in the Pennine Alps.

Gneiss and mica-slate are nearly allied to each other and to granite. Circumstances attending the formation of granite appear to have produced a different arrangement of the component ingredients. This is the more probable, as both gneiss and mica-slate sometimes graduate into granite, and have at other times a porphyritic structure. In some situations the causes which change granite into gneiss or mica-slate have not operated; and we find neither of these substances separating granite from the rocks of the next class.

An opinion has been advanced by Dr. Macculloch, that gneiss and mica-slate have been deposited by water, though he admits the igneous formation of granite: but granite is known, as before stated, to vary much in the proportion and size of its constituent minerals even in the same rock. Now wherever the felspar was deficient, and the mica and quartz abundant, or where the felspar was more granular, and the mica abundant, the same process that formed granite in one part of a rock, would form gneiss or mica-slate in another. Every one who has examined the *granit veiné* of the Alps *in situ*, will admit that it had the same origin as common granite; and again they could scarcely hesitate to say, that gneiss and *granit veiné* are only mere varieties of the same rock, and must have had one common origin. The mica in gneiss is as much an igneous formation as that in granite, or in some volcanic rocks.

Gneiss and mica-slate being nearly similar in their constituent parts and geological position, most of the metallic ores and minerals found in one rock, occur also in the other. Crystalline limestone, hornblende, talc, and serpentine, more frequently form beds in mica-slate than in gneiss. The waved structure is very common in mica-slate, and the beds are often most singularly bent and contorted.

Talcous Slate and *Chlorite Slate* appear to be different modifications of the same mineral substances: in the former the structure is laminated, in the latter it is minutely laminated or granular; the prevailing colour of both inclines to green. These rocks are soft and saponaceous to the touch, and sectile. Mica-slate appears to graduate into talcous slate, particularly in the vicinity of Mont Blanc. In Cumberland and Scotland talcous and chlorite slate pass into common roof slate, and alternate with it: the change appears to be owing to a greater mixture of magnesian earth in talc slate, than in common slate. Some varieties of chlorite slate are harder and darker, and approach nearly to hornblende slate. The passage from talcous slate to serpentine forms potstone. Talcous slate frequently occupies the place of mica-slate in primary mountains, and is sometimes confounded with it; the two minerals, talc and mica, nearly resembling each other. See Chap. III. The large plates of mica, which are made to supply the place of glass in some lanterns and in the slides for microscopes, are always miscalled talc. Sometimes mica-slate, from an intermixture with talc, forms an intermediate rock, which partakes of the characters of both rocks: such mica-slate has generally a greenish colour, and is softer than common mica-slate.

Crystalline or *Primary Limestone*, of which statuary marble is a variety, occurs principally forming beds in primary mountains. Beds of this mineral occur rarely in granite, more frequently in gneiss, but are most common in mica-slate, with which rock it is often much intermixed, and often alternates with it. It is observed that the primary limestone in granite and gneiss, is coarser grained than that in mica-slate or common slate. Primary limestone is often much intermixed with serpentine. When beds of primary limestone occur of considerable thickness, they sometimes contain veins of metallic ores.

Crystalline or primary limestone, when pure, is composed of calcareous earth, which scarcely exists as a component part of granite, gneiss, or mica-slate. No organic remains are found in the crystalline limestone in primary mountains; the structure is granular; the white variety known as statuary marble resembles fine loaf-sugar, and is imperfecly translucent; hence it has been called by the French *chaux carbonatée saccaroide*. The colour of primary limestone is sometimes yellowish, greenish, or inclining to red. From a mixture of mica it has often a slaty fracture and divides in plates. It may be further deserving notice, that primary limestone or statuary marble, frequently contains a considerable quantity of siliceous earth, to which it owes its hardness and durability.

Neither in England nor Wales have any rocks of limestone been found which possess the crystalline translucent qualities of statuary marble, though very beautiful marbles occur which will receive a high polish; these belong to the limestone which will be described in the following chapter. White marble is procured from Italy, Switzerland, and the Græcian Archipelago.

Imperfectly white crystalline limestone occurs in different parts of Scotland intermixed with serpentine and mica-slate. Crystalline limestone is also found in the Hebrides, particularly in the Isle of Sky; but it well deserves attention that this limestone, in the latter island, evidently appears to be secondary limestone (lias), changed in its character by its contiguity to trap rocks, which were in all probability in a state of igneous fusion. In other alpine districts, the limestones called primary, appear also to have derived their crystalline character from the action of igneous rocks in their vicinity, and hence ought not to be classed with primary formations. I have seen many beds of extremely hard white limestone in the Alps, which have all the characters of primary limestone, with the exception of being somewhat less granular. These beds occur over other beds containing the fossils found in green sand, and may therefore be classed with chalk. That the highly crystalline limestone which occurs near primary mountains has been in a state of fusion, is rendered probable by the crystals of garnet and siliceous minerals which are often imbedded in it. These minerals could not have been deposited from an aqueous solution.

It was once supposed that all calcareous rocks and strata were composed of the shells of marine animals, and it cannot be doubted that many of them are entirely formed of these organic remains: but in the beds of primary limestone, and even in some of the secondary limestones, no vestiges of such remains occur. It may be said that the process by which primary limestone was crystallised, destroyed all traces of organisation; and though it would be impossible to disprove this, yet there is no reason to believe that lime may not exist as an elementary earth, like silex or alumine, independent of the operations of animal life. It does so exist as a component part of many minerals, and it may have existed in sufficient quantity to form the mountains of primary limestone.

It is, however, a curious but undoubted fact, that no inconsiderable portion of the earth's surface has been formed by organic secretion; and the process is still going on extensively in the Pacific and Indian seas, where multitudes of coral islands emerge above the waves, and coral shoals and reefs occur at small depths beneath the water, in which, according to the observations of MM. Quoi and Gaimard, the animals may be seen. "Some spread out into fans, or ramify into trees; some are round like balls; their varied and elegant forms mingle and blend together, and reflect the varied hues of red, blue, and yellow." As one generation dies and leaves its calcareous remains another succeeds, until the mass of coral is raised to the surface, when the formation ceases. Fragments of coral are afterwards broken off by the waves during storms, together with shells, weeds, and sand, and are driven upon the other parts of the island, and continue to elevate it until it is above the reach of their action. From the accounts of the above naturalists, and the more recent observations of Captain Beechy, it appears, that the species of polypi that chiefly form coral islands, do not exist at greater depths than a few fathoms below the surface *; therefore, the deep soundings taken near these islands prove, that coral forms the crests of steep submarine mountains, which were probably volcanic, as these crests have frequently a circular shape, but are open on one side, leaving a passage to a circular lagoon or lake within, which is shallow, and supposed to fill the

---

* Some species of coral were brought up by soundings, from the depth of one hundred fathoms or more.

crater of a submarine volcano. Though the beds of coral that form islands are not of the vast thickness which had been supposed, yet they rival, in extent and magnitude, some of the large calcareous formations of our present continents.* Beds of oyster shells, many miles in length, are also known to occur in European seas; thus millions of small marine animals are preparing future abodes for other classes of animals of larger size, and living in another element. From whence do these innumerable zoophytes and moluscous animals procure the lime which, mixed with a small portion of animal matter, forms the solid covering by which they are protected? Have they the power of separating it from other substances, or the still more extraordinary faculty of producing it from simple elements? The latter I consider as more probable; for the polypi which accumulate rocks of coral have no power of locomotion; their growth is rapid, and the quantity of calcareous matter they produce, in a short space of time, can scarcely be supposed to exist in the waters of the ocean to which they have access, as sea-water contains but a minute portion of lime.

It is now ascertained that lime and the other earths are compounds of oxygen united with metallic bases; and the brilliant discoveries of Sir H. Davy respecting the metallic nature of ammonia, would lead to the conclusion, that the metallic bases of all the alkalies and alkaline earths, which have many properties in common, may, like ammonia, be compounds of hydrogen and azote, but differently combined. Now it is well known that hydrogen and azote, which exist as elementary constituent parts of almost all animal substances, may be derived from water and the atmosphere; and should the compound nature of the metallic bases of the earths be ascertained, the formation of lime by animal secretion will admit of an easy explanation.

---

* Some of these islands are considerably elevated above the level of the sea; in all probability they have been upheaved by volcanic

Dolomite, so called in honour of the French geologist Dolomieu, is a variety or modification of limestone; it contains 48 parts of magnesian earth, combined with 52 parts of calcareous earth. Dolomite is found in rocks of different classes; that which occurs at St. Gothard, and other parts of the Alps, closely resembles white primary limestone: it is minutely granular, and the grains are easily separated by the finger; but some varieties are harder. Dolomite and the magnesian limestones in the secondary strata, dissolve with more difficulty in acids than common limestone. Dolomite forms vast beds in the western Alps; it occurs also in various parts of the Apennines; in Carinthia there are entire mountains of Dolomite. The beds of Alpine Dolomite are often much broken, apparently by the protrusion of beds and masses of porphyry. The eminent geologist Von Buch maintains, that limestone has been converted into Dolomite by its proximity to porphyry in fusion, and that the magnesia has been transferred from magnesian minerals in the porphyry to the limestone; the magnesia being reduced to vapour or gas. Great difficulties attend this theory; I shall hereafter notice situations in England, where the theory might be subjected to the test of direct experiment. For the present it may be sufficient to notice, that many strata of magnesian limestone appear far removed from the possible influence of igneous rocks. Magnesia is found in many earthy minerals, and may be regarded as a constituent element of the globe.

Serpentine derives its name from its variegated colours and spots, supposed to resemble the serpent's skin: its chemical composition has been before described. The colours are most generally various shades of light and dark green, which are intermixed in spots and clouds; some varieties are red. When fresh broken it has some degree of lustre, and a slightly unctuous feel; when pounded, the powder feels soapy. It is harder than limestone, but yields to the point of a knife, and will receive a very high polish. When serpentine is found intermixed with patches of crystalline white marble, it constitutes a stone denominated verde-antique, which is highly valued for ornamental sculpture. Some varieties of serpentine are translucent, in others there is an appearance of crystallisation, forming a mineral called diallage or schiller-spar. The minerals associated with serpentine are generally those allied to talc. Compound rocks in which talc and hornblende are predominating ingredients, pass into serpentine. Magnesia enters largely into the composition of these rocks. A late analysis of one kind of serpentine, gave 48 per cent. of this earth. Serpentine commonly occurs in gneiss and mica-slate, in beds which are sometimes so thick as to compose mountain masses of considerable height. Serpentine sometimes becomes magnetic, from an intimate intermixture with minute particles of magnetic ironstone. Many of the alpine districts in Europe contain rocks and beds of serpentine; but, according to Patrin, there is no serpentine in Northern Asia, nor was it seen by Humboldt in the Andes; it is not uncommon in the United States of North America. In the Alps, it is observed that the rocks of serpentine lie principally on that side which faces Italy, and the coast of Genoa. There is a soft kind of serpentine, sufficiently tenacious to be turned in a lathe into vessels of any shape, which resist the action of fire: hence they are used for culinary and other purposes in some parts of Switzerland, in Lombardy, and even in Higher Egypt. The use of this stone is of great antiquity, being distinctly mentioned by Pliny; it is called *lapis ollaris*, or potstone.

In Cornwall serpentine occurs with a micaceous rock lying over granite, and forms part of the promontory called the Lizard Point. It occurs, also, near Liskeard, in the same county. It is not met with in any other part of England that I know of; but I have observed rocks approaching the nature of serpentine in Charnwood Forest, and in the county of Radnor, in Wales.

Beautiful varieties of red and green serpentine occur in the Isle of Anglesea, about six miles from the Paris copper-mine. It is found in beds of great thickness associated with the common slate-rocks of the district, which approach in their nature to talcous slate: asbestus lies in considerable quantities in the partings between the beds of serpentine.

Some of the specimens of this serpentine have the characters of the precious or noble serpentine; the colours are principally dark green, intermixed with spots and clouds of lighter green, and shining laminæ of schiller spar, or crystallised serpentine. The fracture is conchoidal, and it is translucent at the edges. It resists the point of a copper or brass tool, and breaks with great difficulty. Some varieties contain crystalline limestone, but in smaller patches than in the Italian verde-antique; occasional stripes and spots of steatite, asbest, and quartz, occur in it. The red is sometimes intermixed with a great variety of other rich colours in the same stone, as black, white, greenish white, and dark green. It may be considered as a valuable stone for purposes of ornamental architecture, for in beauty and durability it is not exceeded by the costly marbles of Greece or Italy.

By a mixture of serpentine with talc or steatite, serpentine becomes soft and sectile, and forms the mineral called potstone, before mentioned. A different combination of crystallised serpentine (*diallage*) with jade, or felspar, forms one of the hardest and heaviest of known rocks. It was first noticed by Saussure in rounded pieces and loose blocks, scattered over several parts of the valley near the Lake of Geneva: to this mineral the name of Saussurite has been given. It is much harder than quartz, and its specific gravity is 3·35: it is the hardest and heaviest of known rocks composed only of earthy minerals: the colour generally is greenish. Some varieties of saussurite as well as of serpentine acquire an external polish, like a coat of varnish, by exposure to the action of water: this may be observed in the pebbles of bright green saussurite near Mont St. Gothard, and in the serpentine at the Lizard in Cornwall. For a considerable time it was unknown where saussurite occurred *in situ;* it has since been discovered in immense beds, associated with serpentine, in the valley of Sass, in the Haut Valois. Near Nyon, on the Lake of Geneva, one hundred and twenty miles distant, there is a field scattered over with large blocks of the same stone, which the proprietor has been unable to remove by blasting on account of their unconquerable hardness. Beds of saussurite occur on the southern side of the Alps, and in the Apennines. A very interesting description of the saussurite and serpentine of the Apennines has been published by M. Brongniart, entitled *Sur le Gisement ou Position relative des Ophiolites, Euphotides, et Jaspes, dans quelques Parties des Apennins.** In these mountains, the serpentine rests upon saussurite, the saussurite on strata of jasper, and the latter on secondary limestone. This position is remarkable, for geologists had long supposed that all serpentines were more ancient than the secondary rocks. It has, however, been recently discovered, that some trap-rocks which are in contact with beds of limestone, or cut through beds of limestone, are changed into serpentine, apparently by intermixture with calcareous earth. This discovery throws much light on the true nature of serpentine: we can no longer be surprised at finding these rocks in formations of different epochs. Though serpentine may in many instances be considered as a rock whose quality has been changed as before stated,

---

* It is to be regretted that so excellent an observer and mineralogist as M. Brongniart, who is so justly eminent for his scientific labours, should have thought it necessary to burden Geology with two additional new names. Serpentine he has denominated *ophiolite*, and saussurite *euphotide*.

yet it would be contrary to sound induction to maintain that serpentine may not, in other instances, be an original rock formation. Wherever the earths that compose serpentine have occurred together in due proportions, the same causes which have produced other mineral combinations may have formed serpentine: it is rendered almost certain that this has been the case, as many rocks containing chlorite and hornblende, appear to pass by gradation into serpentine.

Hornblende-Rock and *Hornblende-Slate.* — This mineral has been described Chap. III. When it forms the principal parts of rocks, the colour is commonly a greenish black. Massive hornblende in rocks is generally coarsely granular and lamellar; in hornblende-slate, it is frequently radiated or fibrous, and when the fibres are very minute it has a velvet-like lustre. Hornblende-slate occurs in beds in granite, gneiss, and mica-slate, and occasionally in common slate: it appears to pass by gradation into serpentine: the change is effected by an increase of magnesia, which forms one of the constituent parts of hornblende.

Hornblende in large lamellar grains, intermixed with felspar, forms sienite, which it was remarked in the last chapter is not unfrequently associated with granite: the passage of one rock into the other by the increase or decrease of felspar, may frequently be observed in the same mountain. When hornblende and felspar are more intimately blended, they form the rock called by the Germans *Green-stone*, by the French *Diabase;* and, with other rocks of similar composition, are frequently described as trap-rocks, and by the French as *roches amphiboliques:* these will be more properly noticed in the subsequent chapters. When the hornblende and felspar are so closely and minutely intermixed that the rock appears homogeneous, the trap has all the external character of a rock (hereafter to be more fully described) called Basalt.* In examining the geological specimens of saussure in the museum at Geneva, I observed that the rocks which he so frequently mentions under the name of *Cornéene*, are mixtures of hornblende and felspar, in which the former mineral predominates.

Hornblende intermixed with felspar, forming sienite and green-stone, occurs at the Malvern Hills, in Worcestershire; at the Charnwood Forest hills, in Leicestershire; and in Cornwall, Cumberland, and North and South Wales. Very little well characterised hornblende-slate is found in any part of England, but it occurs abundantly in the alpine parts of Scotland, and in most of the principal mountain ranges in Europe. The various intermixtures of hornblende and felspar, to which the name of traprocks is frequently given, may more properly be classed with transition rocks.†

Porphyry derives its name from a Greek word denoting *purple;* the rock to which it was at first

---

* The rock to which the French give the name of Diabase, the compact trap of Werner, resembles basalt (which the French call Dolerite) so closely, both in composition and physical characters, that the division into two species seems principally made to serve the purpose of theory. Diabase is composed of felspar and hornblende, and dolerite of felspar and augite intimately combined. But as hornblende and augite do not differ more in chemical composition, than one species of hornblende differs from another, and as these two minerals are only to be distinguished by their crystallisation; when they occur uncrystallised, may they not be regarded as identical? It is true, augite occurs abundantly in rocks of undoubted igneous origin, and in the lavas of recent volcanoes; hornblende occurs also in basaltic lavas, but more frequently in rocks of which the igneous origin is not so generally admitted: yet it may be fairly doubted, whether the distinction between compact diabase, and compact dolerite, has not been made in order to form gratuitous conclusions respecting the different origin of rocks, which are, in chemical composition and external characters, essentially the same.

† Dr. Macculloch states an instance in Shetland, where slate (clay-slate) appears to be converted into hornblende-slate by approximating to granite; but no inference can be fairly drawn from a solitary instance of this kind, as there is no evidence to prove that the hornblende-schist is not an original rock.

applied had a purple colour. In the modern acceptation of the term, any rock which is compact or finely granular, and contains distinct imbedded crystals, is called Porphyry, whatever be its colour. The base or paste of most porphyritic rocks is felspar; and the imbedded crystals are also felspar, though there may be also small grains or crystals of quartz or other minerals. It has been stated, in the preceding chapter, that granite, by becoming finer grained, frequently passes to the state of porphyry. The *eurite* of the French geologists, and the *weissstein* or *white-stone* of Werner, is a granite in which the felspar is the principal constituent part, and is either finely granular or nearly compact. To this variety English geologists give the name of compact felspar: the white elvan of the Cornish miners is a porphyritic eurite,

Geologists have described four formations of porphyry, but it is generally agreed that there is much uncertainty with respect to the situation of these formations. The porphyry which occurs regularly imbedded in granite, or which appears to be formed by a mere change of structure in that rock, may properly be classed with primary rocks: it is not considered to be an extensive formation; the white elvan of Cornwall, and probably the porphyry associated with mica-slate in Argyleshire, belong to this formation. Porphyry also occurs in enormous masses, sometimes intersecting and sometimes covering primary mountains. The granite of Ben Nevis in Scotland is intersected by veins of porphyry; and at the head of Glen Ptarmagan, a cliff of porphyry 1500 feet high, shaped like an oblique truncated pyramid, passes through granite.* Porphyry; imbedded in transition rocks, or associated with trap or volcanic rocks, must generally be regarded as cotemporaneous with the formations in which they occur. Porphyry is in some instances an undoubted

---

* Phil. Mag.

volcanic formation, and presents a connecting gradation between granitic primary rocks, and those of a more recent igneous origin. Wherever porphyry occurs unconformably, covering other rocks, it is evidently more recent than the rocks on which it rests, and must be classed with basaltic or trap-rocks; this porphyry will be described with them in a subsequent chapter.

Before taking leave of the rocks classed as Primary, it may be proper to notice that some of the rocks associated with granite, gneiss, and mica-slate, occur also in the transition class, and even in the lower secondary strata. The same causes by which they were formed among primary rocks, have also operated at a later period: indeed, one of the well known rocks, limestone, has been deposited or formed in all the different classes of rocks except the volcanic, and must therefore receive its name from the class with which it is associated; as primary limestone, transition limestone, &c. In some instances, the mineral characters, or the fossils, serve to distinguish rocks of the same kind, that occur in the different classes or formations: thus the rocks associated with primary rocks are generally harder and more crystalline than the same species of rock which occurs in the secondary class; but this is not invariably the case.

CHAP. VII.

ON INTERMEDIATE OR TRANSITION ROCKS.

Characters and Classification of Transition Rocks. — Slate or Clay-Slate. — Peculiarities of Structure. — Varieties of Slate. — Flinty Slate. — Greywacke and Greywacke-Slate; its Passage into Red Sandstone and Gritstone. — Errors of Geologists respecting the old Red Sandstone. — Lower Transition-Limestone: remarkable Position of its Beds. — Upper Transition or Mountain Limestone. — Magnesian Limestone, in Mountain Limestone. — Peculiarities in the Stratification of Clouds Hill. — Errors respecting the Mountain Limestone of Derbyshire. — Remarkable Structure of Crich Cliff. — Quartz Rock. — Jasper Greenstone. — Coal Strata in England separate the Upper Transition Rocks from the Secondary. — Observations on the Transition Rocks of distant Countries. — Errors of Geologists respecting them.

Transition or intermediate rocks cover rocks of the primary class, and are distinguished as the lowest rocks in which the fossil remains of animals or vegetables are found; they may be regarded as the most ancient records of our globe, imprinted with the natural history of its earliest inhabitants.

Transition rocks are the principal repositories of metallic ores, which occur (both in veins and beds) more abundantly in many of the rocks of this class than in primary rocks. Metallic veins very rarely occur in the secondary strata.

Geologists have often been perplexed in their attempts to draw a well-marked line of distinction between primary and transition rocks: the difficulty has arisen chiefly from their arranging slate with the primary class; and hence the disciples of Werner have been obliged to introduce the theoretical terms of newer and older primary slate, and newer and older transition slate, &c. If the occurrence of organic remains in rocks be the characteristic distinction between the primary and transition class, slate must certainly be classed with the latter; for it is among the slate rocks that the fossilised remains of animals and vegetables first appear, in every country that has yet been examined. One of the disciples of Werner, M. D'Aubuisson, admits that there is no where any extensive formation of primary slate. M. Bonnard, another disciple of the same school, in his *Apperçu Géognostique des Terrains*, after enumerating various primary slate rocks, candidly acknowledges that it is doubtful whether primary slate can any where be found. It is true, that mica-slate passes by almost imperceptible gradations into common slate; but here, as in other instances, we only find that Nature is not limited by the artificial arrangements of the geologist: yet so long as it may be proper to class rocks containing organic remains with transition rocks, we must place slate among them. Nor can this be invalidated by the fact, that in some slate rocks no vestiges of animal or vegetable remains occur; for among the secondary strata, abounding in such remains, we often meet with alternating beds, in which they are never found; but we do not, on that account, class them with primary rocks. In arranging transition rocks, I most decidedly place the English mountain limestones among them, as I have done in the former editions of this work. I know no circumstance in Geology that evinces more strongly the tenacity with which errors are cherished, when they have been some time entertained, than the determination of English geologists to separate mountain limestone from transition limestone, — in opposition to analogy, and to the universal opinion of geologists on the Continent. This separation, as a mere matter of classification, would be in itself of little importance; but it has tended more than any other circumstance to perplex both foreign and English geologists, in their attempts to assimilate the rock formations of England, with those on the continent of Europe.

When a general attention was first excited in this country to the study of Geology, access to the Continent was extremely difficult, and we were left to explore as well as we could the geology of our own island, enlightened only by the dark-lantern of German Geognosy. Many characters were given of transition rocks, or flœtz or parallel rocks, founded on local observations in Germany, which did not apply to the rocks in other countries: it was found that the characters of our metalliferous limestone did not agree very well with either, and therefore English geologists have retained the name of mountain limestone; and the appellation of transition limestone was restricted to a lower bed, small in extent, and comparatively unimportant. When I first visited the Continent, and examined the cabinets of some eminent geologists, I was particularly struck with finding the *analogues* of our principal beds of mountain limestone exhibited as types of true transition limestone. On my return to Paris the following year, I took specimens of our mountain limestone from Derbyshire, Westmoreland, Somersetshire, and Wales; and also of the lower limestones from Shropshire and Devonshire; and presented them to MM. Brongniart and Brochant. The whole of the specimens they recognised as transition limestones, and selected the encrinal and dark madrepore mountain limestones, as the true types *par excellence des Calcaires de Transition.*

The following arrangement of transition rocks comprises the lowest rocks in which organic remains occur, and those which are metalliferous, or are associated with metalliferous rocks: —

Transition Class
(conformable).

1. Slate, including flinty slate and other varieties.
2. Greywacke and greywacke-slate, passing into old red sandstone.
3. Transition limestone. Mountain limestone.

Rocks covering Transition Rocks (unconformably).

4. Porphyry, passing into trap or green-stone.
5. Clink-stone, passing into basalt.
6. Basalt.

Strata covering Transition Rocks (conformably).

7. The coal measures.*

Slate — of which roof-slate is a well known variety — is called by the Germans *Thon-scheiffer* or *clay-slate;* by ancient English geologists, argillaceous schistus; by the modern French, *Phyllade.* The term *slate* is perhaps the most proper that can be used to designate this rock; as the best variety of it, Roof-slate, is well known. Clay-slate is a name given from an erroneous opinion respecting its constituent parts; and the term is liable to create much confusion, as the softer kind of slate in the coal strata is called slate-clay. I shall, therefore, throughout the present volume substitute the term *slate* for clay-slate, and for slate-clay the more intelligible English term *shale.*

Slate rocks abound in most alpine districts, resting either on granite, gneiss, or mica slate. That slate which lies nearest the primary rocks has a more shining lustre than the other, and partakes more of the crystalline quality of mica-slate. As this rock recedes from the primary, its texture is generally more earthy. Its colours are various shades of gray, inclining to blue, green, purple, and red. Some kinds of slate split into thin laminæ, which are well known as forming roof-slates. Slate rocks are com-

---

* The regular coal strata or coal measures, where they occur in England, separate the transition from the secondary rocks. If they are classed with either, it should be with the former.

monly divided into beds of various degrees of thickness, which generally are much elevated, and from the natural divisions of the rock, they often form peaked and serrated mountains.

Slate has been described by former geologists as distinctly stratified, because it splits easily into thin laminæ, and the direction of the laminæ is asserted to be in the direction of the beds; but, in opposition to the authority of many eminent geologists, I maintain that slate, unless it be of a soft or coarse kind approaching to shale or greywacke, invariably splits in a transverse direction to that of the beds, making with that direction an angle of about sixty degrees; — it has frequently two distinct cleavages.

Few persons, perhaps, have examined more slate rocks, or consulted more workers in slate quarries than I have; and the fact respecting its cleavage is invariably what is here stated, except in very coarse greywacke-slate, and soft slate or shale.

Slate rocks vary much in quality in the same mountain; those which contain a great quantity of siliceous earth pass into flinty slate. When magnesia enters largely into the composition of slate rocks, they are distinguished by their green colour, and pass into chlorite or talcy slate, — a rock before mentioned as occurring also in primary mountains. Whetstone-slate, or hone, is a variety of talcy slate, containing particles of quartz: when these particles are extremely minute, and the slate has a uniform consistence and requisite degrees of hardness, it forms hones of the best quality. Carbonaceous matter is first discovered in slate rocks, and increases in quantity as they approach the secondary strata. Drawing-slate is stated to contain 11 per cent of carbon; where the carbon is very abundant, the slate has a dark colour, and is generally soft. Impressions of vegetables are found in some slate rocks that were formerly regarded as primary; the slate rocks in the vicinity of Mont Blanc, and Mont Cenis, contain impressions of ferns. Slate contains occasionally

That fine variety of slate which is used for roof-slate, seldom forms entire mountains, but is generally imbedded in slate rocks of a coarser kind: the beds of roof-slate are sometimes of considerable thickness, and generally rise at an elevated angle. If geologists had not been induced, by an attachment to theory, pertinaciously to adhere to opinions once received, they could not have failed to recognise the effect of crystallisation in the cleavage of slate, as evidently as in the laminar divisions of felspar.

Those varieties of roof-slate are preferred for the covering of buildings, that are the least absorbent of water, and have the smoothest surface, and split into the thinnest plates; they are, however, frequently made too thin to be durable, and too light to resist the force of the wind during storms.

Quarries of slate are worked extensively in Westmoreland, Yorkshire, Leicestershire, North Wales, Cornwall, and Devonshire. The foreign localities of slate are so numerous, it would be superfluous to name them.

Mountains of slate are seldom so precipitous as those of granite, but have often a sharp serrated outline. They are covered with verdure on their declivities, as they contain less silex, and a more equal admixture of the earths favourable to vegetation.

Flinty slate, as before observed, differs from common slate by containing a greater quantity of siliceous earth; and, as its name implies, it partakes of the nature of flint. Slate and flinty slate not only pass into each other, but frequently alternate. When the latter ceases to have the slaty structure, it becomes hornstone, or what the French denominate petrosilex. If it contain crystals of felspar, it becomes hornstone porphyry: all these varieties may be observed alternating with each other in the same rocks in Charnwood Forest, and in North Wales and Cumberland.

Slate is regarded as one of the most metalliferous rocks: nearly all the principal metallic ores have been found in slate, either in veins or beds; but it is remarkable that flinty slate seldom contains any repositories of metallic matter. Lead and copper are the principal metals found in the slate rocks of England and Wales: they are not so rich in lead as the mountain limestone, but the lead ore in slate rocks contain a larger portion of silver. The killas of Cornwall, so remarkably metalliferous, is a variety of slate.

Greywacke and *Greywacke-Slate;* German *Grauwacké.* — This dissonant term, which we have borrowed from the German, the French geologists have exchanged for a name not more harmonious, though more expressive, *Traumate,* from the Greek *Thrausma* a fragment.

Greywacke, in its most common form, may be described as a coarse slate containing particles or fragments of other rocks or minerals, varying in size from two or more inches to the smallest grain that can be perceived by the eye. When the imbedded particles become extremely minute, greywacke passes into common clay-slate. When the particles and fragments are numerous, and the slate in which they are cemented can scarcely be perceived, greywacke becomes coarse sandstone or gritstone. When the fragments are larger and angular, greywacke might be described as a breccia with a paste of slate. When the fragments are rounded, it might not improperly be called an ancient conglomerate. When rocks of greywacke have a slaty structure, they form greywacke-slate.

Greywacke has by some of the French geologists been described as a transition sandstone, with a cement either of siliceous earth, or of slate. This definition agrees with the gritstones associated with the upper transition or mountain limestone. Where the paste is hard and siliceous, as I have observed in the greywacke of Savoy, that separates the primary from the secondary rocks, many of the siliceous particles may have been original concretions formed at the same time as the paste; and where these concretions are all composed of quartz, we may infer that such has been their mode of formation. In other instances, the fragments are evidently the débris of more ancient rocks, that have been broken down by some great catastrophe, and mixed with more recent beds at the period when they were forming. This mode of formation implies, that a considerable period elapsed between the formation of the primary and secondary rocks. The fragments are always those of lower rocks, and never of the upper strata. In some situations, immense beds of loose conglomerate, composed of large fragments and boulders of the lower rocks, separate the slate rocks from the calcareous formations: such conglomerates may be regarded as occupying the geological place of greywacke, and belonging to the greywacke formation.

The old red sandstone, about which so much has been written and so little understood, is a greywacke, coloured red by the accidental admixture of oxide of iron. In Monmouthshire, the relations of red sandstone with greywacke, and the passage of one rock into the other, may be distinctly observed; the connection also with the lower gritstone, under the mountain limestone, may be plainly traced. Here, then, we have the mountain limestone with its alternating beds of grit, the red sandstone and the greywacke, evidently members of the same formation; and to make the connection more complete, the red sandstone contains beds of limestone, which form the link between the lower transition and the upper transition limestones. This limestone is imperfect, being intermixed with siliceous particles; it is of a greenish colour, and hence called Gooseberry limestone. The red sandstone also passes into claystone, which is as well characterised as that of the Pentland Hills.*

---

* From the quantity of oxide of iron and of red marle in some beds of the old red sandstone, and from its passage into claystone,

The old red sandstone possesses all the mineral characters of greywacke, except the colour, which is a quality that can never be considered of importance, being chiefly derived from local or accidental causes. The old red sandstone also occupies the geological position of greywacke, and greywacke-slate, into which it passes merely by a change of colour. The principal reason why it has not been generally recognised as belonging to the greywacke formation is, that it has frequently been confounded with the red sandstone above the coal formation: some of the beds greatly resemble each other; and it is not yet clearly ascertained, whether the red sandstone in some parts of England and Scotland be the old red sandstone or the new. Until English geologists shall renounce their prejudices, and place the old red sandstone and mountain limestone in the Transition Class, as greywacke, and transition limestone, every attempt will be vain to identify this part of the geology of England with that of the Continent: particularly as the Alpine limestone of foreign geologists, is a very different formation from the transition limestone, comprising the several formations of limestone above the coal strata, and new red sandstone, or what the French call *Grès bigarré*.

Transition Limestone.— This is one of the most important of the transition rocks: its mineral characters vary considerably, according to the nature of the rocks with which it is associated; it has generally a subcrystalline texture, and is more or less translucent on the edges. From the degree of hardness which it possesses, it will take a good polish: most of the coloured marbles are transition limestone. The prevailing colour is bluish grey, but it is sometimes red, brown, or black: the lower beds of

---

I am inclined to believe that the red sandstone of Monmouthshire has partly been formed by the decomposition of an ancient basaltic formation, which has become intermixed with greywacke.

this limestone are often beautifully variegated, veined, and spotted. It may be stated generally, that transition limestones are seldom so perfectly crystalline as primary limestones, and they have rarely the compact and earthy texture of secondary limestones.

Transition limestone occurs in beds alternating with slate, greywacke, greywacke-slate, and coarse gritstone. Some of these beds are of considerable thickness, and form mountain masses. The lowest beds alternate with slate; they contain few organic remains. The variegated limestone of Devonshire is of this kind. Sometimes numerous thin strata of slate and transition limestone alternate, and are much bent and contorted. A very remarkable instance of this occurs at Drewsteignton, near Moreton, in Devonshire, where a series of thin strata of dark limestone alternate with strata of indurated slate, and are bent and folded in various directions. Were we to take a number of alternating sheets of black and brown paper, and fold them nearly round a wine decanter, and then bend them back over the lower folds, we should have a not unapt representation of the singular contortions of the strata in this place, where they are exposed to view by extensive quarries cut in the rock.

The remarkable contortions of the beds of transition limestone and slate, imply the operation of a cause that could not only bend but soften the strata; and were we to admit that granite has once been in a state of fusion, and been protruded through the outer crust of the globe, the immediate contiguity of these bended strata to the granite of Dartmoor, might indicate the agent by which the effects were produced. Near Dudley, in Staffordshire, we have another remarkable instance of the bending of beds of transition limestone; but this is in the vicinity of basaltic rocks, which are now admitted to be of igneous origin.

The limestone at Wren's Nest, near Dudley, consists of two beds — one ten, and the other fourteen yards thick, resting upon beds of soft and imperfect limestone and shale, called *wild measures*. The two beds of limestone are separated by similar strata of wild measures thirty-eight yards in thickness; they are raised up together in a position approaching to vertical, and are folded round the hill, and enclose a space of about fifty acres, with a double wall of limestone rising above the country, like an oval tower widening at the lower part.

If two sheets of pasteboard were separated by a quire of blue paper and laid flat, and a blunt metallic rod were thrust through the whole from beneath, it would force the lower sheet of pasteboard through the upper sheets, and represent the present position of the strata at Wren's Nest Hill. At Dudley Castle Hill, about a mile distant, the beds of limestone are bent, and dip on each side of the hill. (See a section of this hill, Plate III. fig. 4.)

A, Wren's Nest Hill; *a a*, *b b*, the two beds of limestone enfold the hill, as represented in the small compartment E, above the section. The dotted line and open spaces show where the limestone has been quarried away: 1, 2, are deep galleries over each other, along which the limestone is also quarried; the lower is near the level of a canal which penetrates the hill to convey the limestone away: *c*, represents the outcrop of the thirty feet bed of Staffordshire coal, which comes to the surface near Wren's Nest Hill; B, represents the arrangement of the limestone strata at Dudley Castle Hill, similar to that at Wren's Nest Hill; and D, a hill capped with rudely columnar basalt in the vicinity. In this section the proportion of distance has been disregarded, in order to comprise the different objects in one view: the distance between Dudley Castle Hill and Wren's Nest Hill, is about two miles. The strata at Dudley Castle Hill are what is called saddle shaped, declining on each side of the hill.

The transition limestone of Dudley is not covered by any beds of the upper-transition or mountain limestone, but by strata about seventy-six yards in total thickness, composed of imperfect limestone and sandstone, which separate it from the lowest coal measures. It is therefore to be particularly noticed, that the coal strata, which in most of the coal districts in England rest upon the upper transition or mountain limestone, in this part of Staffordshire rest upon the lower transition limestone. The remarkable fossil, the trilobite, called the Dudley fossil, occurs principally if not entirely in a stratum under the first limestone. There are shells in what are called the wild measures, but they are in a soft and decomposing state.

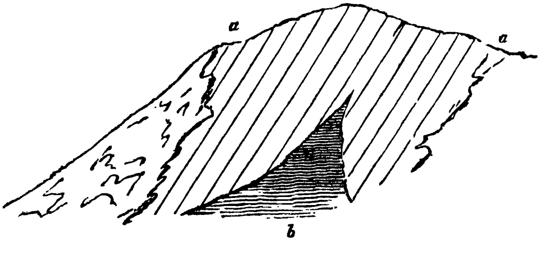
The lower transition limestone in England and Wales, is not a very extensive formation: it skirts the granite of Dartmoor, and part of the Malvern Hills; it extends in a narrow belt from Wenlock, in Shropshire, to Caermarthen, in Wales, and is generally accompanied with soft greenish schistose strata, called dye earth, which contain numerous impressions of shells. A few patches of this limestone occur in various parts of the slate districts in Wales, and Cumberland. This part of the transition limestone series is chiefly remarkable for its organic remains; it is rarely metalliferous.

The upper transition or mountain limestone is, as I have before stated, the limestone to which the French geologists gave, *par excellence*, the name of *Calcaire de transition*. It is by many English geologists considered as a distinct formation from the lower, or what they call the true transition limestone; and it is said to be "separated from it by the important formation of the old red sandstone:" but the latter is only a variety of greywacke, and is acknowledged, even by those who make it a distinct formation, to graduate into greywacke, and to possess all the general characters of that rock, except that it is coloured red. The old red sandstone contains, in some situations, beds of imperfect limestone, which may be said to connect the lower transition and mountain limestones in one formation, together with the associated beds of greywacke, red sandstone, and gritstone.

Mountain limestone is one of the most important calcareous rocks in England and Wales, both from its extent, the thickness and number of its beds, the quantity and variety of its organic remains, and its richness in metallic ores, particularly of lead. In Derbyshire, where the different beds of limestone have been pierced through by the miners, the average thickness of the three uppermost is about 160 yards; the beds are separated by beds of trap or basalt, resembling ancient lavas. The lowest limestone has not been pierced through. In the northern part of Yorkshire, and in Westmoreland and Cumberland, the beds of mountain limestone alternate with beds of greywacke-slate, and of coarse sandstone. In North Wales, and in Somersetshire, mountain limestone forms entire mountain masses, of vast thickness, distinctly stratified; the strata often varying in colour, and sometimes in the nature of their organic remains.

The beds of mountain limestone in England and Wales vary much in colour and quality. The colour is most commonly light grey, but it is sometimes black and sometimes a reddish brown, or is variegated. The limestone is generally sufficiently hard to receive a high polish, and forms what is denominated marble of considerable beauty. The texture is more or less crystalline. — The prevailing characteristic organic fossils are encrinites and madrepores. The upper beds of mountain limestone in Derbyshire appear to be almost entirely composed of encrinites. A bed of black limestone with madrepores occurs in Westmoreland; it is more rare in Derbyshire, but is found in the lower part of the mountain limestone in North Wales, and Shropshire, and also in Devonshire. It takes a beautiful polish, and is much used for chimney-pieces. The black colour appears to be derived from bitumen, for it is injured by heat, and is expelled entirely by burning. Mountain limestone is generally a nearly pure carbonate of lime; but some beds, and even entire hills of this limestone, contain a large portion of magnesia, like the dolomite of the Alps. The mountain magnesian limestone of England is generally harder than the common limestone, and has frequently a reddish brown colour. Bredon Hill, in Leicestershire, and Cloud's Hill, in its vicinity, are entirely composed of magnesian limestone; there are several beds of similar limestone which form low hills in the adjacent country: they may all be regarded as an extension of the Derbyshire mountain limestone, ranging southward towards Charnwood Forest, and terminating at Grace Dieu, where the limestone is nearly in contact with the granitic and porphyrytic rocks. I say these may be regarded as an extension of the Derbyshire mountain limestone, though the continuity is partly concealed by a covering of the red marle, and by coal measures: the limestone contains the same characteristic fossils as the Derbyshire limestone, particularly encrinites (screw stones), and the euomphalus; but these are not abundant. The strata of Breedon Hill and Cloud's Hill are much exposed, having been extensively quarried for lime during a long period; they rise southerly from 45° to 60°. When I visited these hills in 1811, I was forcibly struck with the appearance and elevation of the strata, and I was disposed to attribute their position to the disturbing force which had elevated the granitic range of Charnwood; but such opinions were at that time much discouraged by English geologists. I visited these quarries again in 1830, after having repeatedly observed similar effects produced in the proximity of granite, and I was confirmed in my former views.

The theory of Von Buch respecting the conversion of common limestone into magnesian limestone by the proximity to porphyry (see Chap. XI.), may be considered as deriving some support from the near approach of this magnesian limestone to the porphyry and porphyritic sienite of Charnwood. I shall refer to the subject elsewhere. The reason for entering more into detail, respecting the magnesian limestone of Breedon and Cloud's Hill than may appear consistent with an introductory work, is, that the strata of the latter hill present an anomalous appearance, which I have not observed elsewhere, and which is connected with the enquiry respecting the character of stratified rocks. At Cloud's Hill, the face of the rock which is worked, rises to the height of about 300 feet. The stratification is most distinctly marked by regular strata seams, or partings, which show the elevation of the strata to be about 60°. In the midst of these strata there are masses in which all traces of stratification are obliterated; these masses are not separated by any partings or divisions whatever from the strata which surround them; the masses and strata are precisely of the same quality, and similar in appearance. The masses are more difficult to work because they have no regular partings; these masses are on this account called, by the quarrymen, knobs. The annexed cut represents one of these masses —



a a, strata of limestone; *b*, an unstratified knob.

Instances of unstratified beds and masses of one kind of rock, interposed between regular strata of another kind, are not uncommon; and in the midst of primary rocks, divided by regular cleavages, parts may frequently be seen, in which the cleavages or divisions are obliterated; but, in both these cases, the solution of the cause of this obliteration may be found in igneous fusion, combined with refrigeration. If the unstratified masses at Cloud's Hill owe thier of formation. The whole of that enormous mass of limestone in Craven, from Ingleborough and Whernside to Gordal, is intersected by perpendicular fissures, which are narrow at the top, and become wider as they descend, through which the water may be heard to run at a vast depth below. These unseen but ever-active streams are slowly but progressively wearing down the internal parts of these calcareous mountains, and depositing them in the sea.

The mountain limestone of Derbyshire demands particular attention from the interesting geological phenomena which it presents; though it has been much visited and frequently described, I believe the accounts hitherto given have been in some respects erroneous. I revisited the country round Matlock soon after my return from the Continent, and was then convinced that the structure of the calcareous mountains had been mistaken, but the state of my health did not permit me to pursue the enquiry. Since the publication of the third edition of this work, I have again examined this part of the country carefully, and shall briefly state the result of my observations. Mr. Whitehurst has the merit of being the first observer who discovered some of the leading features of the geology of this district: he boldly pronounced that the beds of trap and amygdaloid, provincially called *Toadstone*, which are interposed in the limestone, were volcanic lava, or at least had an igneous origin. This opinion was much opposed at the time; it is now confirmed by such a weight of evidence, as to leave little doubt respecting its correctness, (See Chap. IX.) though the facts and arguments by which Mr. Whitehurst's views were then supported were in some respects fallacious.

Mr. Farey, who followed Mr. Whitehurst, adopted the same views of the general structure of the country, though his opinions respecting the formation of the toadstone were entirely different; he considered it to be an aqueous deposition, forming regular strata, like those of sandstone in the coal measures.

Mr. Whitehurst and Mr. Farey describe three beds of toadstone, and four of limestone, in a descending series.

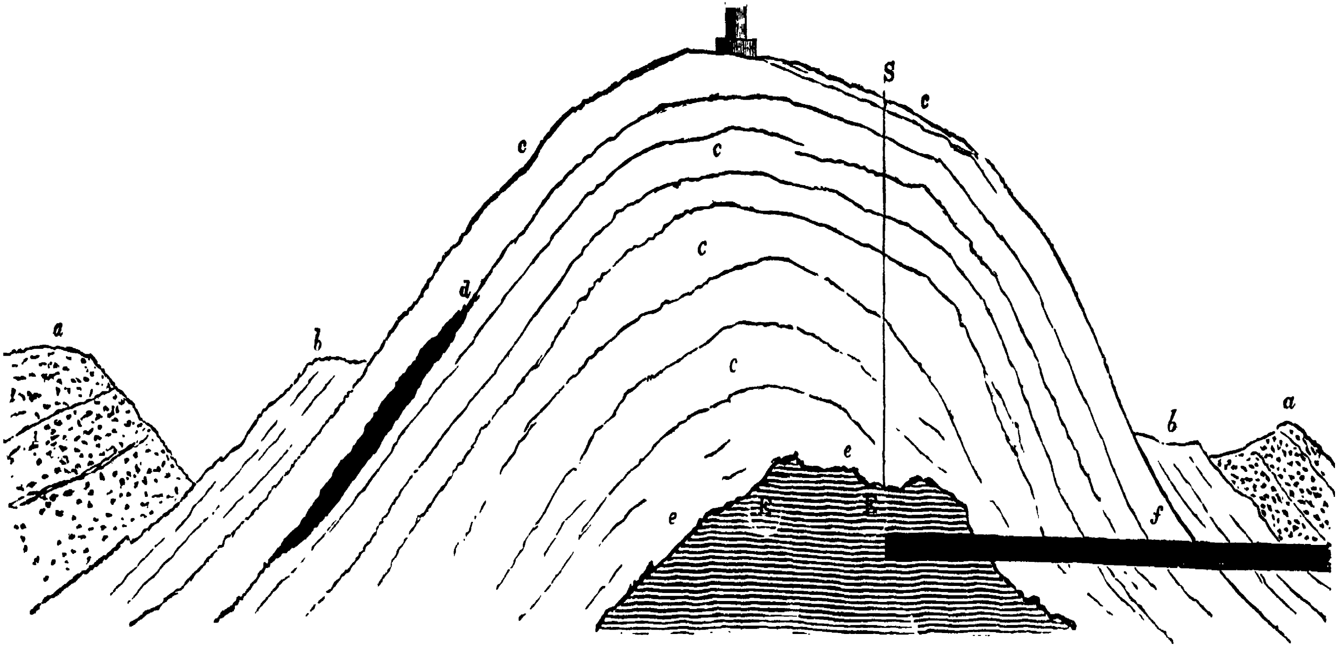
1. The first limestone 150 feet, with much white chert.
2. The first toadstone 48 feet, vesicular and amygdaloidal.
3. The second limestone 150 feet, contains beds of magnesian limestone.
4. The second toadstone 128 feet, more compact than the first toadstone.
5. The third limestone 180 feet, contains black madrepore beds.
6. The third toadstone 66 feet, uncertain.
7. The fourth limestone not pierced through, uncertain.

This may be an approximation to the thickness of the five upper beds near Matlock Bath, but is by no means an accurate statement of the succession and thickness of the beds in other parts of the county. It may be proper to remark also, that the limestone is distinctly stratified, and the strata of limestone are often divided by strata of clay, provincially called *way-boards*, and also by strata or rather seams of siliceous stone called chert, resembling flint, but less splintery in the fracture, and fusible; which latter property is doubtless owing to an admixture of calcareous earth. These strata of chert occur most frequently in the upper limestones; they contain, like the limestones, remains of shells and encrinites. As loose blocks of chert with encrinites are sometimes ploughed up in the fields, Mr. Farey supposed that these blocks have been converted from limestone into chert by some unknown process,—an opinion for which there is not the slightest foundation. The chert blocks are the remains of hard strata, which have resisted decomposition or destruction, in the same manner as nodules of flint in the upper chalk.

Large bivalve shells (*productus*) are found both in the limestone and chert. The thick beds of toadstone that divide the upper from the lower limestones, were supposed by Mr. Whitehurst to have been protruded between them in a state of fusion: this opinion will be examined subsequently. Admitting its truth, it would sufficiently account for the great irregularity in the thickness and succession of these beds, which is known to prevail throughout the Peak of Derbyshire. All the miners that I have examined on the subject, agree that the warm springs which abound in the vicinity of Matlock, rise from under the second toadstone, and that when this bed is first pierced through, the water has often a higher temperature than the Matlock Bath water, but its heat is reduced by admixture with cool springs in the upper beds.

I have now to observe that the descending series of limestone and toadstone to No. 5., or the third limestone, may all be found in the vicinity of Matlock, and many other parts of the mining district; but the beds of toadstone are of very variable and uncertain thickness. With respect to the third toadstone, its occurrence as a regular bed is extremely doubtful. In some situations there are eruptions of toadstone intervening in the third limestone, which is of vast thickness, but these beds of toadstone are generally extremely irregular: where they occur, they of course divide the third limestone into two beds. The irregularity of these beds of toadstone, and the disturbance of the regular strata which they have caused, compelled Mr. Farey to call them *chance beds*, to avoid the admission of their igneous origin. In the same manner he explained the protrusion of the granitic range of rocks in Charnwood Forest; he described them as *chance beds in the red marle;* it was surely an extraordinary chance, which produced rocks that extend under every other rock formation in the midland counties of England. There are, however, circumstances attending the stratification of the mountain limestone of Derbyshire, that have not been noticed by any of the authors I am acquainted with, who have described this country. There are evident indications of an upheaving force acting on several parts, and bending the strata into arches, the segments of large curves as represented Plate II. fig. 1. and fig. 6. These curves are sometimes complete in the same hill, but frequently their continuity is broken. The strata of Matlock high tor have been described by former writers as plain, and when seen in face of the rock they appear to be nearly so, but they are in reality curved, as shown Plate I. fig. 6. They enfold the back part of the hill, and are continued into the opposite hill, Masson, which they also enfold. The continuity of the strata is broken by the vale of the Derwent, which makes their true form more difficult to trace; but the arched stratification of the lower part of the same beds is distinctly displayed westward, and may be seen from the road near Matlock toll bar, where a section is made by the Derwent.

A very remarkable instance of the arched stratification, completely formed in one situation, may be seen four miles east of Matlock, in the isolated mountain called Crich Cliff, which rises about 900 feet above the Derwent. The strata rise all round, and enfold it, forming nearly spherical segments, as represented in the annexed cut. This section through the hill represents the arrangement of the beds of limestone which dip all round the hill *c c c*, but are somewhat flattened at the top; the shale and gritstone surrounding the lower part of the hill are represented *a b*. The true structure of the hill has been discovered by recent mining operations; several valuable metallic veins have been explored in it, and a gallery has been driven into it, as represented in the figure *f*. It is obvious that this arched structure can only be formed by protrusion, whereas the elevation or inclination of plane strata may have been produced by subsidence. Now, when we consider their near proximity


S
e
c
c
c
d
a
b
c
a
b
e
e
K
E
f

to beds of toadstone of igneous formation, we can have little difficulty in assigning a cause for this protrusion; but, fortunately, we are not here obliged to have recourse to conjecture: in driving the gallery towards the centre of the hill, a mass of toadstone was met with (*e e*), which was not cut through when I visited the place in 1830. The same toadstone was found by sinking a shaft upon it, as represented in the cut at s. In this instance we have the effects of protrusion, and the cause, displayed in the same hill. It is true, the black compact toadstone had not been reached in 1830, but a great mass of indurated green earth, which always accompanies it, and is regarded by the miners as toadstone, and is called by the same name, had been penetrated many yards. It was so hard as to require blasting. On one side of this hill is what is called a pipe vein, or opening between the strata, filled with metallic ore. This is represented in the cut at *d;* the workings in this vein have been continued nearly round the hill. Near the top of the hill there are quarries worked, which display the strata rising towards the summit on each side. Having shewn that the mountain limestone of Derbyshire assumes, in many parts, the arched stratification, it may easily be conceived how persons, not aware of the circumstance, may have fallen into great mistakes in attempting to describe the succession of beds along a certain line; for the same beds, if arched, may rise near the surface, or above it, repeatedly, in the same country. (See Plate I. fig. 2.) Other effects of the proximity of trap or toadstone on limestone will be noticed in Chap. IX.

I cannot omit, before leaving the mountain limestone of Derbyshire, to cite an instance of the influence which erroneous observations, combined with false theories, may have in retarding the progress of geology. Some years since, when it was the prevailing desire of many English geologists to make the different rocks agree with Werner's arrangement, and they were perplexed how to dispose of the mountain limestone — whether to place it in the transition class, or what were called the flœtz rocks (or flat rocks), in which class were included the upper secondary strata — an eminent chemist from the North country, who affected a profound knowledge of geology, went into Derbyshire to decide the question, and, observing the strata opposite Matlock Bath to appear horizontal, he published an oracular opinion, *that the limestone of Derbyshire was flœtz*; and this opinion continued for some time to mislead the followers of Werner in this country. Now, had this observer taken the pains to obtain a true section of the strata, he might have discovered, that instead of being flat, they were inclined at an angle of 30 or 40 degrees. (In Plate I. fig. 6.) The strata, seen in the line of bearing, do appear horizontal, whereas the section in the line of dip shows their true elevation. Nothing, however, can be more puerile than to form a classification of rocks, on a circumstance so variable as the position of the beds; and the name flœtz is now banished from geology.*

The upper transition or mountain limestone in England is particularly metalliferous; the principal ores are those of lead and zinc; they occur commonly in veins. Nearly all the lead obtained from the English mines is found in the mountain limestone. Ores of copper sometimes occur in this limestone.

Many of the fossil organic remains, both in the upper and lower transition rocks, are of genera that are not found in the secondary limestones. Some of the upper beds seem almost entirely composed of encrinites: madrepores and corallites occur abundantly in the middle part of this formation.

Quartz Rock. — Rocks composed entirely of cry-

---

* We are not, however, free from the effects of this erroneous classification. Some English geologists, finding that the characters of mountain limestone agreed with that of transition limestone, but in awe of the decision which pronounced it to be flœtz, invented a new name, *Carboniferous limestone*, which is singularly inappropriate.

stalline grains of quartz, sometimes occur among primary and transition mountains. Certain causes appear to have operated locally, and separated the quartz and felspar of granite into masses of considerable size. The quartz rock in the county of Wicklow I observed to be formed of what is called *greasy quartz*, similar to that in numerous veins in the mica-slate, near its junction with granite in the adjacent mountains, and is probably contemporaneous with the veins. According to Dr. Mac Culloch, the quartz rock in many parts of the Highlands, presents evident indications of being composed of fragments and rounded pieces again united, and is in fact a quartzose greywacke or grit. Part of the Lickey Hill, near Bromsgrove, is composed of granular quartz; and similar beds occur near the village of Hartshill, in Warwickshire, between Atherstone and Nuneaton. Quartz rock, as distinguished from quartzose grit-stone, is an inconsiderable formation, and may with more propriety be referred to the Transition, than to the Primary Class.

Jasper. — This mineral is of rare occurrence as a constituent part of beds, or of mountain masses; it differs little from a siliceous flinty slate, but is generally coloured red, brown, or yellow, and is opaque. It contains a large portion of the oxide of iron in its composition. The beds of shale in coal mines that have taken fire, are sometimes converted into a substance in every respect resembling jasper. There are beds of jasper of considerable magnitude in some parts of the Apennines, covered by rocks of serpentine. In some situations, beds of slaty jasper alternate with slate, to which rock they appear to bear the same relation as flinty slate. Lydian stone, which is a black siliceous flint-slate, is by some geologists called black Jasper. The only bed of jasper that I have seen among the English rocks, occurs associated with beds of manganese ore, at Dodscombleigh in Devonshire. Jasper sometimes occurs in veins, and forms nodules in basaltic rocks.

There can be little doubt that jasper has been, in many instances, formed by subterranean heat, acting with great intensity on beds of argillaceous shale containing iron.

Hornblende Rock and *Greenstone.* — Hornblende rock has been described as associated with primary rocks, it also occurs in the lower transition rocks. Transition hornblende presents no variety of character, by which it can be distinguished from Primary. Greenstone composed of felspar and hornblende, in which the felspar is white, and sienitic greenstone, in which the felspar is red, sometimes occur in beds among transition rocks, particularly of slate. But more frequently rocks of greenstone, sometimes called Trap, occur in an unconformable position, covering rocks both of the transition and secondary class, and will be described in the chapter on Unconformable Rocks; after the description of the coal strata, called by the miners *Coal measures.*

OBSERVATIONS ON CONFORMABLE TRANSITION ROCKS.

The order of succession in conformable transition rocks is extremely variable, and the thickness of the same beds differs greatly in different situations. In one district we find a whole uninterrupted series of calcareous strata, forming entire mountains; and in an adjacent district, the same series are widely separated by intervening beds of slate, greywacke, or sandstone; and many of the strata which occur in one place, will often be wanting in another. We have before observed, that calcareous transition strata are subject to sudden variations of quality in the same mountain: we cannot therefore be surprised, that in distant districts a great diversity should exist, both in the number and thickness of calcareous strata of the same formation; no single stratum can be regarded as an universal formation. In whatever manner the strata were deposited, the deposition has been interrupted by causes to us unknown, which have accumulated thick masses in one situation, and prevented their formation in other parts. With respect to beds composed chiefly of the fragments of older rocks, it is evident that the contiguity to rocks which were most easily disintegrated, would produce thicker beds of fragments in certain situations than in others, and that their formation must be local.

The organic remains found in transition rocks, belong almost exclusively to genera no longer existing, and which do not occur in the upper secondary strata. Vegetable remains are rare in transition rocks; they occur sometimes in slate rocks. The trilobite is peculiar to transition rocks; the gigantic species occurs in slate, and the smaller species in limestone. The orthoceratite is chiefly found in transition limestone; univalve shells rarely occur in it. The prevailing fossils in this class are madrepores, coralites, and encrinites. The remains of vertebrated animals are rarely, if ever, found in transition rocks. Many instances cited by foreign geologists of vertebrated animals found in this class of rocks are erroneous; the rocks in which they occur belong to the secondary strata; and it should be noticed, that some English conchologists have described fossil remains from specimens collected in particular counties, without knowing precisely their true localities, or whether they were found *in situ* or in diluvial deposits. In the near vicinity of the transition limestone in Derbyshire, I have collected gryphites and numulites, and even the fossils of the chalk formation, but they had no relation to the ancient limestone; they were found in beds of gravel.

Conformable transition rocks cover the primary, and sometimes alternate with them; they are also associated with the lowest beds of the coal formation, so that no well marked division can be traced between them: but there is one character, independent of all artificial arrangements, which serves to distinguish transition rocks from the upper secondary strata, in countries where the regular coal formation is found. All rocks under the coal formation, belong either to the transition or primary class; and all the strata above the coal formation belong either to the secondary or the tertiary class. The geological position of the regular coal formation thus serves as a simple and intelligible key to the geology of all countries, wherever it occurs. But where the coal strata are absent, the difficulty of determining the class to which certain rock formations belong, is often very great. Of this we have a striking instance in the perplexed attempts of foreign geologists to classify the vast calcareous formations of the Jura, and the outer range of the Alps; and the perplexity is further increased, by the mistakes which are made in referring to the English mountain limestone, by confounding it with the *calcaire alpin*, or alpine limestone. The alpine limestone, according to some geologists, is a transition limestone; but according to other geologists it is analogous to the magnesian limestone under the new red sandstone, and also comprises the lias limestones and the oolites. Indeed, I am convinced that in the vicinity of the Alps, rocks analogous to the chalk formation have not unfrequently been classed with transition limestones. These mistakes have arisen from a desire to make observations agree with preconceived theories, and with the artificial arrangements which Werner had invented. Thus it was taken for granted, that the granitic mountains of the Alps being primary, the calcareous mountains must be primary also; and when organic remains were first discovered in them, the geologists in France were greatly surprised, and seemed unwilling to admit the fact: at length, by a painful and reluctant effort, they removed all these mountains from the primary to the transition class. A more Herculean labour remains to be performed, — that of removing many of these mountains still higher, to the upper secondary class. In the vicinity of Moutiers in the Tarentaise, where M. Brochant first observed some organic remains supposed to belong to transition rocks, I discovered the Patella and other fossils, peculiar to the upper secondary strata.

In parts of France at a distance from the Alps and the Jura, the mineral character of the secondary strata might alone serve to identify them with the English lias, oolites, and chalk ; but in the range of the Jura and the outer ranges of the Alps, the calcareous formations are of such immense magnitude, and the beds are often so highly indurated and crystalline, that it is only from their relative position and imbedded fossils, that we can trace their analogy to the English strata, or to the secondary strata in the north of France.

CHAP. VIII.

ON THE LOWER OR GREAT COAL FORMATION.

The Geological Position and Structure of Coal Districts, called Coal-Fields. — Dislocation and Disturbances of Coal Strata by Faults and Dykes. — Mineral Coal, Anthracite, Plumbago, Wood-Coal or Lignite. — Iron-Stone accompanying Coal Strata. — On Carbon as an original Constituent Part of the Globe. — On the Origin of Coal Strata, and their Deposition in Fresh-Water Lakes or Marshes. — Numerous Repetitions of the same Series of Beds in the same Coal-Field. — Precautions necessary in the Establishment of Iron Furnaces. — On the Mode of searching for Coal. — Hints to landed Proprietors on the Probability of finding Coal in Districts where it has not yet been discovered. — On the Formation of Coal-Beds in Fresh-Water Lakes. — On the Conversion of Vegetable Matter into Coal. — Imperfect Coal Formations. — Salt Springs in Coal Strata. — Coal Mines in France and North America. — Observations on the Consumption of Coal in England, and the Period when the Coal-Beds will be exhausted.

In the transition rocks covering the primary, described in the preceding chapter, we very rarely, indeed, discover any remains of vegetables, either terrestrial or marine. Carbon, which is the principal constituent element of all plants, is seldom found as a mineral substance in these rocks; for, with a very few exceptions, all the vestiges of organic forms which they contain, are of marine animals. Hence we are led to infer, that there were but few islands, or tracts of dry land, rising above the ancient ocean, in which these marine calcareous beds were formed or deposited. The attention of the geological student is now required to contemplate a most important and extensive change in the condition of the globe, — at least, of that part of it which forms the subject of the present chapter. Over the marine rock formations before described, we find a series of strata, two thousand feet or more in aggregate depth, in which remains of marine animals are extremely rare, but which contain, almost exclusively, the remains of terrestrial plants, or such as have grown either on dry land or in marshes. Carbon, in the form of coal, constitutes also numerous beds in the series, varying in thickness from a few inches to thirty feet or more, and alternating with beds of sandstone, indurated clay, and shale or schistose clay. The remains of vegetables are distributed in greater or lesser abundance throughout the whole series, which, taken together, are called by miners, in the north, *coal-measures.* The coal strata were, doubtless, deposited in the vicinity of extensive tracts of dry land, containing rivers, marshes, fresh-water lakes, and mountains: the marine beds which are the foundation of the series of coal strata, and also surround them, must, therefore, have been raised from the bottom of the ancient deep, before the vast accumulation of vegetable matter could be formed. To whatever cause we attribute this change in the condition of the globe, it appears to have been attended with another remarkable effect: after this period, metallic veins have been rarely formed, for they seldom rise into the coal strata. The vegetable remains that are in the coal strata, appear principally to belong to plants that abound chiefly in tropical climates, as will be subsequently noticed. In no country have coal-measures been more extensively worked than in England, or the relations of the strata to the rocks above or below them been more fully examined.

Every coal district has its peculiar series of strata, unconnected with any other: there is a general resemblance in the nature of the different beds in each. A district, with its peculiar series of strata, is called a coal-field. The foundation rock on which the coal-fields of Derbyshire, Northumberland, Durham, Shropshire, and North and South Wales immediately rest, is the mountain and transition limestone, described in Chapter VII. In Nottinghamshire, Yorkshire, and Lancashire, the foundation rock has not been sunk to, nor does it rise to the surface; but we have every reason to believe, that it is formed by a continuation of the same limestone, though this is by no means essential to a coal-field. In some parts of France, I have observed the coal strata resting upon granite ; being only separated from it by a thick bed of conglomerate. A general view of the arrangement of the Derbyshire coal-field may be taken as affording a type of the whole English coal-fields, with certain exceptions, which will be noticed.

The thick beds of mountain limestone (see Chap. VII.), which form entire mountains, decline in height towards the eastern side of the county, and are covered by the coal-measures. The lowest bed of these measures, or, to speak more correctly, the bed which separates the coal-measures from the limestone, partakes of a mixed character, varying from soft argillaceous shale to hard sandstone ; the prevailing colour is a dark reddish or blackish brown. This bed has been called *limestone-shale:* its total thickness varies from five to six hundred feet, but in some situations is much less.

The harder strata of which this great bed is composed, are separated by soft beds that easily disintegrate and fall down ; they form the exposed face of Mam Tor, or the shivering mountain, near Castleton. The peculiar circumstance which renders this bed remarkable is, that though it contains chiefly vegetable remains, it contains also occasional patches or limited strata of dark bituminous limestone, with beds and nodules of ironstone, and thin seams of coal, which, however interesting they may be to the geological enquirer, are too inconsiderable to be worked. The next large bed, which is in some situations from three to four hundred feet in thickness, is chiefly composed of strata of hard silicious sandstone, which is in some places coarse, containing angular fragments of quartz ; in other parts it is a fine grained and very durable stone. Some of the strata of this bed were formerly worked for millstones ; from which circumstance it received the name of Millstone Grit. It contains, as far as I have examined, the remains of vegetables exclusively, but no beds of workable coal occur in it. Where the strata crop or basset out, this rock forms abrupt and picturesque cliffs. Above the grit, are laid the regular series of coal-measures or strata, comprising sandstone of various qualities, indurated clay called *clunch*, ironstone, softer argillaceous beds called *bind*, and schistose argillaceous beds, called shale. There are also two argillaceous strata containing numerous shells allied to fresh-water muscles, and hence called Muscle-bind.

A gentleman extensively engaged in the working of coal mines in this district, had an approximate measure taken of the thickness of the different beds, which he sent me, and was published in the first edition of this work; from which "it appears, that the total depth taken on the level line of the measure of the whole Derbyshire strata, including part of Nottinghamshire, is thirteen hundred and ten yards, in which are thirty different beds of coal, varying in thickness from six inches to eleven feet, making the total thickness of coal twenty-six yards: of course the above estimate can be only regarded as an approximation to truth, since the thickness of the strata was taken upon a level line, and not perpendicular to the line of their inclination or dip." Making an allowance for excess in the above measurement, the true thickness of the strata may fairly be estimated at about two thousand five hundred feet.

What is particularly deserving of notice in the bed of limestone-shale before mentioned, below the coal-measures, and above the mountain limestone, is, that this bed presents a transition from marine calcareous strata with animal remains, to fresh-water strata with terrestrial vegetables: as both occur in different parts of the bed, it would imply, that the subjacent limestone had been gradually but unequally raised above the sea, and during its elevation some parts remained immersed in the ocean, while other parts were covered with vegetable depositions. In the western side of Durham and Northumberland, the alternations of coal of inferior quality, with beds of mountain limestone, are more distinct, and the transition from marine to fresh-water formations on a larger scale; both prove that the elevation of the beds above the sea was effected by the operation of an elevating force acting slowly, or at distant intervals, — a subject which it is proposed to advert to in another part of the volume.

Coal-fields, as before stated, are of limited extent, and the strata frequently dip to a common centre, being often arranged in basin-shaped concavities, which appear to have been originally detached lakes, that were gradually filled by repeated depositions of carbonaceous and mineral matter. In some of the larger coal-fields, the original form of the lake cannot be traced, but in the smaller ones it is distinctly preserved.

The different strata under a bed of coal are frequently similar to the strata over it; and the same series is again repeated, in some mines several times, under different beds of coal, with a perfect similarity both in the succession and thickness of each. In some instances, a single bed of stone of vast thickness separates two beds of coal. In other instances, only a very thin stratum of shale or clay lies between coal beds.

Though numerous beds or seams of coal occur in one coal-field, very rarely more than three of these are worked. The thickness of the coal strata in the same coal-field often varies from a few inches to several yards; but each stratum generally preserves nearly the same thickness throughout its whole extent. Instances to the contrary sometimes occur, in which the same bed will become narrower or wider, and sometimes be divided by a stratum of incombustible earthy matter, in different parts of its course. Few beds of coal are worked at a great depth, which are less than two feet in thickness. The stratum lying over a bed of coal is called its roof, and the stratum under it the floor. The facility of getting coal depends very much on the compactness of the stone which forms the roof, not only on account of the security from falling, but for keeping out the upper water, and preserving the pit in a dry state. The great expense incurred in supporting the roof when it is loose, frequently prevents a valuable bed of coal from being worked, or absorbs all the profit. In some situations, the roof is indurated clay, impregnated with bitumen and pyrites. When this falls down, and is intermixed with water and small coal at the bottom, it takes fire spontaneously; on which account the miners close up the space with common clay, where the coal has been worked, to prevent the access of air to the combustible matter. This kind of combustible clay is called *tow;* it is common in the Ashby-de-la-Zouch coal-field, and in Staffordshire. The floor or stratum on which the coal lies, consists of clay in various degrees of induration, and is almost always of that kind which will resist the action of fire, called fire-clay, suited for furnace bricks and crucibles.

It has been before observed that coal strata are frequently bent in concavities, resembling a trough or basin, dipping down on one side of the field and rising on the other. In Plate IV. fig. 2. the section of a coal-field is represented, in which the coal strata C C C, D D are inclined in this manner, but partially dislocated by a fracture or fault at F. The extremities of the lowest stratum, C C, are several miles distant in some coal-fields, in others not more than one mile.

In the great coal-field in South Wales, which is rather a long trough than a basin, the strata are arranged in this manner over an extent of nearly a hundred miles in length, and a variable breadth of from five to twenty miles. It is partly broken into by Caermarthen Bay, but it forms an extent of surface exceeding twelve hundred square miles. It contains twenty-three beds of workable coal, which are said by Mr. Martin to make together ninety-five feet in thickness of this valuable mineral; this yield sixty-four million tons of coal per square mile. The thickest bed of coal is nine feet; in some parts there are sixteen seams of ironstone. The strata of this vast coal-field are deeply cut through by valleys, and are much broken by faults, and the quality of the coal varies greatly in different parts of the field.

At the Clee Hills in Shropshire, the breadth of some of the coal-fields is not a mile. At Ashby Wolds in Leicestershire, in the central part of the field at *e*, Plate IV. fig. 2., the main bed of coal is worked at the depth of two hundred and forty yards; but by the bending and rise of the strata, the same bed comes to the surface at *b*, about three miles distant. The depth of coal strata, from the inclination or bending of the strata, differs much in the same district, as will be evident from what has been stated, and from an inspection of the last-mentioned figure. Some coal-fields extend in a waving form over a district.

On the eastern side of England, the strata generally decline, or, in the miner's language, dip, to the south-east poiht: on the western side the strata are more frequently thrown into different and opposite directions, by what are called faults and dykes.

A fault is a break or intersection of strata, by which they are commonly raised or thrown down; so that, in working a bed of coal, the men come suddenly to its apparent termination. A dyke is a wall of mineral matter, cutting through the strata in a position nearly vertical. (See Plate IV. fig. 2. and 3.) The name *dyke* is originally derived from our Northern neighbours: it signifies a wall. The thickness of dykes varies from a few inches to twenty or thirty feet, and even yards. The dykes which intersect coal strata are composed of indurated clay, or more frequently of basalt, and will be particularly described in the following chapter. In some coal-fields the strata are raised or thrown down on one side of a dyke one hundred and fifty yards or more; and the miner, after penetrating through it (see Plate IV. fig. 3.), instead of finding the same coal again, meets with beds of stone or clay on the other side at *e:* hence he is frequently at a loss how to proceed in searching for the coal which is thus cut off. If the stratum of stone *e* be the same as any of the strata which were sunk through in making the pit or shaft *g g*, it proves that the bed of coal on the other side of the fault is thrown down, and he can determine the exact distance between that stratum, and the coal he is in search of. But if the stone is of a different kind to any which was above the coal he is working, he may be certain that the strata on the other side of the fault are thrown up, but to what distance can only be ascertained by trial, if the under strata have not been previously perforated. It frequently happens, however, that two or more strata of stone or shale, at different depths, are so similar in their quality and appearance, that it is impossible to distinguish them: in such cases it is necessary to perforate the stratum, to ascertain its thickness, and examine the quality of the strata above or below it, by which its identity with any known stratum may generally be ascertained. The manner in which the strata are inclined towards the fault, will also determine whether they are thrown up or down, provided they are not shattered where they come in contact with it, which is frequently the case.* Each bed of coal in a coal-field has certain characters by which it may generally be known to be the same. Its thickness, and the quality of the roof and floor, with that of the upper and under strata, generally serve to identify it, though it may be much deeper in one place than another.

---

* If the dyke make an acute angle with the upper surface of the strata, they are thrown up on that side; but if it make an obtuse angle, they are thrown down. See Plate IV. fig. 2. D; and fig. 3. *d*.

The dykes which intersect coal strata are generally impervious to water; and it not unfrequently happens, that where the strata decline to them, they hold up the water, and occasion springs at the surface, or keep the coal works on that side of the fault under water, when the coal works on the other side are dry. This will be better understood by referring to Plate IV. fig. 2. and 3., where the coal strata on the right hand decline or dip to the fault or dyke; and the water which passes through or between the strata will be stopped at the faults and dammed up; in which case the coal beds to the right of the dyke will be under water, and those on the other side dry. Now, should a perforation be incautiously made through the dyke, all the water will be thrown upon the works on the left, that were before dry. Where the coal on each side of a fault belongs to different proprietors, a few strokes with a pickaxe may thus do incalculable mischief to those on the one side, and render great service to the other, by laying their pits dry.

The deepest coal mines in England are those in Northumberland and in the county of Durham, some of which are worked nearly three hundred yards below the surface. The thickest bed of English coal of any considerable extent is the main coal in Staffordshire, which is thirty feet. The upper, lower, and middle parts of the bed differ in quality. Mr. Keir, who has written an interesting account of the mineralogy of the south of Staffordshire, says that thirteen different kinds of coal occur over each other in this bed; the uppermost, which is compact, serves as a roof in getting the under coal. At the Wood Mill-hill colliery in this county, the coal is said to be forty-five feet thick; and three beds of coal, from three to four feet in thickness, have been found under it, since Mr. Keir's account was published. The first is only two yards under the thick coal. The main bed of coal in the Ashby-de-la-Zouch coal-field is thirteen feet thick; the upper and lower seams of this bed also vary in quality; and the top serves as the roof, being more compact than the stratum over the coal. Few beds of coal in other parts of England or in Wales exceed from six to nine feet in thickness; but a difference in the quality may generally be observed in the upper, lower, and middle parts of the same bed.

A curious fact is stated by Mr. Keir respecting the main coal of Staffordshire. In one situation the upper part of the bed separates from the lower, and rises to the surface, or crops out. It is at first divided by indurated clay called bind or clunch; but as the distance becomes wider, the intervening stone grows harder, and will strike fire with flint. Similar separations take place sometimes in the beds of coal in the mines of Northumberland and Durham. The largest known bed of coal in the west riding of Yorkshire is near Barnsley: it is ten feet thick, and is supposed to be formed by the meeting of two or more seams, which soon separate again. The miners have not been able to trace the same bed in situations where it might have been found, had it preserved the same thickness, in other parts of its course.

Coal strata, beside the more common dislocations by faults, present remarkable contortions, which it would be difficult to explain, except by admitting a lateral force, which has compressed them into a zigzag form. To the same cause, or perhaps to a partial sinking of the earth, we may attribute the origin of what is called *faulty ground*, which frequently occurs in coal-fields. In this, no actual dyke appears to have been formed; but the beds of coal, with all the accompanying strata, are so broken and shattered, that no workings can be carried on, till the miner has got through them into regular strata. These broken parts of the strata, called *troubles* and *faulty ground*, occasion much more difficulty to the miner than common faults or dykes, and are sometimes of great extent.

In some coal-fields one part of a stratum is inclined, and the other part vertical. A curious fact of this kind may be seen in a small coal-field near the town of Manchester.*

The position of coal strata in many coal-fields may be represented by a series of fresh-water muscle shells, decreasing in size, laid within each other, but separated by a thin paste of clay. If one side of the shell be raised, it will represent the general rise of the strata in that direction; and if the whole series be dislocated by partial cracks, raising one part a little and depressing the other, to represent faults in the coal, it will give a better idea of the coal-field than any description can convey. We are here to suppose that each shell represents a stratum of coal, and the partitions of clay the earthy strata by which they are separated. The outer shell represents the lowest bed of coal, which may be many miles in extent. Now, if a much larger shell be filled with sand, and the lowest shell be pressed into it, we may consider the large shell to represent limestone, and the sand gritstone; we shall then have a model of the coal strata in many parts of England, and their situation over the metalliferous lime, with the beds of sandstone by which they are separated from it.

From the inclination or bending of coal strata, they always rise near to the surface in some parts of their course, and would be visible if not covered by soil or gravel. In the intersections formed by rivulets, or by accidental fractures on the sides of hills in a district, the nature of the strata may often be determined, and should be ascertained before any expense be incurred in boring or sinking for coal. When this is done, a proper station should be chosen; which requires great judgment; otherwise it is possible to bore or sink to great depths, and miss a bed of coal which exists very near the place: this will be evi-

---

* I have given a short account of this coal-field in the second volume of the Transactions of the Geological Society.

dent from the inspection of the two stations, *a* and *b*, Plate IV. fig. 2.: in the latter, it would be impossible to meet with the bed of coal, c, because the search is made beyond the line where it rises to the surface, or, in the miner's language, crops out. At *a*, coal would be found after sinking only a few yards.* In most situations, it is better to search for coal, as deep as can be done without expensive machinery, by sinking a well in preference to boring. By sinking, a decisive knowledge of the nature and thickness of the strata can be ascertained as far you descend, which can only be imperfectly known by boring; for the latter mode is liable to great uncertainty of result, from bendings or slips of the strata. If, for instance, the borer be worked in the situation *a*, Plate III. fig. 2., it will pass through a great depth of coal, which in reality may not be more than a few inches in thickness. Besides the uncertainty of the results, the grossest impositions are sometimes practised to answer interested purposes, and induce proprietors to continue the search, where there is no reasonable probability of success. Where coal strata come to the surface, they are generally in a soft decomposed state, and intermixed with earthy matter. They frequently present no appearance of coal, but the soil may be observed of a darker colour. The real quality of the coal cannot be ascertained until it is found below, in its natural undecomposed state, lying between two regular strata of stone or indurated clay. In general it is observed, that the same bed improves in quality, as it sinks deeper into the earth. Coal strata are generally split or divisible into rhomboidal blocks, by vertical joints: these are called slines; the oblique shorter joints are called cutters.

From what will be stated in the subsequent chap-

---

* In 1811, I saw, in Radnorshire, a fruitless search for coal of this kind; a bed of coal of a bad quality rose near the surface, and the attempts to obtain it were made beyond the outcrop of the bed.

ters, it will appear that there is more than one third of England in which all search for valuable coal is useless: the knowledge of a negative fact becomes important, when it saves us from loss of time, expense, and disappointment.

Common coal is a mineral too well known to require a particular description. Mineralogists divide coal into two species,—Brown coal, and Black coal; the former, sometimes called wood coal, is chiefly found in diluvial or in alluvial ground. It contains, besides charcoal and bitumen, various vegetable principles, and the branches or trunks of trees partially decomposed, which mark the origin of this kind of coal.

Black coal, or *common coal*, is composed of charcoal, bitumen, and earthy matter. The latter forms the ashes which remain after combustion: these vary in proportion in different coals, from two to near twenty per cent. The proportion of bitumen varies from twenty to forty per cent., and the charcoal from forty to more than eighty per cent.

Mineralogists have enumerated many different kinds of black coal: several of these pass by gradation into each other in the same mine. The most important varieties in an economical view are the hard coal, like that of Staffordshire, and bituminous or caking coal, called in London Sea-coal.

Anthracite is a mineral approaching to the state of plumbago; it consists nearly of pure carbon, is extremely hard and difficult to ignite, and has often a semi-metallic lustre. It occurs in rocks which have generally been regarded as belonging to the transition class, but is sometimes found in small quantities in regular coal strata. The coal in the extensive coal formation of Pennsylvania is called anthracite, because it emits but little smoke in burning, but is only a variety of common coal, containing but little bitumen.

Coal strata are frequently accompanied by thin strata of ironstone. This stone has a dark brown or gray colour, it has an earthy appearance and fracture, and is about three times heavier than an equal bulk of water. Some kinds have the specific gravity of 3·6. Though modern mineralogists call this mineral clay-ironstone after Werner, from its resemblance to argillaceous stones, on analysis it is found to contain but a very minute portion of alumine or pure clay, sometimes not more than two per cent. It is principally composed of iron combined with oxygen, carbonic acid, and water, and a small quantity of silex, and in some instances with calcareous earth. If it be of a good quality, it yields more than thirty per cent. of iron. In some of the beds of clay over coal, detached nodules of ironstone occur, which are also smelted for iron.

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

Different opinions have been formed respecting the origin of coal. In the primary and transition mountains, a particular species of coal occurs in small quantities, as before stated, which is extremely hard and splendent, and burns without smoke or flame, and is called anthracite; it resembles, and appears to pass into, the mineral called plumbago or graphite. Common coal also sometimes graduates into plumbago. Plumbago and anthracite are so completely mineralised as to present no indications of a vegetable origin; but the slate, in which anthracite is imbedded, sometimes contains impressions of ferns, and the strata over common coal, abound in vegetable impressions: the cortical part of the vegetable is frequently seen converted into mineral coal. It is not often that vegetable impressions are found in the coal itself; but some of the regular coal beds in the Dudley coal-field, of which I have specimens of considerable size and thickness, are composed of distinct layers of vegetables, converted into true mineral coal: but, when separated, preserving the distinct cortical impressions of plants throughout the whole thickness of the coal. It is reasonable to believe, that all the coal beds in the same field are also formed of vegetable matter, though the impressions may be effaced. I have also a specimen of common coal from Derbyshire, with different cortical impressions. Granting that common coal is originally derived from the decomposition of vegetables, it may be fairly asked, —from whence did the vegetable tribes originally derive the carbon, of which their solid parts are principally composed? Carbon either previously existed in nature, or trees and plants had the power of forming it from more simple elements. Neither of these opinions is improbable, nor are they at variance with each other. If carbon be a compound substance, of which hydrogen is a constituent part, it may be formed by the process of vegetation, or it may exist also in the mineral kingdom, independent of organic productions. That carbon is an original constituent elementary part of the globe, can scarcely be doubted, when we consider that, united with oxygen, it is an important constituent part of all limestone mountains, composing nearly one half, by weight, of their substance, or 44 of carbonic acid to 56 of lime. Now, the quantity of carbon, when separated from the oxygen, would be equal to one eighth of the whole mass of limestone; and, as all the ancient limestone formations were deposited under the ocean, we cannot suppose that this carbon was derived from the vegetable kingdom. Could the carbon be separated from the limestone in the great calcareous ranges of the Jura and the Alps, it would form a bed of pure carbon, nearly a thousand feet in thickness, through the vast extent of these mountains: and were we forced to admit that this carbon was derived from organic secretion, we should rather look to the animal than the vegetable kingdom for its origin; as no small portion of many calcareous mountains is composed of animal remains, and calcareous beds are forming in our present seas, of great extent and thickness, by the accumulation of shells and coral.

M. Adolphus Brongniart, in a recent work on vegetable fossils, has ingeniously suggested another origin for vegetable carbon: he admits, as I have done, that carbon is an original element in the composition of the globe, and its atmosphere. He supposes that the atmosphere of the ancient world, might contain more carbonic acid than at present. This would be highly favourable to the rapid growth of plants; and, in proportion as the plants absorbed the excess of carbonic acid (fixed air), they would render the atmosphere more pure, and fit it for the future respiration of animals.

Bitumen, which is composed of carbon and hydrogen, is known to exude from the lava of recent volcanoes; and the volcanic tufa in Auvergne, which covers a vast extent of surface, is almost every where intermixed with bitumen. In hot weather I have seen it trickling out of the tufa in considerable quantities, resembling melted pitch. As the ancient volcanoes of that district broke out from beneath the granite, we may fairly infer, that the bitumen which abounds in the volcanic tufa is as much a mineral substance as the sulphur which accompanies volcanic eruptions, or which is sublimed from the vapours of quiescent volcanoes.

Though the carbon that exists as a constituent part in some primary rocks may be derived from the mineral kingdom, there can scarcely remain a doubt, that wood-coal and common coal are of vegetable origin. Wood-coal, or brown coal, is found in low situations, and appears to have been formed of heaps of trees buried by inundations under beds of clay, sand, or gravel. The woody parts have probably undergone a certain degree of vegetable fermentation, under the pressure of the incumbent earthy matter, by which they have been carbonised and consolidated. In some specimens of this coal, the vegetable fibre or grain is perceptible in one part, and the other part is reduced to coal. The vegetable principles which this coal contains, united with bitumen and charcoal, have been already stated. In black or common coal, the vegetable extract and resin are destroyed, and the charcoal and bitumen alone remain; but wood-coal and common coal bear in other respects too close a resemblance, to allow us to ascribe to them a different origin, though they were probably formed from different tribes in the vegetable kingdom, and under different circumstances.

*Wood-coal** is found in considerable quantities at Bovey Heathfield, near Exeter. Several beds of coal are separated by strata of clay and gravel: the lowest is seventeen feet thick, and rests on a bed of

---

* The description of wood-coal ought to be given in the account of the tertiary strata and diluvia, but it offers many circumstances which tend to elucidate the formation of mineral coal.

clay, under which is sand resembling sea sand. The coal in contact with the clay has a brown colour, and appears intermixed with earth. In other parts the laminæ of the coal undulate, and resemble the roots of trees: in the middle of the lowest stratum the coal is more compact, and is of a black colour, and nearly as heavy as common coal.

A great repository of this kind of coal exists near Cologne: it extends for many leagues: it is fifty feet in thickness, and is covered with a bed of gravel, from twelve to twenty feet deep. Trunks of trees deprived of their branches are imbedded in this coal; which proves that they have been transported from a distance. Nuts which are indigenous to Hindostan and China, and a fragrant resinous substance, are also found in it. A similar resinous substance occurs in the Bovey coal, and was also discovered with fossil wood, in cutting through Highgate Hill. Mr. Hatchett, by whom it was analysed, has given it the name of retinasphaltum.

In wood-coal we may almost seize nature in the act of making coal, before the process is completed. These formations of coal are of far more recent date than that of common coal, though their origin must be referred to a former condition of the globe, when the vegetable productions of tropical climates flourished in northern latitudes. The vegetable origin of common mineral coal, appears to be established by its association with strata abounding in vegetable impressions; by its close similarity to wood-coal (which is undoubtedly a vegetable product); and, lastly, by the decisive fact, that some mineral coal in the Dudley coal-field is entirely composed of layers of mineralised plants.

But though the vegetable origin of mineral coal may be satisfactorily established, there is considerable difficulty in conceiving by what process so many beds and seams of coal have been regularly arranged over each other in the same coal-field, and separated by strata of sandstone, shale, and indurated clay. It will tend to simplify the enquiry, if we examine a coal-field of very limited extent; such as those which occur in small coal-basins called *swilleys* on the hills in the West Riding of Yorkshire, and which are not more than one mile in length and breadth. It seems evident that these basins have once been small lakes or marshes, and that the strata have been deposited on the bottom and sides, taking the concave form which depositions under such circumstances must assume: and it is deserving notice, that the stratum of coal, which in one of these coal-basins at Hudswell is a yard thick in the lowest part, gradually diminishes as it approaches the edges, and then entirely vanishes. This fact proves that the present basin-shaped position of the strata was their original one; and that the basin, at the period when the coal strata were formed, was a detached lake or marsh, and not part of the bed of the sea.

It has been supposed that coal strata were deposited on the bed of the ocean; but this is not probable, for the vegetable remains, so abundant in the coal strata, belong to families of terrestrial or marsh plants, ferns, gigantic equisetums (horsetail), with jointed and striated stems like reeds, hence called calamites, and lycopodia allied to ferns: these compose the greater part of the fossil plants accompanying coal. In some instances, the coal is decidedly formed of such plants; and, from the plants being sometimes found erect, we may infer that they grew near the place where they occur. There is a stratum of indurated shale and imperfect ironstone in the Yorkshire and Derbyshire coal-fields, called muscle-bind; it is filled with shells: they resemble freshwater muscles; and though there may be shells closely allied to them in form, in some of the marine limestones, it deserves notice, that the substance of the shells in the coal shale, at least wherever I have seen them in the Northern coal-fields, has that cretaceous or chalky appearance and consistence, which I have observed to be peculiar to shells in what are regarded as undoubted freshwater formations.

If the basins in which the coal strata are deposited were originally freshwater lakes or marshes, did any of the plants whose remains compose coal grow where the coal is now found? or, were they carried by rivers or inundations into the lakes, and gradually deposited as the water evaporated? The former is perhaps the most probable hypothesis; and the occurrence of the same peculiar kind of fire clay under each bed of coal, favours the opinion, that this was the soil proper for the production of those plants from which coal has been formed. If we suppose that these lakes were periodically laid dry, and again filled by sudden inundations, we shall have the conditions required for the succession of carbonaceous and earthy strata that take place in a coal-field: a repetition of such inundations would fill up the lake or basin. Nor can such a supposition appear improbable; for, as the species of vegetables in the coal strata are analogous to what at present grow in tropical climates, we may infer that they were subjected to such atmospheric influences as promote the rapid growth and decay of vegetation in hot countries, accompanied with great periodical inundations.

The terrestrial and marsh plants that accompany coal, and of which it was probably formed, might flourish between these successive inundations, their growth being sufficiently rapid to form a thick bed of vegetable matter in a short period; for, as they had not the ligneous structure of wood, their decomposition by vegetable fermentation might speedily be effected. Should it be objected, that some of the coal beds are from nine to thirty feet in thickness, and that a mass of vegetable matter, sufficient to form such beds, could not be collected in one season, it is sufficient to reply, that we know not the duration of the periods during which vegetation might proceed without interruption; and it deserves particular notice, in relation to this subject, that all thick beds of coal are divided into several minor strata, and have frequently thin strata of shale, clay, or sandstone between them, but they are called by the miners one bed, as the coal can be all got at the same level. The Staffordshire coal stratum, which is thirty feet thick, is divided into thirteen minor strata by seams of clay, &c.; and the thirteen feet bed of coal at Ashby Wolds is composed of several seams of different qualities.

Very thin seams of coal sometimes alternate with the shale lying between two large beds of coal. I have on the table before me, a mass from the Dudley coal-field, in which part of two beds of coal are separated by a stratum of indurated clay or shale, about two inches in thickness; this stratum of shale contains more than twenty seams of coal, none of which exceed the thickness of a wafer, but they are distinctly separated from each other by seams of shale. These thin seams of coal and shale, were probably formed by alternate depositions of leaves or minute aquatic plants, and of earthy particles forming layers of clay or sand. These are circumstances which appear to me to prove, that the formation of the coal strata was effected more rapidly than those geologists have hitherto been willing to admit, who have only examined coal mines, seated in an easy chair in their studies. I will first advert to the state in which fossil vegetables are found in coal mines, and shall give a section of a coal mine, which I examined in 1811, belonging to the late Marquis of Hastings. It is remarkable for the frequent repetition of the same series of strata, of precisely the same quality and thickness; proving a periodical recurrence of the conditions under which they were formed.

Vertical stems not unfrequently occur in coal-fields; but, from the mode of working or sinking for coal, it is seldom that they can be seen in that position. Where a stone quarry is open to-day in coal strata, and uncovers a considerable face of rock, there we may sometimes meet with fossil plants in their original position. In 1819, I had an opportunity of examining Burntwood quarry, at Althouse, near Wakefield, in Yorkshire, at which time there were numerous vertical stems in strata of sandstone. One stem which I measured in the quarry was nine feet in length, and ten inches in diameter; but, what is remarkable, this stem passed through three strata of sandstone, parted by regular strata seams. It had, therefore, evidently grown in the situation where it stood; for it is difficult to believe that any vegetable stem could pierce through three strata of sandstone, the lower of which at least must have been partly consolidated. When we consider that these were the stems of hollow tubular plants, equisetums, without any woody support, it is impossible to believe, that they could have remained erect in a warm temperature without speedy destruction or decomposition, even for a very limited time. We are therefore certain, that they were speedily encased in the strata, that now surround them, or, in other words, that three strata of sandstone nine feet in thickness were rapidly deposited.

The coal mines at St. Etienne, in France, present similar appearances; the vertical stems are numerous, and ten or twelve feet in length. From a drawing and description of them given me by M. Alexandre Brongniart, it appears, that they were large equisetums, and the hollow tube is filled with sandstone. The circumstances and the inferences from them agree with those before stated of Burntwood quarry.

In the section of the Ashby-de-la-Zouch coal, given below, it will be seen, that there are no less than sixteen strata of blue-bind, exactly of the same thickness, and alternating with sixteen strata of ironstone, of which the six upper are only one inch in thickness, and the lower two inches. If we should suppose each stratum of bind and ironstone to have been deposited in different parts of one year, we should have a speedy formation of these thin beds. We know nothing, however, certain, respecting the formation of ironstone; but it appears to have been deposited in fresh water, as it occurs in freshwater strata in the regular coal formation, and in the coal strata of the oolites in Yorkshire, and among the clay and sandstone strata, in the wealds of Kent. Few geologists have attempted to explain the formation of ironstone. It may have been a deposition from chalybeate waters, or was, perhaps, the produce of decomposed vegetation, as bog or peat iron is supposed to have been.

Some geologists are of opinion, that coal was formed from peat; but the fossil vegetables in coal strata, and in the coal itself, are not what compose the peat of the present day. However, if northern latitudes had the temperature of tropical climates during the geological epoch when the vegetables flourished that are found in the coal strata, the peat of that period would partake of a different character from recent peat beds, and might be produced by the rapid decomposition of the large terrestrial and marsh plants, before referred to. A bed of modern peat, seven feet in thickness, is said to have been formed in thirty years; but the primitive vegetation of the world, flourishing and decaying under a high degree of temperature, and a moist atmosphere, might form thick beds of peat in a much shorter period.

It is truly deserving attention, that the vegetable fossils found in distant parts of the world, and under very different latitudes, are nearly identical with those in European coal-fields. The plants in the coal-fields of North America, and even the specimens from Greenland, are analogous to those in the English coal-fields; and the few specimens that have been obtained from the tropical regions in America, from New Holland, and from India, belong to the same families as those which we find in the coal strata of Europe. Now, if we admit these distant beds of coal to be of contemporaneous formation, we must admit also, that the temperature of the whole globe was, at that epoch, nearly the same, in very different latitudes; or were we to suppose that these coal-fields were formed in different epochs, we must still grant, that northern latitudes have once enjoyed the same temperature, as countries under the equator.

Before concluding these observations, it may be permitted to remark, that, however ancient the formation of coal and ironstone may have been, the frequent occurrence of these minerals together, both destined in future time to give to man an extensive empire over the elements, and to contribute largely to his means of civilisation and comfort, cannot fail to impress the reflecting mind with evidence of prospective designing intelligence.*

---

* I here subjoin a section of the Ashby-de-la-Zouch coal-field; if ever we arrive at just conclusions respecting the origin of coal and ironstone, it must be by an accurate examination of the strata in which they occur, and the relation of these strata to each other; an investigation hitherto much neglected by geologists.

SECTION OF A COAL MINE, ASHBY WOLDS, LEICESTERSHIRE.

		Yds.	Ft.	In.
	Soil and Clay	2	0	0
1	Blue clunch with ironstone	1	2	5
	Coal	0	1	6
	Blue bind	1	0	0
	Stony bind	0	1	2
	Grey stone	0	0	4
	Stony bind	1	0	9
	Grey stone	0	1	9
	Blue bind	3	2	1½
	Grey stone	0	1	1
	Rubly bind	0	2	0
	Blue bind	4	0	0
	Black bat	0	2	0
2	Blue bind with ironstone	1	1	0
	Coal	0	1	5
	Blue bind	3	1	0
	Black bat and black bind	0	2	3
	Stony bind	2	2	6
	Blue bind in two beds	6	1	0
	Black bat	0	2	0
	Blue bind	3	0	0
3	Ironstone	0	0	1
	Blue bind	0	1	6
4	Ironstone	0	0	1
	Blue bind	0	1	6
5	Ironstone	0	0	1
	Blue bind	0	1	6
6	Ironstone	0	0	1
	Blue bind	0	1	6
7	Ironstone	0	0	1
	Blue bind	0	1	6
8	Ironstone	0	0	1
	Blue bind	2	9	0
	Coal	1	0	0
	Blue bind in two beds	9	0	0
	Stony bind	1	1	0
	Grey stone	3	0	0

The aggregate depth of the Ashby-de-la-Zouch coal-field exceeds two hundred and twenty yards in this part of the coal-field, though, from the basin-shaped form of the beds, the lowest, or main coal,

---

		Yds.	Ft.	In.
9	Blue bind	0	1	6
	Ironstone	0	0	2
10	Blue bind	0	1	6
	Ironstone	0	0	2
11	Blue bind	0	1	6
	Ironstone	0	0	2
12	Blue bind	0	1	6
	Ironstone	0	0	2
13	Blue bind	0	1	6
	Ironstone	0	0	2
14	Blue bind	0	1	6
	Ironstone	0	0	2
	Blue bind	1	2	9
15	Ironstone	0	0	2½
	Black bind	1	1	6
	Blue bind	0	1	6
	COAL	1	0	0
	Blue and black bind	4	2	0
	Dark stone	5	2	2
	Black bat	0	2	6
	Grey stone	1	1	5
	Stony bind	1	0	0
	Grey stone	1	2	4
	Black bat	3	0	2
16	Blue bind with balls of ironstone	3	2	1
	Black bat	1	0	0
	COAL	1	0	4
	Grey stone	10	0	0
17	Blue bind	0	4	10
	Ironstone	0	0	2
	Blue and black bind alternating	6	0	9
	COAL	0	1	9
	Rubly bind with ironstone balls	2	1	2
	Blue bind	3	0	0
	Rubly bind	2	0	0
	Black bind	1	1	6
	Blue bind	1	2	4
	Ironstone	0	0	2
	Black bind	0	2	0
	Blue bind	1	2	0
	Black bind	0	2	0
	COAL	0	2	0
	Stony bind	3	0	3
	Blue bind	3	0	8
	Black bind with coal	1	1	6
	Stony bind	3	0	10
	COAL	1	0	8
	Stony bind	0	1	6
	White stone	3	0	0
	Stony bind	5	0	9
18	Blue bind	2	2	10
	Ironstone	0	0	2
19	Blue bind	2	2	0
	Ironstone	0	0	2
	Blue bind	1	2	6
	Grey stone	0	1	6
	Rubly stone	3	0	0
	Grey stone	2	0	0
20	Blue bind and ironstone	1	1	0
	COAL	1	1	0
	Stony bind with a little ironstone	4	0	0
	Blue bind	0	1	6
	Rubly stone	1	0	0
	Stony bind and grey stone	6	1	6
	Stony bind	1	2	2
	KENNEL COAL	0	2	10
21	Ironstone	0	0	1½
	Blue bind	1	0	0
22	Ironstone	0	0	2
	Blue bind	0	1	6
23	Ironstone	0	0	3
	Blue bind	0	1	6
24	Ironstone	0	0	2
	Blue bind	1	2	1
25	Black ironstone	0	0	6
	Black bind	0	1	6

rises to the surface at about three miles distance from this pit. In this series we find about one hundred and thirty distinct strata, comprising ten beds of coal, of which eight, at least, would be considered workable in some countries, and about twenty-eight seams of ironstone, and strata containing ironstone. The lowest, or great coal bed, contains coal of different qualities, divided by small partings of clay. Near the middle of the great bed, there is a stratum of coal so hard as to form a firm roof, which enables the miners to work out the lower coal with great advantage: this lower coal is about six feet in thickness. A bed of coal of this thickness, with a strong sound water-tight roof, can be worked with greater ease and less expense than any other, as the men can stand upright, and much less timber is required to support the roof or walls, than in very deep coal beds, like the main Staffordshire coal. When the lower coal is worked out, the props or supports of the roof will be removed, the whole upper strata will then sink down, and the upper coal may be safely worked. There is scarcely any water in this mine, and what is found there, is a salt brine, containing common salt nearly pure: it issues from the fissures in the coal with a hissing noise, being accompanied with carburetted hydrogen (fire damp). All the beds of coal rest upon what is called bind, which is an argillaceous shale, more or less indurated, sometimes coloured black by bitumen, and sometimes intermixed with sand resembling sandstone, but generally decomposing into a clayey soil, like the blue and black binds on exposure to the atmosphere.

		Yds.	Ft.	In.
26	Ironstone	0	0	2
27	Blue bind with a little ironstone	6	2	3
	Black bind with ditto	6	2	8
	Blue bind, ironstone balls	6	1	0
	Rider, a roof of coal	1	1	0
	Upper coal	1	0	9
	Main coal	3	1	0

It seems extremely probable that these beds, called bind, which lie immediately under the coal, were once the soil on which the different vegetables flourished that form coal. When I examined the mine, in 1811, the vegetable remains appeared to me the same as those found in other coal-fields; but at that time they did not attract my attention, except one which is a nearly globular mass, composed of a series of cones within each other, and diverging from a common centre. These have been called "cone within cone" by the miners, but their nature is not well understood. Adolphus Brongniart, in his excellent work on vegetable fossils, supposes they may be the seed vessels of a gigantic species of lycopodium.

The recurrence of frequent alternations of seams of ironstone with thin beds of blue bind, each alternation preserving the same thickness, is a circumstance well deserving attention, as it indicates a periodical succession of causes, probably dependent on the seasons.

There are a few beds called *rubly*, or *rumilly*, by the miners; they consist of loose materials and fragments, which indicate that they were deposited during an agitated state of the water. Many of the other beds have evidently been deposited by tranquil water in a lake, which occasionally became dry land. I have dwelt longer on this subject, than is perhaps consistent with an introductory work, but I was desirous to direct the attention of geologists to an enquiry which has hitherto been disregarded.

The conversion of vegetable matter into true mineral coal has been admirably elucidated by the experiments of Dr. Macculloch on wood in different states of bituminisation, from submerged wood, to peat, brown coal, surturbrand, and lastly to jet, in which the traces of organisation are nearly destroyed. These substances, which have been only subjected to the action of water, all yield bitumen by gentle distillation: but they differ from mineral coal, by yielding also a large portion of acetic acid, which marks the remains of undecayed vegetable substances. Common coal has formerly been regarded as a combination of charcoal with bitumen; but as bitumen is itself a combination of carbon with hydrogen, Dr. Macculloch says, it will be more proper to consider coal as a bitumen, varying in its composition from the fattest Newcastle coal to the driest Kilkenny coal, and owing its compactness to the peculiar circumstances under which it has been formed, the changes it may have subsequently undergone, and the substances intermixed with it. The power of yielding naphtha by distillation, is the distinction between one end of the series and the other. The last link (anthracite) contains only carbon; so the last result of the distillation of asphaltum is also carbon.

To convert wood-coal or jet into true coal, some further process than long submersion in water seems necessary. The latter substance, jet, was reduced to powder by Dr. M., and put into a gun-barrel, and covered close with Stourbridge clay; it was then exposed to a moderate red heat. By this process, it was converted into a substance having all the external characters and chemical properties of true mineral coal, and the clay was converted into coal shale. But though, in the laboratory of the chemist, the last stage of the formation of coal requires artificial fire, yet in the great laboratory of Nature, vegetable fermentation and compression may evolve sufficient heat, for the ultimate formation of mineral coal. It may however deserve notice, that most great repositories of coal are intersected by beds and dykes of basalt, which is now admitted to be of igneous origin.*

---

* At Meisner, in Hesse, a thick bed of wood-coal or lignite is covered by an enormous mass of basalt, and is only separated from it by a thin bed of clay. The upper parts of the lignite are converted into anthracite, and even into true bituminous coal, while the lower parts are formed of earthy and fibrous wood-coal.

Pressure and time alone may be sufficient to produce the destruction of vegetable organisation, and the perfect consolidation of beds of coal, as is proved by the complete consolidation of loose materials left in coal mines, when the supports are removed, and the upper strata sink down. In a few years scarcely a trace of former operations remains. In contemplating natural causes, we are too apt to measure their power by the results of artificial processes, and by observations continued for a short portion of human life. The substances found in the neglected vessels of the chemist, often prove to us that changes in the physical properties of bodies are effected by time, which it would be difficult to imitate in common experiments.

The great regular coal formation appears to be confined to the lower secondary strata, generally resting on transition limestone. In some situations, the under transition rocks are wanting, and the series of coal strata rest on granite, with the intervention of a thick bed of conglomerate.

No mineral coal, both good in quality and abundant in quantity, has ever been found either in the primary or in the lower transition rocks, or in the upper secondary or the tertiary strata. It is true, that in the oolite of the upper secondary strata, two series of coal strata occur on the eastern moorlands of Yorkshire, which are thought of sufficient importance to be worked; but the coal is very indifferent, and is chiefly used by the lime-burners. This coal formation will be noticed in a subsequent chapter. The Kimmeridge-clay in the oolites also contains beds of shale impregnated with bitumen, which is used as fuel in a country where coal is extremely dear.

The wood-coal of Bovey Heathfield has been already noticed. I may state in addition, that I visited the mine in 1815: it is worked like an open quarry; it had been for some years previously under water, but was then laid dry by pumps. There are several irregular beds of lignite or wood-coal alternating with what is called dead coal, which is less inflammable, and resembles a bituminous shale; the beds wedge out narrow as they descend. The whole mass is more or less bituminised; but the upper part, which preserves the woody structure more perfectly, seems principally composed of clay. Sulphate and carbonate of iron occur in some part of the beds, and rounded pieces of maltha. Wood-coal occurs chiefly in diluvial deposits. Where wood-coal is covered with basalt, it is converted into a substance nearly resembling mineral coal. This coal occurs in Iceland, in the north of Ireland, and in many basaltic districts on the Continent.

Before concluding this brief account of imperfect coal formations, out of the limits of the regular coal formation, I would direct the attention of geologists to two situations, in which coal is found, that are well deserving of notice. The first is the mine of Entreveines, situated in a mountain valley about 2000 feet above the lake of Annecy, and at least 3500 feet above the level of the sea. The bed of coal consists of three minor beds, separated by thin seams of clay varying in thickness, yielding about four feet of good coal, which has the character and fracture of mineral coal; it is shining, does not soil the fingers, and is highly bituminous, being exclusively used for the gas lights in the cotton-mills at Annecy. The total thickness of the sandstone, shale, and coal strata, which compose the coal formation in this place, is about one hundred and fifty yards; they are placed between thick beds of limestone, and dip together at an angle of about seventy degrees.* It is worthy of observation, that the limestone beds above and below the coal formation, have the hardness, fracture, translucency, and appearance of the transition limestone at Plymouth; yet in

---

* A particular description of this singular coal mine, with a cut illustrating the position of the beds, is given in Vol. I. of my 'Travels in the Tarentaise,' &c.

another part of the mountain, the same limestone is associated with a bed of dark clay, in which I found gryphites and belemnites, clearly indicating that the bed was analogous to our lias or clunch clay; and that the limestone associated with it, notwithstanding its mineral character, belonged to the upper secondary strata; and hence that the coal, in geological position, agreed with the imperfect coal formations in the English oolites. Here, then, we have a further proof of what has before been stated, that in the calcareous formations of the Alps, the upper secondary strata lose the soft and earthy character which distinguish the oolites and chalk in England, and are converted into marble. The coal also, which is very imperfectly formed in the English oolite, has, in the same limestone formation in the Alps, the character of true mineral coal.

A still more remarkable coal formation occurs at Alpnach, near the lake of Lucerne in Switzerland, where a bed of coal is found at the depth of two hundred and eighty feet from the surface. Over the coal, there is a stratum of bituminous limestone containing fluviatile shells, and bones and teeth of the large mammalia, particularly the teeth of a species of mastodon. The specimens which were shown me by Professor Meissner of Berne, on my return from the Swiss Alps, made me regret exceedingly not having visited Alpnach. Notwithstanding the occurrence of the bones of large land quadrupeds in the stratum over the coal, the coal approaches in character nearly to mineral coal, and the strata of micaceous sandstone and shale above it, have a close resemblance to those in our English coal-fields. Though, from the organic remains, we are compelled to place the coal of Alpnach among the tertiary strata, or to admit the occurrence of an anomalous formation like the one at Stonesfield, still I believe the true geological position of the coal of Alpnach is problematical; and it deserves the particular attention of some English geologist, well acquainted with the different coal-fields in his own country, and the lignite formations in various parts of Europe.

It will be seen by a reference to the Geological Map, and the Chapter containing an Outline of the Geology of England, that there is a considerable part of South Britain where coal has not been found. Two important questions may be asked; — Do the coal strata extend under the parts where coal has not yet been discovered? And if they do extend beyond their present known limits, — what practicable means can be employed to obtain the coal? With respect to the first question — it is well ascertained by boring, that the coal strata do in some places extend under the magnesian limestone, by which they are immediately covered in some of the northern counties, though it was formerly supposed that the coal terminated before it reached the magnesian limestone, or was there cut off by a fault. In a considerable part of England, the coal-fields are immediately covered by what is called the red marle or new red sandstone; but there are but few situations where the red marle and sandstone have been sunk through for coal. I am, however, decidedly of opinion, that under the red marle adjacent to the coal districts in my native county, Nottinghamshire, the regular coal strata will be found; and that there is a high degree of probability that rock salt or brine springs will be found in the red marle itself, particularly in those parts of the county where beds of massive gypsum occur. The same remark might be extended to the red marle and sandstone districts adjoining coal strata in Derbyshire, Leicestershire, and Warwickshire.* In confirmation of the opinion here advanced, a saline spring has very recently been discovered about four miles north-west of Nottingham; and coal has been lately found under the red marle and sandstone on the south side of Charnwood Forest, where it

---

* Since the third edition of this work was published, coal has been found under the red marle and sandstone near Manchester.

had not before been suspected to exist. It may, however, be proper to say, that no search of this kind by boring should be undertaken by any one, to whom the expense, in case of failure, would be a serious inconvenience.

The dip and direction of the strata in the coal-fields nearest to the estate where the search is to be made, should be well known. If the strata dip towards the estate, it is probable the coal may extend under it: if they dip from it, the search should not be undertaken. To make this intelligible, see Plate III. fig. 3. *a. a. a.* are a series of coal strata, or, as they are provincially called, coal measures, dipping toward the side B. *c. c. c.* are strata of red marle or sandstone, lying unconformably over the coal strata. Now, according to this arrangement, a search for coal might be successful, though the bed might be at too great a depth to be worked. Whereas on an estate at D, as the coal strata dip from it, were we to bore to the centre of the earth, we could never find the beds 1. 2. 3. 4. If the estate B is situated a considerable distance from a known coal-field, the strata of coal may bend as represented Plate IV. fig. 2. and crop out at *a*, before they reach the station *b*, where the trial is made; and if the outcrop be covered by the red sandstone, this cannot be known but by trial.

Rock salt or brine springs are most likely to be found by boring in the vicinity of massive gypsum, without regarding the stratification. As for the districts where the upper secondary strata of lias, oolite, and chalk occur, all search for the regular coal strata must there be fruitless; as the vast thickness of these calcareous formations precludes the hope of success.

Coal mines, it is well known, are subject to fatal explosions of what is called the fire-damp, or carburetted hydrogen gas. This gas appears to be generated by the decomposition of iron pyrites in coal, and may often be heard issuing from the fissures in coal-beds with a bubbling noise, as it forces the water out along with it. The choke-damp, as it is called, is either carbonic acid gas (fixed air), or the unrespirable residue of air left after explosions, when all the oxygen is consumed. (See Appendix.)

The regulăr or great coal formation has never been discovered at a very considerable elevation above the level of the sea: it generally is found towards the feet of great mountain chains, or in the valleys near to lofty mountain ranges. The geology of large portions of the globe is still unknown; but it appears from those parts with which we are acquainted, that coal is principally found in temperate regions, between thirty-five and sixty-five degrees of latitude. In Europe,—Great Britain, France, Flanders, and Germany, (particularly Silesia, Saxony, Bohemia, and Thuringia,) contain large coal formations; but in the southern and more northern parts of Europe, coal is of rare occurrence. In North America, coal is found in great abundance on the western side of the Alleghany mountains; it has also been discovered in Pennsylvania, extending westward towards Pittsburgh, over a space of three hundred miles. Coal occurs also near Richmond, in Virginia, and in the Missouri. American coal is said to be found in quartz rock, which I apprehend to be merely siliceous grit, composed of nearly pure granular silex, such as abounds in the lower part of the Yorkshire coal-fields. The coal, in a great part of the United States, contains little bitumen, and hence is called anthracite, but it is not the true anthracite of mineralogists, but far more valuable for fuel. The discovery of this immense repository of coal, accompanied with ironstone, must prove of the highest importance to a nation so industrious, intelligent, and enterprising, as the inhabitants of the United States. In the vicinity of Pittsburgh, I am informed, that the strata of coal are nearly horizontal, and that in one situation, the same stratum of coal forms the bed of a river for several miles. Coal has been discovered in New Holland. The only great coal formations in Asia that we know of are in China, where coal is described as existing in large quantities, and as being extensively used for fuel in that vast empire.

As France will probably continue to be for many centuries our great manufacturing rival, it is interesting to know what are her resources, for the supply of an article found so essential to almost all the principal manufactures of Great Britain. Before the late peace, forty-seven of the departments contained coal districts, and the annual consumption was stated to be about five million tons; but a great part of the rich and extensive coal-field extending from Valenciennes to Aix-la-Chapelle, is comprised in that part of Flanders, which was separated from France at the peace. There are, however, extensive coal districts in the north-eastern, the western, the middle, and the southern parts of France. Two miles from Lyons there are coal mines; the coal of St. Etienne and the ironstone beds accompanying it, about twenty miles north-west of Lyons, are of the very best quality. In the year 1822, when I passed through that country, many English workmen were employed in the iron-works, which were rapidly increasing. It cannot be doubted that France possesses every advantage, from its soil, its climate, and its mineral resources, which a great manufacturing nation can require.

OBSERVATIONS ON THE PERIOD WHEN THE COAL MINES IN ENGLAND WILL BE EXHAUSTED.

Coal was known, and partially used, at a very early period of our history. I was informed by the late Marquis of Hastings, that stone hammers and stone tools were found in some of the old workings in his mines at Ashby Wolds; and his lordship informed me also, that similar stone tools had been discovered in the old workings in the coal mines in the north of Ireland. Hence we may infer, that these coal mines were worked at a very remote period, when the use of metallic tools was not general. The burning of coal was prohibited in London in the year 1308, by the royal proclamation of Edward the First. In the reign of Queen Elizabeth, the burning of coal was again prohibited in London during the sitting of parliament, lest the health of the knights of the shire should suffer injury during their abode in the metropolis. In the year 1643, the use of coal had become so general, and the price being then very high, many of the poor are said to have perished for want of fuel. At the present day, when the consumption of coal, in our iron-furnaces and manufactories, and for domestic use, is immense, we cannot but regard the exhaustion of our coal-beds as involving the destruction of a great portion of our private comfort and national prosperity. Nor is the period very remote when the coal districts, which at present supply the metropolis with fuel, will cease to yield any more. The annual quantity of coal shipped in the rivers Tyne and Wear, according to Mr. Bailey, exceeded three million tons. A cubic yard of coal weighs nearly one ton; and the number of tons contained in a bed of coal one square mile in extent, and one yard in thickness, is about four millions. The number and extent of all the principal coal-beds in Northumberland and Durham are known; and from these data it has been calculated, that the coal in these counties will last 360 years. Mr. Bailey, in his Survey of Durham, states, that one-third of the coal being already got, the coal districts will be exhausted in 200 years. It is probable that many beds of inferior coal, which are now neglected, may in future be worked; but the consumption of coal being greatly increased since Mr. Bailey published his Survey of Durham, we may admit his calculation to be an approximation to the truth, and that the coal of Northumberland and Durham will be exhausted in a period not greatly exceeding 200 years. Dr. Thomson, in the Annals of Philosophy, has calculated that the coal of these districts, at the present rate of consumption, will last 1000 years; but his calculations are founded on data manifestly erroneous, and at a variance with his own statements: for he assumes the annual consumption of coal to be only two million eight hundred thousand tons, and the waste to be one-third more, — making three million seven hundred thousand tons, equal to as many square yards; whereas he has just before informed us, that two million chaldrons of coal, of two tons and a quarter each chaldron, are exported, making four million five hundred thousand tons, beside inland consumption, and waste in the working.* According to Mr. Winch, three million five hundred thousand tons of coal are consumed annually from these districts; to which if we add the waste of small coal at the pit's mouth, and the waste in the mines, it will make the total yearly destruction of coal, nearly double the quantity assigned by Dr. Thomson. Dr. Thomson has also greatly overrated the quantity of the coal in these districts, as he has calculated the extent of the principal beds from that of the lowest, which is erroneous; for many of the principal beds crop out, before they reach the western termination

---

* The waste of coal at the pit's mouth may be stated at one-sixth of the quantity sold, and that in the mines at one-third. Mr. Holmes, in his Treatise on Coal Mines, states the waste of small coal at the pit's mouth to be one-fourth of the whole.

of the coal-fields. With due allowance for these errors, and for the quantity of coal already worked out (which, according to Mr. Bailey, is about one-third), the 1000 years of Dr. Thomson will not greatly exceed the period assigned by Mr. Bailey for the complete exhaustion of coal in these counties, and may be stated at 350 years.

It cannot be deemed uninteresting to enquire, what are the repositories of coal that can supply the metropolis and the southern counties, when no more can be obtained from the Tyne and the Wear. The only coal-fields of any extent on the eastern side of England between London and Durham, are those of Derbyshire, and those in the west riding of Yorkshire. The Derbyshire coal-field is not of sufficient magnitude to supply, for any long period, more than is required for home consumption, and that of the adjacent counties. There are many valuable beds of coal in the western part of the west riding of Yorkshire which are yet unwrought; but the time is not very distant when they must be put in requisition, to supply the vast demand of that populous manufacturing county, which at present consumes nearly all the produce of its own coal mines. In the midland counties, Staffordshire possesses the nearest coal district to the metropolis, of any great extent; but such is the immense daily consumption of coal in the iron-furnaces and founderies, that it is generally believed, this will be the first of our own coal-fields that will be exhausted. The thirty-feet bed of coal in Dudley coal-field is of limited extent; and in the present mode of working it, more than two-thirds of the coal is wasted and left in the mine.

If we look to Whitehaven or Lancashire, or to any of the minor coal-fields in the west of England, we can derive little hope of their being able to supply London and the southern counties with coal, after the import of coal fails from Northumberland and Durham. We may thus anticipate a period not very remote, when all the English mines of coal and ironstone will be exhausted: and were we disposed to indulge in gloomy forebodings, like the ingenious authoress of the "Last Man," we might draw a melancholy picture of our starving and declining population, and describe some manufacturing patriarch, like the late venerable Richard Reynolds, travelling to see the last expiring English furnace, before he emigrated to distant regions.*

---

* The late Richard Reynolds, Esq. of Bristol, so distinguished for his unbounded benevolence, was the original proprietor of the great iron-works in Colebrook Dale, Shropshire. Owing, I believe, partly to the exhaustion of the best workable beds of coal and ironstone, and partly to the superior advantages possessed by the iron-founders in South Wales, the Works at Colebrook Dale were finally relinquished, a short time before the death of Mr. Reynolds. With a natural attachment to the scenes where he had passed his early years, and to the pursuits by which he had honourably acquired his great wealth, he travelled from Bristol into Shropshire, to be present when the last of his furnaces was extinguished, in a valley where they had been continually burning, for more than half a century.

Fortunately, however, we have in South Wales, adjoining the Bristol Channel, an almost exhaustless supply of coal and ironstone, which are yet nearly unwrought. It has been stated in the present chapter, that this coal-field extends over about twelve hundred square miles, and that there are twenty-three beds of workable coal, the total average thickness of which is 95 feet, and the quantity contained in each acre is 100,000 tons, or 65,000,000 tons per square mile. If from this we deduct one half for waste, and for the minor extent of the upper beds, we shall have a clear supply of coal, equal to 32,000,000 tons per square mile. Now, if we admit that the five million tons of coal from the Northumberland and Durham mines is equal to nearly one-third of the total consumption of coal in England, each square mile of the Welsh coal-field, would yield coal for two years' consumption; and as there are from one thousand to twelve hundred square miles in this coal-field, it would supply England with fuel for two thousand years, after all our English coal mines are worked out.

It is true, that a considerable part of the coal in South Wales is of an inferior quality, and is not at present burned for domestic use; but in proportion as coal becomes scarce, improved methods of burning it will assuredly be discovered, to prevent any sulphurous fumes from entering apartments, and also to economise the consumption of fuel in all our manufacturing processes.

N.B. These observations are taken from one of the author's geological lectures, which he has occasionally delivered in some of the principal mining districts in England: considering the great national importance of our coal mines, he trusts he shall be excused for inserting them in the present volume.

CHAP. IX.

ON UNCONFORMABLE TRAP ROCKS AND BASALTIC DYKES.

Different Positions of Trap Rocks, as overlying, imbedded, or intersecting other Rocks. — Varieties of Trap Rocks. — Porphyry, Porphyritic Trap, Sienite, Greenstone, Clinkstone, Basalt, Amygdaloid, and Wacke. — Passage by Gradation into each other, and into Volcanic and Granitic Rocks. — Remarkable Instance of this Passage at Christiania in Norway. — Mountains of Porphyritic Trap and Clinkstone with deep Craters. — High Stile, Cumberland; Cader Idris, Monmouthshire.—Basaltic Dykes: Extent of the Cleveland Basalt Dyke. — Isolated Caps of Basalt. — On interstratified Basalt. — Remarks of Professor Sedgwick on the Protrusion of Basalt between regular Strata. — On columnar Ranges of Basalt. — Organic Remains enveloped in Basalt. — Remarkable Basaltic Districts in Europe and America. — Experiments on Basalt. — Theory of Werner. — On the relative Age of Trap Rocks.

The class of rocks about to be described in the present chapter, are extremely interesting to the geologist, as they present him with decided indications of their origin and mode of formation. They not only "reveal the secret of their birth," but, from their close alliance to many of the most ancient primary rocks, they disclose the operations by which a large portion of the earth's surface was consolidated, in the most remote geological epochs. Many of the trap rocks are so similar in structure and composition to the products of active volcanoes, and to beds of lava erupted in our own times, that we may be said to see the very cause in operation, by which they were formed. Many of the trap rocks are also so similar in structure and composition to some of the most ancient primary rocks, that we can scarcely doubt respecting their having had the same origin, though they may have been consolidated under different degrees of heat or pressure, and with different attendant conditions. The name Trap is derived from the Swedish word trappa, *a stair, and has been given to rocks of this class, because many of them divide into regular forms resembling the steps of stairs. Whether the term, in its literal sense, is well chosen as a generic name, may be doubted; but, taken metaphorically, it is extremely appropriate, as these rocks offer a series of gradations or steps, over which the geologist may safely travel in his speculations, from the lava of Etna, to the granite of the Alps.*

To obtain a correct knowledge of trap rocks, the student should first acquire a clear idea of their position. When primary and transition rocks form distinct beds, they are generally arranged conformably, or, in other words, the upper beds are moulded upon the lower, and have the same elevations and depressions, as represented Plate III. fig. 1.

Trap rocks, on the contrary, are found on the surface in overlying, unconformable masses, or are imbedded in other rocks, or intersect them, rising like a wall, and breaking the continuity of the strata. Such walls are called dykes. Trap rocks that are imbedded, seldom preserve the form of regular strata for any great extent, but are extremely variable in their thickness; in many instances, they appear to have been laterally protruded between regular strata. These different positions of trap rocks are represented Plated III. fig. 2. It is obvious that these unconformable rocks were formed at a period subsequent to that of the rocks which they cover or intersect.

As the mineral composition of trap rocks is nearly the same as that of rocks whose igneous origin is now undisputed, we can have little difficulty in admitting, that the overlying masses of trap have been poured over the surface of the conformable rocks in a state of fusion, like streams of lava from recent volcanoes; with this difference, that they were not erupted from one opening or crater, but from fissures of great width and many miles or leagues in extent, and that they were formed under the ocean. I say we can have little difficulty in admitting this, particularly as such rents or fissures, filled with similar matter to that of the overlying unconformable masses, are often discovered in their vicinity.

Trap rocks, however, are not unfrequently observed imbedded between strata of aqueous formation: here their origin appears more obscure. In many of these instances we may, without difficulty, admit that these trap rocks were formed by submarine volcanoes, which have poured beds of lava over the limestone; another bed of limestone may have been subsequently formed over the lava, and this limestone may also have been covered by the lava of a later eruption. In this manner the alternation of beds of basalt, or basaltic amygdaloid, with limestone in Derbyshire, may admit of a probable explanation. See Plate IV. fig. 5. *e. e.* beds of trap between beds of mountain limestone *a. a.*

On the southern side of Etna there are several beds of undoubted lava alternating with limestone, as will be more fully stated hereafter. In some instances, however, the basalt or trap has evidently been protruded between the strata, after the period when the latter were deposited.

Before we proceed, it may be proper to remark, that there are certain porphyritic rocks bearing the general character of trap rocks, which are associated with slate rocks, and appear to pass by gradation into them. We cannot suppose that they have been erupted like lava, or protruded into the slate: they have probably been softened by subterranean heat with the slate *in situ;* but from difference of composition, or different degrees of temperature, these beds may have had a greater facility in acquiring a porphyritic texture. A remarkable instance of the passage of slate into porphyry will be noticed hereafter.

If we sufficiently keep in view that the crust of the globe with which we are acquainted, does not exceed, in comparative thickness, that of a wafer to an artificial globe three feet in diameter; and that a very large portion of the globe is now or has in ancient times been rent and pierced through by active volcanoes, and that these volcanoes are not the seat of subterranean fire, but merely its chimneys, we shall have no difficulty in admitting, that extensive parts of the crust of the globe, far distant from any present volcanoes, may have been softened by internal heat, and the more fusible beds partly crystallized *in situ,* under the pressure of the ocean.

With respect to the overlying formations which pass by gradation into primary rocks (as some porphyries allied to volcanic rocks pass into granite), this fact, so far from proving that the porphyry was not of igneous origin, tends strongly to confirm the hypothesis, which attributes an igneous formation to granite itself.* It is granted by the best observers, that a regular gradation may be traced between granite and the more ancient volcanic rocks, and that there is likewise a gradation between the products of ancient and recent volcanoes, of which we shall afterwards treat more fully. It will be proper, before we proceed, to state the mineral composition of trap rocks. Felspar and hornblende, see Chap. III., constitute the principal ingredients of trap; in many trap rocks the mineral called augite is intermixed with felspar: indeed, hornblende and augite resemble each other so much in chemical composition, and, when uncrystallized, in external character also, that they have till recently been confounded together, and they ofter occur together in the same rock. These compounds of felspar and hornblende, and felspar and augite, chiefly form the different rocks called greenstone, sienitic greenstone, basalt, clinkstone, pitchstone, wacke, and amygdaloid; and also trap-porphyry, and pitchstone-porphyry. All these

---

* However highly and justly distinguished many of the natural philosophers in France may be, it cannot be denied that they adhere more closely to theories once formed, and have a greater dread of thinking for themselves, than the philosophers of other countries. In confirmation of this, I shall translate an extract from M. Bonnard's *Aperçu Géognostique des Terrains*. It is truly amusing to see the alarm which he evinces, lest he should be compelled by stubborn facts to relinquish his cherished theories. — "Another species of difficulty should prevent every prudent man (*esprit sage*) from attempting to explain the formation of these rocks of trachyte by any hypothesis founded on volcanic action; namely, the alarming extent of the consequences which may follow such an explication, relative to other rock formations, hitherto regarded as having a very different origin." With great respect for M. Bonnard, I would say, Let every *esprit sage* yield to the evidence which Nature presents, and leave consequences and theories to take care of themselves.

rocks may be regarded as different modes and combinations of felspar with hornblende or augite, differing chiefly in their internal structure.

When hornblende and felspar are intermixed, and have a granitic structure, they form what is generally called greenstone; and if the felspar be red, sienitic greenstone. When hornblende and felspar, or augite and felspar, are intimately combined and finely granular, they form basalt. The French geologists make a distinction between the basalt in which augite prevails, and that which is composed of felspar and hornblende; but it is admitted that where the structure is finely granular, or nearly compact, it is difficult, if not impossible, to distinguish them.

Basalt has a greenish or brownish black colour, is difficult to break, and possesses a considerable degree of hardness; it will, however, yield to the point of a knife. On examination with a lens, even the more compact varieties of basalt are seen to be composed of minute crystalline grains; it frequently contains yellowish grains of a mineral called olivine; it contains also grains of iron-sand, and a considerable portion of the black oxide of iron. Basalt is fusible into a black glass, and is magnetic. The iron which it contains passes into a further state of oxygenation when exposed to the air: hence basaltic rocks are generally covered with a reddish brown incrustation. Very black basalts are chiefly composed of augite.

Soft earthy basalt, intermixed with green earth, forms the rock called *wacke;* it has frequently a greenish colour. When basalt or wacke contains rounded cavities, filled with zeolites, chalcedony, or calcareous spar, they form amygdaloid.* When the felspar greatly prevails, and the texture becomes nearly compact, basalt passes into the rock called

---

* The names Porphyry and Amygdaloid rather represent modes than substances, and convey no precise ideas, unless the nature of the base be specified.

phonolite or clinkstone, from its yielding a metallic sound when struck: the prevailing colour is gray and greenish gray; it is fusible. Clinkstone, when it has a more earthy texture, passes into the rock called by English geologists claystone. Clinkstone often contains imbedded crystals of felspar, and then becomes a trap-porphyry, which varies in colour according to the prevailing ingredients of its base. Between felspar-porphyry and trap-porphyry there is an almost imperceptible transition; in the former, the base or paste is felspar, nearly pure. Some felspar porphyries pass gradually into granite, by an intermixture with quartz and mica.

Pitchstone has a blackish green, or a nearly black colour; it is a semivitreous substance, having the lustre and appearance of pitch, and does in fact contain a portion of bitumen; its other constituent parts are the same as those of basalt; it approaches nearly to the black volcanic glass called obsidian, which is a lava suddenly refrigerated and perfectly vitrified. Pitchstone and obsidian are sometimes porphyritic. Hence we have on the one hand a series of rocks, (varying only in the increase of felspar, and state of induration,) from granular basalt to clinkstone and claystone, from clinkstone to trap-porphyry, from trap-porphyry to trachyte and felspar-porphyry, and from felspar-porphyry, with the further admixture of mica and quartz, to granitic porphyry and granite. On the other hand, from granitic greenstone there is a transition to sienite, and from sienite to true granite. Again: in the volcanic districts of Auvergne, we see scoriaceous lava become more compact, and at length pass into well characterised black basalt, with the columnar structure. In other situations, currents of lava form obsidian or volcanic glass; and between basalt, phonolite, and pitchstone, there is an almost imperceptible gradation.

Thus it may be seen that the whole family of trap rocks have on the one hand a close alliance with volcanic rocks; and on the other, with the more ancient rocks of porphyry and granite.

The gradation of trap rock, having in some parts a volcanic character, into true granite, has been described by Messrs. Hausmann and Von Buch as distinctly observable, and well marked, in a mountain near Christiania in Norway. The lower rocks are gneiss; over this occurs dark slate; and in the slate are several beds of blackish limestone, containing trilobites, and also orthoceratites several feet in length, with other marine organic remains. In some parts, a bed of gritstone or greywacke rests on the slate. The whole of these beds are covered by an enormous mass of porphyry, varying in thickness from 1600 to 2000 feet. The porphyry is of a smoke gray colour, but is reddish in some parts; it is compact, and moderately hard, and contains large crystals of white felspar, and crystals of quartz, epidote, hornblende, iron pyrites, and magnetic iron ore. In the lower part of the bed the porphyry becomes vesicular, and changes into an amygdaloidal basalt, containing crystals of augite. Near the sea, vast dykes of this porphyry, more than thirty yards in width, are seen cutting through the slate and beds of limestone. In another part of the country, at Holmestrand, the same mass of porphyry, covering beds of sandstone, is seen to pass in the lower part, by almost insensible gradations, into a hard fine-grained black basalt, containing brilliant crystals of augite: in the upper part of the bed, the porphyry passes into a sienite of singular beauty, containing crystals of zircon; and above this, the sienite passes into common granite. The dykes of porphyry cutting through the slate rocks, indicate the mode of formation of this porphyry, in a manner not to be mistaken by those who are acquainted with the basaltic dykes in the northern parts of Great Britain. These dykes were doubtless the fissures through which this vast mass of porphyry had been poured out over the slate rocks, though Messrs. Hausmann and Von Buch describe them as veins descending from the porphyry. The reader may form a more distinct idea of the position of this porphyry and its relation to the subjacent rocks, which are intersected by dykes of the same porphyry, from Plate III. fig. 2. *a*.

Had M. Von Buch seen this remarkable mass of porphyry at Christiania, after his visit to the basaltic districts in England, he would, I am persuaded, have at once recognised the agency of subterranean fire in its formation. I saw this eminent geologist soon after his return from Cumberland and Westmoreland; and if I recollect distinctly his opinion respecting the mountains of porphyritic trap and clinkstone intermixed with slate in these counties, it was, that they bore a striking resemblance to some of the most ancient volcanic mountains in Auvergne, and that, like them, they had been softened *in situ*, and elevated by subterranean heat. The operation of igneous agency in these mountains is much less evident than in the porphyry of Norway, if the description given of it be correct. The only porphyry occurring in unconformable beds that I have seen in Cumberland or Westmoreland, covers part of a mountain of coarse slate, on the right-hand side of the road going from Kendal to the granite mountain of Shap. It forms a nearly horizontal bed composed of red felspar, which has an earthy texture, and contains crystals or grains of quartz; it is what the French would denominate a red trachyte. Considerable fragments of the same rock are scattered in the adjacent valleys, proving that at a former period, this porphyry was more extensively spread over that district. A red porphyritic felspar, nearly similar in composition and appearance, forms the top of the mountain called Red Pike above the Lake of Buttermere in Cumberland. Closely adjacent to Red Pike, and forming part of the same ridge, is the mountain called High Stile. Between the summits of these mountains is a deep crater with a small lake or tarn at the bottom of it: the sides of this crater are very steep; it is partly surrounded by rude columns of clinkstone on one side; the porphyritic felspar of Red Pike forms the other side. The clinkstone has a smooth conchoidal fracture and a greenish grey colour; it contains small crystals of felspar, and is slightly translucent on the edges and very fusible; it is highly sonorous when struck with a hammer. The height of High Stile is 2100 feet above the level of the sea; the depth of the crater is about 500 feet; the side nearest the Lake of Buttermere, by which alone it can be entered, is partly open. Situated as it is on the summit of a very narrow steep mountain range, that divides the valley of Buttermere from Ennerdale, no conceivable operation of water could have scooped out the crater, and the bed of the lake within it.

Though the rocks which surround this crater are closely allied to volcanic rocks, and have probably been subjected to the agency of subterranean fire, yet the crater is not composed of lava and scoriæ, like that of moderm volcanoes. Cader Idris, in Merionethshire, is similar in composition and structure to High Stile; it has also a deep crater, with a small lake at the bottom. The opinion of Von Buch, that some volcanic mountains have been upheaved bodily in a solid mass, would, if admitted, elucidate the formation of these mountains: the craters may not have ejected lava, but may have served for vents to the elastic fluids or steam that, combined with heat, were the agents by which the mountains were upheaved; or we may suppose the craters to be formed by a partial sinking down of the summits, when the mountains were still softened by heat. It may, however, deserve the future enquiry of geologists, whether the red felspathic trachyte on one side of the crater of High Stile, which forms Red Pike, and extends over the mountain, may not once have flowed as lava.

Many mountains in Cumberland and Westmoreland are composed of porphyritic trap, passing into clinkstone. In a deep ravine of Swarthfell in Cumberland, opposite the seat of J. Marshall, Esq. the mountain, which is here composed of clinkstone, presents the columnar structure on a magnificent scale; the columns are slightly bent and inclined.

Porphyry, from an intermixture with hornblende, frequently passes into sienite; when this is the case, the latter rock generally forms the upper part of the mass. Porphyry and basalt, in enormous masses, often cover the primary mountains in the Andes. According to Humboldt, "they are arranged in regular columns, which strike the eye of the traveller like immense castles lifted into the sky." Some geologists describe four formations of porphyry; but this division is purely theoretical, as those who admit it, agree that the different formations of porphyry frequently pass into each other; and, from the evident connection of porphyry and basaltic with igneous rocks, it naturally follows, that such transitions must take place. Many porphyritic rocks may be regarded as more ancient than basaltic rocks, as porphyry frequently occurs intermixed with, or covering, transition rocks, and basalt is most commonly associated with the secondary strata. I am informed by Professor Sedgwick, that the porphyry of the Cheviot Hills has produced frequent and great dislocations of the beds in its vicinity. We have few instances, beside, that I am acquainted with, in England or Wales, of eruptions of well defined porphyry: they are not uncommon in Scotland and in the Alps. We shall proceed to describe the phenomena presented by trap rocks, of which there are numerous striking examples in Great Britain and Ireland.

In describing the phenomena presented by any of the trap rocks, we describe those peculiar to every member of the trap family. Were it allowed to express a geological fact in familiar terms, it might be said, that all the members of this family give indications of a fiery character, and of having been troublesome neighbours to the adjacent rocks, disturbing them, and even changing their nature, when they are closely associated. Beside occurring in overlying unconformable masses, all trap rocks, with porphyry, which may be placed at their head, are occasionally found intersecting other rocks like vertical walls. It has been before stated, that these vertical walls are called *dykes*,—the term dyke and wall being synonymous in North Britain. The substance which most commonly occurs in dykes is basalt; and as these basaltic dykes are well known, from their frequently intersecting coal strata, we shall now give a description of basaltic dykes, and their effects on the adjacent rocks or strata.

The thickness of dykes varies from a few inches to twenty or thirty feet or yards; in some instances they exceed three hundred feet. The extent to which they stretch across a country has seldom been explored beyond the mining districts, where a knowledge of them is important, on account of the disturbances which they occasion in the strata.

The intersection of coal strata by dykes is represented Plate IV. fig. 2. and 3. c. c. and d. d. Dykes generally decline a little from a vertical position; and, as before stated, the depth to which they descend is unknown.

The strata are almost always thrown down on one side of a dyke, and elevated on the other; but the dislocation is not proportioned to its breadth. There is a fault extending from Whitley in Northumberland, to Greenside and Sandgate in Durham, which has thrown down the strata on the north side one hundred and eighty yards; this is a comparatively narrow fissure filled with clay. A great basaltic dyke in the same county, which is seventeen yards wide, has only produced a dislocation of twelve yards.

The whole series of strata which have been raised above the surface on one side of a fault, have sometimes entirely disappeared, and the ground on each side of it is on the same level. See Plate IV. fig. 2, 3.

Trap dykes and basalt dykes are generally harder than the rocks that they intersect; and when the latter are partly decomposed often remain, forming vast walls of stone, that rise above the surface of the ground. There are walls of this kind in the counties of Northumberland and Durham, running along the country several miles. Dykes also extend into the sea, and form reefs of rocks; and when they cross the beds of rivers, they form fords, and sometimes hold up the water and occasion cascades, of which there are numerous instances on the river Tees. In the interior of North America, basaltic walls were discovered by Messrs. Lewis and Clark, of great extent; the walls were composed of columns of basalt arranged horizontally, and were at first supposed to be artificial constructions. Where basaltic dykes are of considerable thickness, the hardness of the stone varies in different parts; sometimes the inner parts are harder, and sometimes softer, than the outer, the substance in the dyke being divided by seams or partings. This may be distinctly seen at Coaly Hill near Newcastle-upon-Tyne, where a large basalt or whin dyke cuts through the coal strata, and rises to the surface. The stone being hard is quarried for the roads along a line of several hundred yards, forming a deep trench, sufficiently wide to admit a cart-road through the quarry, between the sides of the dyke.

The basalt of the dyke is intersected by fissures, and divided into variously shaped masses. In one part of the dyke it appears to graduate into an indurated ferruginous clay, which is in some places divided into minute, well-defined pentagonal prisms. The dyke had charred the coal on each side of it, and rendered it soft and sooty; to use the language of a quarry man, who was working in the dyke when I visited the place in 1813, "it had burned the coal wherever it had touched it." The same dyke extends from the sea to the western side of the county of Northumberland; its termination in that direction is unknown.

The longest mineral dyke that has been traced in England may be called the Cleveland Basalt Dyke: it extends from the western side of Durham to Barwick in Yorkshire; it crosses the river Tees at this place, and proceeds in a waving line through the Cleveland Hills in the east riding of Yorkshire, to the sea between Scarborough and Whitby. It rises to the surface, and is quarried, in many parts of its course, for stone to lay upon the roads. From Bawick-on-the-Tees it may be traced, in an easterly direction, near the villages of Stanton, Newby, Nunthorp, and Ayton. At Langbath-ridge a quarry is worked in it; it passes south of the remarkable hill called Roseberry Toppin, near Stokesly, and from thence by Lansdale to Kildale; it may be seen on the surface nearly all the way in the above track. From Kildale it passes to Denbigh Dale end, and through the village of Egton-bridge, and hence over Leace ridge through Gothland, crossing the turnpike road from Whitby to Pickering near the seven mile stone, at a place called Sillow Cross on a high moor. I examined it at this place, where it is quarried for the roads, and is about ten yards wide. From hence it may be traced to Blea Hill near Harwood Dale, in a line towards the sea, near which it is covered with alluvial soil; but there can be little doubt that it extends into the German Ocean. It is a dark greyish brown basalt which turns brown on exposure to the atmosphere; it is the principal material for mending the roads in the district called Cleveland. I am indebted to Mr. Bird of Whitby for an account of the situations where it may be seen on the surface. He has traced it through Yorkshire and Durham; in the latter county it cuts through the coal strata. Professor Sedgwick, in a valuable paper on the Trap Dykes of Yorkshire and Durham, published since this account of the Cleveland Basalt Dyke was originally written, says that the continuity of this dyke with others west of the Tees, is not fully ascertained: he thinks the length of the dyke may be estimated at from fifty to sixty miles. The course of this dyke is marked in the Geological Map of England, Plate IV. By consulting the large maps of England, the course may be distinctly traced: drawing a line in the direction from Cockfield in the county of Durham to Barwick-on-the-Tees, and extending the line east and west, it will pass near all the places above mentioned. In some situations where the angle in which this dyke cuts the strata can be ascertained, it is about eighty degrees.

A circumstance attending this and other extensive dykes, which has not, I believe, been hitherto regarded by geologists, completely invalidates the theory, that dykes were originally open fissures formed by the drying or shrinking in of the rocks. This dyke in its course intersects very different formations, viz. the transition or metalliferous limestone, the coal district, and the upper secondary strata of lias and oolite. The different organic remains in these formations, as well as their position, prove that they were consolidated at distant periods of time. Indeed the geologists who maintain that dykes were formed as before described, are ready to admit the distant æras of these formations. The transition, or metalliferous limestone, and the lower strata must have been completely consolidated, long before the upper secondary strata were deposited; and the causes which might dispose the upper strata to shrink in, cannot be supposed to act on the lower locks. It is also to be remarked, that in the lower rocks, situated to the west, the breadth of this dyke is more than twenty yards; but at Sillow Cross, where I measured it, it is not more than ten yards: this dyke must, therefore, become wider as it descends. It must also have been filled with basalt at the time of its formation, otherwise it would have contained numerous fragments of the rocks which it intersects.

The effects of this basaltic dyke on the different rocks through which it passes are truly deserving notice. When it comes in contact with limestone, the limestone is often found granular and crystalline, a fact the geological importance of which will be subsequently adverted to. Where it crosses the coal strata, and comes in contact with the seams of coal, the substance of the coal is for several feet converted into soot. At a greater distance from the basalt, the coal is reduced to a coke or cinder, which burns without smoke, and with a clear and durable heat. At the distance of fifty feet from the dyke, the coal is found in its natural unaltered state. It is particularly remarkable that the roof immediately over the coal is lined with bright crystals of sulphur. In some situations in the same county, the shale, in contiguity with basaltic dykes, is converted into flinty slate or jasper, and the sandstone is changed to a brick colour. There is another great basaltic dyke in the same district, which crosses the western extremity of Durham from Allenheads to Burtreeford on the river Tees, hence called the Burtreeford Dyke. It throws down the strata on the west side of it, one hundred and sixty yards.

Dykes, being generally impervious to water, they obstruct its passage along the porous strata, and occasion it to rise; hence it frequently happens that numerous springs make their appearance along the course of a dyke, by which it may be detected, when there is no other indication of it visible on the surface.

Basaltic dykes intersect both primary and secondary rocks, but they every where present indications of their action on the adjacent rocks. At Nigg, near Aberdeen, I examined a basaltic dyke on the coast, which intersects a rock composed of gneiss; the dyke is about thirty feet in width. Where the basalt is in contact with the gneiss, it becomes nearly compact, and approaches to the character of hornstone, and the gneiss has a red and burnt appearance, approaching in its nature to porphyry. It is probable that the action of the basalt on the sides of the gneiss rock had softened it and rendered it more liable to disintegrate than the other parts; for the sea has here made an indentation inland, forming a deep narrow ravine or bay, with a lofty wall of basalt running through it. The wall of basalt completely divides the bay, and the sea enters on both sides of the basalt. It has been before observed, that when basaltic dykes extend into the sea, they form reefs of rocks, and small islands. These basaltic walls, whether rising above the surface of the country, or extending into the sea, serve to mark the destruction of the land; for we are certain, that these walls of mineral matter, were at one period supported on each side by rocks or strata which they have intersected, but which are now worn away. The Cleveland basalt dyke, it has been stated, cuts through the transition limestone; the coal strata, and the upper secondary strata, comprising a part of the oolite formation. On the northern coast of Ireland, Messrs. Buckland and Conybeare discovered a considerable basaltic dyke, passing through the chalk rocks. In the immediate contiguity of basalt, the chalk on each side of the dyke was rendered highly indurated and crystalline, this effect decreasing as the distance from the dyke increased.

The constant occurrence of dykes in basaltic districts, gives a high degree of probability to the opinion, that overlying unconformable trap rocks have been erupted through these dykes in a melted state like lava, and have been poured over the surface of the ground. Where extensive beds of basalt occur in low situations, there can be little difficulty in admitting this mode of formation; but the frequent occurrence of beds of basalt, forming isolated caps on distant mountains, was for a long time considered as opposing completely the hypothesis of the igneous origin of basaltic rocks. A more attentive examination of basaltic districts has however established the fact, that these isolated caps of basalt are parts of extensive continuous beds, which have in remote ages been excavated and intersected by valleys, in the same manner as the beds of other rocks which frequently form isolated caps on detached mountains. Isolated caps of basalt are also in some situations formed like caps of modern lava, which extend to no great distance from the summit of a volcano. Professor Sedgwick of Cambridge, in an interesting description of "*The Phenomena connected with some Trap Dykes in Yorkshire and Durham,*" given in the Transactions of the Cambridge Philosophical Society, states that "In the quarries now excavating near Bolam, the vertical dyke is unusually contracted in its dimensions; but, on reaching the surface, it undergoes a great lateral extension, especially on the south-west side, so that the works are conducted, in a perpendicular face of columnar trap, more than two hundred feet wide." The drawing below (copied from that of Professor Sedgwick) will give a distinct idea of this mode of formation. It may be proper to observe, that the dyke is a continuation of the Cleveland basalt dyke, which I have before described. The horizontal measures through which it passes are coal measures.

There can be no more doubt respecting the cap or expansion of basalt having been erupted through the dyke, than there can be of the origin of a bed of lava, which may be traced to the mouth of an adjacent volcano.

Beds of trap or basalt, interstratified with other rocks, have given rise to much speculation respecting their origin: that such beds are not unfrequent in the coal measures, is a fact well known to miners in the North of England. From the great hardness of trap beds (provincially called beds of whinstone) they increase the difficulty and expense of sinking shafts. These interstratified masses have been frequently described as regular measures or strata. There is a thick bed of trap in some of the coal-fields in Durham, called the Great Whinstone Sill; the word *sill* being used for stratum by Mr. Westgarth Forster, in his section of these strata published in 1809. This bed or mass of whinstone, though described by Mr. Forster as a regular stratum with the series of strata in which it is found, is admitted to vary in thickness from twelve to sixty yards. It is found at a great depth in some mines, in other situations it rises to the surface. An objection has been suggested, if this bed be of igneous origin, in what manner did it become interstratified with beds that are evidently aqueous depositions? Those who first raised this objection could scarcely have kept in mind, that every bed in the whole series of the coal measures was once the upper surface of the solid ground, whether that surface was covered with water, or was dry. An eruption of lava might therefore flow over any particular bed in the whole series, and this lava might become covered by subsequent aqueous depositions. But there is another mode in which the lava might be introduced among the strata at a later period; it might be protruded laterally between them. That such lateral protrusions have actually taken place in some instances, is proved by Dr. MacCulloch's observations on the coast of Scotland, where trap may be seen forming beds between strata of sandstone, then suddenly cutting through the upper strata and forming other beds above. See Plate III. fig. 3. where strata of sandstone are intersected vertically by a dyke of basalt, and laterally by nearly horizontal beds of the same basalt. Professor Sedgwick has bestowed much labour in investigating the true position of the Great Whinstone Sill, and its relations to the different strata in its vicinity, and has given a very luminous and satisfactory description of the remarkable phenomena which it presents, proving unanswerably the igneous origin of this rock.

It would be doing great injustice to this valuable paper, to attempt an abridgment of the detail of interesting facts and arguments which it contains: I shall briefly recapitulate some of the observations. The whin sill is not a regular bed interposed between the same strata in different parts of its range, but it cuts through or overlies very different strata. It has had an extraordinary effect in converting beds of shale, on which it lies, into a porous slagg; and where the whin sill comes in contact with limestone, the limestone is converted into a dull white granular and crystalline mass. (Query Dolomite?)

This conversion takes place not only in the subjacent limestone, but sometimes on the limestone which covers the whin sill, — a fact deserving particular attention, as it indicates that the whin sill was protruded between the beds of limestone, otherwise it could scarcely have produced any chemical or mechanical change on the upper bed of limestone. In some parts, beds of limestone are seen bent upwards and imbedded in the whin sill.

Indeed Professor Sedgwick thinks it probable, that the whin sill was produced by a lateral injection of volcanic matter, in a state of igneous fusion.

The beds of trap or toadstone, imbedded in the mountain limestone of Derbyshire, were supposed by Mr. Whitehurst to have been protruded or driven, in a melted state, between the strata: this opinion was chiefly founded on the supposed fact, that the metallic veins, which cut through the limestone, 1. 2. 3. do not pass into the toadstone, (see Plate IV. fig. 5.) and were therefore supposed to have been broken through when the latter beds were protruded. It has, however, since been discovered, that the veins do often pass into the toadstone, though they seldom bear ore in this rock; hence the conclusion of Mr. Whitehurst was deprived of its main support. Subsequently, Mr. Farey, in his survey of Derbyshire, misled by an attachment to theory, described the beds of toadstone as regular strata, preserving their thickness and continuity through the Peak of Derbyshire. This is by no means the case; the beds of toadstone are extremely variable in their thickness and order of succession, and the intermixture of green-earth, toadstone, and limestone, near the junction of toadstone with the limestone beds, certainly favours Mr. Whitehurst's original theory of protrusion; but this protrusion took place before the formation of metallic veins, and might be the cause of those fissures in which the veins were formed. It is not improbable that some of the more regular beds of toadstone may have flowed as lava. Professor Sedgwick justly observes, "that our reluctance to admit the theory of protrusion arises from the difficulty of conceiving any powers in nature adequate to produce such an effect. But all the phenomena of Geology show, that the great disturbing forces by which the crust of the globe has been modified, acted in former times with incomparably more energy than they do at present. Volcanic forces are now employed in lifting a column of melted lava to the lip of a crater. The same kind of forces, acting with more energy and through a wider region, may in the early history of the globe have been employed in lifting islands and even continents from the bottom of the ocean. During an operation like this, the elastic forces, acting from below, may often have driven masses of fluid lava among the superincumbent strata; and, in every case, the lava would naturally be propelled through those portions which were most easily penetrated — the lateral must, at every point, have been equal to the vertical pressure. The expansive forces may not at any point have been able to drive a column of lava through all the solid unbroken beds, but the lateral forces may have driven a portion of the fluid between the partings of two horizontal beds; and when a penetration of this kind was once effected, the lava would act like a wedge to mechanical advantage, and rush in an horizontal stream to a distance proportioned to the elastic forces which were in action."

The formation of basaltic dykes is sufficiently explained by what takes place in the vicinity of volcanoes. Before the confined vapour that afterwards issues through the crater finds a vent there, the surface of the ground in the vicinity of the volcano is frequently upheaved, and fissures of great extent are made, into which melted lava is sometimes forced, which on cooling forms a wall or dyke, in every respect similar to a basaltic dyke. During an eruption of Vesuvius that took place in 1794, a rent of this kind was formed near the bottom of the mountain, 2375 feet in length and 237 feet in breadth, which became filled with compact lava. Rents or fissures of some miles in length have been opened on the sides of Etna. There is abundant evidence to prove, that most basaltic rocks were erupted under the pressure of the ocean and it is probably owing to circumstances attending their refrigeration, that they have frequently a columnar structure.

The occurrence of thick beds of basalt, divided into regular pentagonal or hexagonal columns, and disposed in ranges of vast extent and height, could not fail to arrest the attention of the most careless observer, and give rise to speculations respecting their origin and formation. Basaltic columns are frequently seen in countries that are the seat of volcanic fires, but they occur also in countries very remote from any known volcanoes. The theories respecting their formation will be subsequently adverted to.

Few countries in the world present more magnificent basaltic columnar ranges than the north part of

Ireland, and some of the Hebrides: probably these are connected under the ocean, and have had the same origin.

The Giant's Causeway constitutes a small part of a vast basaltic range, along the north coast of Ireland, in the county of Antrim. The promontory of Fairhead and Borgue, in the same range, are situated eight miles from each other: these capes consist of various ranges of pillars and horizontal strata, which rise from the sea to the height of five hundred feet: from their abruptness they are very conspicuous, and form a pile of natural architecture, in which the regularity and symmetry of art are united with the wild grandeur and magnificence of nature. Many of the columns in the ranges at Fairhead are one hundred and fifty feet in height, and five feet in breadth. At the base along the shore is a wild waste of rocky fragments, which have fallen from the cliffs. Immense masses that have withstood the force of the shock lie in groups, resembling the ruins of enormous castles. At the Giant's Causeway the columns rarely exceed one foot in breadth, and thirty feet in height: they are sharply defined, and the columns are divided into smaller blocks, or prisms of one foot or more in length, which fit neatly into each other, like a ball and socket. The basalt is close grained, but the upper joint is cellular. The columns are most frequently formed with five or six sides; but some have seven or eight, and others not more than three. Beds of basalt that are not columnar, in some situations lie over, and also under the columns. The basalt in these beds is cellular, and contains zeolites in its cavities. The columns at Fairhead are not articulated like those at the Giant's Causeway; but the blocks, which are of great length in each column, lie flat on each other. Basalt appears to extend on the coast and inland about forty miles in length, and twenty in breadth.

A full and perspicuous account of the geology of this part of Ireland is given by Messrs. Buckland

and Conybeare, in the fourth volume of the Geological Transactions. It appears that this basaltic range rests upon lias limestone containing marine shells and ammonites; the basalt also enters chalk-rocks, which are much broken by it, and in one part a considerable mass of chalk is completely enveloped in basalt. The effect of a basaltic dyke, in crystallising the chalk on each side of it, has already been mentioned. Former observers, unacquainted with the nature of the rock on which the basaltic ranges of the Giant's Causeway rest, have mistaken it for basalt; it is a dark coloured highly indurated limestone, and as it contains shells and other organic remains, these remains were erroneously supposed to prove the marine origin of basalt.

The basaltic columns of the Island of Staffa are too well known to require a description; but, according to Dr. MacCulloch, the columns which form the lofty promontory called the Scuire of Egg, another of the Hebrides, exceed in grandeur and in picturesque effect those of Staffa: they are formed of black pitchstone, containing crystals of glossy felspar. "The promontory rests on a bed of compact grey limestone, approaching to a stone marle. This bed, which is three or four feet thick, rests on a still lower bed of hard reddish stone. Masses of bituminised wood, penetrated with carbonate of lime, are found in the marle stratum not at all flattened. Portions of trunks of trees, retaining their original shape, but petrified (silicified), are found in the same stratum; the rifts are filled with chalcedony, approaching in aspect to semi-opal. The columns on this island are both perpendicular and inclined, and some of them are bent or curved."

In various parts of Scotland and the Hebrides, the tendency to a columnar arrangement in the basaltic rocks may be distinctly seen: it is obscurely developed in the basalt of Arthur's Seat near Edinburgh. The basalt of this hill appears identical with some of the volcanic mountains I examined in

Auvergne, particularly near the summit of Montadoux, a mountain near Clermont.

In England the columnar structure of some of the basaltic and trap rocks is observable in the northern counties, particularly on the banks of the river Tees, and at Swarthfell near Ulswater. In some of the basaltic hills near Dudley, the columnar structure is developed, but the columns are not separated and well defined. Prismatic blocks of sienite, are scattered over a hill of sienite called Markfield Knowl, at Charnwood Forest in Leicestershire.

Columns of porphyritic trap or greenstone occur in groups, on the northern side of Cader Idris in Merionethshire. One of these columnar groups is represented Plate V. fig. 1.; the outline of the columns was taken with a camera lucida by Henry Strutt, Esq. of Derby, and cannot fail to be correct; the figure is introduced, to show the relative magnitude of the columns. Rocks of trap and basalt, both in solid beds, and also arranged in columns like those of Staffa, were observed by Sir G. Mackenzie on the coast of Iceland, and also in the interior; the lower parts of the beds and columns contained scoriæ and slags, and empty cavities. A successive range of beds of basalt was also observed alternating with beds of tufa, the lower parts of which presented the same appearance of the action of fire.

From the situation of these rocks, and from the existence of submarine volcanoes near Iceland, Sir G. Mackenzie conceives that these beds of basalt were formed under the sea by the ejection of lava, which, flowing over the moist submarine ground, would confine a portion of water beneath the melted mass: this water would be converted into elastic vapour, or steam, which would endeavour to expand: but where the superincumbent pressure of the ocean, or the tenacity of the lava, prevented its escape, it would be compressed, and form cavities, or air bubbles, at the bottom of the melted mass. In other instances, where the fluidity of the lava permitted the steam from below to escape through it, the mass would be compact, and form solid basalt, or greenstone. It might sometimes happen that water would be enclosed in the cavities of the mass, which is found to be the case in some basalt rocks.

Thus, according to the different circumstances of pressure from the depth of the ocean, and from the tenacity of the melted mass, Sir G. Mackenzie supposes that porous and vesicular lava, or compact basalt, might be formed from the same eruption; or the mass might be porous below and compact above.

As Iceland is at present the seat of active volcanoes, and as submarine volcanoes are forming rocks near the shores of that island, Sir George Mackenzie's explanation of the causes which have produced the various appearances in the basaltic ranges of that island, seems highly probable. In Sicily the connection of basaltic with volcanic rocks has been clearly established by Ferrara, professor of Natural Philosophy at Catania.

In the vicinity of Clermont Ferrand in Auvergne, a thick bed of basalt has once covered an extensive tract of country; it rests upon a bed of volcanic tufa, and the latter frequently covers beds of freshwater limestone. This bed of basalt, and the subjacent tufa and limestone, have evidently been furrowed and excavated by the same causes, which have excavated valleys in other parts of the world; hence the basalt occurs, forming isolated caps on many of the mountains. In some parts a gradation may be traced in the same bed from a compact basalt, similar to that of Arthur's Seat near Edinburgh, to porous basalt, approaching more or less to the state of scoriaceous lava. But the basalt of Auvergne belongs evidently to volcanic products, and will be described in the chapter on volcanoes. It may be proper to remark, that as the basalt of Auvergne covers beds of freshwater limestone, which belong to the tertiary strata, its age is evidently posterior to that formation of limestone, which is regarded as the most recent.

Basalt sometimes presents a globular structure, globes of hard basalt being imbedded in a mass of basalt of a softer kind.

Wacke or earthy basalt has frequently a greenish or reddish brown colour; it often contains cavities which are generally filled with nodules of agate, or with zeolite or calcareous spar. The agates are composed of concentric layers, and have apparently been formed by siliceous infiltration, depositing successive coats within each other, until the cavity is filled up. Basaltic rocks of this kind are called amygdaloids. The Hill of Kinnoul, in the vicinity of Perth, is formed of basaltic amygdaloid, containing agate nodules in great abundance, of various dimensions and beautifully striped. At Woodford Bridge, in Gloucestershire, there is a low rock of amygdaloidal wacke, which is much intermixed with green earth, and has in some parts a saponaceous feel; the agates which it contains are decomposing, and the inner concentric layers are separated from each other, and present the appearance of edges of folded paper, with small interstices between each. I examined this singular rock in 1816; it was then quarried for stone to mend the roads. In some parts of the rocks I found masses of corallite of considerable size, enveloped in the basaltic amygdaloid. I found also, in this rock, well defined groups of prehnite, which was not then known to be an English mineral: it has since been discovered in the basalt of Staffordshire.

The occurrence of organic remains enveloped in basalt, of which there are various instances, may admit of an easy explanation, if we allow that basalt has once flowed like lava at the bottom of the ocean. Modern lavas often envelope bones and other substances that they meet with in their course.

Having before stated the phenomena presented by imbedded trap, which indicate that, in some instances, it has been protruded between regular strata laterally, it will be useful to cite an instructive example of beds of trap alternating with limestone, by successive deposition, which is stated by Dr. Daubeny, the present chemical professor at Oxford, in an interesting sketch of the Geology of Sicily. The facts seem clearly to ascertain, that beds of amygdaloidal trap, alternating with beds of limestone, have, in that island at least, been formed by successive currents of lava flowing over the bed of the sea, at intervals of time so distant, as to allow the deposition or formation of a bed of limestone, over each current of lava. A considerable district near Lentini, on the southern side of Mount Etna, and also a part of the island near Cape Passero, are composed of alternating beds of lava, with tertiary limestone abounding with organic remains of madreporites, nummulites, cerithea, and the remarkable fossil called the Hippurite. Santa Venera, the loftiest mountain in the south of the island, is capped with cellular lava; beneath it is a bed of limestone with minute shells; at a lower level, towards Lentini, there is a second bed of volcanic matter similar to the first; and two other similar alternations of beds of limestone and lava occur still lower down. Dr. Daubeny says that the cellular and semivitreous aspect of many of the volcanic beds associated with the beds of limestone, precludes all doubt repecting the manner of their formation: the character of other portions present strong analogies to rocks of the trap family; "they are compact, and have a stony fracture; they contain crystals of olivine, and the cavities are filled with calcareous spar or zeolites, like the amygdaloids of more ancient strata. In some of the beds, a tendency to a columnar arrangement is discernible."

This account of Dr. Daubeny's, affords additional proof of the close connection of ancient volcanic rocks with trap rocks, — may we not add, of their perfect identity? It is beside highly illustrative of the alternation of the beds of basaltic amygdaloid, with beds of limestone in other situations. But in both instances, we must admit that the beds were formed under the ocean, before the present islands and continents had emerged from the watery abyss. With respect to Etna, the alternation of lava and limestone affords decisive evidence, that this mountain was upheaved from the ocean, though its height may have been greatly augmented by eruptions of lava, since the period of its first elevation. Before concluding the account of interstratified basalt, it may be proper to mention, that Mr. William Hutton, in a paper lately read to the Geological Society of London, maintains, that the great bed of basalt in Northumberland, called the whinstone sill, was deposited over the limestone beds on which it rests, and not protruded laterally between them: though he admits, with Professor Sedgwick, that the basaltic beds in Teesdale were protruded in the manner before described. In some cases it may be extremely difficult to determine whether a bed of basalt has flowed like lava, or been protruded laterally, because two strata of hard limestone, for example, are often separated by seams of soft clay, which would dispose the beds to yield to a lateral pressure in the direction of the strata, and the injected basalt would take the form of a regular stratum.

Mr. Hutton admits, that in some instances the limestone over the basalt had suffered the same effects of igneous action as the limestone below it. These instances, I think, afford satisfactory evidence, that the basalt was protruded between the beds of limestone.

The disturbances and contortions of some of the lower beds of transition limestone, in the vicinity of trap rocks, were mentioned in Chap. VII. In such instances, though frequently no visible connection between the rocks of trap and limestone can be traced on the surface, there can be little doubt that such connection exists. The singularly bent limestone beds at Wren's Nest Hill near Dudley are at a considerable distance from the nearest basaltic hill; but I observed in the town of Dudley, where a well was sinking, that the stone thrown out was granular basalt, intermixed with calcareous spar.

Some species of trap rocks, and particularly the softer kinds of basalt, decompose rapidly, and form productive soils and marle. I am inclined to believe, that some of the most fertile soils in England were formed, by an intermixture with decomposed basaltic rocks. What has been called basaltic tufa, is a volcanic substance, and will be described among volcanic products. Some of the trap rocks, particularly the porphyritic traps, are metalliferous; but it is rarely the case with any of the British trap rocks, and it has before been stated, that the veins of lead ore in Derbyshire, are either cut off by beds of basalt, or generally cease to yield ore, when passing through basalt.

Having described the principal phenomena attending trap rocks, whether occurring in dykes, in unconformable masses, or interstratified with other rocks, it may be proper to mention certain experiments that have been made, to elucidate the formation of basaltic rocks. All trap rocks are fusible, and most of them form a blackish-green glass after melting: hence it was inferred, that trap rocks had never been in a state of fusion; for if they had, they would have been rendered vitreous. Sir James Hall, however, reflecting on the long period of refrigeration that vast masses of melted rock would necessarily require, before they were cooled to the common temperature of the earth, was induced to make experiments on lava and basalt; from which it was ascertained, that if a small portion of liquid lava were suddenly cooled, it formed a black glass, as was well known to be the case with basalt, but if the process of cooling were slow, both melted lava, and basalt became stone. When the glass which had been formed by sudden cooling was melted again, and suffered to cool very gradually, it lost its vitreous character, and was converted into a substance resembling basalt. Mr. Gregory Watt made some experiments on the fusion and refrigeration of basalt, in one of his father's furnaces, which throws much additional light on the formation of the globular and columnar structure of basaltic rocks. He fused seven hundred weight of the Dudley basalt called Rowley ragg, and kept it in the furnace several days after the fire was reduced. It melted into a dark-coloured glass, with less heat than was necessary to melt the same quantity of pig-iron. In this glass, small globules were formed, which afterwards disappeared; and as the cooling proceeded, the mass was changed from a vitreous to a stony substance: other globes were again formed within the stony mass, which continued to enlarge until their sides touched and pressed against each other, by which pressure the globes formed polygonal prisms. If part of the mass were cooled before the globular structure was destroyed, these globes were harder than the surrounding stone, and broke in concentric layers. In this manner the balls of basalt and porphyry which fall out of decomposing rocks were probably formed; they derived their superior hardness from the crystalline arrangement of the particles, when in a melted state. When these globes were enlarged by a continuation of the same process, they might press on each other, and form prisms. The upper prisms pressing by their weight upon the lower, might form concavities or sockets, into which they would sink, and remain joined together or articulated. Such is frequently the structure of basaltic columns.

Another experiment, made by Sir James Hall, on the crystallisation of common limestone by heat, and its conversion into marble, tends to elucidate the effects produced by basaltic rocks, on limestone and chalk before mentioned. Dr. Hutton had advanced the opinion, that beds of limestone were formed of the shells and exuviæ of marine animals, which had been melted by central fire, and crystallised. The first part of this theory respecting the entire formation of calcareous rocks from animal remains, it is not necessary to discuss at present: that a considerable portion of many limestone rocks were so formed, cannot be denied. It was however objected to this theory, that the well-known action of fire on limestone rocks would expel the fixed air, and render them soft and pulverulent. To this objection it was replied, that as the action of central heat on beds of marine shells took place under the ocean, the pressure of the water would prevent the escape of the fixed air, and would probably render the calcareous earth more fusible. This answer was regarded as a mere hypothesis for some time, but Sir James Hall determined to try its validity by experiments. Having calculated the resistance which a column of water fifteen hundred feet, or any given depth, would present to the escape of fixed air, he enclosed a quantity of powdered chalk in a gun-barrel, and confined it in such a manner as to present an equal degree of resistance. He subjected the powdered chalk thus confined, to the action of a furnace; after some time it was then drawn out and cooled, and was found converted into crystalline limestone or marble; and in one instance, where the chalk enclosed a shell, the shell had acquired a crystalline texture, without losing its form. Hence in situations where chalk or earthy limestone are found to have a crystalline texture, when in contiguity with trap rocks, we may with a high degree of probability infer, that the limestone had been fused by the trap.

A recapitulation of the facts and experiments which prove the igneous origin of trap rocks, would afford a mass of evidence which might convince the most sceptical enquirer; but such a recapitulation is needless, as in many situations undoubted currents of lava pass into trap rocks, and we have ocular demonstration of the fact.

The reason why geologists were so long opposed to the igneous origin of basaltic rocks, may partly be explained by the attachment to received theories, and partly by the reluctance to admit a condition of our planet, so remote from present experience. It was thought an ample claim on our credulity, when we were required to believe, that all the habitable parts of the globe had been for ages submerged in the ocean, without requiring the further belief, that countries now remote from active volcanoes, had been repeatedly subject to the agency of subterranean fire. Yet both these positions must be granted, if we will allow a legitimate induction from established facts.

The advocates of the aqueous origin of basaltic rocks, while they advanced theories, which made claims upon our faith, equally unsupported by present experience, failed entirely in their attempts to explain the causes of existing phenomena in a satisfactory manner. The theory of Werner was for some time zealously supported, and particularly the least tenable part of it, — the formation of basaltic rocks by a second rising of the ocean, which deposited them on the summits of elevated mountains. — It may be proper to give a brief account of this part of the Wernerian system, before it entirely sinks into oblivion.

According to the theory of Werner, all the superficial parts of the globe were once in a state of aqueous solution, from which the materials were at first separated by chemical deposition in a crystalline state, and formed a thick mass of granite round the globe. Upon granite, the primary rocks were successively deposited, forming layers over each other like the coats of an onion. Over these again were laid the transition rocks; and next, the earthy stratified rocks. Each of these layers was supposed to encircle the globe, or to be an universal formation. While this process was going on, the waters were gradually retiring, and became turbid: hence the materials which they deposited to form the upper strata, were more earthy than those of the primary rocks; they were also intermixed with fragments of the rocks previously formed. According to this system, mountains and valleys were caused by the original inequality of the nucleus of the earth. So far the parts of Werner's theory are consistent; and we have a world ready made, in which every thing might be supposed to remain quiet; but—*non sic Fata sinunt;*—Neptune, ashamed of his late retreat, and indignant at his confinement in such narrow limits, calls the infernal deities to his assistance, and rising in his might, once more takes possession of the globe. He covers it with the depurgations of his turbid waves: but again he is compelled slowly and reluctantly to retire from the field, leaving behind him the basaltic rocks, the monuments of his triumph and his shame.—Such is in substance the theory of Werner respecting the origin of all the superincumbent rocks of basalt and trap. They are also, according to this theory, universal formations. It is scarcely possible for the human mind to invent a system more repugnant to existing facts. Were basaltic rocks deposited from a solution which covered the globe after the formation of secondary strata, as Werner supposes, every part of the dry land and every valley must have been incrusted or filled with basalt,—it would be the prevailing rock of every district. On the contrary, basalt exists only in particular situations, forming dykes, and overlying masses or beds of limited extent: nor do fragments of basalt occur in any quantity, to warrant the belief that it was ever formed universally over the globe: and what is here said of basalt, applies equally to all unconformable rocks of porphyry, and the other trap rocks. Nothing but the obscure language in which this doctrine of Werner was advanced, could have prevented its absurdity from being instantly perceived and acknowledged.

With respect to the relative age of trap rocks, it is evident that if they are of igneous origin, they may have been formed at any period. We have certain indications that basaltic rocks were formed at different epochs; some of the basaltic dykes which cut through the coal strata in the northern counties, do not enter the magnesian limestone that covers the coal strata. Hence it is clear, that such basaltic

Among the localities of columnar basalt given in a preceding part of the present chapter, I omitted to state that there are very extensive ranges of columnar trap in some of the Northern United States in America. Professor Silliman, in the seventeenth volume of the American Journal of Science, has given a very clear description of the basaltic range which divides the states of Connecticut and Massachusets, extending one hundred and twenty miles in length, and from three to twenty miles in breadth. It was believed a few years since in England, that there were no basaltic rocks in the United States. Messrs. C. T. Jackson and Francis Alger of Boston in New England have recently published "Remarks on the Mineralogy and Geology of Nova Scotia," with coloured plates, representing the immense ranges of basaltic rocks on the shores of that peninsula.

CHAP. X.

A RETROSPECTIVE VIEW OF CERTAIN GEOLOGICAL FACTS AND INFERENCES. — RELATIVE AGES OF MOUNTAIN RANGES. — PRELIMINARY OBSERVATIONS ON THE SECONDARY STRATA.

Before we proceed to the Upper Secondary Rocks, it may be useful to review some of the leading facts stated in the preceding chapters, and to notice certain enquiries, which may naturally present themselves to the mind of the geological student. It appears from an examination of the crust of the globe, whereever it has been scientifically explored, that there is an order of succession or superposition in the rocks of every country, which may often be traced over a considerable extent; and that in countries very remote from each other, an approximation to a similar order is observable, except in one class of rocks which are obtruded irregularly, and cover other rocks without any determinate order of succession, as described in the last chapter. The succession of the several *classes* of rock, — the primary, transition, secondary, and tertiary, — may be regarded as certain, where they occur together. Nor is the universality of this succession affected by accidental disturbances, which in a few instances have overturned beds of primary rocks, and thrown them upon secondary strata. In such cases the latter are thrown out of their natural position, as much as when a block of granite is carried by inundations, upon rocks of recent formations. The few cases in which granite is described as rising through and covering secondary strata require critical examination; and geologists should be particularly upon their guard to avoid being misled by erroneous or fabulous sections of foreign localities. See p. 94.

The succession of the different members of any one class of rocks, is by no means so definite as that of the classes themselves. Many beds common in one country cannot be discovered in another, and hence it may be difficult to determine what part of a series they occupy.

It is easy to conceive that the cause or causes, whatever they may be, which have formed certain rocks, have been limited in the extent of their action, as we know to be frequently the case on a smaller scale, where a stratum of sandstone, &c., after preserving its regular thickness for several miles, becomes gradually narrower, till at length, in the language of the miner, it *wedges out*, and the stratum above and beneath come in immediate contact. In other instances, the rock which is interposed between two well known and identical rocks in distant districts, is not the same in both: this may be frequently observed among the secondary strata, which will next be described. In such cases, the different rocks that occur in the same geological position, have been called equivalents of each other. An instance mentioned in a preceding chapter, may serve to explain what is meant by a geological equivalent. In the beds of transition limestone at Llanymynah, which are very regularly stratified, one stratum of the best limestone suddenly terminates, and its place is supplied by a bed of marle of equal thickness; in the same manner as we might suppose part of a course of bricks to be taken out of a wall, and its place filled up with clay; the clay would be the equivalent of the course of bricks.

In many of the lower conformable rocks, there is a tendency to reproduction in the upper parts of the series: thus, though the regular order of succession may be granite, gneiss, mica-slate, and slate (the clay-slate of Werner), we often find beds of granite among gneiss and mica-slate, and sometimes even in slate. When, however, we consider, that the chemical composition of all these rocks is very nearly the same; that silex forms on the average three fourths of their constituent parts, and alumine about one sixth or one eighth, — the proportions of the remaining parts cannot greatly affect the condition of the mass; and it is to the circumstances (whatever they may be) which have occasioned a more or less rapid consolidation of the parts, that we ought, probably, to attribute the formation of granite in one part of a mountain, and of gneiss, mica-slate, or slate in another, and the re-appearance of granite above the latter rocks. An enquiry naturally suggests itself, on observing that the order of succession in rocks is not invariably the same in distant countries. Are the similar rock formations in distant parts of the world contemporaneous? or were rocks of different classes forming at the same period? Is the granite of England, for instance, more or less ancient than the granite of the Alps? Or, are the secondary strata of one country as old as the primitive rocks of another?

Were it not for the organic remains in different rocks, we could not (as Cuvier has well observed) be certain that all rock formations were not contemporaneous. With respect to those rocks which contain no organic remains, and under which there are no other beds containing organic remains, we cannot ascertain whether they were contemporaneous, or formed at different and distant epochs. The beds of granite which are nearly vertical in mountain ranges, must have acquired a considerable degree of solidity, before the period when the beds were raised: but if we date their age from the epoch of their elevation, we shall be obliged to admit the different ages of granite mountains, and that the granite of Charnwood Forest is more ancient than that of the Alps. Of this we have as direct proof as we could possibly require. In the Alps, the beds of the upper secondary strata, analogous to our magnesian limestone, lias, and oolite, where they approach the central granitic range, are raised into nearly a vertical position conformable to that of the beds of granite, and they must all have been elevated at the same time. —See Plate II. fig. 2., where the relative situation of the beds of upper secondary limestone is represented, *a*, *a*.*

At Charnwood Forest, in Leicestershire, very highly inclined beds of granitic and slate rocks are covered with horizontal beds of the upper secondary strata, analogous to those in the Alps.—See Plate II. fig. 4. *a*, *a*. Now it is evident that the beds of granitic and slate rocks were raised, before the horizontal strata were deposited upon them. Hence we attain the knowledge of an interesting fact in the natural history of our island: its beds of primitive and transition rocks were raised before the beds in the mountains of Savoy and Switzerland, nor can this conclusion be invalidated, unless we admit, what would be contrary to analogy, that secondary strata, possessing the same geological relations and the same organic remains, were formed at different epochs. I have cited the Charnwood Forest hills, because there the proof is more direct and palpable than at the Malvern Hills or elsewhere, for the horizontal upper secondary strata may be seen resting immediately on highly inclined beds of granitic and schistose rocks.

The horizontal beds resting on the Charnwood Forest granite and slate, are composed of sandstone (a part of the red marle and sandstone formation), and at a little distance the sandstone is covered by strata of lias limestone, *e*, which determine its relative age. In some parts, the sandstone strata also cover the coal strata; the latter, *d d*, rise very abruptly as they approach the granite in the north. At the Vosges mountains in France, the same red marle and sandstone, associated with lias, covers the granite and coal strata unconformably.

---

* The calcareous mountains in the outer ranges of the Alps, removed from the central granite, are often bent into arches as represented in Plate II. fig. 2. *x*, *y*, *z*. Such beds, of course, cannot be conformable to those nearer the granite.

When M. Daubuisson published his *Traité de Geognosie*, in 1819, he asserted, that the beds of granite in the Alps were raised into their present vertical or highly inclined position, soon after their original formation. I visited the Alps in the two following years, and the appearances presented by the secondary strata compelled me to draw a very different inference respecting the period when the beds of granite were elevated, which I stated in the second volume of my Travels, published in 1823.

" One important fact may be deduced from these elevated beds of pudding-stone, sandstone, and other strata, comparatively modern, ranging conformably with beds of granite and gneiss; namely, that the beds of granite did not acquire their elevated position till after the formation of the secondary strata. In England, the elevation of the beds of granite was anterior to the deposition of the upper strata, consisting of magnesian limestone, lias limestone, oolite, chalk, and the intervening sandstones; for all these strata lie nearly flat over the edges of the inclined under strata. On the contrary, in Savoy, strata of similar formations occur nearly vertical, and frequently conformable to the range and dip of the granitic formations. These facts would prove, that the causes which have elevated granite, have acted at different epochs on various parts of the globe, unless we are prepared to admit, that similar calcareous formations, containing similar organic remains, were not contemporaneous in different countries."

In the latter part of the same volume I further stated, that as some of the strata on the Diableret mountains in the Vallais contain, at the height of seven thousand feet, fossils similar to those of the tertiary strata in the Paris Basin, it was more reasonable to believe that they had been raised since their deposition, than that fresh-water formations had covered any part of the earth at such a vast elevation; and hence we may infer, that the epoch when the granite of the Alps was raised, is comparatively recent.*

When M. Daubuisson published his *Geognosie*, both he and almost all French geologists adopted the theory of Werner, respecting the formation of granite prior to all other rocks: if, therefore, the elevation of its beds took place soon after its original formation, this elevation preceded the deposition of the secondary strata by many geological ages, and could have had no effect on the position of beds which did not then exist. My views with respect to the different ages of granitic ranges, and the discovery of the true secondary character of the calcareous mountains in the Tarentaise, have since been brought forward by some French geologists, as their original discoveries. My observations were made in the year 1820, at which time they would have been warmly opposed in France; and the answer to them would have been, " Have we not had an *Ecole de Mines* at Moutiers in the centre of the Tarentaise, where some of our first chemists and geologists resided for a long time? we must therefore know the true character of the country better than any occasional visiter."

It is not however certain, that the elevation of beds of granite or other primary rocks might not take place deep under the ocean, and a far more extensive elevating power may at a later period have been required to raise them above the waves, until they formed islands and continents. Indeed such must have been the case, where primary rocks are covered with nearly horizontal strata of marine or aqueous formation. Even the nearly horizontal beds of red marle, that cover the elevated beds of granite on Charnwood Forest, must have been formed or

---

* Since the author published his opinion, in 1823, respecting the recent elevation of the Alps, founded on an attentive examination of the structure of the Pennine and Bernese Alps, M. Von Buch, M. L. Elie de Beaumont, and M. Andre de Luc, of Geneva, have advanced similar opinions, and stated that the elevation of those mountains took place after the formation of the tertiary strata.

deposited under water: the whole, therefore, have been raised together, when that part of England emerged from the ocean; unless the red marle was formed in a mediterranean lake or sea, surrounded by distant high ground. Adopting this view of the subject, though we may be certain that the beds of granite in England were elevated before those of the Alps, it does not follow that England must necessarily have been dry land, before the Alps of Savoy. Since, therefore, the elevation of the beds in mountain ranges, may have preceded their final emergence above the ocean, this consideration deprives the investigation into the relative antiquity of the elevation of the beds in mountain ranges of much of its value.

Before proceeding to describe the secondary and tertiary formations, I shall offer some preliminary observations, connected with the enquiry respecting the relative age of the different beds. Where a similarity of mineral character, and a similar association with other beds is observed in different districts, we may sometimes infer that their origin was cotemporaneous; but when the organic remains are also the same in both, we attain a full conviction of the fact.

It will not be denied that the chalk and oolite in Yorkshire, were cotemporaneous with certain parts of the chalk and oolite formations, in the southern and western counties. In the same manner, we may admit, that the chalk, and oolite, and lias, on the opposite side of the Channel, in France, are cotemporaneous with similar formations in England, with which they preserve an identity of mineralogical and zoological characters. Having once traced these formations to the north of France, we may admit their identity with similar formations, preserving the same identity of character through many of the inland departments of France, and to the Salins at the foot of the Jura range. Over so large an extent of country we may expect to find, as we do in distant districts in England, that certain parts of a series which occur in a certain formation in one place, are wanting in another. In France, some beds occur, under the lias, for instance, which have not hitherto been found in Great Britain: but making allowance for such partial variations, we cannot hesitate to admit the identity of the formations in both countries, and also their identity of age. When we enter the Jura, or the great calcareous ranges of the Alps, the enormous thickness of the beds, which are frequently inaccessible, and the indurated and subcrystalline texture which they often assume, present considerable difficulties, if we attempt to identify them with well known formations. Much confusion and contrariety may be observed in the classification of these rocks by different geologists; but this has partly arisen from the observers not being thoroughly acquainted with the formations with which they were to make the comparison, and partly from the vague and contradictory use of the terms Alpine limestone (*calcaire Alpin*) and Jura limestone (*calcaire de Jura*). There is, however, in some parts of these mountains, both an identity of mineral, and of zoological characters, with some of the formations in the upper secondary strata in England. A thick bed of blue lias, filled with the *Gryphæa arcuata*, in the mountains on the lake of Annecy, and fragments of oolite, like that of Gloucestershire, from the top of Mont Grenier, near Chamberry, left me no doubt of the identity of the formations of England, France, and Savoy; and no reason can be assigned, which might lead us to infer, that the similar formations in each country were not cotemporaneous. With respect to very remote countries, or the countries in opposite hemispheres, we have as yet few data to determine whether there be a similarity of fossil remains, which can identify formations that may appear analogous, or even whether such a similarity could identify them, when they occur in very different latitudes, and under very different degrees of temperature.

There is another circumstance, independent of climate or remote distance, that may have occasioned a change in the genera, and even in the orders and classes of animals, whose remains are found in similar strata. The ocean may have been much deeper in one part, than in another not very remote, and the deepest bed of the ocean might support genera of pelagian animals*; while a more shallow adjacent part might be tenanted by different genera, and even different orders and classes of animals, whose organisation fitted them for moving near the surface of the water. The transition strata were probably formed under a great depth of the sea: and few of the animals, whose remains are found in these strata, possessed the power of locomotion in an eminent degree. The animals possessing this power were chiefly chambered univalve Mollusca; their shells are divided, and have a tube or siphunculus passing through each cell, by which they were enabled to exhaust the water, and rise to the surface from immense depths. The shells of these animals did not form an outer covering, but were partly enveloped in their bodies, and appear to have performed the function of an air bladder. They had heads surrounded by feelers and large eyes; their beaks were like those of the parrot.† The feelers which surrounded their heads served them for seizing their prey, and for swimming and walking at the bottom of the sea; they swam with their heads

---

* Pelagian animals, so called by naturalists because they live in deep seas.

† The animals of this Order, to which Cuvier has given the name of *Cephalopodes*, from their feelers, which serve as feet, being attached to their heads, comprise several genera, as the cuttle-fish, the calmar, &c. but the latter animals have no shells. The Argonauta, common in the Mediterranean, has an open unchambered shell. There are numerous minute microscopic chambered shells found in the present seas, but according to Cuvier the living animal has never yet been observed. — *Règne Animal*, tom. ii. p. 367.

behind them; and when they walked, their heads were downward. There are only two known genera of chambered animals of this class inhabiting the present seas; the Nautilus, and the Spirula, — their shells are spiral: the greatest number of chambered fossil shells found in the upper secondary strata are also spiral, and are well known, as Ammonites and Nautilites. It is probable that the animals that had straight chambered shells possessed greater facility of rising to the surface than the spiral ones, and accordingly we find them chiefly in the oldest and lowest formations. The animals of this class having heads and various senses, seem to rank high in the scale of sentient organic beings; but they are not numerous, till we rise into the secondary strata, above the coal formation.

Very few spiral unchambered shells occur in the transition rocks*; for these animals crawl on their bellies like the snail, and do not seem fitted to live in deep water, unless, like the Helix Janthina, which nearly resembles the snail, and lives in the Southern Ocean, they had little appendages like bladders, which enabled them to rise to the surface. Univalve unchambered spiral shells become numerous in the upper strata, probably from the circumstance that these strata were deposited under shallower seas.

With respect to that class of the testaceous Moluscæ which did not enjoy the privilege of having heads and eyes, their motives for travelling, whether for pleasure or necessity, must have been few indeed; and they may be supposed to enjoy life as well in the deepest recesses of the ocean, as nearer its surface. The tenants of bivalve shells, called by Cuvier *Acephales*†, have, however, a power of locomotion which they effect, some by thrusting out a membrane called a foot, and with it they also

---

* All unchambered spiral shells were occupied by animals which had an organ of motion placed under the body, as in snails: they had heads, and are called by Cuvier *Gasteropodes*.

† Acephales — having no heads.

attach themselves to rocks or other bodies, by a number of filaments called the Byssus, which they can remove at pleasure: others have two tubes, with which they force out water with considerable violence, and impel themselves in an opposite direction; and others again, by a strong muscular action in opening and shutting their shells, can jump twelve inches at one leap.

All these modes of motion, however, though sufficient for the wants of the animal, are very limited in their operation, and are equally adapted for animals in deep or shallow seas, in rivers or lakes: accordingly we find numerous testaceous Mollusca of this class, both in the transition, the secondary, and the tertiary strata, and in our present seas and lakes, and at various depths.

CHAP. XI.

TABULAR ARRANGEMENT OF SECONDARY STRATA. — RED SANDSTONE. — MAGNESIAN LIMESTONE. — ROCK SALT AND GYPSUM.

Relative Geological Position of the Secondary Class of Rocks. — Their Mineral and Zoological Characters. — Tabular Arrangement. — New Red Sandstone and Red Marle. — Upper, Middle, and Lower Beds, chiefly formed of the Fragments of more ancient Rocks, broken by some great Convulsion. — Lowest Red Sandstone, or Roth-todte Liegende of the German Geologists. — Separated from the Middle Beds, by Beds of Magnesian Limestone. — Middle and Upper Beds of Red Sandstone and Marle; their Accordance with those of France and Germany. — Muschel Kalk wanting in England, but probably exists in Ireland, as the Lily Encrinite has recently been discovered there. — Magnesian Limestone of the Northern Counties. — English Red Marle and Sandstone formed of more ancient Rocks, particularly of Porphyry and Trap. — Gypsum accompanying Rock Salt originally Anhydrous. — Rock Salt Deposits, in different Formations.

Secondary rock formations, comprise all the regular strata that cover the transition rocks and coal measures, and terminate with chalk. Their mineral characters may be briefly described, as they occur in England, France, and part of Germany. They consist of vast depositions of sandstone and conglomerate beds, and of numerous calcareous beds, separated by beds of clay and sand. The limestones are less crystalline, and more soft and earthy than transition or mountain limestone. They abound in remains of testaceous animals, which are chiefly marine shells; but remains of freshwater animals occur in some of the secondary beds; and parts of fossil terrestrial vegetables are also sometimes found, proving the existence of dry land, at the period when the strata were deposited. Secondary strata cover a large portion of the habitable globe, and are the immediate subsoil of the most fertile districts in England, and various parts of Europe. No beds of good mineral coal are found in any part of the secondary series of strata, above the regular coal measures in England; but some beds of imperfect coal, and wood coal, occur in the secondary formations: and this is also the case in similar formations on the Continent. Neither metallic veins nor metallic beds deserving notice (except of iron ores) occur in this class of rocks; nor do they afford any of the rare species of crystallised minerals. Rock-salt and gypsum are the most valuable minerals found in the secondary strata; and it is from them that all the important salt-springs issue. Some of the rocks in this class yield useful materials for architecture; but the stone is generally soft and perishable. To the rocks of this class, Werner gave the name of flœtz or flat rocks, because in the northern parts of Europe they are generally arranged in nearly horizontal strata; but this character is altogether inapplicable to the upper secondary strata in the outer ranges of the Alps, and in the Jura chain, where they may be observed bent in every possible direction, and sometimes nearly vertical. In these mountain ranges, the mineral characters of the upper secondary limestones also frequently undergo a considerable change, and become indurated and crystalline, like transition limestones.

It has been stated in the preceding chapters, that the coal strata, which are interposed between the transition rocks and the secondary strata, contain almost exclusively the organic remains of terrestrial and lacustrine or marsh plants, while the fossils in the lower or transition class, belong almost exclusively to marine animals. Another great change appears to have taken place in the condition of our planet after the deposition of the coal strata, for the upper secondary strata contain principally the remains of marine animals. It is in the strata belonging to this class, that the bones and entire skeletons of enormous reptiles are first discovered. It is, however, truly remarkable, that throughout the whole series of the upper secondary strata, no bones of mammiferous land quadrupeds have yet been found; the strata at Stonesfield alone present a solitary exception.

In England, the order of succession of the upper secondary rocks may be more distinctly ascertained, than in any other country that has yet been examined. I shall therefore describe them as they occur in our own country, with references to foreign localities, where the same beds or formations are well identified with the English strata. Geologists on the Continent, and particularly in France, had, till very recently, no accurate knowledge respecting several of these formations; and their classifications of them were vague and contradictory. More attention, however, has very lately been directed to this part of the geology of France; and the clear accounts which have been published by M. Elie de Beaumont in particular, of some of these formations, remove much of the obscurity which prevailed respecting them, and prove, in a satisfactory manner, the great similarity which may be observed, in the secondary formations of England and France.

In the following tabular arrangement of the secondary formations, above the transition and coal formations, I have not thought it expedient to introduce all the minor subordinate beds in each formation: those which possess any geological importance will be subsequently noticed. It may be frequently observed, that particular beds which occur in one part of a formation, and are considerably developed, cannot be traced even into an adjacent district, or they vary so much in thickness and mineral characters, as scarcely to be recognised. If we take an extensive formation, like the oolites, as an example, it is not possible to assign any one part of the range, as affording a correct type of all the series in distant or even in neighbouring parts of the range, though we may trace a general resemblance in all the principal beds;

and this I hold to be amply sufficient for every valuable purpose in geology. (See Note *, p. 235.)

SECONDARY FORMATIONS,

above the transition and regular coal formations, and terminating with chalk.

1. RED SANDSTONE AND MARLE WITH MAGNESIAN LIMESTONE.

a Lower beds of new red sandstone	a *Grès rouge ancien et rothtodte liegende.*
b Magnesian limestone	b *Zetchstein et rauche wacke.*
c Upper red sandstone (Muschel kalk wanting in England.)	c *Grès bigarré et grès des vosges, muschel kalk.*
d Red marle with fibrous gypsum	d *Keuper, marnes irrisees.*

2. LIAS. — LIMESTONE AND LIAS CLAY.

a White lias and micaceous sandstone	*Calcaires à gryphites.*
b Blue lias with marlstone	
c Lias clay and shale	

3. OOLITE LIMESTONE AND BEDS OF CLAY AND SANDSTONE.

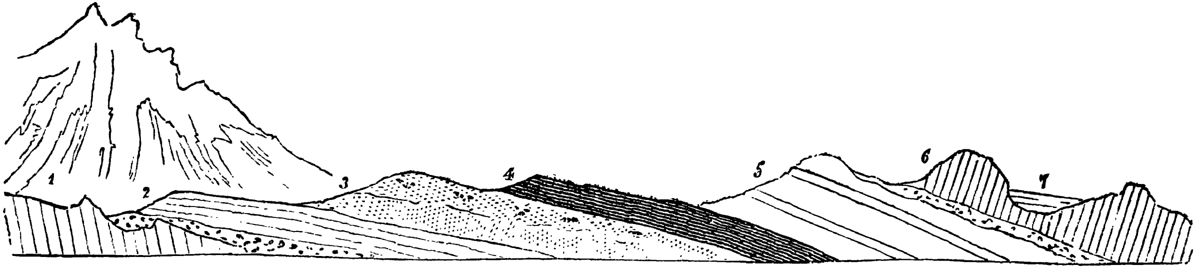
a Inferior and Bath oolites with sandstone, Oxford or clunch clay	*Calcaires oolitiques*, and sometimes *calcaires de Jura*, and also *calcaire Alpin.*
b Middle oolites	
c Bituminous or Kimmeridge clay	
d Upper or Portland oolite	

4. WEALDEN OR SUSSEX BEDS.

a Weald clay with sandstone	This may be regarded as a local formation of limited extent, but extremely interesting on account of its fossil remains.
b Sandstone, calcareous grit	
c Petworth and Purbeck limestone	

5. GREEN SAND AND CHALK.

a Lower green sand and iron sand	*Grès vert et grès ferrugineux.*
b Blue clay, called Galt	
c Upper green sand	
d Chalk marle	*Craie tufeau.*
e Chalk without flints	*Craie inférieure, et Craie supérieure.*
f Upper or flinty chalk	



2 Lower red sandstone and magnesian limestone, resting unconformably on transition rocks or coal strata, No. 1.
3 Middle and upper red sandstone and marle, with rock salt and gypsum.
4 Lias clay and lias limestone.
5 Oolite formation, and beds of clay.
N.B. Where the wealden beds occur, they are placed between the oolite and green sand.
6 Green sand and chalk.
7 Tertiary strata, filling a depression in chalk.

New Red Sandstone is so called to distinguish it from a red sandstone found among transition rocks, (see Chap. VII.). The new red sandstone is a very extensive and complex formation: its prevailing mineral character is siliceous; but it sometimes comprises calcareous beds of considerable magnitude and extent. The new red sandstone may be conveniently divided into three series, or the upper, the middle, and the lower beds; where the beds of limestone occur, they serve to mark the divisions in the series with sufficient distinctness, but where they are wanting, these divisions cannot always be observed. A limestone containing magnesia, separates the lower from the middle series, in the northern counties of England, but is wanting in the midland and western counties.

In France a calcareous bed, called muschel kalk, separates the middle series from the upper; but this has not been discovered in England. The red sandstone in England covers the lower rocks unconformably, which proves that the lower rocks were tilted up, before the strata of red sandstone here were deposited: this upheaving of the lower beds must have been attended with great convulsions, which probably supplied the sand and fragments, of which many of the beds of red sandstone are composed. Indeed, it is highly probable, that this sandstone, and the conglomerate beds in different parts of it, were formed by the violent disintegration of the older rocks, and of trap rocks, that were protruded at the era of some great convulsion, which broke down a large portion of the

---

* Those who know into how many mistakes even eminent geologists have fallen into, respecting the formations in their own immediate vicinity, by attempting to introduce numerous subdivisions of strata, and to identify them with those in other situations, will be ready to acknowledge that such labours are too micrological, and that by endeavouring to mark divisions, where Nature has not established them, we lose our time, and introduce needless perplexity into the science. A reference to the two sections of the oolite formation, given at the end of the next chapter, will serve to evince the truth of the above remarks.

ancient crust of the globe, and spread the debris far and wide over the bed of the existing ocean. Fragments of the older rocks occur in the different beds of this sandstone, and some of the beds are almost entirely formed of such fragments. This mode of formation, would sufficiently account for the great diversity, both in the nature and thickness of the beds, in different districts. I am inclined to believe, that the disintegrating causes which broke down part of the ancient rocks, and spread their ruins over a great extent of surface, acted at successive periods of comparatively short duration, succeeded by long intervals of repose, during which the calcareous strata were deposited.

The lower red sandstone was not known as a member of the red sandstone formation in England, before Professor Sedgwick ascertained, that it formed beds of considerable magnitude below the magnesian limestone in Durham and Yorkshire. It does not, however, extend, as he supposed, to the southern termination of the magnesian limestone in Nottinghamshire; for there I have found the lowest beds of magnesian limestone resting immediately on the coal measures, and a part of the upper red sandstone covering the limestone. The lowest beds of red sandstone are in some situations conglomerates; in others coarse siliceous sandstone is often much intermixed with decomposing crystals of felspar. Sometimes it is found finer grained, and mixed with micaceous shale and reddish marle. The beds are generally more or less impregnated with the oxyd of iron, and coloured red or yellow. The thickness of the beds differs much in different situations, as might be expected from its lying upon the lower beds unconformably, and therefore resting upon an uneven surface. The lower new red sandstone in the western counties of England, and in various parts of the Continent, contains fragments of different rocks cemented by ferruginous sand or marle, and masses of imperfect porphyry, and abundance of felspar, both in a decomposed state and in perfect crystals. The magnesian limestone, over the lower red sandstone, should here be described in the ascending series; but the description would disconnect the account of the upper and lower red sandstone, which are strictly but one formation. I shall, therefore, defer the description of the magnesian limestone, until that of the red sandstone is gone through. In fact, the magnesian limestone does not always occur in the red sandstone.

New Red Sandstone and Marle above magnesian limestone. The beds have generally the prevailing colour which the name implies, but are often marked with irregular veins and spots, of a yellowish or bluish colour, and the sandstone is sometimes yellow or grey, with occasional spots of red.

The composition of different strata in this formation is extremely various: in some parts we find an argillaceous marle in different states of induration, and more or less intermixed with calcareous earth. In other parts we meet with regular strata of siliceous sandstone; and sometimes we have a conglomerate sandstone, or a soft sandstone, enclosing rounded pebbles of quartz and Lydian stone, granite and porphyry, as in the rock on which Nottingham and the Castle stand. In the lower part of this division, as well as in that beneath the magnesian limestone, the beds are porphyritic, and contain imperfect crystals of felspar; sometimes they pass into amygdaloid and trap. The fine siliceous sandstones, when closely examined, are often found to contain fragments of the neighbouring rocks: thus the sandstone in the vicinity of Charnwood Forest, as before stated, contains fragments of slate and chlorite slate; and the conglomerate beds on the northern side of that range of hills, are principally composed of fragments of granitic and slate rocks. No formation presents such a great variety of mineral characters as the red marle and sandstone. In England it has frequently been confounded with the red sandstone and conglomerate, that occur under the upper transition limestone, called by English geologists the old red sandstone. But the old red sandstone of foreign geologists, or *roth-todte liegende* *, the *grès ancien* of Daubuisson, covers the coal formation, and therefore corresponds with the lowest beds of the English red marle and sandstone.

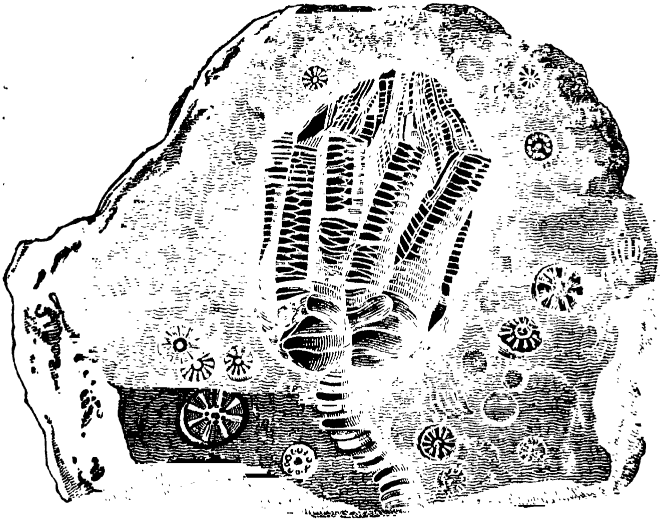
Where the red marle and sandstone formation is fully developed, it may be arranged, as before stated, under three divisions: the lower, which corresponds with the *roth-todte liegende*, consisting of fragments of different rocks cemented by sand or marle, and of beds of imperfect porphyry; this occurs below magnesian limestone: the middle beds, consisting chiefly of sandstone, called by the French *grès rouge* and *grès des Vosges:* and the upper, consisting of marle and variegated sandstone, in which beds of rock-salt and gypsum occur; this corresponds with the *grès bigarré* and *marnes irrisées* of the French. In England the three divisions of this formation rarely if ever occur together, accompanied with magnesian limestone; but it should appear, from the situation of these different beds on the Continent, that the place of the magnesian limestone is between the lower and the middle division; for the magnesian limestone or *zetchstein*, rests on the conglomerate beds of red sandstone.

In the third number of the *Annales des Mines*, 1827, there is a very full account of the different arenaceous strata that separate the coal strata from lias limestone, along the feet of the Vosges mountains on the eastern side of France, by M. L. Elie de Beaumont. This account throws considerable light on a part of geology hitherto obscured by the conflicting

---

* The name Roth-todte liegende, or *red dead lyes*, was first applied to what the English call the old red sandstone, below the coal formation, because no coal was found under it.

fossil, the lily encrinite, is found. (See the cut.) The muschel kalk occurs also in Germany, but is entirely



wanting in England. In its mineral characters it bears a near resemblance to the limestone called lias, but it is separated from the lias of the Vosges by thick beds, corresponding with the English red marle, but called by the French *marnes irrisées*, from their spotted and variegated colours. The fossils in the muschel kalk bear a nearer relation to those in the lias than to the shells in the magnesian limestone below it; but neither belemnites nor gryphites occur in this limestone in the Vosges. Its chief fossils are the lily encrinite, two species of ammonite, the terebratula subrotunda, and a species of muscle. According to M. E. Beaumont, were it not for the intervention of the muschel kalk, there would be a complete passage of the red sandstone into the red marle, as occurs in England. It deserves attention, that the lily encrinite has just been discovered in limestone brought from Ireland to the Isle of Wight. The drawing I have seen of it leaves no doubt of the fact; but whether the limestone be mountain limestone, as it is called, or the muschel kalk, remains to be determined. Thick beds of red marl, with fibrous gypsum, compose the upper part of the new red formation in the midland counties of England: the red marl is generally spotted, and striped by greenish and yellow marl.

The beds of red marl and sandstone of this formation, occupy a considerable part of the midland counties in England, extending from the eastern side of Yorkshire into Devonshire, and on the west, with some interruption, from Cumberland to Gloucestershire. The beds or strata never attain any considerable elevation in England; they cover or enclose rocks of other formations: in Leicestershire and Warwickshire they surround rocks of sienite, granite, porphyry slate, greenstone, and quartz. The granite and greenstone of the Malvern Hills, are covered on the southern side by the same red marl and sandstone. In Devonshire, several rocks of greenstone and amygdaloidal trap are also surrounded by it; and at Rouvray in France, on the road to Dijon, I observed a low range of sienitic and granitic rocks, rising from a similar red marl, which, like the English red marl, was covered by blue lias with gryphites. It was formerly maintained by Mr. Farey, that the sienitic and granite rocks of Charnwood Forest and Malvern, were merely anomalous masses in the red marl; and though this opinion was deemed extravagant, and afterwards abandoned by Mr. Farey himself, I am inclined to believe, that there is a greater connection between these different formations, than has hitherto been admitted.

The red marl and sandstone of England, appear to me to have been principally formed by the disintegration of rocks of trap, greenstone, sienite, and granular quartz: the iron in the decomposing trap rocks, has probably given to this formation its red colour. I conceive that the argillaceous marls have also been principally formed from the trap rocks, and the siliceous sandstones from the granular quartz rock. That rocks of sienite, trap, and quartz, were once extensively spread over the districts now covered with red marl, might, I think, be sufficiently ascertained, by tracing them through the red marl districts, where they just peep above the surface, or they might be discovered by sinking. The sienitic rocks of Charnwood Forest may be distinctly traced into Warwickshire; from thence to the Malvern Hills the connection may be followed; and from the Malvern Hills to the trap rocks in Gloucestershire, Somersetshire, and Devonshire; but every where accompanied by the red marl, or near to it. The quartz rock at the Lickey, near Bromsgrove, is not, as has hitherto been believed, the only rock of the kind in the midland counties; it may be found near Atherstone in Warwickshire, and is doubtless associated with the greenstone rocks in that neighbourhood, as members of the Charnwood Forest range of hills.*

I was informed by T. Johnston, Esq. of Exeter, that he had frequently examined the red ground in the vicinity of the different trap rocks in Devonshire, and that he invariably found it composed of fragments of these rocks, increasing in size as he approached nearer to them. The sand rock on which Nottingham and Nottingham Castle are built, has evidently been formed of the ruins of more ancient rocks in its vicinity; and the rounded pebbles of quartz and of Lydian stone, granite, porphyry, jasper, and mica-slate, indicate that they have come from rocks, formerly connected with the Charnwood Forest range. Still nearer the Charnwood hills, the finest sandstone contains fragments of slate, and the

---

* In the village of Hartshill, near Atherstone, when the author was at school there, the quartz rock was employed in mending the roads: it is granular without cement, and breaks into sharp edged fragments; it has a light reddish colour. When a handful of the fragments are taken from the roads, and thrown upon the ground forcibly in the dark, they produce numerous scintillations like stars, — an experiment which has often excited the surprise of the author and his schoolmates.

lower conglomerate is almost entirely composed of the fragments of the Charnwood rocks, as before observed. In the Vosges, the red sandstone every where accompanies the granitic and transition rocks, of which it also contains fragments. It must be recollected that the rocks most disposed to decompose or disintegrate, would be the soonest worn down. With the exception of the Malvern range we have no rocks of soft granite, or sienite in England, like those of Auvergne, or of the Forez mountains in France; and the reason why we have not, may be, that, from their smaller magnitude, they were probably carried away by those mighty inundations, that have swept over our present islands and continents. The Malvern Hills, the Lickey, the Charnwood Forest Hills, and the trap rocks in Gloucestershire, Somersetshire, and Devonshire, are the remaining nuclei of much larger ranges, as the scattered fragments in the adjacent, as well as in distant districts attest. If the red marl and sandstone in England, and in other countries, were formed of decomposing rocks of trap, granular quartz, porphyry, sienite, and granite, the frequent occurrence of porphyroidal beds in this formation may admit of a probable explanation.

It is not intended to maintain, that every bed or stratum in this extensive formation is composed principally of the fragments of transition and trap rocks; but it may safely be affirmed, that there are few strata, in which some of these fragments may not be discovered.

The red marl produces some of the most fertile soils in England, which may be partly owing to its formation from soft trap rocks. Some basaltic rocks decompose rapidly, and are known to form soil favourable to vegetation; several basaltic rocks in Staffordshire decompose into a reddish brown clay, moderately tenacious.

A very remarkable discovery has been recently made (1828), of the foot-marks of some unknown quadruped in strata of new red sandstone, at the

Corn Cockle Muir, three miles from Lochmaben in Dumfries-shire. They were found forty-five feet under the present surface; the strata are inclined thirty-seven degrees. This circumstance was communicated to the author by Mr. Murray, jun. of Albemarle Street, who showed him at the same time a plaster cast, taken from a slab of stone, in which the impressions were tolerably distinct, and also part of a thin stratum of the stone itself, with indistinct impressions of a similar kind. There can scarcely be a doubt, that they were the real foot-marks of a digitated animal having short toes and claws, and the foot broad in proportion to its length. The breadth of the foot is above one inch. The part of the sandstone in Mr. Murray's possession, appeared principally composed of granular fragments of reddish quartz rock and felspar, with spots of chlorite or hornblende. As remains of reptiles have been found in the zetchstein or magnesian limestone on the Continent, which is as ancient as the new red sandstone, may not this animal have been a reptile allied to the tortoise?

Since the publication of the third edition of this work, Professor Buckland has, I believe, ascertained that the foot-marks are similar to the foot-marks which some species of tortoise make in sand.

Before concluding the account of the red sandstone, it may be proper to repeat, that in a formation of such complexity, it is often difficult to determine to which part of the series any particular bed belongs, unless its situation be indicated by some of the limestone beds, which sometimes occur in different parts of it. Thus, in Devonshire, the porphyritic beds and conglomerates may belong to the lowest, or to the middle series of sandstones: their position, with respect to the rocks on which they rest unconformably, does not assist in the discovery. In Yorkshire, the very lowest series rest on coal measures, as stated by Professor Sedgwick, in his masterly and luminous description of the geological relations of the magnesian limestone, from Northumberland to Nottinghamshire. At Charnwood Forest, the uppermost series rests on ancient granitic and slate rocks, as represented in Plate III. fig. 4. *a*, *a*. In the lowest beds, resting on the slate, I observed indications of their mode of formation, which I intend afterwards to describe. Professor Sedgwick first ascertained the true relations of the lower sandstone; but twenty years before, in the first edition of this work, (1813, p. 270.) I gave a brief account of the Pontefract sand rock, as the last of the rock formations over coal, in a description of a section from the Yorkshire to the Lancashire coast: — "The magnesian limestone is succeeded by yellow siliceous sandstone, on which the town of Pontefract is built. We may consider this as the boundary of the low calcareous district: proceeding in a direction to Wakefield, we soon come upon the argillaceous coal strata of the middle district."

Professor Sedgwick arranges the red sandstone and magnesian limestone in an ascending series.

1. Lower red sandstone, yellow and red.
2. Marl slate and compact limestone.
2 *a*. Compact and shelly limestone, and variegated marls.
3. Yellow magnesian limestone.
4. Lower red marl and gypsum.
5. Upper thin bedded limestone.
6. Upper red sandstone.
7. Upper red marl and gypsum.

It may deserve notice, that the red sandstone generally occupies the depressions in the more ancient strata, or what were once deep valleys, and also fills up hollows on the surface of ancient rocks, as represented in Plate III. fig. 4. *a a*. Now, as these depressions and hollows were originally filled up when the surface was under the ocean, and are now raised some hundred feet above its present level, without any apparent disturbance, this fact proves, that there were two elevating causes acting at different epochs,

— the first violent and transitory, which tilted up the lower beds; the second, more extensive, but more gradual in its operation, which upheaved the whole country above the ocean, and formed islands and continents.

Magnesian Limestone.—The geological position of this rock is over the lowest beds of new red sandstone; but where this is wanting, it lies unconformably over the regular coal formation: see Chap. VIII. It is covered by the middle and upper series of new red sandstone.

The dolomite found in primitive and transition rocks has been before described; it is commonly white, or light grey and granular. That in the secondary strata has generally a dark brown or a yellowish-brown colour: it contains a variable proportion of magnesia, sometimes more than fifty per cent.

The presence of magnesian earth, in the proportion of nearly one half, in certain limestones, is a fact that strongly militates against the theory, which ascribes the formation of all limestone rocks to animal secretion; unless it shall be found that magnesian earth is contained in the shells and exuviæ of marine animals. I believe no anaylses of shells or coral have yet been made, in order to ascertain the presence of magnesia as one of their constituent elements. Should magnesia be found in the exuviæ of certain orders of marine animals, and not in others, it would not only favour the opinion that limestone was of animal origin, but might also explain the cause of the alternation of beds of magnesian limestone with beds of common limestone, in the same mountain. Or should some shells of one species contain magnesia, and others none, it would prove that, under different circumstances, the same animal might form its shell of different constituent parts.

Professor Sedgwick is inclined to derive the magnesian limestone from the debris of beds of mountain or transition limestone which contain magnesia; but many beds of the magnesian limestone, above the coal formation, have as much the character of original rocks as the beds of transition limestone, and the difficulty is not removed by this hypothesis; for it still remains to enquire, from whence did the mountain or transition limestones derive their magnesia? Von Buch ascribes the change of the common limestone into dolomite in the Tyrol, to the action of volcanic rocks and volcanic vapours containing magnesia; but this opinion is not likely to obtain many supporters. Can the magnesia found in some of the chalk rocks in England or France be derived from volcanic rocks? Were the theory of Von Buch true, we ought to expect all limestone rocks in the immediate vicinity of basalt to be magnesian; but some experiments which I made on the mountain limestone of Derbyshire, in near proximity to the toadstone, proved that it did not contain so much magnesia, as the beds that were much farther removed from the latter rock.

The magnesian limestone is distinctly stratified; the strata vary in thickness from a few inches to several feet: in the northern counties of England they are nearly horizontal; they border the great coal formation, and cover it on the eastern side. This formation of limestone extends from the mouth of the Tyne to near Nottingham. The colour of the limestone is generally a yellowish or reddish brown, varying in intensity from a fawn colour to that of an overburnt brick. Some of the lowest beds are bluish and slaty, and intermixed with marl; but these beds seldom rise to the surface, and their nature is little known. Some beds of magnesian limestone have a granular sandy structure, others are imperfectly crystalline: they possess a considerable degree of hardness. A cellular variety of this limestone occurs near Sunderland, which has received the name of Honeycomb limestone: it agrees in most of its characters with the rauche wacke of Thuringia, which is part of the zetchstein formation.

Many beds of magnesian limestone yield a fœtid smell when rubbed. At Sunderland, the beds of magnesian limestone are more developed than in any other part of England that I am acquainted with. In an account I published of the Geology of Durham, in the Philosophical Magazine for 1815, I estimated the total thickness at one hundred and fifty yards. Below the surface, this limestone has been bored into to a considerable depth; the limestone was, as before mentioned, of a bluish colour. According to Mr. Farey, "under the yellow beds of magnesian limestone, there are several beds of compact blue limestone, abounding with Anomia (Terebratulæ) and other shells; some of these beds differ entirely from the yellow and red beds, and are more useful for agricultural purposes, particularly on the yellow limestone lands." * This is the marl slate of Professor Sedgwick. The lower beds of this formation are, I believe, more fully developed in many parts of the Continent than in this country, which occasions some uncertainty in classing them. The limestone of Thuringia, it is agreed by the most respectable geologists, is zetchstein, corresponding with our magnesian limestone; the lower part is a slaty marl, sometimes impregnated with bitumen, and sometimes with sand. This bed contains impressions of fish, like the lower beds of the slaty Sunderland magnesian limestone: it contains also a small quantity of copper pyrites, and the ores of lead, cobalt, zinc, bismuth, and arsenic, and is in some places worked by the miners for its mineral treasures. Above this bed their occurs a blackish-grey compact limestone, very hard and tenacious, and distinctly stratified; over this is a cellular limestone; and above this, a blackish brown limestone, which yields a fœtid smell when struck with a hammer, and is in some places more than one hundred feet in thickness. All these different beds Humboldt comprises under the name of zetchstein, and agrees with other geo-

---

* Survey of Derbyshire, p. 157.

logists in referring them to our magnesian limestone; the lowest bed rests on the red sandstone, and sometimes alternates with it: but according to some geologists, the connection between the two formations of red sandstone and zetchstein is such, that the latter may be regarded as a subordinate formation to the former. The upper beds of what has been called zetchstein alternate in Switzerland with beds of gypsum, which is intermixed with rock-salt: some of the beds are argillaceous limestone, containing ammonites and belemnites, and appeared to me to have a greater resemblance to lias, than to magnesian limestone.

In the lower part of the magnesian limestone in the West of England, there is a conglomerate limestone, which contains fragments of transition limestone, varying in size from several inches in diameter, to very minute grains.

The fossils in magnesian limestone are not numerous, at least in the upper beds. Fossil fish have been found in some of the lower beds in the county of Durham. One or two species of univalves, and about nine species of bivalves, occur in this limestone; but these shells are extremely rare, except in one or two situations. Some of the shells, the *productus* and *spirifer*, nearly resemble those in the mountain limestone, with which the magnesian limestone appears to bear a greater analogy, than to any of the secondary strata above it.

Magnesian limestone furnishes the most durable building stone that is any where found in the upper secondary strata.

I do not agree in opinion with those who regard the magnesian limestone districts as unfertile; and perhaps no parts of England are more salubrious, than those which have a subsoil of this limestone.

A few small strings of lead ore have been found in the magnesian limestone rocks near Sunderland. The limestone rocks on the coast of Durham are wearing away by the violence of the ocean: they have evidently extended much further to the east than at present.

It has before been stated, that beside magnesian limestone, gypsum and rock salt are associated with the new red marl and sandstone. Neither of these minerals are however confined to this formation. Salt springs rise in many of the coal strata, and gypsum and rock-salt are found both in the upper, secondary, and the tertiary beds; but the repositories of these minerals are more characteristic of the new red sandstone, and may therefore, with propriety, be described in the present chapter.

Gypsum occurs in the new red marl and sandstone, both fibrous and massive: the fibrous gypsum forms numerous alternating seams in cliffs of red marl: the seams vary in thickness from one to three inches, and might be mistaken for strata, but they are irregular and of limited extent. In Nottinghamshire, the fibrous gypsum on the banks of the Trent is often beautifully white and translucent, and is accompanied with scales of chlorite, exactly similar to what I have observed in the beds of gypsum in the Valais, in Switzerland. The white fibrous gypsum is employed by the paper-makers to whiten writing-paper and add to its weight.

Massive gypsum is granular: it occurs in irregular beds and blocks, in the red marl, and is evidently a local formation. Anhydrous gypsum is occasionally met with in Nottinghamshire. Gypsum is associated with rock-salt, wherever the latter mineral is found. It is now discovered, that the gypsum in the Alps, when uncovered in its native beds, is always anhydrous. Common gypsum contains 21 per cent. of water. Anhydrous gypsum is entirely free from water, and is much harder and heavier than common gypsum. Should it prove a general fact, that the gypsum associated with rock-salt is always originally anhydrous, it might tend to elucidate the formation of both minerals; a subject which will be referred to, after describing some of the principal repositories of rock-salt.

Many repositories of rock-salt are situated near the feet of mountain ranges, and have probably been originally deposited in salt-water lakes: beds of rock-salt are now found at the bottom of some of the salt lakes in Africa. But though many salt formations are in comparatively low situations, there are others that occur at great altitudes, both in the Alps and the Cordilleras. In England, the principal beds of rock-salt are situated at a little distance from the western side of the range of hills, which separate the rivers that flow into the eastern and the western seas.

The rock-salt of Cheshire cannot properly be said to lie in or under the red sand rock before described, but is surrounded by it, and probably rests upon it; but as the lowest bed of salt has not been sunk through, this cannot be yet ascertained. The upper bed of rock-salt in that county is about forty-two yards below the surface: it is twenty-six yards thick, and is separated from the lower bed of salt, by a stratum of argillaceous stone ten yards thick. The lower salt has been sunk into forty yards. The upper bed was discovered about a hundred and forty years since, in searching for coal. Rock-salt at Northwich, extends in a direction from N.E. to S.W. one mile and a half; its further extent in this direction has not been ascertained: its breadth is about fourteen hundred yards. In another part of Cheshire, three beds of rock-salt have been found. The uppermost is four feet, the second twelve feet, and the lower has been sunk into twenty-five yards, but is not cut through. Besides the beds of rock-salt, numerous brine springs, containing more than 25 per cent. of salt, rise in that county. The transparent specimens of rock-salt are nearly free from foreign impurities, and contain scarcely any water of crystallisation.

In sea-water a large portion of muriate and sulphate of magnesia is found, which gives it that bitter nauseous taste, distinct from its saltness. This difference in the composition of sea-water and of rock-salt, might seem to indicate that rock-salt was not, as some suppose, produced by the evaporation of sea-water; but if it were formed in detached lakes, it is possible that the waters of these lakes did not contain precisely the same salts in solution, as those of the sea. We know that the waters of some of the salt lakes existing at present, differ in their contents from sea-water. If, however, the evaporation were very slow, the salt of the ocean would separate from all its impurities by crystallisation; these impurities, being more deliquescent, might be washed away.

It may deserve notice, that few, if any, remains of marine or other organised bodies are found in the beds accompanying the rock-salt of Cheshire. In the Polish salt mines, bivalve shells and the claws of crabs are met with in the upper strata of marl; and vegetable impressions in the bed covering the lower salt, at the depth of two hundred and twenty-five yards from the surface. But some of these mines are now believed to occur in tertiary formations.

The salt-formation at Droitwich in Worcestershire, appears to be surrounded by the same kind of red sand rock, and covered with similar beds of gypsum and marl, to that of Cheshire. Here the rock-salt, though its existence has been proved by boring, is no where worked. The salt is procured by evaporating the water, which is nearly saturated with it.

Salt springs rise in some of the coal strata, adjacent to the red marl and sandstone: in all probability the brine is infiltered from that formation, into the basset edges of the strata overlying coal. There are salt springs in some of the coal mines in Northumberland, Derbyshire, and Yorkshire; and a spring of brine rises in the river Wear, in the county of Durham.

Brine springs, containing from five to six per cent. of salt, rise in the coal mines near Ashby-de-la-Zouch in Leicestershire, at the depth of two hundred and twenty-five yards under the surface. A weaker brine also arises in the upper strata: it springs through fissures in the coal, attended with a hissing noise, occasioned by the emission of hydrogen gas.

I examined these mines belonging to the Earl of Moira in the summer of 1812: they are situated at Ashby Wolds, in the very centre of England*; and what may appear remarkable in this situation, they are worked one hundred and forty yards below the level of the sea, which is ascertained from the levels of the canal that passes by the pits. Had this circumstance been known before the attention of geologists was directed to the structure of the earth's surface, it would have been inferred, that brine springs so far below the level of the sea, had their source from the waters of the ocean, percolating through fissures in the earth.

There are many salt springs in France, but no mines of rock-salt. The salt springs at Salins, in the department of the Jura, rise in the red marl formation; and the gypsum with which they are associated is exactly similar to the massive gypsum in the English red marl. The strongest of these springs contains 15 per cent. of salt.

In Switzerland the rock-salt and gypsum do not occur in the red marl, but between calcareous beds, which are, I believe, analogous to the English lias, and will be again mentioned.

In Spain there are several salt springs and beds of rock-salt: the principal formation of rock-salt at Cardona in Catalonia, has been described by Count Alexander Laborde, in his magnificent work entitled *Voyages Pittoresques dans l'Espagne.*

"The salt district of Cardona comprehends the

---

* Baths and hotels are now erected there for the accommodation of visiters: they are called the Moira Baths, near Ashby-de-la-Zouch.

hill on which the town is situated, and the environs of more than a league in circumference. The surface is almost every where covered with vegetable soil to the depth of six inches or more, which renders it productive. The place where the rock-salt is procured is a valley forming an oval, about one mile and a half in length, and half a mile in breadth from east to west, extending from the Castle of Cardona to the promontory of red salt at the other end. The last is the most considerable of the salt rocks, and has not yet been worked: it is six hundred and sixty-three feet in height, and twelve hundred and twenty feet in breadth at its base. This valley is also traversed by a chain of hills of rock-salt: besides these, there are other rocks of salt at the feet of the fortress, and upon the declivity of the mountain which stretches to the fountain called Cancunillo. The mountain of red salt is so called because that colour predominates; but the colours vary with the altitude of the sun, and the greater or less quantity of rain. At the foot of this mountain a spring of water issues, which comes through a fissure we perceive on the summit. The rivulet runs all along the valley from the east, but passes under ground in part of its course, particularly under the hill where the rock-salt is mined: it rises again to the surface at a little distance, and, after running along the plain, discharges itself into the river Cardona. This brook in rainy seasons swells the waters of the river, which then become salt, and destroy the fish; but at three leagues lower, the water has no perceptible taste of salt. All these salt mountains are intersected by crevices and chasms; and have also spacious grottoes, where are found stalactites of salt, shaped like bunches of grapes, and of various colours."—"Nothing can compare with the magnificence of the spectacle which the mountain of Cardona exhibits at sunrise. Besides the beautiful forms which it presents, it appears to rise above the river like a mountain of precious gems, displaying the various colours produced by the refraction of the solar rays through a prism." —*Count Laborde.*

"Hungary and Poland afford the most numerous and extensive repositories of rock-salt in Europe. The salt mines of Wieluzka near Cracovia have been long celebrated and frequently described; they are worked at the depth of 750 feet. The rock-salt is covered by alternate beds of marl and conglomerate; blocks of salt occur also in the marl. The beds of rock-salt are inclined at an angle of 40 degrees. It is remarkable, that in these mines of rock-salt, there are springs of fresh as well as of salt water. At Paraid in Transylvania, there is a valley the bottom and sides of which are pure rock-salt. The mine of Eperies is about 990 feet deep. Water is sometimes enclosed in the blocks of rock-salt."—*Brongniart, Minéralogie.*

There is an extensive formation of rock-salt, stretching on each side of the Carpathian Mountains for six hundred miles, from Wieluzka in Poland towards the north, to Rimnic in Moldavia on the south. It has indeed been observed, that rock-salt and brine springs most generally occur near the feet of extensive mountain ranges, which adds probability to the opinion, that these ranges were once the boundaries of extensive salt lakes.

In the lofty deserts of Caramania in Asia, according to Chardin, rock-salt is so abundant, and the atmosphere so dry, that the inhabitants use it as stone, for building their houses. This mineral is also found on the whole elevated table-land of Great Tartary, Thibet, and Indostan. Extensive plains in Persia are covered with a saline efflorescence; and according to the account of travellers, the island of Ormus, in the Persian Gulf, is one large mass of rock-salt.

In the elevated mountains of Peru, rock-salt is said to occur at the height of 9000 feet above the level of the sea. In North America there are various salt springs called Licks, because the herds of wild cattle formerly repaired to them, to lick the soil impregnated with salt. Near to these places the immense bones of the great Mastodon are frequently found, at a small depth below the surface. According to the account of Hornemann, there is a mass of rock-salt spread over the mountains that bound the desert of Libya to the north, so vast that no eye can reach its termination in one direction; and its breadth he computed to be several miles. Rock-salt has also been found in New South Wales.

It would exceed the limits intended for the present volume, to enumerate the different places in which this valuable mineral occurs. I only propose to note the more remarkable situations, presenting phenomena that may tend to illustrate the mode of its formation. Among these should not be omitted the salt lakes on the borders of Caffraria, east of the Cape of Good Hope, which contain, at their bottom, thick beds of rock-salt variously coloured.

There is a remarkable formation of salt at Posa near Burgos, in Castille, placed in an immense crater of an extinct volcano, in which are found pumice-stone and puzzolana. The volcanic mountain of Cologero, near Sciacca, in Sicily, contains in its beds a considerable intermixture of common salt; and masses of rock-salt occur in other parts of the island, imbedded in clay.* In these, and in some other instances, it is probable that subterranean fire may have been an active agent in the formation of rock-salt, by evaporating the waters of salt lakes, or of countries recently emerged from the ocean.

The rapid formation of rock-salt in Syria, during one of those igneous eruptions which have at times overwhelmed certain portions of the globe, is, perhaps, obscurely alluded to by the sacred writer, who has narrated the early history of the human race. Gen. chap. xix.† The salt lakes existing in that country are well known.

---

* Travels in Sicily, by Lieut.-Gen. Cockburn.

† Jerome, who resided in Syria in the fourth century, informs us, that the rock of salt was existing in his time; and fancifully

Whether all the repositories of rock-salt above enumerated occur in the red marl, cannot in the present state of our information be accurately ascertained. The great formation of rock-salt and gypsum near Bex in Switzerland, constitutes two large and extensive beds. The lowest rests upon black limestone, argillaceous limestone, and sandstone; and between the lower gypsum and the upper, there are thick beds of argillaceous limestone, and similar argillaceous limestone forms caps over the upper gypsum. The gypsum in the large beds is anhydrous, and contains particles of rock-salt and common gypsum disseminated through it. The prevailing fossils are ammonites and belemnites.—(*Travels in the Tarentaise*, p. 415.)

The mineral characters of the strata at Bex, and the imbedded fossils, incline me rather to refer the argillaceous limestone, over and under the gypsum and salt beds, to the English lias, than to magnesian limestone. Many beds of the lias in England contain much muriat of soda and sulphat of magnesia.

The saliferous gypsum, in the Tarentaise is anhydrous, and contains a considerable quantity of silex; it occurs interstratified with limestone, which bears a nearer resemblance to the magnesian limestone than to lias. The tops of some of the mountains are covered with beds of common gypsum, intermixed with native sulphur. In one of the rocks associated with the gypsum formation, I discovered a fossil Patella. Though a branch of the *Ecole des Mines*, with able instructors from Paris, had been for some years established at Moutiers, close to the salt formations, a very erroneous opinion respecting the gypsum of the Tarentaise was maintained by the professors; namely, that the gypsum merely formed an unconformable covering over the adjacent mountains. I observed it in several parts of the valley of

---

relates certain peculiarities respecting it, which equal in absurdity the legends of the darkest ages of papal superstition.

the Doron near Moutiers, as distinctly interstratified in the calcareous mountains, as the gypsum of Montmartre is interstratified between the tertiary formations near Paris. In one of the beds of gypsum, there was a thin stratum of carbonaceous matter, which soiled the fingers like coal smut; this is the only instance of carbonaceous matter found in gypsum that I am acquainted with.

Transparent colourless rock-salt consists of muriat of soda, nearly in the highest state of purity; or, according to Sir H. Davy, of chlorine and sodium. It has so little water of crystallisation, that it scarcely decrepitates when thrown on burning coals, in which it differs from salt prepared artificially by evaporation. Specimens of rock-salt brought from the Polish mines, are less desposed to deliquesce, than those from Cheshire. The deep red colour, very common to rock-salt, is derived from the oxide of iron. Rock-salt frequently lies imbedded in clay or marl, in detached masses; the clay is often much impregnated with salt, which is extracted from it by solution in water. The almost constant occurrence of sulphat of lime (gypsum) with rock-salt, is also a fact of considerable interest. It is curious to observe the two most powerful acids, the sulphuric and muriatic, so nearly associated in the same place. This fact, in a more advanced state of science, may elucidate the chemical changes which have effected the formation of these minerals.

The most natural hypothesis respecting the formation of rock-salt, at least in some situations, is that before stated, which attributes it to the gradual evaporation of lakes and pools of salt water, which remained, when the ocean retired from the present continents. This mineral by slow evaporation would be separated from the impure salts that exist in sea water; and as these salts are more deliquescent than rock-salt, they might be washed away, before the beds of rock-salt were covered with earthy strata.

The occurrence of anhydrous gypsum with rock-salt, which is also anhydrous, would, however, indicate the action of heat in the formation of these minerals; for it is scarcely possible to conceive any mode of aqueous deposition, that could form anhydrous gypsum: but common gypsum might be fused by heat, and its water of crystallisation expelled; it would then be converted into anhydrous gypsum. From the observations of M. Carpentier at Bex, it appears that the great beds of gypsum associated with rock-salt, are always found to be anhydrous when they are laid open to the atmosphere, but they soon absorb water, and are converted into common gypsum. The saliferous gypsum in other parts of the Alps, is also anhydrous; and if it should appear that the beds of gypsum associated with rock-salt in other countries are anhydrous, where they have not been exposed to the action of moisture, it would add much probability to the opinion, that the consolidation of rock-salt and gypsum had been effected by heat.

Before concluding the account of the red marl and sandstone formation, it may be proper to state, that foreign geologists contend for the existence of a red sandstone over coal, which is laid conformably with the coal strata, and is a part of that formation.* If such a red sandstone, distinct from the new red sandstone, exist any where in England, it is near

---

* Le Grès, masse principale de terrain houiller, prende souvent une grande extension, en abandonnant au moins en majeure partie la houille avec l'argile schisteuse qui l'envelloppe. — *Daubuisson, Traité de Géognosie*, tom. 2.

M. A. H. Bonnard, in his *Apperçu Géognostique des Terrains*, p. 144., describes the red sandstone as the upper part of the coal formation.

A. Humboldt, in his *Essai Géognostique sur le Gisement des Roches*, p. 199., mentions a red sandstone passing into porphyry, as the upper part of the coal formation in Germany.

Messrs. Daubuisson and Bonnard appear to have mistaken the lowest part of the red marl and sandstone, for a portion of the regular coal strata. M. Humboldt makes a distinction between the unconformable red sandstone and the porphyritic red sandstone, which he cites as a part of the regular coal formation.

Oldham and Rochdale in Lancashire. The sandstone of Lancashire is coloured in Mr. Greenough's Geological Map of England, as the new red sandstone, and in Mr. Smith's Geological Map, as the old red sandstone; but I am inclined to believe, that the true position (*gisement*) of this sandstone in many parts of Lancashire, is not yet ascertained: its relations with the coal strata are different from those of the new red sandstone in other parts of England. — I propose to revert to this subject in a subsequent chapter.

Professor Sedgwick, in a paper recently read at the Geological Society of London, but not yet published, has described the red sandstone formation on the north-western side of England, which had not before been sufficiently examined. The formation agrees with that on the eastern side of England in its leading features. First, there rest unconformably over coal measures of Whitehaven.

1. Coarse sandstone of great thickness, or the lower red sandstone.
2. Magnesian conglomerate beds of considerable thickness.
3. Magnesian limestone.
4. Lower red marl and gypsum.
5. Red and variegated sandstone.

The sandstone No. 2. and also other beds of red sandstone, sometimes approach to a position nearly conformable to that of the coal measures. *Too much importance appears to me to be attached to this circumstance; for whenever the coal strata take nearly an horizontal position, the upper unconformable strata will take the same position, and may therefore be conformable in such situations, and unconformable in others where the subjacent strata are more inclined.*

CHAP. XII.

ON THE LIAS AND OOLITIC SERIES.

Geological Position of Lias Clay and Limestone. — Their Mineral Characters. — Alum-Slate in Lias. — Remarkable Organic Remains and Characteristic Fossils. — Extent of the Lias Formation in England. — Interesting Junctions of Lias and Red Marl. — Lias of France and the Alps. — Oolite or Roestone, the Jura Limestone of Foreign Geologists. — Mineral Characters, and remarkable Organic Remains. — Lower Oolite. — Oxford or Clunch Clay. — Middle Oolites. — Kimmeridge Clay. — Upper or Portland Oolites. — Stonesfield Slate with Organic Remains of Insects, Birds, Flying Reptiles, and small Land Quadrupeds. — Extent of the Oolite Formation in England, and its abrupt Termination. — Sections of the Oolitic Series of Beds in Yorkshire and the West of England, compared with a Section of the Secondary Strata in Germany.

THE great bed of dark grey argillaceous limestone, divided into thin strata (and associated with beds of clay) called Lias, is the best characterised of all the secondary strata (except chalk), both by its mineral characters and the fossil remains imbedded in it; and it presents the same characters through a considerable part of France and Germany.

The geologist who has taken a comprehensive view of different rock formations, and has compared the resemblance as well as the diversity they present, must frequently have observed a tendency in nature to reproduce similar strata in distant parts of a series of strata, and even in different formations. In the chapter on the Coal Measures, I have given examples of the repeated recurrence of similar strata at different depths, implying a recurrence of the same conditions under which each had been formed.

In the lowest part of the magnesian limestone in the northern counties, there are thin strata of marly limestone, called by Professor Sedgwick Marl-slate, which may be regarded as the first approach to a formation, resembling lias in many of its characters. Again, over the middle beds of the sandstone there occurs a considerable thickness of strata, in many respects resembling lias, called the Muschel kalk; it may, perhaps, when viewed on a large scale, be considered as a lower formation of lias, separated from it by the variegated marls of the upper red sandstone. This bed, as before stated, has not been discovered in England. The lias, therefore, cannot be mistaken for any of the lower strata; it serves as a key to the geology of the secondary formations in England; and the first enquiry which the student should make, when he is in doubt respecting the position of any of the secondary beds, should be, *Does it occur above or below the lias?*

The name *Lias* was probably given to this formation by the provincial pronunciation of the word *layers*, as the strata of lias limestone are generally very regular and flat, and can easily be raised in slabs from the quarry. When the lias beds are fully developed with their associated beds of clay, they form a mass of stratified limestone and clay, several hundred feet in thickness, which rests upon the red marl described in the preceding chapter.

The regularly stratified lias limestone occupies the lower part of the bed, and the lias clay the upper. The lower beds of the limestone have often a yellowish white colour, and are called white lias. The blue lias limestone has generally a dark smoke-grey colour, a dull earthy texture, and an imperfectly conchoidal fracture: the purest beds contain from 80 to 90 per cent. of carbonate of lime, combined with bitumen, alumine, and iron. If iron enter largely into the composition of this limestone, it forms a lime, when burned, which has the property of setting under water.

The finer kinds of white lias will receive a polish, and may be used for lithographic drawings. Between the lower lias limestone and the lias clay, there occur, in some situations, beds of sandy lias, with layers of ironstone in nodules: this part of the lias formation has been called *marl-stone* in some of the midland counties.

The lias clay frequently occurs in the form of soft slate or shale, which divides into very thin laminæ. This shale is often much impregnated with bitumen and with iron pyrites, and will continue to burn slowly when laid in heaps with faggots, and once ignited: during this slow combustion, the sulphur in the iron pyrites is decomposed, and combines with the oxygen of the atmosphere and with a portion of the alumine in the shale, and forms sulphat of alumine or alum. The alum shale of Whitby in Yorkshire is of this kind; it has rather a soapy feel, and a slight silky lustre. When the lias clay or alum shale falls in large masses from the cliffs upon the sea shore, and gets moistened by sea water, it ignites spontaneously, and continues burning a considerable time. The cliffs of lias clay near Lyme, in Dorsetshire, took fire after heavy rains, and continued burning for several months, about the middle of the last century: at the present time, a hill near Weymouth is ignited by a similar cause; it is composed of bituminous clay with pyrites, but it is an upper bed in the oolite formation called Kimmeridge clay.

Lias clay is impregnated with a considerable portion of muriat of soda, and sulphat of magnesia and soda. The mineral springs of Cheltenham and Gloucester rise in this clay; but the mineral qualities decrease after the springs have been opened some time, which proves that the saline matter is derived from parts of the bed adjacent to the springs, and is therefore soon exhausted.

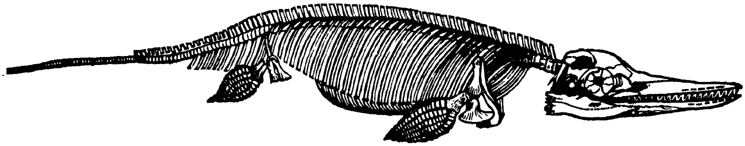
The beds of lias clay and limestone are particularly distinguished by the number and variety of the organic remains which they contain. Twenty different kinds of ammonites have been discovered in lias, and also nautilites, belemnites, and other species of chambered shells. Univalve unchambered shells are not numerous in this formation, but a great variety of bivalve shells occur in it. The gryphite (*Gryphea incurva*), a deeply incurved bivalve shell, abounds so much in some of the beds of lias, that in France it has received the name of *Calcaire à gryphites.** Pentacrinites also abound in the upper part of the lias; and in conjunction with gryphites, and the ammonites that have a ridge between two furrows round the back of the shell, are characteristic of the lias formation. The pentacrinite and encrinite were zoophytes with long articulated stems and branches: in the encrinite the stem is round, in the pentacrinite pentagonal. The annexed cut represents part of the branches or arms of the Briarean pentacrinite.

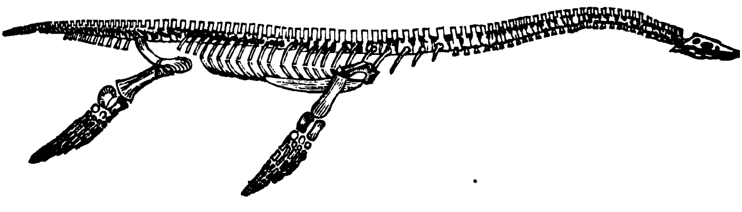
The most remarkable organic remains are, however, certain species of fish, and vertebrated animals allied to the order of lizards: the fossil fish are generally found in the middle of flattened balls of limestone, in which the form of the body and the scales is often well preserved. The saurian or lizard-shaped animals have left no trace of the form of their bodies, except what can be ascertained from the remaining skeletons. To the Rev. W. D. Conybeare we are

---

* The Gryphea incurva has not, that I know of, been found in England either above or below the lias, and therefore may alone be regarded as characteristic of this formation. These shells occur very abundantly, and are provincially called Millers' Thumbs.

indebted for having determined the forms of two genera of these animals. The ichthyosaurus, or fish-lizard, had a head resembling a dolphin more than a lizard, and numerous conical teeth; the orbit of the eye is uncommonly large. Some idea may be formed of the magnitude of these animals, when I mention that the orbit of the eye in a head belonging to Mr. Johnson of Bristol, which I measured, was ten inches long and seven broad: the orbit in another head, belonging to the same gentleman, measured nine inches in breadth.* The vertebræ of the ichthyosaurus nearly resemble those of a shark, which enabled it to bend its tail with great facility, and assisted the motion of its paddles, in propelling the body with great velocity through water. The skeleton of the ichthyosaurus, as arranged by Mr. Conybeare, is represented in the annexed cut. Of the ichthyosaurus, several species have been discovered. The plesiosaurus resembles the former genus in many important parts of its osteology; but its vertebræ have a closer approximation to those of the crocodile; they are only slightly concave: its neck was longer than its body, and was composed of thirty vertebræ, which exceeds the number of the cervical vertebræ of the swan. (See the annexed cut.) Five species of





---

* Mr. Johnson of Bristol has, during many years, devoted much time and labour, and has liberally expended considerable sums of money, in collecting organic remains of these saurian animals; and

plesiosauri have been determined; some of them were twenty feet in length. The bones of both animals are found very commonly in the cliffs of lias at Lyme in Dorsetshire, and on the southern bank of the Severn. The organic remains in lias are chiefly, but not exclusively, marine. Bones of the turtle and crocodile have been discovered in lias: the fossilised remains of terrestrial plants also occur in it. This proves that dry land must have existed in its vicinity, at the period of its deposition.

The lias formation extends in a waving line through England, from near Whitby in Yorkshire to Lyme in Dorsetshire; at both its extremities it is fully developed, and presents similar features, namely, — dark cliffs of blackish clay or alum shale, with a nearly flat floor of lias limestone extending into the sea, forming a natural pavement, on which the observer may walk secure, treading at almost every step on the organic remains of the inhabitants of a former world, disseminated through the rock. These animal remains are generally surrounded by stone harder than the other part of the stratum, and project above the surface. At Sandsend, near Whitby, the alum shale has been perforated near the sea, to the depth of one hundred and thirty yards, without penetrating into the subjacent rock; to which if we add the height of the cliffs above, it will make a total thickness of lias exceeding two hundred and twenty yards: the upper parts are more productive of alum than the lower.* In Dorsetshire the whole thickness of the lias formation may be seen in succession: a few miles west of Bridport, the uppermost bed rises above the level of the sea; and three miles west of

---

it is to the collection of these remains, in his private museum, that we are principally indebted for the discoveries which have been made respecting them.

* Mr. John Phillips, in his recent survey of the Yorkshire coast, estimates the average thickness of the lias, comprising the lower, middle, and upper beds, at 850 feet, or 283 yards.

Lyme it terminates, and the white lias (the lowest part of this formation) may be observed at low water resting on red marl.

The lias formation is extensively developed on the eastern side of France. In passing by Rouvray to Dijon, in the year 1820, I was exceedingly struck with the complete resemblance of the geology of the country, with that of Leicestershire and Worcestershire. Before arriving at Rouvray, we pass over red marl; after leaving that town, the road traverses a very low range of decomposing sienite and granite rocks, exactly similar to those of Malvern; after which it passes for several miles over well characterised lias, filled with gryphites and belemnites: masses of the harder parts, filled with these fossils, are collected for keeping the road in repair.

In England, lias limestone occurs almost always in nearly horizontal strata, and never attains any great elevation. On the west of Gloucester, at Highnam Park, lias limestone forms a nearly flat pavement, resting on red marl, on the summit of a hill about two hundred and fifty feet above the level of the Vale of Severn. From this point to the north-west there is no bed of lias known in England or Wales; but it is found in the north-west part of Ireland, and in some of the Hebrides. At Barrow-on-Soar, in Leicestershire, lias rises considerably above the level of the river; it is in the flattened balls that occur in the Barrow limestone, that the finest specimens of fossil fish are found. The most interesting junction of lias and red marl, that I have observed, occurs in the south side of the Severn at Aust psssage, where the red marl may be seen for a considerable distance, supporting the lias, but separated from it by a micaceous bed, filled with broken bones of saurian animals, and other organic remains. Another junction is mentioned Chap. II. p. 29. The lias clay, from its comparative softness, has been more affected by the action of torrents and inundations than the strata above or beneath it: hence it is frequently excavated into valleys. Some of the mountain valleys in the Alps are cut in lias clay. The lias limestone of the Alps and the Jura, loses its flat and parallel stratification, and is bent and contorted in various directions; it also frequently loses its earthy texture, and is hard and semicrystalline, like transition limestone.

The Rev. R. Halifax, of Standish, near Gloucester, obligingly showed me part of the lias and oolite beds in the vicinity of Cheltenham, which he had particularly studied. Between the upper lias clay and the oolite, there is a thick bed of reddish earth with ferruginous nodules inclosing portions of lias; this earth may be seen cropping out at the foot of Leckhampton Hill. No well-marked natural division exists, which can determine whether this bed should be classed with lias, or the oolites. The fossils in lias clay and limestone are nearly black, and are sometimes incrusted with pyrites.

The most valuable mineral substances obtained from lias in England, are water-setting lime and alum shale. The property of setting under water may be communicated to any kind of lime, by an admixture with burned and pulverised ironstone. Many of the bituminous and pyritical shales in the coal strata would yield alum by slow combustion, if they could be obtained with facility. When alum shale is burned, and the soluble part is extracted by water, it is necessary to add potass before the process of evaporation, as crystallised alum is a triple salt, composed of sulphat of alumine and potass.

Oolite. — The numerous beds of yellowish limestone alternating with beds of clay, marl, sand, and sandstone, that compose the oolite formation in England, are of variable thickness; their aggregate average depth, from the top of the upper oolite to the lias, may be estimated at 1200 feet. These beds may be traced with little interruption along a waving line from the Cleveland Hills in Yorkshire, into

Dorsetshire. In Gloucestershire they compose a lofty range of hills on the south side of the Vale of Severn, called the Cotteswold Hills; but no strata of this formation are found in any part of England or Wales north-west of the river Severn. In many parts of France, the oolite strata, accompanied with lias, present all the characters of the same formation in England; but in the Jura mountains, where they are fully developed, the mineral characters often differ considerably; and it is only from the geological position and the imbedded fossils, that they can be identified with the English series.

Oolite or Roestone receives its name from the small globules like the roe of a fish, that are imbedded in many of the strata: in some instances these globules attain the size of a pea, and this variety has obtained the name of *Pisiform oolite.* In England, nearly all the beds of limestone that are oolitic, in this formation, have a yellowish brown or ochrey colour, by which they may at first sight be distinguished from lias. The limestone in which the globules are imbedded has generally an earthy texture, and is dull and incapable of receiving a polish: some varieties of oolite have been much used for architecture. Somerset House, and many of the public buildings in London, are constructed of this stone; but it is not durable. The occurrence of small oviform globules in limestone is not exclusively confined to the oolite formation: in the magnesian limestone, and even in transition limestone, a tendency to an oolitic structure may sometimes be observed. It is not yet ascertained, whether these globules are the result of a tendency to crystalline arrangement, or whether they are of animal origin.

The organic remains that occur in the different beds of oolite are so numerous and various, that it would require an ample volume to describe them fully. It will, however, be necessary to notice those fossil genera that differ remarkably from the genera whose remains are found in the lower strata, and indicate a considerable change in the condition of the globe, or at least in those parts of it where the strata were deposited.

It has been already observed, that the shells in the lower strata were chiefly different species of internal chambered shells, such as nautilites, ammonites, and belemnites, and that univalve unchambered shells were rarely found among them. By far the greater number of genera that have left their remains in these strata belong to the acephalous Mollusca, or such as had neither heads nor eyes, and inhabited bivalve shells. Even in the lias, only about five genera of spiral univalve unchambered shells have been well ascertained, and the number of species or of individual shells is small. In the oolite, the genera and species of univalve unchambered shells are more numerous, and the individual shells of several species abound in some of the strata. Now, as these animals had heads and eyes, and moved on their bellies like the land-snail, we may infer that they did not live in deep seas, where the sense of vision could not be available; they lived and moved in comparatively shallow water near the shore.

The vertebrated animals, whose remains are found in oolite, are fishes and reptiles of the same genera as those discovered in lias; some undoubtedly belong to the crocodile genus, and had feet, like the living species of crocodiles; hence we may infer, that there were dry land and rivers in the vicinity.

It may well excite surprise, that calcareous strata should so rarely be found, which present distinct indications of having been formed exclusively by coralline polypi; particularly as coral rocks and reefs, of great extent, are so rapidly forming in our present seas. There are, however, among the strata of oolite, some which are almost entirely composed of madreporites, and have received the name of coral ragg. There are other strata which abound in the remains of fossil sponges and alcyonia, and with congeries of minute millepores and madrepores. More than twenty species of trochiform or top-shaped spiral shells, and several species of echinites, are found in the oolite strata; but in the lias below, as before stated, only a few genera and species occur, and the individual shells are scarce. The *gryphea incurva*, so common in the lias, is rarely if ever found in the oolite strata; but another species, with a broad expanded shell, called the *gryphea dilatata*, is a fossil frequently found in different beds of the oolite formation. The shells and bones in the oolite limestone, have the yellowish ochrey colour of the stone in which they are imbedded; which may serve at once to distinguish them from the lias fossils, that invariably partake of the colour of the beds in which they occur. English geologists make three divisions of the oolite formation,—the *upper*, the *middle*, and the *lower*: they are separated by thick beds of clay, and some variety may be observed in the fossils of each division, but the general characters are nearly the same. In an elementary treatise, a too minute description would only perplex the student, particularly as some of the beds appear to be of limited extent.

The *lower division* of *oolite* comprises; 1st, an imperfect dark brown limestone, much intermixed with sand and the oxide of iron; 2dly, beds of sterile clay and fuller's-earth; and, 3dly, the great oolite, sometimes called the Bath oolite, which is of considerable thickness, and yields freestone for architecture: it is composed of minute globules and broken shells, united by a yellowish earthy calcareous cement. With the lower division of oolites may also be classed, 4thly, the forest marble and Stonesfield slate; the latter is a sandy calcareous stone, dividing into thin strata, accompanied with shale and carbonaceous matter. The beds of forest marble are not numerous, and are chiefly composed of large fragments of shells; small entire turbinated shells abound in some of the strata. It deserves attention, that the univalve shells are most frequent in the thin beds, and the bivalves in the thicker beds, of this stone; 5thly, cornbrash. This is the upper part of the lower division of oolites; it does not compose beds of any considerable thickness, nor does it frequently occur in regular strata of any great extent, but generally in detached masses, cemented by clay: the external part of the stone is brown, but the inner part has often a grey or bluish colour. The cornbrash is so thin a bed, as scarcely to be entitled to a place in the division, but it is remarkable for the abundance of its fossils. The above arrangement of the lower oolites was formed from their occurrence in Somersetshire and the vicinity, where they were first studied, but it by no means represents the general succession of the beds in other countries. In the eastern moorlands of Yorkshire, the oolitic series are well displayed on the coast, and have recently been described by Mr. J. Phillips. Two vast depositions of sandstone, shale, and coal, occur below the cornbrash in the following order, ascending from the lias: —

1.	Ferruginous beds above lias, thickness	60 feet.
2.	Lower sandstone, shale, and coal	500
3.	Impure limestone, supposed to represent the Bath oolite	60
4.	Upper sandstone, shale, and coal	200
5.	Cornbrash	5
		825 feet.

This imperfect coal formation appears to be entirely wanting in England south of the Humber. In Savoy, I examined a coal formation which is placed between two beds of limestone and over lias: this I believe to be analogous in position, to that in the eastern moorlands of Yorkshire.[*]

Travels in the Tarentaise.

Between the lower and the middle oolites occurs a bed of dark blue clay called Oxford or clunch clay; the thickness has been estimated at two hundred feet. Some of the beds are bituminous, and bear a near resemblance to lias clay; they abound in Septaria: other beds are much intermixed with calcareous earth. In the lower part of the Oxford clay, irregular beds of limestone occur, which have received the name of Kelloway rock, from being found near Kelloway bridge, in Wiltshire. The bones of one species of icthyosaurus, different from those in the lias, have been found in the Oxford clay.

The MIDDLE DIVISION *of oolite* consists, 1st, Of beds of siliceous and calcareous sandstone. 2d, Coralline limestone beds, containing numerous madrepores, in some parts called coral ragg. 3d, Oolite, sometimes called Oxford oolite, which agrees in many of its characters with the Bath oolite, in the lower division. The beds of the middle oolite pass into each other, and may be regarded as one formation. They vary much in their thickness and succession in different districts. The average thickness of the whole, has been estimated at two hundred feet.

Between the Middle and the Upper division of oolites, there occurs, in the western counties of England and on the coast of France, near Boulogne, another thick bed of clay, which has received the name of Kimmeridge clay.* It is a greyish clay passing into the state of shale, and is sometimes so bituminous as to be used for fuel: its thickness in some parts is more than one hundred feet. Bones of saurian or lizard-shaped animals have been found in this clay.

The UPPER DIVISION *of oolite* comprises the beds of Portland stone, which have been well described as a calcareo-siliceous freestone, with beds and nodules of flint. In the Isle of Portland, where the

---

* From Kimmeridge in Dorsetshire, where the bituminous shale is called Kimmeridge coal.

middle bed of the Portland stone is quarried for architectural purposes, it is covered by a cream-coloured stone called *cap*, which is only burned for lime: under this, there are two beds of workable stone, each five feet thick, separated by grey flint, and a third bed of the best stone below. The total thickness of the three beds of building-stone varies from 17 to 24 feet. The Portland series, which form the upper termination of the English oolites, are neither of great extent (being confined to the county of Dorsetshire), nor are they of considerable thickness. They are succeeded by beds of limestone, called the Purbeck beds, which, however, properly belong to the Wealden formation described in the next chapter. Between the Portland and Purbeck limestone, there is a bed of dark earth, called the dirt-bed, in which roots and stumps of trees occur, sometimes erect, proving that this bed was once dry land, and the soil on which the plants grew.

It would not be compatible with the plan of the present work, to enter into a detailed description of the numerous beds in this great formation: they present general features of resemblance, both in their characters and fossils. There is one bed, however, which is so remarkable for its extraordinary organic remains, that it merits the particular attention of the geologist. This is the Stonesfield slate in Oxfordshire, before mentioned: it is now regarded as an undoubted member of the oolite series, comprised in the forest marble of the lower division.

The Stonesfield slate consists of two beds of yellowish or greyish oolitic limestone, each about two feet thick, and separated by a bed of loose calcareous sandstone about the same thickness. The Stonesfield slate, on exposure to frost, divides into thin plates, which are used for roofing. The stone is obtained by working horizontal galleries in the hill, which galleries communicate with deep perpendicular shafts. It is to be regretted that no account has been yet published of the different strata of stone sunk through by these shafts, as we might hence derive decisive evidence, respecting the true geological position of the Stonesfield slate.

The fossil remains in the Stonesfield slate consist of the impressions of the outer cases or elytra of winged insects, and the bones of small animals of the opossum or didelphis genus, and also the bones of the megalosaurus or gigantic lizard, supposed to be analogous to the Monitor. From the size of these bones, it is estimated that the animal to which they belonged was forty feet in length and twelve feet high. Legs and thigh bones of birds are also found in the Stonesfield slate, with the teeth, palates, and vertebræ of fishes, and two or three varieties of crabs and lobsters. Several varieties of marine shells and of plants occur in the same beds. The most remarkable circumstance attending these fossil remains, is, that they should occur in strata which are generally believed to have been deposited, before the creation of terrestrial mammalia. If, however, there were islands, inhabited by the higher class of animals, when the oolite beds were forming, their bones may have been carried down by rivers into the sea, and deposited with those of marine animals. But though this hypothesis might satisfactorily explain the occurrence of these remains in the Stonesfield slate, it would still be not less extraordinary, that similar remains should have been nowhere found in any of the upper secondary strata in England, nor in other countries; and that they are never met with, except in strata considerably above the chalk formation. The occurrence of wood, and beds of lignite (or wood coal) in oolite, confirms the opinion that dry land existed somewhere in the vicinity, at the period when the oolitic beds were formed or deposited; but no indication that the land was inhabited by terrestrial quadrupeds of the class mammalia, has been hitherto discovered, except in the slate of Stonesfield. In Sussex the strata above the oolite contain the bones of the megalosaurus and crocodile, and those of turtles, birds, and fish, similar to the fossils of Stonesfield; but the bones of mammiferous quadrupeds are wanting, and many of the shells are fluviatile. *Where was the island on which the animals lived and flourished, that have left their bones in the strata of Stonesfield?* This question will be considered in the brief chapter I propose to give of the Geology of England.

The oolite formation extends from the sea coast of Dorsetshire near Bridport, to the northern extremity of the Cleveland Hills in Yorkshire, in one waving range of hills, broken only by the vale of the Humber. The outcrop of the oolite beds forms the south-western escarpments of this range; and it is truly remarkable, that not a vestige of this formation is found beyond this range, in any of the midland and north-western counties of England. But some traces of the oolite series have been discovered by Professor Sedgwick, on the north-eastern coast of Scotland, and in the Isles of Sky and Mull in the western Hebrides.

It may be useful to present the reader with the order of succession and thickness of the beds of oolite and lias, as they occur in two distant parts of England, the Bath district, Somersetshire, by Mr. Lonsdale, and the eastern moorlands of Yorkshire, by Mr. J. Phillips. They are given in a descending series.

Bath District.	Feet.	Eastern Moorlands.	Feet.
Kimmeridge clay	150	Calcareous grit	60
Upper calcareous grit	10	Coralline oolite	60
Coral ragg	40	Calcareous grit	80
Clay	40	Oxford clay	150
Calcareous grit	50	Kelloway rock	40
Oxford clay	300	Corn brash	5
Kelloway rock	5	Upper sandstone, shale, and coal	200
Corn brash	16		
Forest marble: —		Impure limestone	30
Clay	15	Lower sandstone, shale, and coal	500
Sand and grit	40		
Clay	10	Ferruginous beds and lower oolite	60
Coarse oolite	25		
Sandy clay and grit	10	Upper lias	200
Bradford clay	50	Marlstone	150

Bath District.	Feet.	Eastern Moorlands.	Feet.
Great oolite	140	Lower lias resting on red marl and sandstone	500
Fuller's earth	150		
Inferior oolite with sand and grit	130		
Marlstone	10		
Upper lias marl	200		
Blue lias	50		
White lias	10		
Lower lias marl, resting on red marl and sandstone	20		

In the above sections it will be seen, that though there is a great general resemblance between the principal members in each series, there is a considerable difference in the number and succession of the minor beds; there is also some diversity in the fossils in each series. By a comparison of both sections, it will appear, that the attempt to establish an identity of beds, or even of what are called equivalents in the minor strata of a great formation in different districts, is a useless labour, and serves only to perplex the student, without leading to any useful conclusions. Nor do I think the long lists of marine shells, in a formation decidedly marine, can be of any great use, unless such shells discover some new forms of organic life distinct from what has been before observed, or enable us to infer some change in the condition of the globe, when the inhabitants of such shells first appeared. The section of Mr. J. Phillips being a coast section has the disadvantage of not being made in the true line of dip, and that of Mr. Lonsdale was unavoidably taken in different situations where the upper and under strata were not always displayed; hence such sections can only be regarded as valuable approximations to truth in each district. In Yorkshire the Kimmeridge clay is wanting, and the oolites are covered by the chalk formation, in the lower part of which, called the Speeton clay, some fossils of the Kimmeridge clay were discovered.

The imperfect coal formations in the Yorkshire oolites contain impressions and remains of fossil plants of the same families as those in the regular coal formation, but which are stated by M. Adolphe Brongniart to belong to different species.

The attempt has been frequently made, to identify the secondary strata of Germany with those of England. The following abridged view of the secondary strata in the north-east part of Bavaria, in Bohemia, and in Westphalia, by R. J. Murchison, Esq. taken partly from his own observations, and partly from what he believes to be the best authorities, appears to be the most satisfactory and intelligible approximation to the English series of secondary formations that has yet been made: it confirms the previous statement given by Professor Sedgwick and Mr. Murchison. The order of succession in a descending series is here given.

Chalk.	In Hanover, clearly separated from green-sand.
Green-sand.	Divisable into upper calcareous and lower siliceous sandstone.
Portland oolite.	Oolite and coral ragg, not yet discovered in central Germany.
Solenhoffen slate, or supposed Stonesfield slate.	Between Kehlheim on the S.E., and Pappenheim on the N. W.; the quarry at Solenhoffen is worked for lithographic stone. The fossil contents are pterodactyli, insects, crustaceous animals, and tellenites, with certain plants: these fossils are similar to those found in Stonesfield slate, and occur in a similar geological position.
Middle oolite. Jura kalk.	The beds of this formation differ much in their mineral characters in different parts of Germany, but contain many of the fossils in the English middle oolites.
Inferior oolite.	The inferior oolite of Wurtemberg, Bavaria, Hanover, and Westphalia, analogous to that found on the Yorkshire coast; it rests upon lias.
Lias.	Lias marl and gryphite limestone occur in the countries named in the preceding section.
Keuper. Upper red and yellow marl.	A formation of purple, red, and green sandstone, and marl of enormous thickness, reposing on muschel kalk, and surmounted by lias. Mr. Murchison believes that the Keuper is the true representative of the English red and green marls.

Muschel kalk, wanting in England.	More than 600 feet in thickness, contains remains of the icthyosaurus and plesiosaurus, the crocodile, and turtle: the salt mines of Wurtemberg are in this formation.
Bunter sandstone. Lower red sandstone.	Analogous to the English lower red sandstone with magnesian limestone.
Roth-todteliegende. Lowest red sandstone.	The lowest red sandstone of Professor Sedgwick, like the English sandstone: it rests on transition limestone or coal measures.

It is deserving notice, that many of the beds in the above section not only contain the same fossils as those in the English series, but also preserve the same mineral characters. Where this is the case, we can arrive at satisfactory conclusions; and such beds serve as a key to the discovery of the true nature of the beds above and below them, where the characters may be less clearly defined.

CHAP. XIII.

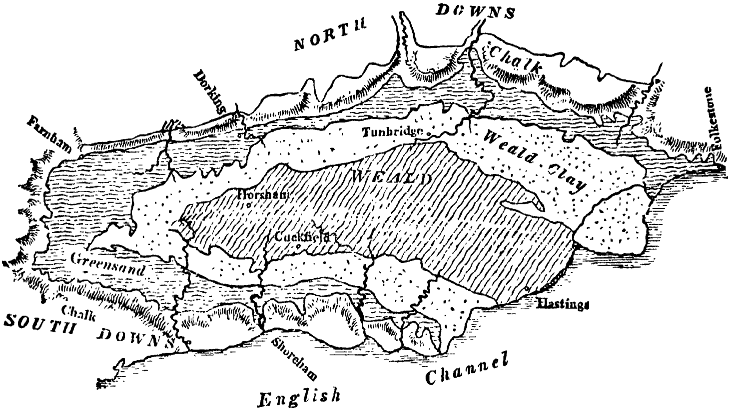
ON THE SUSSEX BEDS, OR WEALDEN, CONTAINING REMAINS OF LAND PLANTS, AND AMPHIBIOUS AND FRESH-WATER ANIMALS.

Extent of the Sussex Beds. — Their Geological Position and Mineral Characters. — Remarkable Organic Remains of enormous Lizards and Plants, analogous to those of Tropical Climates found in the Sussex Beds. — Supposed Appearance of the Country when these Animals flourished. — Petworth Limestone. — Hastings' Sand and Weald Clay. — The Wealden Beds formerly furnished the greatest Part of the Iron manufactured in England. — Mr. Mantell's Enumeration of the Species of Terrestrial and Fresh Water Fossil Remains in the Wealden Beds. — Observations on the Wealden Beds, and the Change from Marine to Fresh Water Formations.

In an elementary treatise on Geology, it is desirable to present to the view of the reader, not the geology of a single country, but that of the whole globe, as far as it has been ascertained. In certain countries, particular formations occupy a considerable extent, and are of great thickness; in other countries, similar formations are often wanting altogether, or the beds are so thin as scarcely to excite notice. The secondary strata cover more than one half of England, and hence the English geologist might be suspected of bestowing upon them too great a portion of his attention; but a more accurate examination of other countries has fully proved, that many of the British strata, which were formerly believed to be of very limited extent, are spread over a great part of Europe, and preserve the same order of succession as in our own island: — a description of these strata is therefore an essential part of general geology. The formations of the magnesian limestone, the red marle, the lias, the oolites, and the chalk, have risen into geological importance within the last fifteen years; and the reproach cast upon South Britain by our neighbours on the other side of the Tweed, namely, "that there was little or nothing in England worth the attention of a geologist," has lost all its force. The beds of sand and clay, that intervene between the upper oolites and the chalk, were, however, still more recently regarded as unworthy of particular notice; but the labours of Mr. Mantell and of Dr. Fitton have made us acquainted with facts respecting these earthy and sandy deposits, which are scarcely exceeded in interest, by any discoveries in the lower strata.

The beds which are about to be described as the Wealden, because they occur principally in the Wealds of Kent and Sussex, are supposed to rest on the upper beds of oolite in these counties: they dip under the chalk hills by which they are every where surrounded, except on the east, where they are cut off by the sea. The oolite below, and the beds of chalk and green sand above, are admitted to be marine formations, but the beds of limestone, conglomerate, sandstone, and clay, that compose the Sussex beds, or Wealden, contain almost exclusively the remains of fresh-water animals and terrestrial plants, and that over a surface exposed to observation nearly sixty miles in length, and from fifteen to twenty miles in breadth. The marine beds on which the Wealden rest, must, at a remote period, have been raised a considerable height above the ocean, and become dry land, having extensive rivers, lakes, or estuaries filled with fresh water, in which the Wealden beds were deposited. Again, at a subsequent period, the whole must have sunk deep beneath the surface of the sea, and been covered by a deposition of chalk and other marine strata, a thousand feet or more in thickness. At a more recent epoch, the chalk, with the subjacent beds of Wealden, were raised to their present elevation above the neighbouring sea. However the present quiescent state of the earth may seem opposed to the admission of such great geological changes, we are irresistibly compelled to resort to these changes for a satisfactory solution of existing phenomena.

The relative position of the Wealden beds will be understood from the annexed map.



The chalk hills of the North and South Downs will be seen surrounding the Weald country. Below the chalk is the green sand, marked with waving lines, containing, like the chalk, marine fossils exclusively. The fresh-water formations of Weald clay and Hastings' sand and sandstone rise from under the lower green sand. The Weald clay and Hastings' sand have generally been represented as distinct formations, but in reality the whole of the Wealden is composed of beds of clay, limestone, and sandstone, though in the outer part, marked with dots, the clay predominates. The sand and sandstone predominate in the central parts marked by diagonal lines, extending east and west from beyond Horsham to Hastings. In this direction the sandstone forms a range of hills of considerable elevation. Crowborough beacon, the loftiest part of the range, attains the height of more than 800 feet.

It is true that nowhere in Kent or Sussex do we obtain a section of strata on which the Wealden beds rest. At Lulworth Cove, in Dorsetshire, where a portion of these beds have been traced, they appear to have covered the upper or Portland oolites. Some portion of the same beds have been observed in the Isle of Wight; but they have not been found in the midland counties of England. The ferruginous character of some of the beds occasioned them to be, for a long time, mistaken for the iron sand belonging to the green sand formation, hereafter to be described. The name of Hastings or iron sand, Weald clay, and Petworth and Purbec limestone, have been given to different parts of this accumulation of sand, sandstone, and argillaceous limestone, to which the name of the Wealden or Sussex beds may be collectively applied. The clay called the Weald clay may be regarded as the principal member of this formation, to which the sandstone, calciferous grit, and limestone, are subordinate; for though the sand and sandstone form lofty cliffs on the coast, they alternate with marl and clay, and rest on beds of clay.* We shall therefore describe the Weald clay in conjunction with the beds of limestone and sandstone. The clay is a bluish or brownish tenaceous clay, sometimes indurated and slaty. Thin beds of limestone, separated by seams of clay, occur in different parts of the Weald clay: they have been known for furnishing a stone for architectural purposes, called Sussex marble, and Petworth marble. Some of the more compact varieties are sufficiently hard to receive a good polish. These beds abound with shells of the paludina, and crusts of the Cypris faba †, and other fresh-water shells. Masses of calciferous sandstone, nearly re-

---

* Below the Castle rock at Hastings, borings were made in 1829; they were chiefly in clay. The clay from the depth of 120 feet, which I examined, was a whitish-grey pipe-clay. The borings were made to obtain water for the Pelham Baths, which was found at the depth of 260 feet, of a good quality, and rose nearly to the surface.

† The Cypris faba is a crustaceous animal in a roundish shell or case, not much larger than a grain of millet. The living species are aquatic monoculi, which swim in fresh water, and deposit their eggs on the leaves of aquatic plants, or in the mud. The paludina is a fresh-water univalve shell.

sembling the well-known sandstone of Fontainbleau, occur in various parts of the Wealden, both in what may be called the Weald clay, and the lower beds of sand and sandstone, called Hastings' sand. The Hastings' sandstone is composed of yellowish or whitish grains of sand, very loosely adhering, alternating with beds of clay, and with a small sandstone conglomerate, containing rounded fragments of bones, and scales of fishes. Over this bed there occurs, in some parts of the Weald (particularly at Tilgate Forest), a bed of coarse conglomerate, consisting of quartz pebbles, and rounded pieces of Lydian stone and jasper, and containing bones and teeth of fishes and saurian animals. The upper sands are generally fawn-coloured, and contain lignite, bituminous matter, and vegetable impressions.

Ironstone occurs in considerable quantities in the Sussex beds. In the sixteenth century, before the coking of coal for smelting of iron ore was discovered, two thirds of the iron manufactured in England was obtained from the Sussex beds.* The Wealds of Kent and Sussex, being then covered with forest trees, supplied the fuel for smelting the ore.

To the indefatigable and scientific researches of Gideon Mantell, Esq., F.R.S., we are indebted for a knowledge of the true zoological characters of the Wealden beds, which he has described in his "Illustrations of the Geology of Sussex, with Figures of the Fossils of Tilgate Forest." This work contains the most interesting details of local geology which have appeared in this country. The fossil remains of the Wealden beds consist of petrified trunks of large plants, bearing a resemblance to the palms, arborescent ferns, and the gigantic reeds of tropical climates; also of the shells of fresh-water genera, as the fresh-water muscle, the mya, cyrena, paludina, and Helix

---

* For a knowledge of this fact, I am indebted to a gentleman who has in his possession an ancient work on the iron trade of England, previous to the use of coke.

vivipara. Some remains of fish, and three distinct species of turtles, have also been discovered; and the bones, teeth, and scales of at least five gigantic species of the lizard family; namely, the crocodile, the plesiosaurus, the megalosaurus, the iguanodon, and the hylæosaurus or forest lizard.

The crocodilian remains are pronounced by Cuvier to be almost identical with those of the fossil crocodile discovered at Caen in Normandy, which belongs to the genus gavial, the crocodile of the Ganges.

The Plesiosaurus. — This animal has been noticed, Chaps. II. and X.

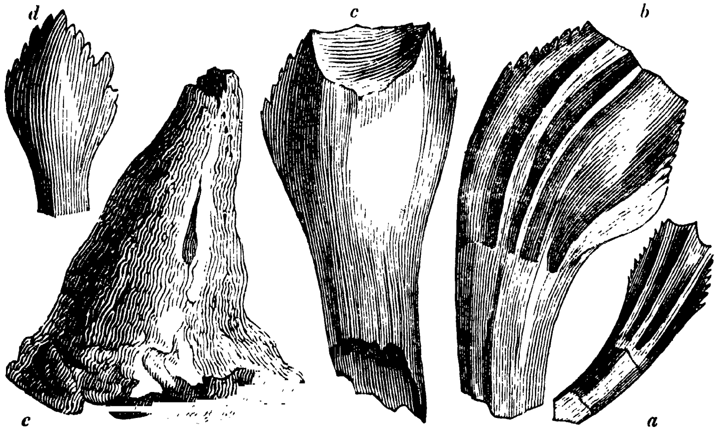
The Megalosaurus. — The bones of this animal, found at Tilgate, are similar to those discovered by Mr. Buckland in the Stonesfield strata. The megalosaurus is supposed to approach nearer to the form of the Monitor* than to any other species of living lizard; but its size is so enormous, that Cuvier says, if we suppose it to have possessed the proportions of the monitor, it must have exceeded seventy feet in length.

The Iguanodon. — A nondescript herbivorous reptile, which Cuvier pronounces to be the most extraordinary animal yet discovered. Its structure approaches the nearest to that of the Iguana, a large species of lizard in the West Indies: its length was between sixty and seventy feet, which is double that of the largest living crocodile. But the great peculiarity of the iguanodon is the form of its teeth, which bear a striking resemblance to the grinders of herbivorous mammalia, being evidently intended for mastication, in which respect it differs from all living animals of the lizard family. The herbivorous amphibiæ gnaw off the vegetable productions on which they feed, but do not chew them. — "Since the vegetable remains," says Mr. Mantell, "with which the teeth of the iguanodon are associated, consist

---

* The Monitor — a species of lizard which is said to give warning of the approach of the crocodile by a hissing noise.

principally of those tribes of plants that are furnished with rough thick stems, and which were probably the principal food of the original animal, we may be permitted to remark, that this peculiar structure of the teeth seems to have been required, to enable the animal to accommodate itself to the condition in which it was placed." — The iguanodon appears also to have possessed a horn, equal in size and not very different in form from the horn of the rhinoceros: in this respect, it resembles a living species of iguana, a native of St. Domingo.



a. b. c. represent the teeth of the iguanodon of the natural size; *a* is the front view of the perfect tooth of a young animal; *b* is the front view of a full grown tooth, with the points worn down; *c*, the back view of the tooth; *d* represents a highly magnified tooth of the living iguana. The reader may be surprised at the smallness of the teeth of the iguanodon; but the same proportion takes place in the teeth of all reptiles. A living iguana, five feet in length, has teeth not larger than those of a mouse. *e* is a reduced drawing of the horn.

One of the thigh bones of the iguanodon, in Mr. Mantell's museum, is twenty-three inches in circumference. The condyle, or joint of another bone which I measured, was thirty-four inches in circumference: enormous claws and toe bones have also been discovered. Mr. Mantell, in his interesting work, the "Fossils of Tilgate Forest," justly observes, "Were this thigh bone clothed with muscles and integuments of suitable proportions, where is the living animal that could rival this extremity of a lizard of the primitive ages of the world?"

Mr. Mantell concludes his "Illustrations of the Geology of Sussex" with the following interesting observations: —

"We cannot leave this subject without offering a few general remarks on the probable condition of the country, through which the waters flowed that deposited the strata of Tilgate Forest, and on the nature of its animal and vegetable productions. Whether it were an island or a continent, may not be determined; but that it was diversified by hill and valley, and enjoyed a climate of a higher temperature than any part of modern Europe, is more than probable. Several kinds of ferns appear to have constituted the immediate vegetable clothing of the soil: the elegant *Hymenopteris psilotoides*, which probably never attained a greater height than three or four feet, and the beautiful *Pecopteris reticulata*, of still lesser growth, being abundant every where. It is easy to conceive what would be the appearance of the valleys and plains covered with these plants, from that presented by modern tracts, where the common ferns so generally prevail. But the loftier vegetables were so entirely distinct from any that are now known to exist in European countries, that we seek in vain for any thing at all analogous without the tropics. The forests of *Clathrariæ* and *Endogenitæ*, (the plants of which, like some of the recent arborescent ferns, probably attained a height of thirty or forty feet,) must have borne a much greater resemblance to those of tropical regions, than to any that now occur in temperate climates. That the soil was of a sandy nature on the hills and less elevated parts of the country, and argillaceous in the plains and marshes, may be inferred from the vegetable remains, and from the nature of the substances in which they are enclosed. Sand and clay every where prevail in the Hastings' strata; nor is it unworthy of remark, that the recent vegetables to which the fossil plants bear the greatest analogy, affect soils of this description. If we attempt to portray the animals of this ancient country, our description will possess more of the character of a romance than of a legitimate deduction from established facts. Turtles, of various kinds, must have been seen on the banks of its rivers or lakes, and groups of enormous crocodiles basking in the fens and shallows."

"The gigantic *Megalosaurus*, and yet more gigantic *Iguanodon*, to whom the groves of palms and arborescent ferns would be mere beds of reeds, must have been of such prodigious magnitude, that the existing animal creation presents us with no fit objects of comparison. Imagine an animal of the lizard tribe, three or four times as large as the largest crocodile, having jaws, with teeth equal in size to the incisors of the rhinoceros, and crested with horns;—such a creature must have been the iguanodon! Nor were the inhabitants of the waters much less wonderful; witness the plesiosaurus, which only required wings to be a flying dragon; the fishes resembling *Siluri, Balistæ*, &c." Another large fossil reptile, scarcely less remarkable than the iguanodon, was discovered by Mr. Mantell, in the strata of Tilgate Forest, in 1832. This animal was less than the iguanodon. Mr. Mantell, from his profound knowledge of comparative anatomy, has been able to ascertain, that it differs in structure from every known species of living or fossil lizard or crocodile, though it agrees with some of them in many important parts of its osteology. It appears to have had a row of scaly fringes on its back, some of which are seventeen inches in length: when erected, they must have given the animal a truly terrific appearance.

To this new animal Mr. Mantell proposes to give the name of Hylæosaurus, or Forest lizard.

In the preceding chapter it was stated, that the Portland oolite composed the upper beds of the oolite formation. The annexed table will show their position with respect to the Wealden beds, and the chalk formation, in a descending series:

1. Upper chalk, with flints.
   Lower chalk and chalk marl.
2. Upper green sand.
   Blue clay, called galt.
   Ferruginous or iron sand.
   Lower green sand.
3. Weald clay and sandstone.
   Sand, gritstone, and conglomerate.
   Argillaceous limestone and slaty marl, comprising Purbeck and Petworth limestone.

The whole supposed to be resting upon the upper or Portland oolite. (See the preceding Chapter.)

The Purbeck limestone does not occur in the Weald country, though evidently a lower member of that formation.

According to the tabular arrangement of the fossils in the different beds in Sussex, given by Mr. Mantell, the chalk, chalk-marl, green sand, galt, and lower green sand, contain remains of two hundred and ninety-four species of marine animals, and thirteen species of plants, chiefly marine.

The Wealden beds contain remains of fifty-two species, which, with few exceptions, are either of terrestrial or freshwater animals, and nine species of terrestrial plants.

Of the numerous species of chambered marine shells, such as nautilites, ammonites, and belemnites, that abound in the secondary strata, below the Wealden, and in the chalk formation above it, not an individual shell has been hitherto found in any part of the Weald formation; a fact decisive of the different character of the latter beds. With respect

It may be proper to call the attention of the reader to what has been before stated, respecting the submersion of the coal strata, and their being covered with marine formations, and again elevated; see Chapter VIII. The circumstances that attended the elevation and depression of the coal strata, appear to have been similar to what took place at a subsequent period in the Sussex beds or Wealden: other instances of similar submergence might be given, ere it necessary.

While this part of the work was passing through the press, the author received a copy of a Geological Sketch of the Vicinity of Hastings, by William Henry Fitton, M.D. F.R.S. &c. It gives a brief, but very clear description of the Wealden formation, the extent of which Dr. Fitton has taken great pains to discover. According to this statement, the Wealden gradually becomes thinner near its limits in Dorsetshire, and the interior of England. It disappears westward, somewhere about Durdle Cove, on the Dorsetshire coast. The existence of the Purbeck beds in the vale of Wardour has long been known; in that place Dr. F. has detected also some traces of sands, corresponding to those of Hastings. " Slaty limestone, like that which occurs in the upper part of the Isle of Portland, is found above the equivalent of the Portland stone at Brill and Whitchurch, west of Aylesbury, in Buckinghamshire, and on the coast of the Boulonnois, in France.

But besides these places, Beauvais, in the interior of France, is the only other locality in which any members of the Wealden have yet been shown, on good evidence, to exist."

The position of the extreme points of this formation from west to east, or from Lulworth Cove to the boundary of the lower Boulonnois, is about 200 English miles N. W. to S. E., or from Whitchurch to Beauvais, about 220 miles: the depth or total thickness, where greatest, being about 2000 feet.* Dr. Fitton remarks, that this is a wide diffusion of the strata, if they were the product of an estuary, but by no means greater than that of many of the actual deposits, in some of the larger rivers on the present surface of the globe. Dr. Fitton cites the Deltas of the Ganges, the Mississippi, and the Quorra or Niger in Africa, as presenting an extent of surface nearly equal to that of the Wealden formation. I think it evident however, that certain parts of the Wealden were once dry land, or shallow water. The Cypris faba in the clay beds, probably lived and died where its crustaceous remains are so abundant, and many of the plants must have flourished on dry land. Indeed, we do not remove the necessity of admitting a submergence, by supposing the Wealden to have been deposited in a deep estuary; for to form a large river, and such an estuary, filled with fresh water, extensive mountain ranges of great elevation would be required, and these must have been submerged or removed, before the deposition of the chalk formation, which it cannot be doubted took place in a deep ocean, as that formation is more than one thousand feet in thickness.

---

* In the section it is stated at 1000 feet.

CHAP. XIV.

ON CHALK, AND THE SUBJACENT BEDS OF GREEN SAND.

Extent of the Chalk Formation. — Green Sand divided into lower and upper Green Sand by a Bed of Clay called Galt. — Chalk Marl. — Chalk, its Mineral Characters. — Change of Character in the Alps. — Flints in the upper Chalk. — On the Formation of Flints. — Remarkable Organic Remains in Chalk. — Recent Discovery of Beds belonging to the Chalk Formation, in the United States of America. — On the Scaglia of the Alps supposed to represent Chalk.

THE well-known mineral, chalk, with its subjacent beds of green sand, comprises a formation or series of strata of great depth, which are spread over a large portion of the south-eastern and eastern counties of England, and are found covering a large extent of surface in the northern parts of France, preserving nearly the same characters as the English chalk. Similar beds are found in Germany and in the north of Europe; but on approaching the mountain ranges of the northern chain of Alps, the mineral characters of chalk undergo a considerable change. Scarcely a trace of chalk is found in any part of Scotland; but it occurs in the north coast of Ireland.

The animal remains in chalk and its subjacent green sand, are exclusively marine, proving that this great calcareous and arenaceous deposition, a thousand feet or more in thickness, was formed under the ocean.

Chalk is regarded as the last, or uppermost, of the secondary strata; and there is a marked difference between the organic remains in chalk, and those in the tertiary strata that in many situations cover it. The geological position of chalk is over the oolite formation; but we have seen, in the last chapter, that in the counties of Sussex and Kent, chalk and green sand rest immediately upon the freshwater beds of the Wealden; and in the western counties of England, where the oolite is wanting, chalk covers lias and red marl. The thick beds of green sand under chalk are regarded as constituting, with the chalk, one marine formation, as they contain many of the same genera of fossil remains, both in England and on the continent of Europe; and the lower beds of chalk or chalk marl, pass gradually into the green sand, by a close intermixture with it, and have, on account of their greenish or yellowish colour, been denominated *Glauconie crayeuse* and *Craie chloritée*, by the French.

Green sand has received its English name from its intermixture with particles of green earth; it is very variable in its mineral characters, being sometimes found composed of loose siliceous sand; in other situations it forms sandstone, cemented by calcareous earth; it abounds in siliceous concretions, which vary from an opaque bluish white chert or hornstone, to flint and chalcedony. The geodes found in the green sand near Sidmouth, are composed of opaque chert on the outside, and contain within, mammillated concretions of beautiful chalcedony, and occasionally perfect minute rock crystals. Some of the sandy concretions near Sidmouth have a beautiful green colour, which I found to proceed from green sulphate of iron.*

The total thickness of the green sand where it is fully developed, is more than 400 feet. The lower sand is generally ferruginous, and has been called iron sand, from the large quantity of oxide of iron disseminated through it; but the lowest beds often contain green particles like those in the upper green sand. The upper and lower green sand are in many

---

* On the east of Sidmouth, immediately above the town, I observed green sand, intermixed with black particles which I ascertained to be the black oxide of manganese, as they gave a violet colour to glass when fused.

situations separated by a "bed of stiff marl, varying from a light grey to a dark blue." According to Mr. Mantell, its greatest thickness in the south of Sussex is about 250 feet. This bed has been called the Folkstone Marl, but is more generally known by the provincial name of Galt. The marine shells, in which it abounds, are generally distinguished by their brilliant pearly lustre; they consist of ammonites, nautilites, a small species of belemnite, and various other shells.

The upper green sand is remarkable for the chalcedonic appearance of the flint or chert which it contains. This sand has been sometimes called fire stone, to distinguish it from the lower green sand. The green particles are chiefly composed of the protoxide of iron and silex, denominated by M. Berthier a silicate of iron. In some parts of the Savoy Alps, the beds analogous to green sand are of enormous thickness, and are nearly black, but contain many of the same fossils as the English green sand. From these beds I obtained hamites, scaphites, and various species of small echinites. The upper green sand, as before observed, becomes intermixed with an argillaceous and calcareous bed called chalk marl, which may be regarded as the lowest bed of the under chalk. It is of a darker colour than common chalk, but burns into useful grey lime.

Chalk. — This rock is better known by its mineral characters in England and the northern parts of Europe, than any other of the secondary strata. Its prevailing colour is nearly white; it has an earthy texture, and is generally so soft as to yield to the nail. These are, however, not the universal characters of chalk. The lower beds in Yorkshire are red, and the scaglia of the northern Alps, which is a mode of chalk, has also a red colour; and in some parts of the Alps this rock is highly indurated, and resembles more, white statuary marble than English chalk. The greatest thickness of the chalk strata in England may be estimated at from 600 to 800 feet.

The upper beds contain numerous nodules and short irregular veins of flint; the lower chalk contains fewer flints, and is generally harder than the upper chalk, and is sometimes used for building stone. In France, the beds of chalk seldom attain the thickness which they have in England. The French divide the chalk formation into the lowest or chalk marl, with green particles, *craie chloritée*, or *glauconie crayeuse;* the middle or coarse chalk is of a greyish colour, and intermixed with sand; it contains whitish chert (*craie grossière*, or *craie tufeau*); the upper or white chalk (*craie blanche*), which contains nodules of common flint.

M. Humboldt, after noticing the great intermixture of the sandy calcareous and argillaceous beds, in the formations below chalk, and which is greatly increased in the tertiary strata above chalk, observes, "that nature seems to have relented in her tendency to form complex mixtures, when chalk was deposited." In the chalk formation, we find a vast assemblage of calcareous strata, composed of carbonate of lime, with very little intermixture of the other earths, and without any alternation with argillaceous or siliceous strata. Chalk is not, however, absolutely pure; for, beside the nodules and veins of flint that occur in it, but which bear no sensible proportion to the whole mass, some of the strata contain an intermixture with siliceous sand, and in other strata, calcareous earth is combined with magnesia. In some of the chalk strata in France, the magnesia exceeds ten per cent., and, I believe, many of the English chalk strata contain as great a proportion of magnesian earth.

Chalk, which contains a notable portion of magnesia, may generally be known by an appearance of dendritical spotted delineations on the surface of the natural partings, and by minute black spots, like grains of gunpowder, in the substance of the chalk.

The stratification of chalk is seldom so distinct as in many other calcareous formations: this may be partly owing to the softness of the beds, which appear to have yielded to pressure; and to the same cause we may probably ascribe the fractured state of the nodules of flint in chalk, which often appear whole, when they are imbedded in the rock, but when taken out, are found to be shivered into innumerable angular fragments. The nodules of flint are commonly arranged in pretty regular layers in the chalk; they occur in detached concretions of various shapes and sizes: some of them are believed to be the casts of spongiform zoophytes, and this is rendered more probable by the frequent occurrence of fossil echini in chalk, in which the internal part is filled with flint, and forms a perfect cast of the animal. In some of the chalk flints near Paris, there are beautiful small crystals of sulphate of strontian.

The constant occurrence of flint in the upper chalk, and the apparent conversion of animal remains into flint, has formerly given rise to much speculation respecting the origin of flint; and it was at one time maintained, that flint and chalk were convertible or capable of undergoing a mutual transmutation: but whatever hidden processes there may be in the great laboratory of the earth, by which all mineral substances, held to be elementary by the chemist, may be resolved into original elements still more simple, and afterwards recompounded into other substances, we have no reason to mount so high in our speculations, respecting the origin of flint.

Flint is siliceous earth nearly pure; and we find the same earth under different forms, combined with almost all calcareous rocks in a greater or lesser proportion.

Primitive limestone is often much intermixed with siliceous earth. Transition limestone occasionally contains rock-crystals imbedded in the mass: this is not unfrequently the case in some of the transition limestones of Derbyshire. The magnesian limestones and oolites, are also very commonly intermixed with siliceous grains, and often alternate with strata that are more or less siliceous: hence we need not be surprised to find siliceous earth in chalk, either combined with calcareous earth, or separated in distinct concretions. When the cavities of a sponge or of a crustaceous animal admitted the siliceous earth to enter, it appears to have been infiltered from the chalk, in the same manner as the nodules of chalcedony have been infiltered into the cavities of lava or basalt. Between chalcedony and flint there is a near resemblance, they are only different modes of the same substance, and the flint nodules in the western counties of England are frequently chalcedonic. The hardest rocks and stones are permeable to water; and flint when first got out of the chalk is easily fractured, and the fractured surface is found covered with moisture.

The organic remains in the chalk formation are exclusively marine. They are too numerous to be described in the present work, but it will be proper to notice those that are the most characteristic. These are, first, echinites, particularly the helmet-shaped species called ananchytes, and the heart-shaped species spatangus cor anguinum. The chambered shells called scaphites, hamites, turrilites, and baculites, are regarded as peculiar to the chalk formation: it also contains ammonites, belemnites, and nautilites. Numerous organic remains of zoophytes, in the state of flint, particularly of sponges and alcyonia, occur in chalk, and various species of bivalve shells; but there are comparatively few spiral univalve shells in this formation. It is probable that the deep ocean in which chalk was deposited, was not suited to the inhabitants of such shells, for the animals had heads and eyes, and required shallow water to see their food. Several specimens of fossil fish from chalk may be seen in the valuable museum of Mr. Mantell, at Lewes, and some vertebral remains of large saurian animals, but these are rare. Teeth, palates, and scales of fishes, occur more frequently in chalk than vertebræ. The great preservation in which some of states, which contain the characteristic fossils of the chalk formation, particularly baculites and scaphites, together with ammonites, belemnites, echinites (the ananchytes), the mososaurus and plesiosaurus, also bivalve and univalve shells of the same epoch. This formation in some parts is covered by tertiary strata. Mr. Mantell, whose accurate knowledge of the chalk formation in England will not be disputed, has received specimens of these organic remains from America, and refers them decidedly to the chalk formation, though he considers that some of them are analogous to the superior chalk beds at Maestricht, which are wanting in the chalk formations of France and England. See Silliman's Journal, February, 1832.

Dr. Morton is about to publish a more full account of his discoveries.

Between the epoch when chalk was deposited, and the period when it was covered with the tertiary strata, there appears to have been a considerable interval, during which the surface of the extensive mass of chalk was deeply furrowed and excavated, before a new series of strata were deposited upon it, destined to support a new creation of animals of a superior class, altogether different from those which have left their remains in the subjacent strata. In some situations, however, the tertiary strata appear to rest conformably on chalk, and present no indications of any interruption in the regular series of successive deposits. In an interesting paper, by Professor Sedgwick and R. J. Murchison, Esq. on the relations of the secondary and tertiary strata on the southern flanks of the Tyrolese Alps, published in the Phil. Mag. for June, 1829, the tertiary strata are described as forming a vast series of beds resting on scaglia or chalk: the lowest of these beds contain, exclusively, the remains of marine animals, and no interval of repose can be traced between the epochs of the formation of the secondary and tertiary strata. The scaglia occurs in beds nearly vertical: the upper ones contain nodules and layers of flints: their colour is red, and their structure fissile. The lower beds are thicker, and more compact, and pass into a beautiful white saccharoid marble. The scaglia contains in some parts ammonites and belemnites. It cannot, however, be denied, that where the beds are so much broken and contorted as they are on the Tyrolese Alps, and where their mineral characters differ so much from beds of the chalk formation in England and France, it becomes extremely difficult to ascertain the identity of these secondary depositions in distant countries. In the calcareous formations of the Savoy Alps, I not only discovered the characteristic fossils of the English strata, but observed some of the beds possessing the true mineral characters of the English oolites, and lias; but where these characters are entirely wanting, and where, from the over turning and contortion of the strata, the aid of relative geological position cannot be obtained, the inferences from a few fossil organic remains must be received, with a certain degree of caution.

CHAP. XV.

ON THE FORMATION OF SECONDARY LIMESTONE AND SANDSTONE, AND ON THE PROGRESSIVE DEVELOPEMENT OF ORGANIC LIFE.

On the Deposition of Chalk. — Whether formed by Animal Secretion, or by Eruptions of Water holding calcareous Earth in Suspension or Solution. — Mud Volcanoes. — Animal Bodies suddenly encased in Chalk indicate the Time required to form a Stratum of a given Thickness. — Oolite and Ecrinal Limestone partly formed by Animal Secretion. — Formation of Sandstone. — Repeated Appearance of Dry Land during the Epoch when the Secondary Strata were deposited. — Progressive Developement of Organic Life in the Secondary and Tertiary Epochs. — Disappearance of enormous Reptiles and chambered Shells from the Seas of Northern Latitudes. — Probability of the Icthyosaurus existing as a living Species in the present Seas.

Having travelled with the reader over the secondary strata, from the lowest new red sandstone, to the upper chalk, he may not be disinclined to pause awhile, and look back upon the ground which he has already passed, comprising a series of calcareous, sandy, and argillaceous beds, whose aggregate thickness may not be less than ten thousand feet. It is scarcely possible, in observing these beds, and the bones and shells of extraordinary animals which they contain, not to feel some desire to ascertain the causes by which they were thus entombed, and to enquire in what manner, or by what agents, the different beds were deposited or consolidated. Such researches form rational and legitimate subjects for the meditation of the geologist, though he may frequently have to lament the imperfection of his present knowledge, and the mystery in which many of the processes of nature are still involved.

One of the most ancient geological enquiries relates to the formation of limestone rocks and strata. *Whence was the calcareous matter derived?* Some limestone rocks are chiefly composed of shells, or other calcareous remains of marine animals, and in such instances we can have little hesitation in ascribing their formation to animal secretion, similar to what is taking place in the numerous coral reefs in the Pacific ocean. There are other beds, however, such as chalk, to which a similar formation cannot be ascribed; for though they contain numerous organic fossils, these do not bear the proportion of one to one hundred millions, when compared to the whole mass, and the chalk does not appear to have undergone any chemical change, from heat or other causes, that could have obliterated the traces of organic existence. In no formation are the most delicate organic textures of animals better preserved. In Mr. Mantell's splendid collection of chalk fossils at Lewes, there are specimens of fish, in which the body is entire and the air-bladder is uncompressed —and the beautiful forms of many shells covered with spines, prove that they could not have been drifted from a distance, or deposited in an agitated ocean.

I have never been able to comprehend, why any peculiar difficulties should be supposed to attend the enquiries respecting the origin of calcareous or magnesian earths; or of the carbon and sulphur occurring in rocks, in the state of carbonic or sulphuric acids. It would be equally proper to institute an enquiry into the origin of silex or alumine. I hold the earth itself, and its ancient atmosphere, to have been the great chemical laboratories, in which all the solid and fluid parts of the surface were originally prepared and formed. This opinion I stated at some length in Chap. XVI. of the second edition of this work in 1815, and also in the third Edition, in a chapter on the agency of subterranean fire in the formation of rocks, and on igneous and aqueous eruptions of earthy matter. It has been too much the fashion to consider all the secondary strata as mechanical depositions; but the siliceous strata in the Paris basin, the layers of flint in chalk, and the beds of chert or hornstone in transition limestone, are certainly as much original formations as granite itself.

In referring to the vast magnitude of ancient volcanoes, I have stated that they had doubtless an important office to perform in nature: and can it be unreasonable to believe, that the earth itself is the great laboratory and storehouse, where the materials that form its surface were prepared, and from whence they were thrown out upon the surface in an igneous, aqueous, or gaseous state, either as melted lava, or in aqueous solution, or in mechanical admixture with water in the form of mud, or in the comminuted state of powder or sand? Inflammable and more volatile substances may have been emitted in a gaseous state, and become concrete on the surface.

These primeval eruptions, judging from the size of the ancient fissures and craters, may have been sufficient to cover a large portion of the globe. Nor can it be deemed improbable, that still larger and more ancient craters have been entirely covered by succeeding eruptions. In proportion as the formation of the surface advanced, these eruptions might decline, and be more and more limited in their operation.

It is not necessary to suppose, that these subterranean eruptions consisted only of lava in a state of fusion. The largest active volcanoes at present existing, throw out the different earths intermixed with water in the form of mud. Nor should we limit the eruptions of earthy matter in solution or suspension, to volcanic craters: the vast fissures or rents which intersect the different rocks, may have served for the passage of siliceous solutions to the surface. We know no instances in nature of siliceous earth being held in aqueous solution, except in the waters of hot or boiling springs; and hence it seems reasonable to infer, that many siliceous rocks and veins have been deposited from subterranean waters, at a high temperature.* Calcareous or cretaceous matter is also ejected during aqueous volcanic eruptions. According to Ferrara, streams of liquid chalk, or chalk in the state of mud, were ejected from the mud volcano of Macaluba, in Sicily, in 1777, which, in a short space, formed a bed several feet in thickness. Beds of limestone may have been formed by similar calcareous eruptions, in which the lime might be sometimes in solution, and sometimes mechanically suspended; and the numerous remains of testaceous animals in limestone appear to indicate, that the calcareous solutions were favourable to the growth of animals, whose coverings contain so much calcareous matter. Nor is it necessary to suppose, that these aqueous eruptions were always sudden, and attended with violent convulsions, for when a passage was once opened, they may have risen slowly, and have been diffused in a tranquil state, and by gradual deposition, or condensation, may have enveloped the most delicate animals or vegetables, without injuring their external form. — Second edition, 1815.

If the geologist can admit such a condition of the ancient world as above described, a condition which, on a smaller scale, might be proved to have existed since the period of authentic history: if he will further admit, that, before the formation of chalk, a great portion of what is now England, and the northern Continent of Europe, was covered by a deep ocean, interspersed with islands, and surrounded by ancient continents, and this few modern geologists will deny. Then, if we allow submarine aqueous eruptions of calcareous matter, and siliceous solutions from thermal waters, to have been poured into this deep

---

* M. Brogniart, to whom I sent the edition of 1815, subsequently admitted a similar formation of the siliceous beds and millstone in the Paris basin, that they were deposited by thermal waters holding silex in solution.

ancient ocean, we shall have all the circumstances required, to form thick beds of chalk, interspersed with nodules of flint. In an experiment on clay formed into a stiff paste, by admixture with a saturated solution of alum, it was found, on breaking the clay when dry, that alum was interspersed through the mass in distinct crystals and concretions. In the same manner, we may suppose that the silex in the siliceous solutions, spread through the calcareous matter, would separate into distinct concretions, filling the cavities and pores of zoophytes — such as sponges and alcyonia, or of shells deposited in the chalk. Every fact connected with the history of chalk, proves that it was formed in a very tranquil sea, and not by the drift or detritus of more ancient rocks. Mr. Mantell, whose almost daily observations on the chalk formation scarcely suffer an important fact to escape his notice, says, that, in the whole of these immense beds that he has examined, the occurrence of a single fragment or pebble of more ancient rocks in chalk is extremely rare; a fact decisive against its being formed by mechanical deposition of drift, or detritus of older limestones. The preservation of the most delicate textures of animals before referred to, proves beyond doubt, that those organic bodies had not been transported from a distance, or subjected to the violent action of inundations or currents.

The fossil fish found in chalk with the body preserving the natural form, and with the air bladder uncompressed, proves beyond doubt, that the animal was encased in mineral matter, before the putrefactive process had effected the destruction of the fleshy parts. A sudden eruption of thermal water holding calcareous earth in solution or suspension, might instantly deprive the animal of life, and protect the body from decay. The matter, called *creta* by Ferrara, erupted from Macaluba, was certainly a soft limestone, analogous to chalk; and though the eruption lasted only part of a day, it formed a stratum many feet in thickness. Had this eruption taken place under water, the earthy matter would have been more widely diffused, and the stratum of limestone deposited, would have been proportionably thinner. In the case of the fossil fish before stated, we are not obliged to suppose the deposition to be so rapid: several days might elapse before the body was entirely buried under calcareous earth. If we say seven days, and estimate the thickness of the fish at three inches, we shall have a chronometer to measure the time required to form a stratum of chalk three inches in depth, which is one week. This is equal to one foot in a month, or twelve feet in a year; and could we suppose the deposition to proceed without interruption, it would not require more than ninety years, to form a mass of chalk beds, one thousand feet in thickness; which is more than that of all the chalk beds in England. It is by no means intended to support the opinion, that the chalk beds were all deposited in so short a period; long intervals of repose might pass between different eruptions. My object in calling the attention of geologists to this subject is, to show that strata may be formed more rapidly than they are generally disposed to believe, and that the feeble operations of natural causes in our own times, however similar in kind, bear no proportion, in their intensity, to the mighty agents that have formed the ancient crust of the globe. The deposition of a bed of calcareous earth, a few feet in thickness in some of the Scottish lakes, as described by Mr. Lyell, would appear to have required many centuries for its completion. In some of the beds of oolite, the quantity of animal remains bears a considerable proportion to the whole mass, and the beds of encrinal limestone in some of our mountain limestones, are formed principally of the stems and branches of encrinites, probably broken by the violent action of the sea; but it is not improbable, that the interstices have been filled by calcareous depositions. It is obvious, that limestone strata of considerable thickness, if composed chiefly of organic remains, would require centuries for their completion.

Let us now take a brief survey of the beds of secondary sand and sandstone. The lowest or new red sandstone, appears to have been formed in an epoch of volcanic action over a large portion of the present European continent, which broke up the foundation of primary and transition rocks, and scattered their fragments over the bed of an ancient ocean. In many parts we observe a tendency to form beds of porphyry, but the process appears to have been often more or less interrupted by disturbing causes; and we observe porphyritic beds, with well defined crystals of felspar, alternating with sandstone of mechanical formation. We may further observe, that in this epoch of disturbance there were long intervals of repose, during which the beds of magnesian limestone and muschel-kalk, were deposited in certain situations.

The operation of mechanical causes are obvious in almost all sandstone rocks, and beds of conglomerate; and the experiments of Sir James Hall prove, that beds of loose sand may be agglutinated into sandstone, if permeated by steam from saline water at a high temperature. With respect to beds of clay, their formation by sedimentary deposition will not be doubted; but we are not certain that in some instances, the matter may not have been ejected by submarine mud volcanoes, containing the sulphur, iron, and saline matter, in which several of these beds abound.

One of the most interesting circumstances attending the secondary strata is, the convincing evidence they afford, that at different periods of their formation the earth had extensive tracts of dry land, either islands or continents; for though the prevailing character of the secondary strata is that of marine beds, yet we find among them, beds containing exclusively freshwater shells, and also terrestrial and marsh plants, and in almost all the secondary strata (except chalk), though the organic remains may be chiefly marine, we find remains of some freshwater animal, or terrestrial plant, which were probably brought by rivers from the land, and floated into the ancient ocean. We have, beside the above evidence, the regular coal strata, 3000 feet or more in thickness, abounding in terrestrial plants. We have also a great thickness of freshwater strata in some part of the oolite formation, and again the Wealden strata, more than a thousand feet in thickness, appear to have been deposited in a freshwater estuary or river, which would require a large continent of dry land for its formation. Now, it is remarkable, that, in all the above beds, we do not find a single bone of any large mammiferous land quadruped, nor even of the smallest species, except in the anomalous instance of Stonesfield.

To maintain that such bones not having been discovered, is no evidence that they may not exist, appears to me to be making a retrograde step in science. It is true, that "the bottom of the sea has not been dredged," to discover what species of animals have existed in former ages: the geologist, however, can have no need of such an operation, for the land beneath the former sea has been laid bare, and is now exposed over an extent equal to that of all the habitable parts of the globe. Every island and continent has formed part of an ancient bed of the ocean, and that not once, but repeatedly. This extended surface of the ancient bed, is exposed to the examination of thousands of observers, in every degree of latitude not covered by polar snows. The absence of remains of the higher orders of animals in all the secondary strata, and the frequent recurrence of these remains in the more recent or tertiary strata, appears to afford presumptive evidence, amounting almost to certainty, that the higher orders did not exist, at least in the northern hemisphere, till an epoch subsequent to the deposition of all the secondary formations.

When we ascend to the strata deposited at a later period than chalk, we find a remarkable change in the character of the organic remains. The ammonites, and other chambered shells, which are so numerous in the secondary strata, disappear entirely in the tertiary strata, except the fossil nautilus, which is occasionally found in these strata; and the animal now exists as a living species in the Indian Ocean. The enormous lizards, and animals allied to the lizard and crocodile, whose bones abound in the secondary strata, from lias to chalk, disappear also in the tertiary strata, with the rare exception of a small species of crocodile;—a fact which indicates, that animals of this order ceased to be inhabitants of northern latitudes when the tertiary strata were deposited. In the tertiary strata, the place of these enormous reptiles is occupied by the remains of the higher order of terrestrial mammalia, but belonging to genera or species now extinct; the gigantic mastodon, the mammoth, and magatherium, rivalled in magnitude the enormous reptiles of a more ancient world. Other species of mammalia of lesser size, both herbivorous and carnivorous, but equally perfect in their organisation with the land quadrupeds of the present epoch, have left their bones in many of the tertiary beds. Here we may stop; for we approach to a period connected with the present order of things, a period immediately preceding that mysterious operation of divine power and intelligence, the creation of man.

The doctrine of the progressive developement of organic life here briefly stated, has been recently opposed by highly ingenious arguments, which display the great talents and ability of the author, but which, in my opinion, do not invalidate the truth of the doctrine,—a doctrine, however, that, like almost all general conclusions, requires to be admitted with certain limitations and restrictions. Every instance hitherto adduced, of bones of the higher orders of animals being found in ancient secondary strata, have proved, on accurate examination, to be fallacious. An instance of this kind came under my observation, when on a visit to my native town, Nottingham, in 1831. A medical gentleman showed me the portion of the thigh-bone of an ox, which he had treasured with great care, as it was obtained from a deep excavation on the side of a hill of sandstone, near Nottingham. As this sandstone belongs to the more ancient of the secondary strata, the red sandstone and marl (see Chap XI.), and as the bone was placed deep under the surface, and the workmen declared there was no fissure or opening near to where the bone was found, the specimen was regarded as affording a remarkable exception to a general law in geology. Knowing from the structure of the rock, that it is almost every where intersected by deep vertical fissures, I was persuaded that the true position of the bone, had not been correctly stated by the workmen; and, on carefully examining the cave, a deep fissure, extending to the surface, was discovered close to the situation where the bone was found. There can be no doubt that the bone had fallen into this fissure, and was thus introduced into a lower stratum of sand rock.

When we consider the violent convulsions and overturnings to which the crust of the globe has been subjected, it is truly surprising that remains of the higher orders of animals should not have been frequently buried in the lower ancient strata, if they had previously existed. Perhaps the bones of small terrestrial animals in the calcareous slate of Stonesfield may have been carried thither by subterranean streams of water during the tertiary epoch; as such underground streams and rivers are of frequent occurrence in many limestone countries.

In the long ages of change and disturbance, during which the solid surface of our planet was approaching to its present state, we may reasonably believe that the earth was not fitted to be the residence of man and the higher order of animals. Even those geologists who deny the progressive developement of organic life, admit that man is a recent inhabitant of the globe; but if, as they maintain, the essential conditions of the earth have been the same as at present, during an indefinite series of ages; if the same causes have always been in operation, without any increased intensity of action; if the earth, from the remotest imaginable epoch, had islands and continents, rivers and seas, enjoying a similar temperature to the present, though placed in different latitudes: if such, I repeat, were, from the remotest epoch, the condition of the globe, no assignable reason can be imagined why it might not have been inhabited by man. — If the same changes were only taking place as we observe at present, or even supposing them to be more extensive in their operation, yet the human race might still have flourished in

> " Some safe retreat in depth of woods embraced,
> " Some happy island in the watery waste."

But the more ancient strata present evidence of overwhelming changes and mighty convulsions, that have elevated mountain ranges, and broken the solid crust of the globe, and scattered the fragments in every direction, during these epochs of disturbance, neither the earth nor the atmosphere could be fitted for the residence of man, or the higher order of animals; nor do we find, among the secondary strata that have once been dry land, any remains of its former inhabitants, except the bones of enormous reptiles.

Though man and the higher orders of animals could not exist during an epoch of universal disturbance, yet we can discover no reason why many genera and species, particularly of marine animals, that have formerly existed, should be now extinct, unless a change have taken place in the temperature of the globe. Indeed, it is found that many genera and species, which are only discovered in a fossil state in Europe, still inhabit the seas of tropical climates, and some species that were supposed to be entirely extinct, have recently been discovered living in southern latitudes. More important discoveries of this kind may probably be made, as we know little respecting the state of animal existence at the bottom of the sea, or what monsters

> " The deep unfathom'd caves of ocean bear."
>
> " Et quæ marmoreo fert monstra sub æquore pontus."

I am inclined to believe, that the ichthyosaurus, or some species of a similar genus, is still existing in the present seas. About sixteen years since, a large animal was seen for several summers in the Atlantic, near the coast of the United States, and was called the great sea serpent. Its appearance was frequently announced in the public journals, but the existence of the animal was for some time disbelieved in this country. I am informed by Professor Silliman of Yale College, Connecticut, of whom I made enquiry, that many persons who attested the existence of the sea serpent from their own observations, were so highly respectable, both for intelligence and veracity, that their evidence could not be disputed.

I remember one of the most particular descriptions of the sea serpent was given by an American captain, who saw the animal raise a large portion of its body from the water: he represented it as of great length, and about the bulk of a large water cask; it had paddles somewhat like a turtle, and enormous jaws like the crocodile. This description certainly approaches to, or may be said to correspond with, the ichthyosaurus, of which animal the captain had probably never heard. An animal of the magnitude attributed to the sea serpent would certainly require paddles or fins to impel it swiftly through the water. I very much regret that I am unable to refer to the American paper from which the account was taken, and must be content to direct the attention of future observers to the above statement, should the sea serpent again appear in the Atlantic Ocean.

In the memoir and correspondence of the late Sir

James Edward Smith, just published, there is a letter from Dr. Goodenough, Bishop of Carlisle, referring to the American sea serpent, from which the following passage is extracted: — "The famous American serpent is at length ascertained to be no fiction. It seems that there has always been a rumour of this animal: Aldrovandus mentions it among others. However, it has never been caught and described. It has now been seen by three hundred people at once, and hopes are entertained that ere long this will be taken. It is of immense length and size." — Nov. 1819.

I cannot conclude these brief observations on the progressive developement of organic life on our planet, without remarking, that if man were recently created, as geologists generally maintain, this circumstance alone affords strong presumptive evidence, to those who admit the doctrine of final causes, and of a presiding intelligence, that the ancient condition of the globe, and the changes then in operation, were very different from what we observe at present; or, in other words, that the world was not then prepared by the Creator for the residence of man.

CHAP. XVI.

ON THE LOWER OR MORE ANCIENT TERTIARY STRATA.

Formation of Tertiary Strata in Lakes or Inland Seas. — Lakes of North America. — Falls of Niagara. — Alternations of Marine and Freshwater Strata. — Arrangement of the Tertiary Strata in the Paris Basin. — Plastic Clay and London Clay. — Geology of the lower Vale of the Thames. — Remains of Crocodiles and the Nautilus in London Clay. — Molasse of Alpnach in Switzerland, with Coal and Teeth of the Mastodon. — *Calcaire Grossier*, or Coarse Limestone of the Paris Basin, supposed to be of the same Age as the London Clay. — *Calcaire Siliceux.* — Gypsum and Gypseous Marl of the Paris Basin, containing Bones of numerous extinct Species of Land Quadrupeds. — Remarks on their Discovery and Organisation by Baron Cuvier. — Marine Sandstone. — Millstone. — Upper Freshwater Formation. — Tertiary Strata in the Isle of Wight. — Crag of Norfolk, its true Geological Position not determined. — Cliffs of Brighton.

The name of tertiary has been given with much propriety to all the strata that are more recent than the secondary; the term is intelligible, and ought not to be changed without sufficient reason; the introduction of new names in science serves only to perplex the student, and is attended with no advantage. The name of super-cretaceous, *which has recently been applied to the tertiary strata, is peculiarly inappropriate, as these strata may cover any of the lower rocks, and in Auvergne they may be seen resting on granite. If a new name were necessary,* post-cretaceous *should have been chosen; as all geologists are agreed, that the tertiary strata were deposited after chalk.*

THE tertiary formations comprise all the regular strata of limestone, marl, clay, and sandstone, that have been deposited after chalk. It is only since the commencement of the present century that they have attracted the notice of geologists: their true nature was before unknown, or they were supposed to be local and alluvial depositions. It is now discovered that tertiary formations are widely spread over many parts of the globe, and are often of considerable thickness.

The first circumstance which proved that the tertiary beds were distinct from the secondary, was the discovery that many of these beds contain the bones of the higher order of animals, as perfect in their organisation as any of the existing species of land quadrupeds. The tertiary beds were farther remarkable, for presenting frequent alternations of beds containing the remains of marine animals, with other beds that contain exclusively the remains of land animals, and plants, and freshwater shells: hence the latter beds were denominated freshwater formations. A more accurate examination of the secondary strata has since discovered, that freshwater formations occur also among the more ancient strata, but their characters are not so distinctly marked. When the first edition of this work was published, viz. early in 1813, the name of freshwater formations was scarcely known in England, but the author ventured to offer an explanation of their formation, from what is now taking place in extensive lakes: a similar explanation has since been generally adopted. " The lakes of North America are seas of fresh water, more than 1500 miles in circuit; they are placed at a considerable elevation above the Atlantic, and at different levels. They unite by small straits or rivers, which have a rapid descent. On some of the rivers are prodigious waterfalls, which are continually enlarging and deepening the passage from one to the other; and will ultimately effect the drainage of the upper lakes. The falls of Niagara are well known; the water is divided by a small island, which separates the river into two cataracts, one of which is 600 yards, and the other 350 yards wide: the height of the fall is from 140 to 160 feet deep. It is estimated that 670,000 tons of water are dashed every minute with inconceivable force against the bottom, and wearing down the adjacent rocks. Since the banks of the cataract were inhabited by Europeans, they have observed that it is progressively shortening the distance of the falls from Lake Erie. When it has worn down the intervening calcareous rocks, the upper lake will become dry land, and form an extensive plain or valley, surrounded by rising ground, and watered by a river or smaller lake, which will occupy the lowest part. *In this plain, future geologists may trace successive strata of freshwater formation, covering the subjacent ancient limestone. The gradual deposition of minute earthy particles, or the more rapid subsidence of mud from sudden inundations, will form distinct beds, in which will be found the remains of freshwater fish, vegetables, and quadrupeds.*" —1st edition, 1813, pp. 182, 183.

In the frontispiece to the present volume will be seen a bird's-eye view, or map of the country round Niagara, drawn by my eldest son, who passed several days at the falls of Niagara in 1830. In this drawing the accurate proportion of distance is disregarded, in order to bring the several objects into one point of view. The deep chasm formed by the cataract is seen in front, from which the water is issuing into a lower country at Lewis Town, nearly on a level with Lake Ontario, into which the river flows. Mr. Joseph Henry, in a topographical sketch of the state of New York, says, " The descent of the country from Lake Erie to Ontario is principally by a step, not at the falls, but at Lewis Town, several miles below :" this is the position from which the drawing in the frontispiece was taken. Mr. H. adds, " In viewing the position of the falls, and the features of the country round, it is impossible not to be impressed with the idea, that this great natural race-way has been formed by the continued action of the irresistible current of the Niagara, and that the falls, beginning at Lewis Town, have, in the course of ages, worn back the rocky strata to their present site. The deep chasm through which the Niagara passes, below the falls, is nearly a mile wide, with almost perfect mural sides." — *Transactions of the Albany Institute.*

In Mr. Loudon's Magazine of Natural History, March, 1830, there is an account of the falls of Niagara, and of the physical structure of the adjacent country, by my son, Robert Bakewell, junior. I preferred making the above extract from Mr. Henry's description, as it confirms the general accuracy of the drawing in the frontispiece. Below will be seen a statement of the levels and the extent of the North American lakes.* These lakes may justly be styled seas of fresh water. Though their present surface is considerably elevated above the level of the ocean, the bottom of some of the largest lakes is much below the tide line; and were these lakes situated nearer to the Atlantic, we might easily imagine that after the fresh water had subsided to the sea level, they might be subject to frequent irruptions of salt water, which would produce a change in the nature of the inhabitants of these lakes; or, in other words, would occasion alternations of marine with fresh-water strata, without any change in the relative level of the land and sea.

In England and France, there appears to have been a considerable interval between the deposition of the chalk, and of the lowest beds of the secondary strata; for the surface of the chalk is deeply furrowed and broken, apparently by the action of torrents, or inundations, and the hollows filled by the tertiary

---

* From Lake Erie to the falls of Niagara, the distance is 21 miles. From the falls to Lewis Town, at the mouth of the chasm, the distance is 7 miles. From Lewis Town to Lake Ontario the distance is 7 miles.

	Elevation above the sea. Feet.	Mean depth.	Length. Miles.	Mean breadth.
Lake Superior	641	900	300	80
Lake Huron	596	900	200	95
Lake Michigan	600	900	300	50
Lake Erie	565	120	230	35
Lake Ontario	231	492	180	30

Total quantity of square miles covered by the lakes, 72,930.

beds. In some parts of the Continent, however, the line of separation between the secondary and tertiary strata is not so distinctly marked, and they are both elevated together conformably.

The tertiary strata form the outer crust of the globe, and have every where been subjected to erosion from torrents and inundations, that have swept over parts of its surface, and transported the fragments into distant countries or into the ocean. We cannot, from the present localities of the upper strata, determine, with any precision, the boundaries of the inland lakes or seas in which they were deposited. Many of these strata have evidently once extended far beyond their present limits; but have been so completely destroyed, that we can only infer their former existence, by a few remaining detached portions.

In France, the tertiary strata are more widely spread, and many of them more fully developed, than in England: it is indeed scarcely possible to imagine a more distinct display of the series of strata in any class of rocks, than is presented close to the very gates of Paris. In a capital so distinguished for scientific investigation, and possessing so many able and acute observers, it does, indeed, seem extraordinary, that the strata with which they were surrounded, should never have been properly examined until so recent a period, as the early part of the present century. What is daily before our eyes seldom excites attention, or is deemed deserving of much notice; but there was another cause which long prevented the philosophers of Paris from observing the remarkable objects around them. Captivated with the generalisations of Werner, who, it was firmly believed, had unlocked all the hidden mysteries of geology, and comprised in his system all the different formations that composed the crust of the globe, they saw before them a series of strata which had no agreement with any part of the Wernerian classification; hence they could not avoid the painful persuasion, either that the system of Werner was incomplete, or that they were unable to apply it properly. To avoid an acknowledgment so little satisfactory, the geologists of Paris averted their attention, and that of their pupils, from nearer objects, and directed them to the mountains of Germany or Switzerland. Had not another science (comparative anatomy) come to the aid of geology, we might yet have remained unacquainted with the tertiary strata around Paris. At length, the number of skeletons of strange and unknown animals discovered in some of the strata, forcibly attracted the notice of that distinguished naturalist, Cuvier, and it was resolved to investigate attentively the geology of the whole district. M. A. Brongniart was associated with Cuvier in the investigation; and in 1811 the result of their labours and observations was given in a work entitled *Essai sur la Géographie Minéralogique des Environs de Paris*, — the most luminous and interesting exposition of local geology ever presented to the world; and from this period we may date the first accurate knowledge of the tertiary strata.

The following extract from the Essay of MM. Cuvier and Brongniart, presents a general view of the arrangement of the strata round Paris: —

" The country in which the capital of France is situated, is perhaps the most remarkable that has yet been observed, both from the succession of different soils of which it is formed, and from the extraordinary organic remains which it contains. Millions of marine shells, which alternate regularly with freshwater shells, compose the principal mass. Bones of land animals, of which the genera are entirely unknown, are found in certain parts; other bones remarkable for their vast size, and of which some of similar genera (*quelques congenères*) exist only in distant countries, are found scattered in the upper beds. A marked character of a great irruption from the south-east is impressed on the summits (*caps*), and in the direction of the principal hills. In one word, no country can afford more instruction respecting the last revolutions, which have terminated the formation of the present continents."

Though chalk is the foundation rock of the country, for a considerable extent round Paris, it only rises to the surface in a few situations, being covered by tertiary strata. The total thickness of the tertiary strata over the chalk, as given in an ideal section of the country, is nearly five hundred feet.*

Many of the tertiary beds in the Paris basin are not found elsewhere, and therefore cannot be taken as types of other tertiary formations; and the lower bed, called the plastic clay, is but very imperfectly developed near Paris. In attempting to generalise the tertiary formations, a difficulty presents itself, if we are to class them by their zoological characters; for some of the formations, which contain exclusively the remains of marine animals in certain situations, contain in other situations river or lake shells, with wood and the bones of land animals. It is, therefore, probable, that while the waters in one lake or basin might be saline, those in another lake might be fresh; and two cotemporaneous formations may hence contain very different organic remains.

The tertiary strata in England and in the north of

---

* The following ascending series of beds in the Paris basin was first given as a correct account of their succession: more extended observations have proved that the position of No. 3., or the Calcaire siliceux, is higher in the series.

1. Plastic Clay and Lower Sand.
2. Calcaire grossier.
3. Calcaire siliceux and Sandstone.
4. Gypseous Marl.
   Gypsum with Bones.
   Upper gypseous Marl.
5. Sandstone and Sand without Shells.
   Upper Marine Sandstone.
   Millstone without Shells.
6. Freshwater Limestone, including Marls, and Millstone, with freshwater Shells.
7. Alluvial Soil, ancient and modern, including Pebbles, Pudding-stone, Black Earth (*les marnes argilleuses noires*), and Peat.

France, may be arranged under four divisions, which are given below: after describing these, the more recent tertiary strata, called by some French geologists Quaternary, will be noticed in the following Chapter.

TERTIARY FORMATIONS.

1. Lower Marine Beds. -	Sometimes intermixed with freshwater beds.
a Argillaceous and Sandy deposits, Plastic Clay, Sand, London Clay - -	*Argile et Grès tertiaires à lignites.*
b Lower Marine Limestone -	*Calcaire grossier.*
2. Lower Freshwater Beds.	Sometimes intermixed with Marine.
a Marl.	
b Gypsum.	
3. Upper Marine Formation.	
a Sand, Sandstone and Millstone without Shells.	
b Sandstone with Shells.	
4. Upper Freshwater Formation.	
a Limestone - - -	With freshwater Shells.
b Siliceous Millstone - -	

The tertiary strata supposed to be more recent, and called Quaternary, are nowhere observed covering the above formations, because they were deposited in detached seas or lakes: the evidence of these being more recent than the strata in the Paris and London basins, rests on the species of shells they contain, being in a large proportion analogous to existing species.

Plastic Clay and London Clay. — These, with the various associated beds of sand, may properly be regarded as one formation, of which the plastic clay is the lowest member resting on chalk. Near Paris the plastic clay is a very thin bed; but in the south of France it acquires a great degree of thickness, and appears to comprise the upper argillaceous beds, or what we call the London clay: it is remarkable for the vegetable fossils and beds of lignite, which it frequently, but not invariably, contains. In England, in the lower beds of this formation, there are found beds of imperfect wood coal; but both in the plastic clay and the London clay, remains of marine animals are chiefly prevalent, though intermixed with some freshwater shells; whereas, on the Continent, beside the great quantities of fossil wood and wood coal found in the same argillaceous beds, there are numerous remains of freshwater shells, which render their title to be denominated marine formations more than doubtful. The beds of sand are sometimes of considerable thickness. By many geologists it is maintained that the beds of soft sandstone (called *Molasse*), and of sandstone conglomerate (called *Nagel flue*, in Switzerland), belong to this part of the tertiary formations. That some of these beds may be tertiary I will not deny; but I am fully convinced, that many beds called molasse, in Savoy, are covered by the Jura limestone and oolites, having repeatedly seen them in contact, and got specimens from each bed at the line of junction.*

---

* As the opinions of geologists have been much divided respecting the molasse, or soft sandstone, of Switzerland and Savoy, I shall here insert some observations upon it, given in the first volume of my Travels in the Tarentaise.

" The outer calcareous mountains on the western side of Savoy, all rest upon an immense formation of soft sandstone (molasse), and are interstratified with it; and, so far from this sandstone being more recent than the limestone (as Saussure supposed), it constitutes a considerable part of the bulk of these mountains that are called calcareous. In the Valley of les Echelles, the immediate junction of the limestone with the sandstone may be seen soon after entering the valley form the archway. This vast wall of limestone, nearly one thousand feet in thickness, rests upon a mass of sandstone of unknown depth: there is very little dip where the first junction is seen, but about a mile below, you meet with the limestone again in conjunction with the sandstone, and thrown into a vertical position. The workmen that I met with near the mouth of the gallery said they always found sandstone below the limestone, and they considered it as the lowest bed in the country: but this is obviously a mistake. The sandstone, or molasse, on which the limestone in this part of Savoy reposes, or which is subordinate to the limestone, is composed of smallish grains of quartz and chlorite, pretty equally mixed. In the sandstone of les Echelles, which I got from its junction with the limestone, there were some particles of rose

The bones of horses, with the tooth of an elephant, have been found in a bed of unctuous clay, resting on chalk, near Margate; but as the clay is superficial, it may be a diluvial formation.

In France, near d'Auteuil, and south of the Dordogne, according to Humboldt, bones of vertebrated land animals are found in a formation resting on chalk, analogous to the plastic clay. Baron Cuvier says, however, that he has not discovered the bones of land quadrupeds in any strata below the *calcaire grossier* which covers the plastic clay. But neither the plastic clay nor the gypsum beds of Paris can be taken as types of the tertiary strata in other countries.

The London clay is placed over the plastic clay and sand, and is, in fact, an upper member of the great arenaceous and argillaceous formation that covers chalk. Some geologists attempt to identify the London clay with the beds of calcaire grossier, and of gypsum, in the Paris basin, but their mineral characters are most essentially different. By attempting to force an agreement with artificial classifica-

---

quartz and mica. It scratched glass strongly when rubbed upon it; but when put into a dilute muriatic acid, it effervesced violently, and became friable, owing to the solution of the calcareous cement by which it appears, from this experiment, to be agglutinated. The molasse, which is interstratified with limestone and associated with coal on the lake of Annecy, also effervesced; but, the particles being smaller, it appeared nearly homogeneous when examined without a lens. It has been recently stated, that the molasse of the Alps belongs to the same formation, as the sandstone above chalk near Paris. There may be sandstone of that formation in the canton of Berne; but the molasse or sandstone in this part of Savoy, I am well convinced, is a member of formations that are lower than chalk. It is possible, however, that beds of this molasse may have been worn down during the great destruction of the strata, that has evidently taken place since they were deposited, and from the debris of this sandstone, upper beds may have been formed covering strata that are above chalk. The molasse which covers the bones and teeth of the mastodon and other large mammalia, near Alpnach, nearly resembles that in this part of Savoy; but the particles are smaller, and more intimately mixed."— P. 176.

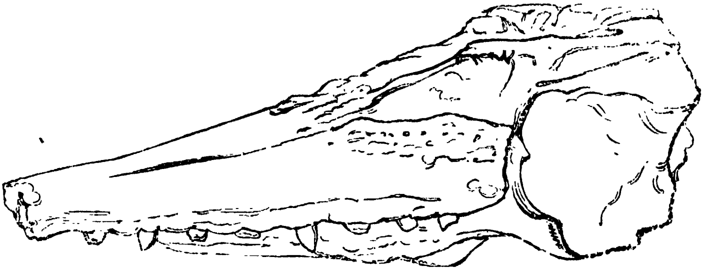
tions, where it does not exist, we mystify what is clear and simple, and retard the progress of knowledge.

The uppermost bed of the London clay is of a reddish brown colour, and is more arenaceous than the lower beds: the colour of the lower beds varies from a bluish lead colour, to a blackish brown; they are often considerably indurated, and have somewhat of a slaty structure. The thickness of the London clay varies from one hundred to four hundred feet or more: this variable thickness is occasioned by the upper beds which form the surface of the land in the Vale of Thames, having been more excavated in some parts than in others.

As the London clay and plastic clay and sand, taken together, equal or exceed in thickness the beds of plastic clay, calcaire grossier, and gypsum in the Paris basin, the London clay may properly be regarded not as identical with the calcaire grossier and gypsum, but as their geological equivalent. While the beds of limestone and gypsum were depositing in the Paris basin, the London clay might be deposited in the London basin; and this may explain why many species of marine shells in the London clay are similar to those found in the calcaire grossier; but we nowhere discover the astonishing variety of species that occur in some of the strata of the calcaire grossier; nor have any bones of land quadrupeds, similar to those in the Paris basin, been found in the London clay. The two sides of the trough or basin in which the London clay and plastic clay were deposited, are formed on the north, by the range of chalk hills in Hertfordshire and the adjacent counties, and on the south, by the range of chalk hills in Surrey and Kent.

The relative geological position of the chalk, the plastic clay and sand, immediately upon it, and the upper beds of London clay covering the Vale of Thames, is represented in a small section at the bottom of the map of England. (Plate VI.) In some parts of the Vale of Thames, as at Hampstead, north of London, and near Cobham in Surrey, the London clay rises into hills three hundred feet above the Vale of Thames, and is capped by a bed of sand, which has received the name of the upper marine sand. *a, a,* chalk, *b, b,* plastic clay, *c, c,* London clay, *d, d,* marine sand. From this small section, the geological student may form some idea of the devastating effects of mighty inundations, which have swept over the surface of the globe, and carried away considerable portions of the upper beds. The marine sand, *d, d,* which forms isolated caps on several of the hills in the Vale of Thames, was probably part of one continuous bed, which has been excavated with a portion of the subjacent London clay; such excavations and denudations are common phenomena in almost every country.

Balls of imperfect ironstone, called *septaria* (of which Parker's cement is made), are common in some parts of the London clay; branches and stems of trees, penetrated by the *Teredo navalis,* are found in it, and a species of resin, to which the name of *retinasphaltum* was given by Mr. Hatchett. Remains of turtles have been dug out of this clay at Highgate and Islington. Some bones of a crocodile were discovered by Mr. Parkinson, who considers this as a solitary instance of the occurrence of the remains of these animals in the London clay. In 1830, the head of a crocodile was found by E. Spencer, Esq. of Highgate, in the London clay in the Isle of Sheppey, of which the annexed cuts give a correct repre-



a front view of the head, with the two small cavities for the lobes of the brain, and the larger cavities for the orbits of the eyes. The length of the head, when entire, and clothed with scales and muscles, must have been about one foot; hence we may infer, that the entire length of the animal was about six feet. Whether this was the head of a young animal, or of an adult of a small species, cannot, perhaps, be determined. From the rare occurrence of the bones of saurian animals in the tertiary strata, we may infer that these animals whose remains are so abundant, and of such large magnitude, in the secondary strata, had nearly disappeared in northern latitudes, at the epoch when the tertiary strata were deposited.

The teeth and tusks of elephants have been discovered in many situations, in what is supposed to have been London clay, but which may have been a covering of diluvial clay; for the patches of diluvial gravel that are spread over many parts of the Vale of Thames, frequently contain the remains of elephants.* Ammonites and belemnites, and many

---

* In clearing away the bed of gravel on the north side of the Regent's Park, the tusks of elephants were found, but in a mouldering state, in 1818.

genera of testaceous animals, that have left their remains in chalk and the lower strata, appear to have been extinct before the deposition of the London clay. Nautilites are, however, found in it, similar to the species inhabiting the Indian Ocean, and bivalve and univalve shells are so numerous, that it would be difficult to select any particular species, as peculiarly characteristic of this formation. The shells mostly belong to genera inhabiting our present seas; yet slight variations of form may be perceived, which have induced naturalists to regard them as distinct from living species.

The springs that rise in the London clay are generally impregnated with sulphate of iron and sulphate of lime, and some of the springs contain sulphate of magnesia; the quality of the water, however, varies much in different situations, and at different depths. To obtain soft water, it is necessary to bore or sink through the London clay to the sand above the chalk, and sometimes into the chalk itself.* The London clay and the under beds have been perforated to the depth of three or four hundred feet in some situations, before good water could be obtained; when the stratum is pierced which holds the best water, it rises almost immediately, and sometimes overflows the surface. This admits of an easy explanation, by referring to the section of the Vale of Thames. (Plate IV.) The

---

* At the village of Wilsden, three miles north-west of London, the boring for water was made two hundred and eighty feet into the clay, and seventy-five feet below it into the chalk, when the water immediately rose to within thirty-five feet of the surface. Chalk rocks, and other calcareous rocks in which the strata are divided by fissures that are not filled with clay, always contain water in the fissures when the strata dip under the surface of the ground, or when they are covered by argillaceous beds. This is also the case with coal strata; and the presence of water is necessary to keep the coal in good condition. If the water be entirely drained from a bed of coal a considerable time before it is worked, the quality of the coal is much deteriorated. This may be occasioned by air penetrating the fissures, and promoting the decomposition of pyrites in the coal.

water which enters the edges of the porous strata, say at *x x*, descends to the lowest part of the trough or basin, and when perforated would rise to near the level of *x x*, were the strata deposited in a circular basin, the edges of which rose on each side from the bottom of the Vale of Thames; but the strata are deposited in a longitudinal basin or trough between the chalk hills of Hertfordshire and Surrey, and the river Thames cuts through the porous edges of the strata below Greenwich; so that the water being there let out, can seldom rise in wells much above the high-water mark. Were it not for this, we might have natural *jets d'eau* of considerable height and magnitude in all the squares of London, to cool and refresh the air during the summer months, and supply the inhabitants in the vicinity with salubrious water. In order to preserve the water pure, that is obtained from chalk or the sand over chalk, it is necessary to line the inside of wells, or to put down tubes, to prevent the water from the London clay, intermixing with the pure water from below.

As the plastic clay and London clay contain wood coal, or lignite, which is supposed to be characteristic of these beds, probably the strata with wood-coal at Alpnach (see Chap. VIII.), may be regarded as belonging to a similar epoch. Some French geologists would place these strata still higher in the tertiary series. The strata at Alpnach are peculiarly remarkable for containing the remains of the narrow-toothed mastodon, and of other mammalia, at the depth of nearly three hundred feet from the surface. The annexed cut is taken from a drawing of one of these teeth in the possession of the late Professor Meisner, of Berne, who also gave me specimens of the strata below which the tooth was found.

It is deserving notice, that teeth almost exactly similar were found on the volcano of Imbaburra in the Andes, which is ten thousand feet above the level of the sea. I have one tooth in my possession from thence, purchased at the sale of the late M. Faujas de St. Fond, of which the annexed cut may also serve as a correct representation.

The strata at Alpnach consist of the following beds, in a descending series: —

		Feet.	Inches.	
1.	Light grey sandstone - -	24	0	
2.	Light grey limestone like Jura limestone - - -	24	0	
3.	Different beds of Molasse or soft sandstone - -	227	0	
4.	Light grey sandstone with mica, like No. 1. - -	6	0	
5.	Light grey argillaceous limestone - -	1	6	
6.	Bituminous shale in layers -	7	0	
7.	Stinkstone, a bituminous limestone with bones and river shells, the roof of the coal	1 to 2 feet.		
8.	Coal - - -	0	6	In.
9.	Bituminous schist - -	0	6	to 8

	Feet.	Inches.
10. Coal - - -	2	0
11. Bituminous clay - -	6	0
12. Molasse and sandstone -	66	0

The bituminous strata, and shaly limestone, possessed all the characters of beds in the regular coal formations in England: probably the fetid quality of the limestone No. 7, was derived from the abundance of animal matter which it might contain. No. 2. is subcrystalline, and bears a near resemblance to mountain limestone in its mineral characters.

Above the London clay there is no calcareous formation, except in the Isle of Wight, but in the Paris basin there are two; of which the lowest is called *Calcaire grossier.*

Le calcaire grossier, or coarse limestone of Paris, is deposited upon the plastic clay, as the latter is upon the subjacent chalk: between the plastic clay, however, and the *calcaire grossier,* there is a bed of sand; but geologists are not determined, to which of the two formations it belongs. The *calcaire grossier* differs in its quality in the different beds, but it may be described generally as a yellowish earthy limestone, which bears some resemblance to Portland stone in its fracture, texture, and colour; but it is not oolitic. The strata of limestone alternate with argillaceous marl and shale, and with calcareous marl.

The lowest bed of *calcaire grossier* is soft, and much intermixed with green particles and sand; it contains a great number of the fossils called nummulites, on account of their being flat and round, and resembling in shape a small coin. The shells in this bed are in high preservation. In the beds immediately above, called the middle beds, there are a prodigious number of marine shells, and also the stems and impressions of leaves of plants that are not marine. In the lowest and middle beds of the *calcaire grossier,* no less than six hundred different species of shells are found.

In the upper part of the *calcaire grossier,* the strata are several feet thick, and yield a hard coarse-grained and durable limestone: it is from these strata that the best building-stone is procured. It is often nearly filled with shells of the genus *cerithium*, and has hence been sometimes called *calcaire à cerites.*

Between the strata of building-stone, there often occur thin strata of flint or chert; in some parts these siliceous strata enlarge into thick beds of chert (*silex corné*), or into beds of sandstone containing marine shells; in the beds of this sandstone, at Pierrelaie, freshwater shells have been discovered, mixed with numerous marine shells. The total thickness of the beds of *calcaire grossier*, near Paris, is about ninety feet.

No beds of limestone resembling the *calcaire grossier* of Paris, are found in the tertiary strata of England. The *calcaire grossier* in the departments of La Dordogne and La Gironde, and other parts of France, presents a considerable difference from that in the Paris basin. In Hungary, extensive strata of the *calcaire grossier* have been described by M. Beudant; they are in every respect analogous to the strata in the Paris basin, both in their mineral and zoological characters. The lower beds also are intermixed with shelly sand, and green particles, which bear a close resemblance to the shelly depositions in the plain of Lombardy. M. Humboldt thinks he discovered a formation similar to the *calcaire grossier*, in some parts of South America.

Calcaire siliceux is composed of limestone, sometimes grey and compact, and sometimes tender and white: it is penetrated by silex in every direction, and in all its parts. According to the early opinion of M. Brongniart, the *calcaire siliceux* occupies the place of the *calcaire grossier* where the latter is wanting; others regard it as an upper formation above the middle gypsum. Some of the beds of the *calcaire siliceux* furnish mill-stones, and contain river shells. In this bed, the siliciate of magnesia was discovered by

M. Brongniart. The siliceous infiltrations sometimes form plates of chalcedony, and mammillated concretions of chalcedonic chert, coloured red, violet, and brown.

Gypseous Marl and *Gypsum.* — This remarkable formation occurs in detached hills along the course of the rivers Marne and the Seine; it is supposed to have originally extended as one continuous bed from east to west, twenty-five leagues in length and eight in breath: its greatest thickness is about two hundred feet.

The gypsum formation consists of alternating beds of gypsum and argillaceous and calcareous marl, which are regularly arranged, and preserve the same order of succession wherever they have been examined. The gypsum forms three distinct masses. The lowest consists of thin strata of gypsum containing crystals of selenite, which alternate with strata of solid calcareous marl, and with argillaceous shale. The middle is like the lowest mass, except that the strata of gypsum are thicker, and the beds of marl are not so numerous; it is chiefly in this mass that fossil fish are found. The uppermost mass is the most remarkable and important of all; it is in some parts more than seventy feet thick; there are but few beds of marl in it; the lower strata of gypsum in this mass have a columnar structure: the gypsum is pure, and finely granular; it has a light yellowish brown colour, which might perhaps more properly be called a dirty white. In this upper mass of gypsum the skeletons and scattered bones of birds and unknown quadrupeds are discovered; sometimes they are found in the solid gypsum, and sometimes in the marl that separates the beds. Remains of turtles and crocodiles have also been found in the same strata. It is to the indefatigable and enlightened labours of Baron Cuvier that we are indebted for a knowledge of the different genera of remarkable land quadrupeds, belonging to a former world, found in the gypsum quarries; they differ from any genera of living animals. These land quadrupeds were herbivorous; they belong to the order which Cuvier has denominated *Pachydermata*, or thick-skinned non-ruminant animals. One of the genera called *Palæotherium* (or ancient animal), appears to bear some relation to the rhinoceros, the hippopotamus, and horse, and in some respects to the pig and the camel.

Of this genus there are eleven or twelve species; five of them have been found in the Paris gypsum. The largest was the size of a horse, but its form was heavy, and its legs thick and short; its grinders resemble those of the rhinoceros and the daman*; it had six incisive and two canine teeth, like the tapir, and, like that animal, had a short fleshy trunk: it had three toes on each foot, and is supposed to have inhabited marshy ground, and to have lived on the roots and stems of succulent marsh plants. One of the species, however, possessed the size and the light figure of the Antelope, and is supposed to have browsed on aromatic plants, or the buds of young trees in dry situations, like other light herbivorous animals. Probably, says Cuvier, it was a timid animal, with large movable ears, like those of the deer, which could apprise it of the least danger: doubtless its skin was covered with short hair; and we only want to know its colour, in order to paint it as it formerly lived in the country where, after so many ages, its bones have been dug up.

One species of the *palæotherium* was not larger than a hare.

The *Anoplotherium*, or animal without defensive teeth, has only been found in the gypsum quarries near Paris. It has two very distinctive characters: the feet have only two toes, which are separated the whole length of the foot; the teeth, of which there are six incisive in each jaw, a canine tooth of the same height, and six molares or grinders, all form a

---

* An African quadruped, the size of a rabbit, but closely resembling the rhinoceros.

continued series without any interval, which is the case with no other known quadruped. The most common species is of the height of a boar, but much longer. There are remains of other animals, in the same quarries, allied to the anoplotherium, but which differ in the form of their teeth. The bones of six species of birds have been discovered in these quarries, and also the remains of a few carnivorous animals allied to the dog and the weasel. It is remarkable, that in the middle of the gypsum formation, and throughout the greater part of it, we find the remains of land animals and of freshwater fish and shells; but near its upper and lower limits, both in the gypsum and the gypseous marl, the fossils are those of marine animals. A bed of green marl, which may be very distinctly traced near the termination of the upper mass of gypsum, separates the freshwater from the sea shells; and in the lower part of the gypsum formation, marine shells are found in the gypsum itself.

It may be useful to those strangers who visit Montmartre for the first time, to state, that this thin green bed, which can be distinctly seen and traced, may serve them as a key to the geology of the place; as it separates all the lower marine and freshwater formations from the upper.

The gypsum of the Paris basin was probably deposited in an extensive lake, on the borders of which the land animals, whose remains are discovered in it, flourished and perished. Some of them appear to be formed for swimming, or living much in the water, like the otter or water-rat. Whether the water in this lake was salt or fresh, is by no means certain; though M. Brongniart thinks that a single freshwater shell found in the gypsum would decide the question: but this opinion, however high the authority of so distinguished a naturalist and geologist may be, cannot, I conceive, be maintained; for in some of the beds, we meet with a mixture of marine and freshwater shells, — and in this case who shall determine, whether such beds are of marine or freshwater origin? The intermixture of shells clearly shows, that they have been transported from their native situations, or that marine and freshwater mollusca may live in the same estuary or lake, if the water be brackish, which is confirmed by recent observations and experiments.

The fossil bones found in the gypsum quarries near Paris are light and porous, and appear to have been scarcely penetrated by gypsum: this is very remarkable; for if we suppose the gypsum to have been held in solution by water, like the sulphate of lime in recent springs, it seems extraordinary that it should not have penetrated into the pores of the bones. I am not aware that the circumstance has before been noticed by geologists, but I think the state of the bones proves, that they were rapidly enveloped by the gypsum, before the animal matter in the pores was decomposed; and also, that the gypsum was speedily consolidated. The same observation would apply to the bones of land animals I found in the freshwater limestone, under the volcanic mountain of Gergovia, in Auvergne; the state of these bones was similar to those in the Paris gypsum.

Baron Cuvier was the first naturalist who successfully applied the knowledge of comparative anatomy, to ascertain the forms of vertebrated fossil animals. The publication of his *Recherches sur les Ossemens Fossiles* may be regarded as an epoch in geology: since that time, many other important discoveries respecting fossil quadrupeds have been made. It will not, therefore, be deemed irrelevant to our subject, to insert the very interesting account he has given of his own feelings when he first became able to arrange the bones of each genus and species of unknown animals, found in the gypsum quarries near Paris: — "When the sight of some bones of the bear and the elephant, twelve years ago, inspired me with the idea of applying the general laws of comparative anatomy, to the reconstruction and the discovery of fossil species; when I began to perceive that these species were not perfectly represented by those of our day, which resembled them the most; — I did not suspect that I was every day treading upon a soil, filled with remains more extraordinary than any that I had yet seen; nor that I was destined to bring to light whole genera of animals unknown to the present world, and buried for incalculable ages at vast depths under the earth. It was to M. Veurin that I owe the first indications of these bones furnished by our quarries: some fragments which he brought me one day, having struck me with astonishment, I made enquiries respecting the persons to whom this industrious collector had sent any formerly: what I saw in these collections served to excite my hopes and increase my curiosity. Causing search to be made at that time for such bones in all the quarries, and offering rewards to arouse the attention of the workmen, I collected a greater number than any person who had preceded me. After some years I was sufficiently rich in materials to have nothing further to desire; but it was otherwise with respect to their arrangement and the construction of the skeletons, which alone could conduct me to a just knowledge of the species. From the first moment, I perceived that there were many different species in our quarries; and soon afterwards, that they belonged to various genera, and that the species of the different genera were often of the same size; so that the size alone rather confused than assisted my arrangement. I was in the situation of a man who had given to him, *pêle mêle*, the mutilated and incomplete fragments of a hundred skeletons, belonging to twenty sorts of animals, and it was required that each bone should be joined to that which it belonged to. It was a resurrection in miniature; but the immutable laws prescribed to living beings were my directors.* At the voice of comparative

---

* In the following passage Cuvier has more fully explained what he denominates "the immutable laws prescribed to living beings:"—"Every organised being forms a whole and entire

anatomy, each bone, each fragment, regained its place. I have no expressions to describe the pleasure experienced, in perceiving that, as I discovered one character, all the consequences, more or less foreseen, of this character, were successively developed. The feet were conformable to what the teeth had announced, and the teeth to the feet; the bones of the legs and the thighs, and every thing that ought to reunite these two extreme parts, were conformable to each other. In one word, each of the species sprung up from one of its elements. Those who will have the patience to follow me in these memoirs, may form some idea of the sensations which I experienced, in thus restoring by degrees these ancient monuments of mighty revolutions. This volume will afford much interest to naturalists, independent of geology, showing them, by multiplied examples, the strictness of the laws of co-existence, which elevate zoology to the rank of the rational sciences, and which, leading us to abandon the vain and arbitrary combinations that had been decorated with the name of *systems*, will conduct us at last to the only study worthy of our age — to that of the natural and necessary relations, which connect together the different parts of all organised bodies. But geology will lose no-

---

system, of which all the parts mutually correspond and co-operate, to produce the same definite action, by a reciprocal re-action; none of these parts can change, without a change of the others also. Thus, if the intestines of an animal are organised in a manner only to digest fresh flesh, it is necessary that his jaws should be constructed to devour the prey, his claws to seize and tear it, his teeth to divide the flesh, and the whole system of his organs of motion to follow and overtake it, and of his organs of sense, to perceive it at a distance. It is necessary, also, that he should have seated in his brain the instinct to hide himself and spread snares for his victim: such are the general conditions of a carnivorous regimen; every carnivorous animal must infallibly unite them, — without them the species could not subsist. But, under these general conditions, there are particular ones with respect to the size of the species, and the abode of the prey, for which each animal is disposed."

thing by this accessary application of the facts contained in this volume: and thus the numerous families of unknown beings, buried in the most frequented part of Europe, offer a vast field for meditation."

Upper Marine Sand and *Sandstone.*—In the Paris basin this formation covers the gypsum, or where that is wanting, it rests on the *calcaire grossier.* The marine sand and sandstone is divided into two beds; the lower is without shells *in situ,* though some broken fragments occur in it. This sandstone is frequently composed of grains of transparent pure silex, and occasionally small scales of mica. In some situations this sandstone is penetrated by calcareous infiltrations. In other situations there are balls and masses of much harder sandstone, which are used for paving stones in Paris, but they are not durable. At the forest of Fontainebleau in France, the thickness of this sand and sandstone, exceeds one hundred and seventy feet; the sandstone occurs in loose blocks and irregular masses, and sometimes is distinctly stratified. In some parts the sand is so pure that it is used in making the finest glass. In other parts the quantity of calcareous earth is so large, that it assumes the form of calcareous crystals. There is no stratum of this marine sandstone in England, but detached blocks of similar stone, called (grey weathers) are scattered over some of the southern counties, and some of the large stones at Stonehenge are of the same kind. South of Nemours, in passing from Lyons to Paris, I observed masses of this sandstone loosely imbedded in sand, at considerable elevations, and as the sand becomes washed away, these masses fall out, and are scattered over the lower ground; in this manner the occurrence of the blocks of grey weathers may be accounted for: they are the remains of a formation of upper sandstone, which has disappeared in England.

The Upper Marine Sand and *Sandstone* contains numerous marine shells; it has frequently a reddish colour; it is a thin bed, compared with the sandstone without shells, and is not of general occurrence. It may be studied at Montmartre. Whether any analogous beds have been found in England, is not well ascertained, but the beds of sand at Bagshot Heath, and in other situations resting on London clay, have been generally classed with the upper marine sandstone of the Paris basin. The Bagshot sands consist according to Mr. Warburton, of ocherous sand, foliated green clay, with green sand, and various coloured marls; a few marine shells have been found in this sand. The Crag of Norfolk has been often classed with the upper marine sand, but it probably belongs to a more recent series, and will be noticed at the end of the present chapter.

The marine sand and sandstone is in some parts covered with a bed of argillaceous and ferruginous marl, from three to fourteen feet in thickness, in which are imbedded irregular layers of compact silex or hornstone, full of pores and cavities, which give it a corroded and cellular appearance. It is this asperity of surface that renders this stone peculiarly fitted for mill-stones. The substance of mill-stone, when unmixed, is pure silex; it has generally a reddish or yellowish colour, but that of the best quality is nearly white. All the best mill-stones used in England are brought from this bed, and are known by the name of Burrh stones. There are no shells or organic remains in this bed.

Upper Freshwater Formation. — This formation, though extensively spread over many parts of the Continent, is scarcely known in England: it occurs in the Isle of Wight. In the Paris basin it covers all the other tertiary strata, and is itself covered with vegetable soil. The upper freshwater formation is so called, because all the shells it contains are analogous to freshwater shells: it consists principally of calcareous earth, and siliceous earth, sometimes separated, and sometimes intermixed. Calcareous earth, in the state of pure limestone, is the most common: large masses of freshwater silex are more rare. The silex occurs sometimes as a pure translucent flint, and sometimes opaque, with a resinous fracture; sometimes it approaches to the state of jasper, and sometimes it has all the characters of mill-stone.

Freshwater limestone, in the vicinity of Paris, has generally a greyish white, or a yellowish colour; it is sometimes as tender as chalk, and sometimes hard and compact, with a fine grain and conchoidal fracture: in the latter state it is brittle, and breaks into sharp-edged fragments like flint. Some of this limestone, at a distance from Paris, particularly that of Château Landon, presents the character of a transition marble, and will receive a fine polish. Several of the basins with *jets d'eau* in the gardens of the Thuilleries are made of this marble. Many of the harder-freshwater limestones, however, rapidly disintegrate on exposure to air and moisture, and fall to the state of marl, and are used as manure. This formation is characterised by containing exclusively freshwater and land shells, similar to what are found in the neighbouring marshes; they belong to a small number of genera or species, being chiefly lymnites, planorbes, turbinated shells, (allied to *cerithea*,) cyclostoma, and helices.

Having described the tertiary strata round Paris and London, I shall proceed to the tertiary strata in the Isle of Wight, which contain many beds that are wanting in the London strata. The formations of the north of France and of England, do not, as it was once imagined, compose the whole of the tertiary deposits, but only the lower and middle parts. A brief account of the tertiary formations in other countries will be subsequently given.

For the first accurate account of the tertiary strata in England, we are indebted to Mr. Webster, who published, in vol. ii. of the Transactions of the Geological Society of London, a description of these strata in the Isle of Wight, and their connection with the subjacent chalk. The chalk covered by the London clay passes under the channel, called the Solent, and rises in the middle of the island, forming a range of hills which extends from Culver Cliffs on the east, to the Needles on the west. Here we meet with a remarkable derangement of the beds of chalk, and of the superior strata; part of the strata of this range of hills are thrown into a position nearly verticle from the western to the eastern side of the island, evincing the action of a mighty disturbing force, which can be so often observed to have broken or upheaved the secondary and tertiary strata, in the vicinity of the Alps. Evidence of the same dislocation of the strata, extends from the Isle of Wight into Dorsethsire.

The whole thickness of the beds at Alum Bay, in the Isle of Wight, which are nearly verticle, according to Mr. Webster's measurement, is not less than three thousand feet, comprising fourteen hundred and eighty-one feet of strata above the chalk, about nine hundred and eighty-seven feet of chalk, and five or six hundred feet of lower strata. Farther south, the strata under chalk are seen again in their original horizontal position; and on the northern side, there are hills composed of horizontal strata, evidently of a formation posterior to the time when the chalk strata were overturned. That the latter were once nearly horizontal, may be inferred from their generally occurring in that position in the southern counties, and is rendered certain from the following circumstance described by Mr. Webster. In one of the vertical beds consisting of loose sand, are several layers of flints, extending from the bottom to the top of the cliff. "These flints have been rounded by attrition, are from an inch to eight inches in diameter, and appear to have belonged to the chalk. Now it is inconceivable that these flints could have been originally deposited in their present position: they distinctly point out the former horizontal direction of this series. There are no signs of partial disturbance in these beds; the whole appears therefore to have been moved together."

Close adjoining the verticle strata on the northern side of the island, occur a series of horizontal strata, which are distinctly visible in a hill called Headon:—these strata consist of an alternating series of freshwater and marine deposits, bearing a striking similarity in their fossil contents, to the strata in the vicinity of Paris. According to Mr. Webster, they consist of

1. A calcareous stratum, containing only freshwater shells.—*Upper freshwater.*
2. Greenish marl with marine shells.—*Upper marine.*
3. Marl with freshwater shells.—*Lower freshwater.*
4. Dark blue clay without shells.—*Lower marine.*

Thus we have over chalk four distinct formations. No. 4. A lower marine formation, which includes the London clay. A lower freshwater formation, No. 3. The strata of this formation consist of sandy, calcareous, and argillaceous marl; some of them appear to be formed almost wholly of the fragments of freshwater shells, without any mixture whatever of marine shells. "From the quantity of these shells, and the regularity and extent of the strata, we are compelled" says Mr. Webster, to admit, that the spot where they now are, was once occupied by fresh water, in which these animals existed in a living state. Over this freshwater occurs an upper stratum, No. 2, which contains a vast number of fossil shells wholly marine. Again, over this marine formation, in the same hill, is a calcareous stratum fifty-five feet in thickness, No. 1, every part of which contains freshwater shells in great abundance, without any admixture of marine exuviæ. Many of the shells are in high preservation; and the animals must formerly have lived in the very spots where they now are, the shells being so fragile, that they could not have been removed from their original situation without breaking. Part of the stone of this formation is very hard and compact, and has long been extensively used for building-stone. This stratum appears to have extended over the whole of the northern part of the Isle of Wight; but it has not yet been discovered in any other situation on this side of the water: it may be considered as the latest formation of rock we are acquainted with in England, and agrees in many of its mineralogical characters, and the fossils it contains, with the freshwater limestone, *calcaire d'eau douce*, in the vicinity of Paris; they are different from any other known rock." But nowhere has there been discovered, in the series of freshwater strata in England, any trace of the remarkable beds of gypsum containing bones of unknown genera, and species of quadrupeds, similar to the gypsum of Montmartre.

During a recent visit of the author to the Isle of Wight, he was induced to conclude, that some of the remarkable phenomena which this island presents, would admit of a more simple explanation than what has generally been given. He proposes to state his opinions on this subject in a subsequent work.

Dr. Buckland has pointed out many situations west of the London clay, where patches of the lower beds occur. These patches indicate that what is called the London basin, and the basin of the Isle of Wight, were once continuous, and that their continuity was broken by the upheaving of the chalk, which, in several parts, had lifted up the portions of tertiary strata that still remain.

The formation called Norfolk Crag, remains to be noticed as the last of the English tertiary formations.

In the counties of Norfolk and Suffolk, there are a series of irregular beds of ferruginous sand and clay, mixed with marine shells, which have received the name of crag. The beds are much contorted and broken, and are intermixed with London clay and chalk, on which they rest; they are covered in many parts by diluvium. The crag is considered as the most recent of the tertiary beds in England; its true geological position, in relation to the tertiary strata on the Continent, is not precisely ascertained. According to an account of Mr. S. Woodward of Norwich, the crag is of limited extent *in situ*, in the county of Norfolk. If a line be drawn from Cromer, on the northern coast of Norfolk, to Wayburn, about six miles west, and from thence extending southerly towards Norwich (about 18 miles), it will comprise all the regular beds of crag. Mr. Woodward supposes that these beds were deposited in an estuary; eastward of this tract, ligneous and mammalian remains have been found in abundance, indicating that it was once dry land. Mag. of Nat. Hist. Sept. 1832. According to Mr. R. C. Taylor, the crag forms the base of the cliffs, from Cromer to Trimmingham. In a valuable paper on the Geology of East Norfolk, by the same gentleman, published in the Philosophical Magazine and Annals of Philosophy, April 1827, and the following numbers, there is an interesting account of the geological position of the crag near the coast, with explanatory sections. "The crag rests in part upon the London clay, and a laminated clay without fossils, and partly upon chalk, occupying the lowest sites; rarely rising to eighty feet above the present level of the sea; and in general not more than half that elevation. The average level of its base may be considered to be about that of the present ocean. In certain cases, where the chalk hills attain a higher level than the crag, that deposit could only be expected to envelope or surround their sides, and not to penetrate into the chalk: such eminences would then present the appearance of tongues or promontories of chalk, protruding into the crag; and this circumstance accounts for the occasionally apparent absence of that formation. But the crag has been subjected to abrasion by diluvial currents. Portions of its western edges have been swept away. Their fragments, mingled with those of chalk and preceding formations, piled in enormous heaps, form the cliffs of Cromer and Trimmingham, 250 or 300 feet in thickness, upon the original crag, which rests *in situ* at their base." — No. 4. (New series.) p. 288. The fossils in the crag are not mineralised; many of them appear to belong to species living in the present seas. The general characters of the crag are ably given by Mr. Taylor. "A district, bordering a hundred miles upon our eastern coast, is occupied by an ancient marine deposit, continually changing its aspect, yet constant in its peculiar characters, and always to be understood by unerring data: now appearing as a ferruginous sandstone, then a compact clay, and again considerably indurated; sometimes blended in a mass of extinct zoophytes, sponges, and alcyonites, forming a soft rock; oftener an irregularly accumulated mass of decomposed and broken littoral shells, loosely imbedded in sand like an ordinary sea-beach, yet accompanied with the remains of unknown animals. Sometimes forming the substratum of a considerable area; or, overwhelmed beneath the debris of older strata, only detected at intervals. At one point exhibiting groups of shell fish allied to those of the neighbouring sea; and at another, composed of numerous genera, which are neither to be recognised living in any part of our globe, nor assimilating to the fossil shells of other formations." —*Phil. Mag.* page 350.

Mr. Taylor, in his account of the Norfolk crag, appears to associate with it the beds which Mr. Woodward describes as diluvium; hence he gives a greater extent to the crag formation than Mr. Woodward. The latter gentleman states, as a well ascertained fact, that the tooth of a mastodon was obtained from the crag stratum at Whitlingham near Norwich; and he has also a fragment of a tooth of a mastodon, which he took out of the crag at Bramerton. These are the only instances at present known, of the remains of this animal being found in any part of

Great Britain. Teeth of the fossil elephant or mammoth are very common. A similar formation to crag is said to be discovered on the French coast between Calais and Cape Blanc Nez: also in the neighbourhood of Tangres near Antwerp, and in other parts of the Netherlands.

Mr. Mantell pointed out to me, when at Brighton, that the cliffs there are composed of sand and chalk-flints not worn by attrition, and that they rest on an ancient sea beach, with rolled shingles: in some of their characters, there is a great similarity to the Norfolk crag. The sand is in some parts cemented into hard masses of sandstone, and teeth of the elephant and the horse are found in the cliffs, indicating the high antiquity of this deposition. It has been formed in the valleys or depressions in the chalk, but it is not very easy to explain, how the chalk flints were collected in such masses, and deposited without having been subjected to attrition, It is probable that future discoveries may make it necessary to place the crag, the Bagshot sands, and the conglomerate in the cliffs of Brighton and other parts of the English coast, among the upper tertiary strata, which will be described in the following chapter.

CHAP. XVII.

ON THE RECENT TERTIARY STRATA, OR WHAT ARE CALLED BY SOME GEOLOGISTS QUATERNARY.

The Methods for determining the relative Age of Formations explained, and their Value examined. — Evidence from Position. — Evidence from Organic Remains. — System of M. Deshayes founded on Fossil Shells. — Uncertainty attending the Evidence from Organic Remains. — Arbitrary Classifications of Naturalists. — Supposed Limits to the Transmutation of Species of Molluscous Animals examined. — System of M. Elie de Beaumont. — Geological Age of Paleothœria — of Mastodons — of Elephants. — Recent Tertiary Strata of the Basin of the Loire. — Of the Subappenine Ranges. — Of the Freshwater Formations in the Appenine Valleys. — Remarkable Intermixture of the Skeletons of Whales, Elephants, &c. at Castello Arquata explained by what has taken place in England. — Freshwater Limestone of Œningen, one of the most recent Tertiary Formations. — Human Skeletons erroneously supposed to have been found there. — Observations on the relative Age of the Strata of Œningen.

After the discovery of the true character of the tertiary strata of the Paris basin, and of England, it was for some time believed that the former was a complete representation of the whole tertiary formations in every country; and that the strata of the London basin, and of the Isle of Wight, represented a portion of the strata of the Paris basin. It is now, however, ascertained, that in the central and southern parts of France, and in many other countries, there are extensive tertiary formations which contain organic remains, very different from those in the Paris basin.

These strata are, with much probability, believed to have been deposited in detached lakes or estuaries, at a subsequent period to that in which the Paris basin was laid dry.

It also appears probable, that these newer tertiary strata are of different ages; and that some of them approach in their characters to the depositions at present forming on the shores of the ocean, or in the deltas of great rivers, or in freshwater lakes.

The relative antiquity of these recent tertiary formations, is a subject of high geological interest, as it is connected with the history of the latest revolutions of the globe, and the catastrophes that have destroyed the ancient races of its inhabitants.

But how are the relative ages of the strata in different tertiary basins to be ascertained? The relative ages of two groups or formations of strata, or of two strata in distant parts of the same series, may be determined by two methods: one founded upon the evidence of position, the other upon that of organic remains. As the comparative value of these two kinds of evidence, and their relations to each other, has nowhere, that I know of, been briefly and clearly stated, for the benefit of the geological student, I trust I shall be excused for attempting to give a simple and familiar explanation of each method. The evidence from the superposition of strata, or what the French call *gisement*, is based upon a self-evident truth. In all stratified rocks that have been formed or deposited by water, the lowest stratum is the most ancient; or, in other words, every stratum is older than the stratum that covers it; unless by some violent dislocation the strata have been overturned, or removed from their original position. What is true with respect to two strata, may be applied to two series of strata, that occur under each other: thus, we are certain that the red sandstone and marl under the lias beds, are more ancient than the latter; and as both formations preserve the same character over a great extent, whenever we meet with them in other situations, where the superposition is not apparent, we may safely conclude, that the red sandstone is more ancient than the lias, and occurs under it.

We cannot, however, apply the same evidence to two groups of strata formed in detached lakes or basins, because, being deposited in different localities, they never occur superimposed on each other. Let us suppose that two ancient lakes, situated at a considerable distance, had become dry in remote ages, and that a stratum of calcareous marl were found in the ancient bed of each lake; it would be evidently impossible, from these data, to determine which stratum was the most recent, or whether their ages were coeval. Let us, for the better distinction of the stratum of calcareous marl in each lake, call the one stratum A, the other B. Suppose the geologist, who had seen the marl beds, were to observe, in a neighbouring steep bank or cliff, two marl beds similar to A and B, but separated by a bed of sandstone, he would have no doubt that the lower marl was the most ancient; but he could not apply this to determine the relative ages of the lake-marl strata, A and B. Were he, however, to discover a number of shells of one species in the lower marl bed of the cliff, and another species in the upper marl bed; and were he afterwards to find the same species of shells that were in the lower cliff marl, in the lake-marl bed A, and the species that were in the upper cliff marl, in the lake marl bed B; he would then have strong presumptive evidence, that the lake-marl A was more ancient than the lake marl B. The evidence from organic remains, or what is technically called the zoological characters, becomes more satisfactory in proportion to the number of instances in which it can be supported by the evidence from position.

In the above example of the strata of calcareous marl in the two ancient lake beds, the evidence of their relative ages derives all its value from the original evidence of position observed in the marl beds of the cliff. The evidence from organic remains alone, must ever be attended with uncertainty, unless originally confirmed by the evidence from superposition. Animals whose remains are deposited in distant basins, may be of different species; but this does not prove that they did not live at the same period, as we find in the present day different species inhabiting different latitudes; and difference of temperature in the waters of different lakes in the same latitude, might occasion a great change in the character of the inhabitants. The consideration that the value of the evidence from organic remains, was originally derived from the evidence of position, and must ever remain more or less dependent upon it, appears to have escaped the attention of many geologists, exclusively attached to the study of zoological characters. Among our ingenious neighbours, the French, perhaps too ready to form generalisations from a limited number of facts, the value of the evidence to be derived from the study of fossil conchology is greatly overrated, when they would make it independent of position or *gisement.* Could the most scientific chonchologist or naturalist have discovered from the organic remains in the Wealden beds, whether they were deposited before or after the green sand? Certainly not. He might have ascertained that they were freshwater, and not marine beds; but this would not have assisted him in discovering their relative age. Fortunately we have here the evidence of superposition; for the green sand lies over the upper Wealden beds, and, therefore, is a later deposition. When the different periods of time shall be known, in which different species of animals first appeared in different latitudes, then, and not till then, can we predicate with certainty respecting the relative age of strata, from their organic remains alone.

I shall now proceed to state the rules attempted to be established for determining the relative ages of the tertiary strata by organic remains.

M. Deshayes considers that the relative ages of different groups of strata or formations may be determined by their zoological characters alone; that is, by the species of shells they contain. He forms two grand divisions of stratified formations: —

1. Those which contain no species of shells analogous to existing species.*

This division is stated to comprise all the secondary strata.

2. Strata which contain a greater or lesser number of species analogous to existing species.

The last division comprises all the tertiary formations. Again he subdivides this division into three groups, according to the greater or lesser proportion of species of shells that they each contain analogous to living species.

In the more ancient group he places the tertiary formations of the Paris basin, the London basin, the Isle of Wight, and of a part of Belgium, a small part of the Gironde, and the tertiary strata of the Vicentin.

In the tertiary beds of this group, nearly fourteen hundred species of shells have been found, of which thirty-eight species are analogous to existing species, or about three in every hundred. Only forty-two of these species appear in the upper tertiary, and none of the fourteen hundred species found in this group, have any analogy with those found in the secondary strata, not even in the most recent or chalk formation.

The second or middle group comprises the marls of Touraine, and other parts of the Loire, a great part of the basin of the Gironde, of Dux, of Austria, Hungary, and Poland, and a small portion of the sub-Appenine hills, in the environs of Turin. Geologists and naturalists had before only admitted one group of tertiary strata in Austria and Italy.

Of nine hundred species of fossil shells found in this group, and compared by M. Deshayes, one hundred and sixty are analogous to living species, or eighteen in every hundred, and one hundred and thirty species have continued to live, during the formation of the upper or more recent group.

The upper group comprises the sub-Appenine hills, the tertiary strata of Sicily, those of the Morea,

---

* By *espèce analogue* M. Deshayes means identical species.

the small basin of Perpignan, and the small basins bordering the Mediterranean. In this group M. Deshayes is inclined to place the Norfolk crag, at least until its characters shall be better known.

M. Deshayes has recognised seven hundred species in the upper group, of which the greater half are analogous to living species. Thirteen species alone, M. Deshayes observes, have yet been found common in all the three tertiary groups, and have resisted the destructive causes that have successively modified the organisation of submarine animals. The living species, analogous to the fossil shells in the more ancient and middle groups, are chiefly inhabitants of tropical climates, whereas the greater number of species found in the most recent group are analogous to those now living in European seas.

The results of M. Deshayes' researches, if fully confirmed, would establish the following rules for determining the relative ages of strata:

1. That in proportion to the greater number of fossil species in strata analogous to living species, such strata may be determined to be more recent.
2. That a great change in the organisation of fossil species, and in the proportion of the number analogous to living species, ought to be considered sufficient to constitute different formations.
3. That different tertiary basins, were not formed or filled contemporaneously.

Before admitting the conclusions of M. Deshayes, it will be right to pause, and consider well how little we know of the inhabitants of the shells which are divided by conchologists into such a multitude of species, from a trifling difference of form. Molluscous animals, having no internal skeleton, appear to possess great power of adaptation, and of forming and renewing their shells, according to the circumstances in which they are placed. It therefore seems to be travelling far beyond the bounds of sober experience, to establish such sweeping generalisations, on the evidence of shells alone. Where other concurrent evidence can be adduced, either from the organic remains of plants, or the higher classes of animals, the presence or absence of certain species of shells may serve conjointly, as distinctive characters of formations; we may farther admit, that the greater abundance of supposed species of shells, in any formation, analogous to existing species, implies that the conditions under which the strata were deposited, were analogous to the present condition of the globe, whether all the shells designated as different species were really so or not.

Change of form, much greater than what exists in the coverings of many testaceous animals, said to be of different species, may be observed to take place in the same species of mammiferous animals in different countries. The sheep of Africa, of Asia, and of Europe, present great varieties of form; and even in Europe, the difference between one breed of sheep and another, in respect to form, size, or horns, is much greater than between the forms of many different species of shells. Let us suppose the race of sheep to be entirely destroyed in some future revolution of the globe, and the skins and horns alone to be preserved in a fossil state, without any portion of the skeleton or of the hoofs or teeth. The future geologist or naturalist would have as much reason to establish specific distinctions from the fossil skins, as the conchologist has to establish them from fossil shells. The external covering is all that can guide either of them; for of the animals themselves the conchologist knows nothing, absolutely nothing, that can serve for a specific character. The future dealer in fossils might establish forty species or more of the genus Ovis. Thus he would have his *Ovis maximus*, *O. medius*, *O. minimus*, *O. lanigerens*, *O. crinigerens*, *O. cornutus*, *O. bicornutus*, *O. quadricornutus*, *O. longicaudatus*, *O. pinguicaudatus*, *cum multis aliis*. Much ingenious and learned speculation would doubtless be expended, to prove the epochs in which each species flourished, and to determine the geological ages of the horned, and the fat-tailed sheep.

Few persons ever made more experiments, for a long series of years, on the change of form and other qualities of animals, that might be permanently produced, than the late Mr. Robert Bakewell, of Dishley in Leicestershire. I have heard him say, that he scarcely knew any assignable limits beyond which these changes, both external and internal, might not be carried. I am fully convinced that the Author of nature has established laws for the preservation of distinct classes and orders of animals; but be it ever remembered, that these laws are not limited by the artificial classification of naturalists. The principle on which Mr. Bakewell proceeded was this: — He first travelled over England, and part of the continent, to discover and select animals of different kinds, possessing certain peculiarities of form, and other qualities, which he was desirous to render permanent. By selecting two animals to breed from, which possessed the desired qualities in an eminent degree, and afterwards selecting from their offspring those in which these qualities were most conspicuous, and breeding again from these, the peculiarities were farther increased. By continuing the same selection through four or five generations, he obtained races that would transmit the same qualities permanently to succeeding generations.*

---

* Mr. Bakewell, of Dishley, was in a considerable degree self-educated, but he possessed a strong original mind, which was enlightened by study and meditation: he was also a man of great moral worth, and was intimately acquainted with Dr. Priestley, Dr. Darwin, and other eminent philosophers who inhabited the central parts of England, towards the close of the last century. The late Countess of Oxford once asked the author of the present work, *whether he was related to the Mr. Bakewell who invented sheep.* He replied, that he was of the same Leicestershire or originally Derbyshire family, and that Mr. Bakewell the *inventor* of sheep said, that "he felt satisfaction, not in having provided for the tables of the

Some naturalists have maintained, that an additional vertebral bone was amply sufficient to establish a distinct species; but the number of vertebræ are not invariably the same even in man. In some of the negro tribes, an additional vertebral bone is not uncommon. To apply what has been said to fossil conchology: — The molluscous animals that inhabit and construct their shells, have no internal skeleton, and must, therefore, be susceptible of greater change, and possess greater power of adaptation to circumstances, than vertebrated animals, in which the solid bones present obstacles to any essential departure from their original form.

Let us, however, imagine what is very possible; that a number of individuals of one species of bivalve or univalve shell, were driven, during a violent storm, into a distant part of the ocean, where the animals could no longer obtain their accustomed food, but were still able to support life by aliment of a somewhat different kind. Let us suppose that the annoyances to which they had before been subject, from natural enemies or other causes, were changed for annoyances of another kind. Under these different circumstances, is it not probable that the animals themselves would undergo some change, and modify the construction of their shells in some degree, to render them better suited to the new conditions in which they were placed? Thus, in the course of a few generations, we should have a race which conchologists would call a distinct species.

Where a series of tertiary strata of great depth are exposed to observation, as in the case of the sub-Apennine strata, we have the evidence of position, that the uppermost beds are the most recent; and if, in ascending from the lower to the upper part of the

---

rich, but for the families of the labouring classes, to whom a pound of his fat mutton over a dish of potatoes made a cheap and nutritious dinner."

series, we find the proportion of the species increase, that are analogous to what now live in the Mediterranean, we obtain the evidence of position, to support some of the conclusions of M. Deshayes. The evidence from position forms, however, the fundamental basis of our conclusions respecting the relative age of the secondary and tertiary formations; and we can only proceed safely when we have the aid of this evidence.

M. Elie de Beaumont proposes a division of the tertiary strata into three groups, according to the organic remains of large mammiferous animals which they contain. He supposes that each of these groups indicates a period of tranquillity, intermediate between two periods of change and convulsion; and that each generation of animals was destroyed by a different convulsion. His first period extends to the marls above the gypsum, in the Paris basin. The second to the Fontainebleau sandstone, the upper freshwater formation, the calcareous beds at the mouth of the Rhine, and the molasse of Switzerland. The third period extends to the diluviun (*terrain de transport*) of Bresse, to the beds of Œningen, the sandstone of Aix, the upper marine formation of Montpellier, and the ranges of sub-Apennine hills in Italy, to the tertiary beds of Sicily, and to the Crag of Suffolk.

The first or lowest group is characterised by the remains of Paleotheria; the second, by those of mastodons; and the third, by the remains of elephants. It is admitted, however, that in marine tertiary depositions, these periods seem to pass insensibly into each other. In the marls of the Loire, and the calcareous beds of Montpellier, the bones of the Paleotherium are found mixed with bones of the mastodon and hippopotamus; and in the Plaisantin, the bones of the elephant are added to the above. Without admitting at present that the division of M. E. de Beaumont is supported by sufficient evidence (and the exceptions stated prove that it is not), yet we may still allow that there is a considerable degree of probability, that each of the three genera of animals, flourished most at the different epochs he has stated, but not exclusively of other genera. In England, we have only a few traces of animals of the Paleotherian age; these occur in the freshwater formation at Binstead, in the Isle of Wight: and in the second group we have only two known instances; they occur in the Crag, in which two teeth of the mastodon have been found. In the third, or elephantine group, we have numerous instances; for teeth and bones of elephants have been found in clay, marl, or gravel, in almost every county in England. The instances cited above, in the two lower groups, are too few to support any hypothesis; but it is only fair to admit, that, conjointly with the elephants in the third group, they are conformable to the divisions of M. E. de Beaumont. Should these divisions be more fully confirmed, we must range the strata of Alpnach not in the lower, but in the middle group of tertiary strata.

In a work like the present, it would not be possible or desirable to follow the French and German geologists, in their descriptions of the different basins that contain the upper tertiary or quaternary strata, supposed to be superior to any of the tertiary beds in the Paris basin, or in England; but the most remarkable of these formations may be noticed: — "The Faluns, or marls of Touraine and the Loire, constitute an extensive formation of marl beds, which are now admitted to be of later date than the most recent of the freshwater beds in the Paris basin. From the soft quality of the marl, it might hence be inferred that the beds had been disturbed or changed by inundations, or might be classed with diluvial beds; but they are regular depositions, formed during an epoch of tranquillity, and subjected to laws of which the action is continued on the present shores. The great mass of fossil shells which these beds contain, differ from those of the Paris basin: in nearly four hundred species, there are only about twenty identical with the Paris fossils. The terrestrial and river shells are in the same state of mineralisation as the marine shells. The bones of the mastodon, rhinoceros, and hippopotamus, are in the same state of preservation as those of whales, and other cetaceous animals, with which they are intermixed. They are coated with marine polypi and serpulæ, which proves that they were long covered by a tranquil and stationary sea. These Faluns are distinct from the tertiary beds of the Seine, and more recent than any of them; but they are themselves the lowest term of a new system, more important, more extensive, than the formations of the Paris or London basins, and which has been continued to the present epoch, during all the numerous up-heavings of the ground, the changes in the relative level of seas and continents, and the successive modifications of organic beings." — *Bulletin de la Société Géologique de France*, 1831-32, tom. ii.

It is stated that the lowest bed of the Faluns, rests upon a bed analogous to the upper part of the Paris basin, which is supposed to have extended so far. If this were clearly made out, we should have the evidence of position, as well as of organic remains, to determine the relative age of the Faluns of the Loire, which is supposed to be the age of mastodons. In opposition to this, I have part of the tooth of an elephant, which, in the hand writing of Faujas St. Fond, is said to have been found at Montmartre, and is evidently from the marl beds. Here, then, we have remains of an animal of the most recent tertiary age, occurring in a formation more ancient than the age of mastodons. Such instances should lead us to receive the evidence from animal remains alone with much caution. Indeed, there is good reason to believe, that in North America, the age of mastodons was continued to nearly the present epoch, if the animal be not still living in some of the unexplored recesses of that vast continent.

The range of mountains in Italy, called the Apennines, that rise in some parts to the height of from six to eight thousand feet, and extend north and south from the borders of Piedmont to Calabria, are accompanied, both on the Adriatic and Mediterranean flanks by ranges of lower hills, which have, from their position, received the name of sub-Apennine. The sub-Apennine hills rise to the height of from one to two thousand feet; they are composed of tertiary beds of marl, sand, clay, and calcareous tufa, and abound in marine shells, many of which are identical with existing species in the Mediterranean sea, or with other existing species of tropical climates. It is observed that the upper beds contain the greatest proportion of species similar to what exist in the neighbouring seas. The sub-Apennine beds rest unconformably upon the inclined beds of the Apennine range. It has been ascertained by dredging the bed of the Adriatic sea, that there are beds now forming at the bottom, which closely resemble beds in the sub-Apennine hills, more than a thousand feet high. There can be no doubt that these sub-Apennine beds have once formed the bottom of an ancient sea, and have been raised to their present elevation by subterranean action. The occurrence of numerous volcanic vents, in the whole of that part of Italy, can leave little doubt respecting the agent by which this elevation has been effected.

In the third edition of this work, I had, on the authority of M. Brongniart, referred a great part of the sub-Apennine beds to the upper marine sandstone of the Paris basin, above the gypseous marl. Whether any portion of the sub-Apennine strata belong to the same epoch as the upper strata in the Paris basin, may be doubtful; but we may safely infer, both from their organic remains and position, that the superior sub-Apennine beds, belong to a far more recent epoch than that in which the tertiary strata round Paris and in England were deposited. Mr. Lyell, who has recently examined this interesting range of tertiary hills, and from whom geologists may expect much valuable information respecting them, has extended his researches into Sicily, where he found that "there were many places in which the extinct species had nearly disappeared; and that amid vast accumulations of marine shells, entering into the composition of mountains of no inconsiderable altitude, nearly all were specifically identical with those now inhabiting the adjoining sea." According to the principles of M. Deshayes, these Sicilian beds must be more recent than the sub-Apennine.

One thousand species of shells have been collected by Signor Guidotto from the sub-Apennine beds; and if the rules laid down by M. Deshayes, respecting this formation, can be relied upon, the greater number of the species of shells belong to existing species; and of these the *greater proportion* belong not only to existing species, but to species inhabiting the neighbouring sea. In Sicily, however, we approach much nearer to the present state of things, as *nearly all* the shells in the tertiary strata are identical with living species, and probably existed under similar conditions of temperature, &c. to what these latitudes are now subjected to. Approaching the northern termination of the sub-Apennine range at Sienna, Parma, and Asti, (according to Mr. Lyell,) the proportion of species identifiable with those now living in the Mediterranean is still considerable; but it no longer predominates (as in the south of Italy) over the unknown species.

As these sub-Apennine hills, resting on each side of the Apennine range, were formed under the sea, they must have been elevated together with the Apennine range, subsequently to their deposition. Before this period, the Apennines were consequently much lower, and formed a narrow mountainous peninsula extending into the Mediterranean. Their sides were probably clothed with forests, and afforded food and shelter to the elephants and other large mammalia, that have left their bones so abundantly in some of the present valleys, particularly in the vale of Arno. These valleys, it is supposed, were once the beds of ancient freshwater lakes, in which depositions were forming at the same time as the marine depositions were taking place, which constitute the beds of the sub-Apennine range. By the observations of M. Bertrand Geslin, published in the *Journal de Géologie*, t. iii., it would appear, that between the source of the Arno and Florence, three distinct basins can be traced. The beds of these basins are composed of argillaceous blue marl of considerable thickness, containing fossils in the upper part of the marl. Above this are beds of sand, containing numerous bones of large mammalia. These sands are covered by beds of rolled siliceous pebbles, intermixed with sand, above which there is a bed of yellow argillaceous sand. The pebbles appear to have been derived from the mountainous range on the north. Neither remains of marine shells nor lignites occur in these depositions. The animal remains in the upper valley of the Arno are those of the elephant, as of the large hippopotamus, the rhinoceros, the tapir, the deer, the horse, and the ox. There are also bones of carnivorous animals belonging to the hyena, the bear, the fox, and some species allied to the tiger. From the character of the animal remains we may infer, that these freshwater depositions are of a comparatively recent date; they were, probably, coeval with the uppermost marine beds in the sub-Apennine hills. The beds, both in the sub-Apennine hills, and in the valleys of the Apennines, consist principally of marl, sand, and loosely adhering materials; hence they are exposed to rapid degradation. On the north-east side of the Apennine range, in the district of Placenza, there is a marine deposition deserving particular notice, from the extraordinary mixture of animal remains which have been found in it, and are at present preserved in the Museum at Milan.

A friend of the author, S. Banfill, Esq. of Exeter, who visited the Museum the last spring, obtained from the director of that institution, an account of the principal organic remains from this deposition, with a brief notice of the locality, of which the following is a translation: —

"Organic remains from near Castello Arquata, in the neighbourhood of the ancient Vellcja, in the district of Placenza.

"A pretty extensive collection of shells.
"A small whale, entire.
"A portion of another whale, of a larger species.
"The entire skeleton of an elephant, united together.
"The head of a rhinoceros, with some bones.
"Two skeletons of dolphins.

"They were all found in a confined space, in the midst of marine mud, deposited in a tranquil sea, at the present height of thirteen hundred feet." The director adds, "This singular geological combination, comprehending organic vestiges of every latitude, resembles that recently discovered in New Siberia, at Behring's Straits. Many eminent writers have spoken of it; among others, the brothers Bondi were some of the first who noticed it; and Signor Corlesi, a landed proprietor at Castello Arquata, and author of 'Geological Essays on the States of Parma;' also Signor Brochi, in his *Sub-Apennine Fossil Conchology*."

The occurrence of the remains of large terrestrial and of marine mammalia in the same deposition may admit of an easy explanation, by observing what has taken place in some parts of England. On the Sussex coast, there was, at no remote period of history, an estuary extending inland from Newhaven to near Lewes. This estuary is now filled up, and forms a level meadow, through which the river winds its way to the sea. It is not difficult to explain how the filling up of the estuary was effected: the immense mass of loose pebbles or shingles which lie upon the Sussex coast, change their position during violent storms, and are accumulated in new situations. A drift of pebbles, forming a bank or bar near the mouth of the estuary, would prevent the sudden return of the sea after each tide, and retain the water, until it had deposited the mud and sand which it contained. Thus, the estuary would gradually become shallower, and its dimensions would contract from year to year. The waters of the river and rivulets which flowed into the estuary would also contribute their depositions of freshwater mud.

By the joint operation of these causes, the estuary would be first converted into a marsh; and when the drainage was more complete, this marsh was converted into a plain or meadow. By sinking beneath the soil, the various depositions of silt, sand, and vegetable matter, prove the means by which the estuary was filled. At a considerable depth, large vertebræ of a whale were discovered, and are now in the museum of Mr. Mantell, at Lewes. Instances of whales entering estuaries at high tides, and being unable to return at low water, are of not very unfrequent occurrence on the coast of Great Britain. Let us suppose the sides of the hills bounding the estuary near Newhaven to have afforded herbage for deer and oxen; their bodies or bones might be washed down into the estuary, and thus we should have all the conditions required for the intermixture of the large bones of terrestrial and marine animals. Let us farther suppose, that subterranean fire, like that which exists under various parts of Italy, should upheave the chalk hills of the South Downs, and all the surrounding country, to the height of two thousand feet above the present level: the bed of the Newhaven estuary would then resemble, in all its essential characters, the deposition at Castello Arquata, in Italy.

The freshwater strata at Œningen, near Constance, are, perhaps, the most recent of all that have been described as tertiary or quaternary formations. Quarries have for many years been worked in these strata, and they have been long celebrated for the great variety of organic remains which they contain, consisting of quadrupeds, birds, a vast number of fishes, reptiles, insects, and innumerable plants. These quarries were, for a considerable time, supposed to contain human skeletons: it has been ascertained by Cuvier, that the bones belonged to the aquatic salamander, an animal nearly resembling the lizard in form. The body is about four feet in length, and it had beside a long tail. One of these skeletons is in the British Museum. The strata are chiefly indurated calcareous marl, and freshwater limestone or marlstone. Mr. Murchison, who has lately visited the quarries at Œningen, and brought from thence the entire skeleton of a fossil fox, has given a brief but very clear description of this formation: —

"The Rhine, in its course from Constance to Schaffhausen, flows for many miles in a depression of the molasse (or sandstone), which being cut through transversely, is exposed in hills on both banks, at heights varying from seven to nine hundred feet. These hills, consisting of micaceous sandstone and conglomerate, from the western prolongation of that great range of tertiary deposits, which extends along the flanks of the Austrian and Bavarian Alps, and has been described by Professor Sedgwick and myself. The marls and limestone of Œningen are recumbent on the molasse, and they are seen in various patches on the sides of the hills, and are worked in two quarries at different elevations above the Rhine. The lowest is about two hundred feet above the level of the Rhine; the highest is about six hundred feet above its level. The marl beds in both, rest on molasse, which forming the bottom of the basin, is exposed beneath the lower quarries in the denudation of the Rhine, and rises behind them into the hills of Schienen. It would, therefore, appear, that the valley in which the Rhine now flows was, at a remote period, deeply excavated in the molasse; and that subsequently a lake was formed in one of the broader parts of the valley, in which marls and limestones were deposited. The nature of the organic remains, and their deposition in successive layers, not only prove the long period of time which must have elapsed during their accumulation, but also demonstrate the lacustrine origin of the deposit."

Mr. Murchison has annexed some judicious observations on the relative geological age of the tertiary limestone of Œningen: — "From the intermixture of species undistinguishable from those now existing, with others decidedly extinct, this deposit may be considered as an important link in the history of the earth's structure; indicating an intimate connection between the ancient state of nature, and that which now prevails.

"The deposit differs essentially in its organic remains, from any other freshwater formation, either in France or in the adjacent regions of Germany: from its superposition over tertiary sandstone (molasse), this formation must be regarded as one of the most recent. Yet recent as must have been the (geological) epoch of this formation, the basin in which it was deposited has subsequently been re-excavated to a considerable depth: the proof of which is, that horizontal beds still present escarpments several hundred feet above the Rhine, without any barrier between them and that river."

As no bones of elephants or mastodons have been discovered in the strata of Œningen, and as the plants and animals for the most part resemble existing species, it is reasonable to believe that the mean temperature of this part of the globe had considerably decreased, and that the country round Œningen could no longer support the plants and animals of tropical climates.

The strata of Œningen may be regarded as posterior to many of the beds or accumulations of clay, sand, and gravel, in England and other countries, that contain the remains of elephants, hippopotami, and other inhabitants of warm regions. These beds (called diluvial and alluvial), together with vast tracts of moveable sand, cover no small portion of our present continents: they may be regarded as the loose vestments of the globe. Their description will be deferred till we complete the account of the fixed and solid parts, presented to observation by volcanoes, and the repositories of metallic ores.

The county of Norfolk appears to be the *Ultima Thule* of English geologists, who know less of the crag of that county and of Suffolk than would probably have been the case, had its locality been beyond the Carpathian mountains. I have never had an opportunity of examining this singular formation, and scarcely any thing was known respecting it before Mr. Taylor's account was published in 1827. We may, however, soon expect a more full and satisfactory description of the crag, in Mr. Samuel Woodward's forthcoming volume on the Geology of Norfolk. While the present sheet was passing through the press, I received from that gentleman the following account of the extent of the crag: — Its western boundary may be traced from near Weyborn, on the northern coast, to Norwich, and from thence to Bungay; and from this place a line drawn along the map of Suffolk to Halesworth, Wickham-market, Woodbridge, and Ipswich, gives its western outline in that county. The eastern boundary of the crag trends off to the sea.

CHAP. XVIII.

ON EARTHQUAKES AND VOLCANOES.

Phenomena that precede the Shock of an Earthquake. — Extent to which the Waters in Lakes and Springs are agitated during Earthquakes. — Extent to which Earthquakes are felt on Land. — More severe in Mountains than in level Countries. — Connection between Earthquakes and Volcanoes. — Electrical Earthquakes. — First Appearance of a Volcano. — Common Phenomena attending Volcanic Eruptions. — Remarkable Eruption of Sumbawa in 1815. — Long Periods of Repose in some Volcanoes. — Volcano of Popocateptl in Mexico. — Submarine Volcanoes; their Appearance preceded by violent Agitation of the Sea. — Submarine Volcanoes in the Azores — in the Grecian Archipelago. — Recent Submarine Volcano near Sicily. — Craters of Eruption. — Craters of Elevation. — Theory of Von Buch confirmed by analogous Geological Facts. — Eruptions of Mud and Water from Volcanoes. — Groups of Volcanic Islands. — Fall and Extinction of a Volcano. — Vast Extent of some ancient Volcanoes. — Extinct Volcanoes of Central France. — Puy de Pariou, the best preserved of ancient Volcanoes. — Extinct Volcanoes in Germany and Asia. — Pseudo-Volcanoes. — Volcanic Rocks and Products. — Observations on Volcanic Fire.

Accustomed to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains and another soil in the space of a single night; yet such changes have been produced, by the united agency of earthquakes and volcanoes, within the limits of authentic history. For a particular description of recent volcanic eruptions, and the changes they have produced on the surrounding countries, I must refer the reader to the works of Spallanzani, Dolomieu, Sir William Hamilton, and M. Humboldt, and to the recent account of the Island of Java, by Lieutenant-Governor Raffles.

In the present chapter I propose, 1st, to describe those phenomena that indicate the connection between earthquakes and volcanoes, and between the volcanoes in distant countries; 2dly, to take a view of the most remarkable recent volcanic eruptions, and of the remains of ancient volcanoes, that prove the extensive action of internal heat on the crust of the globe; and, 3dly, to give a concise account of volcanic rocks and products.

Earthquakes and volcanoes may be considered as different effects produced by the agency of subterranean fire. They frequently acccompany each other; and in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanoes do not make their appearance in every country where the shock of an earthquake is felt: but earthquakes are more frequent in volcanic districts than in any other. Earthquakes are almost always preceded by an uncommon agitation of the waters of the ocean, and of lakes. Springs send forth torrents of mud, accompanied with a disagreeable stench. The air is generally calm, but the cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise, like that of carriages over a rough pavement — a rushing sound like wind — or a tremendous explosion like the discharge of artillery, —immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side, with violent and successive vibrations. The shock seldom lasts longer than a minute; but it is frequently succeeded by others of greater or less violence, which continue to agitate the surface of the earth for a considerable time. During these shocks, large chasms and openings are made in the ground, through which smoke and flames are seen to issue: these sometimes break out where no chasms can be perceived. More frequently stones, or torrents of water, are ejected from these openings. In violent earthquakes, the chasms are so extensive, that large cities have in a moment sunk down and for ever disappeared, leaving a lake of water in the place. Such was the fate of Euphemia in Calabria, in 1638, as described by Kircher, who was approaching the place, when the agitation of the ocean obliged him to land at Lopizicum. "Here," says he, "scenes of ruin every where appeared around me: but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound, which every moment grew louder. The place where we stood shook most dreadfully. After some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

The extent to which earthquakes produce sensible effects on the waters of springs and lakes in distant parts of the world, is truly remarkable. During the earthquake of Lisbon, in 1755, almost all the springs and lakes in Britain, and every part of Europe, were violently agitated, many of them throwing up mud and sand, and emitting a fœtid odour. On the morning of the earthquake, the hot springs at Toplitz, in Bohemia, suddenly ceased to flow for a minute, and then burst forth with prodigious violence, throwing up turbid water, the temperature of which was higher than before: it is said to have continued so ever since. The hot wells at Bristol were coloured red, and rendered unfit for use, for some months afterwards. Even the distant waters of Lake Ontario*, in North America, were violently agitated at the time. These phenomena offer proofs of subterranean communications under a large portion of the globe; they also indicate, that a great quantity of gas or

---

* It has been observed during many earthquakes in the Eastern States, that the subterranean noise and motion appeared to commence from the Lakes, and proceed towards the Atlantic Ocean, in a direction from the north-west.

elastic vapour was suddenly generated and endeavouring to escape. From the fœtid odour perceived in some situations, it may be inferred that this gas is hydrogen or sulphuretted hydrogen. In other instances it may be steam, which condensing again would produce a vacuum, and occasion the external air to press downwards; this has been observed in mines, immediately after the shock of an earthquake.

The space over which the vibration of the dry ground is felt is very great, but generally wider in one direction than another; and where a succession of earthquakes has taken place in the same district, it is observed that the noise and shock approach from the same quarter. It has been before mentioned, that earthquakes are most frequent in volcanic districts; but the shocks are not the most violent in the immediate vicinity of volcanoes. On the contrary, they are stronger in the more distant part of a volcanic country. The ground is agitated with greater force, as the surface has a smaller number of apertures communicating with the interior. "At Naples and Messina, and at the foot of Cotopaxi and Tungurahua, earthquakes are only dreaded when vapours and flames do not issue from the craters." — *Humboldt.*

The connection of earthquakes with volcanoes was noticed by ancient writers, and the latter were properly regarded as the openings through which the inclosed vapour and ignited matter, that occasion earthquakes, found a passage. Strabo, in his Geography, states, that "the town of Regium, situated on the Italian side of the Straits of Messina, was so called, according to Æschylus, from the circumstance that the island of Sicily was rent off from the continent by earthquakes. Proofs of this arise out of the phenomena attending Ætna, and other parts of Sicily and of the Lipari Islands, and even the opposite continent. Now, indeed, when craters are opened, through which fire and ignited matter and water are poured out, it is said that the land near the Straits is seldom shaken by earthquakes: but formerly, when all the passages to the surface were obstructed, the fire and vapour confined in the earth occasioned frequent earthquakes, and the land, being rent, admitted the ocean. At the same time, Prochyta and an adjacent island were also torn off from the continent, while other islands rose from the ocean, as frequently happens at this day." — (Strabo flourished in the reign of Augustus.)

It is highly probable that every extensive earthquake is followed by a volcanic eruption more or less remote, unless (as not unfrequently happens) the elastic vapour immediately escapes from fissures made at the time, in the countries that are the most violently convulsed. An earthquake was strongly felt in Geneva when I was there, February 19. 1822, and did considerable damage in several towns and villages in Savoy and France. A few weeks afterwards, I travelled from Geneva to Lyons, and from thence to the ancient volcanoes near Clermont. In the course of my route, I made frequent inquiries respecting the effects of the earthquake: it appeared to have been most strongly felt along the valley of the Rhone, and the shock was not less severe in the volcanic district of Auvergne; its direction was from the south-east: and on that and the following days, there were several eruptions from Vesuvius.

The frequency of earthquakes at particular periods is well deserving notice. In the fourth and fifth centuries, some of the most civilised parts of the world were almost desolated by these awful visitations. Thrace, Asia Minor, and Syria, according to cotemporary historians, suffered most severely: the earth was agitated continually for long periods, and flames were seen to burst from the earth, over a vast extent of surface. On the 26th of January, A.D. 447, subterranean thunders were heard from the Black to the Red Sea, and the earth was convulsed without intermission for the space of six months; in many places the air seemed to be on fire; towns and large tracts of ground were swallowed up in Phrygia. On the 20th of May, A.D. 520, the city of Antioch was overturned by a dreadful earthquake, and two hundred and fifty thousand of its inhabitants are said to have been crushed in the ruins. A raging fire covered the ground on which the city was built, and the district around; spreading over an extent of forty-two miles in diameter, and a surface of fourteen hundred square miles.

About the middle of the last century, after the earthquake at Lisbon; Europe, Africa, and America, were for some time repeatedly agitated by subterranean explosions; as may be seen by referring to the journals of that time. Ætna, which had been in a state of profound repose for eighty years, broke out with great activity; and, according to Humboldt, some of the most tremendous earthquakes and volcanic eruptions ever recorded in history were witnessed in Mexico. In the night of the 19th of September, 1759, a vast volcano broke out in a lofty cultivated plain; a tract of ground more than twelve miles in extent, rose up like a bladder to the height of five hundred and twenty-four feet, and six new mountains were formed, higher than the Malvern Hills, in Worcestershire. More recently (in 1812) the tremendous earthquakes in the Caraccas were followed by an eruption in the Island of St. Vincent's, from a volcano that had not been burning since the year 1718; and violent oscillations of the ground were felt both in the islands and on the coasts of America. It may be inferred from these circumstances, that the cause of earthquakes and volcanic eruptions is seated deep below the surface of the earth; in confirmation of which, it will only be necessary to state, that on the same day on which Lisbon was nearly destroyed, all Europe, and a great part of northern Africa, felt the shock more or less severely: its effects were also sensible across the Atlantic, both in the United States and the West Indies. Incredible as it may seem, one fourth of the northern hemisphere was agitated by the same earthquake. The bed of the Atlantic was raised above the surface of the ocean, and flame and vapour were discharged: this was observed by vessels at sea. If we take a terrestrial globe, and cover those parts of it that were thus affected by the earthquake with black crape, we shall obtain a more distinct idea of the extent of surface shaken, than a mere verbal description can convey. This appears to have been one of the most severe shocks that the old continent had experienced for several centuries. The cause which could effect a simultaneous concussion over such a vast extent, must probably have been seated nearly midway between the centre of the globe and its surface.

It has been remarked, that in general earthquakes are more severely felt in mountainous than in low countries: this might be expected from the structure of the earth.* In alpine districts, the primary mountains are not pressed with the incumbent mass of secondary rocks; and, consequently, in such situations, the resistance to a force acting from beneath will be much less, as all the weight of secondary rocks is removed. In very violent earthquakes, the secondary strata are broken or agitated; but proofs are not wanting, of lesser vibrations being stopped by their pressure. Humboldt says, he has seen workmen hasten from the mines of Marienburgh, in Saxony, alarmed by agitations of the earth that were not felt at the surface. During the earthquake at Lisbon, the miners in Derbyshire felt the rocks move, and heard noises which were scarcely perceived by those above. That an expansive force acting from beneath is the proximate cause of earthquakes, can scarcely be denied; and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. It is said that a single drop of water falling into a furnace of melted copper, will blow up the whole

---

* See a paper on Earthquakes, by the Rev. Mr. Mitchell, Philosophical Transactions, 1759.

building. This may be an exaggerated statement; but the prodigious force of steam at high temperatures is well known, and there can be no difficulty in admitting, that if a current of subterranean water were to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake more or less violent, in proportion to the quantity of steam generated, and its distance from the surface. When the hydrogen gas exploded in a mine near Workington, in Cumberland, a shock like that of an earthquake was felt by ships in the river, at two miles' distance.

The horrid crash, like the rattling of carriages, which precedes earthquakes, may be occasioned by the rending of the rocks, or parting of the strata through which the confined vapour is forcing a passage.

All the phenomena that accompany earthquakes indicate the intense operation of elastic vapour, expanding and endeavouring to escape where the least resistance is presented, and producing vibrations of the solid strata. The intimate connection between earthquakes and volcanic agency, is too obvious to require much illustration. All volcanic eruptions are preceded by earthquakes of greater or lesser extent; but all earthquakes are not attended by volcanic eruptions. The elastic vapour may sometimes find vent through existing fissures and apertures; or the aqueous vapour may meet with subterranean currents of cold water, and suddenly collapse, producing a second earthquake in a contrary direction. In common language, the agitation of the ground, when the surface is not broken, is called the shock of an earthquake. Since the records of history, there have been no earthquakes in Great Britain equal in intensity to what have taken place in the southern parts of Europe. In the year 1247, a general earthquake is said to have extended over England; it threw down the church of St. Michael's, on the Hill at Glastonbury. The greatest earthquake recorded in England, took place November 14. 1318. On April the 6th, 1580, an earthquake, felt in London and Westminster, threw down a part of St. Paul's church, and of the Temple church. Perhaps, in the present time, ten years seldom elapses without the shock of an earthquake being felt in some part of Great Britain; but these are too feeble to require historic notice. We have evidence, however, of mighty earthquakes having shaken the surface of this part of the globe. The faults and dislocations of the strata, of which some account has been given in different parts of the present volume, must have been accompanied, during their formation, with more violent agitation of the ground than any recorded in history; but it is probable that, at that period, the land which now forms Great Britain had only partially emerged from the ocean.

Soon after the discovery of the Leyden Phial, many natural phenomena were ascribed to electric action, and earthquakes were supposed to be the result of electric shocks, acting with great intensity in the interior of the earth. The electric theory of earthquakes was soon discarded as untenable; but now the identity of magnetic and electric agency seem, in many respects, to be established, it may deserve consideration, whether an interruption to the magnetic or electric currents which circulate through the earth, may not sometimes occasion earthquakes, acting almost instantaneously over large portions of the globe.

If, as some philosophers maintain, there is a central fire under every part of the globe, or if certain spaces only are filled with ignited matter, we can scarcely doubt that chemical changes are taking place, which will also change the electrical relations between mineral beds. A series of strata may act like the plates of an immense voltaic battery, and discharge the electricity from one internal part of the globe to another, exciting vibrations that may agitate a whole hemisphere. I was informed by a gentleman who resided several years near the feet of the Himmahlaya mountains, that peals of subterranean thunder were sometimes heard which resembled atmospheric thunder, but were inconceivably louder and more appalling: they were followed by earthquakes. Humboldt also mentions the frequency of subterranean thunder in some districts bordering the Andes.

In volcanic phenomena, we observe a cause in present activity, that can overthrow mountains, form new islands, and raise up the bed of the ocean: hence the geologist may infer, that the same cause, acting with greater intensity and more extensively, has been the agent employed by the Author of nature, to elevate new and submerge ancient continents, and to change and renovate the surface of the globe. We are indeed acquainted with no other natural agent, that can have effected the mighty changes which the crust of our planet has undergone. The products of volcanoes, particularly of ancient ones, are analogous in their composition and internal structure to the oldest rocks of granite, sienite, and porphyry, and indicate, not obscurely, the mode in which these rocks were formed: hence the study of volcanoes and volcanic rocks, is an important branch of the science of geology. Werner and his disciples, however, held that volcanoes were merely produced by the ignition of beds of coal, in the secondary strata.

VOLCANOES are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapour, flame, large stones, sand, and melted stone called lava. Some volcanoes throw out torrents of mud and boiling water. Volcanoes most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface of the ocean, and form new islands and reefs of rock. When a volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock, with flame, smoke and lava, are thrown out, and choke up part of the passage, and confine the eruption to one or more apertures, round which conical hills or mountains are formed. The concavity in the centre is called the crater. The indications of an approaching eruption from a dormant volcano, are an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine-tree. Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by red-coloured flames, and showers of stones. At length the lava flows out, from the top of the crater, or breaks through the sides of the mountain, and covers the neighbouring plains with melted matter, which, becoming consolidated, forms a stony mass, often not less than some hundred square miles in extent, and several yards in thickness. The eruption of lava has been known to continue several months. Intensely black clouds, composed of a kind of dark-coloured sand or powder, improperly called ashes, are thrown out of the crater after the lava ceases to flow, and sometimes involve the surrounding country in total darkness at noon-day. Towards the conclusion, the colour of the volcanic sand changes to white: it consists of pumice in a finely comminuted state. During an eruption of Ætna, a space of one hundred and fifty miles in circuit was covered with a stratum of volcanic sand or ashes twelve feet thick. When the lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confinement of the erupted matter, both gaseous and solid. The smoke and vapour of volcanoes are highly electrical.

The quantity of lava thrown out during a single eruption of a volcano, seems almost incredible to those who have not observed volcanic countries. Kircher, in his *Mundus Subterraneus*, lib. vi. cap. 8., published in 1660, says, that the ejections of Mount

Ætna would, if collected, form a mass twenty times as large as the mountain itself; and a few years afterwards, viz. in 1669, the same mountain covered with a fresh current of lava eighty-four square miles; and again in 1775, according to Dolomieu, the same volcano poured out another stream of lava, twelve miles in length, one mile and a half in breadth, and two hundred feet in height. Hence it is evident, that the seat of the fire is not in the mountain itself, but deep in the earth : the volcano is not the furnace, but the chimney; and it will be necessary to bear this in mind, if we would form an adequate idea, of the extensive effects of volcanic action. Seneca appears to have formed a distinct notion of the seat of volcanic fire, when he remarks, that the volcano does not supply the fire, it only affords it a passage "*in ipso monte non alimentum habet, sed viam.*" The largest known current of modern lava was formed by a volcano in Iceland in 1783; it is sixty miles in length, and twelve broad, equalling in extent any continuous rock formation in England. The most extraordinary volcanic eruption recorded in history for the extent of its effects, took place in Sumbawa, one of the Molucca Islands, in April, 1815. It is described in the history of Java by Lieutenant-Governor Raffles.

"This eruption extended perceptible evidences of its existence over the whole of the Molucca Islands, over Java, a considerable portion of Celebes, Sumatra, and Borneo, to a circumference of a thousand statute miles from its centre, by tremulous motions and the report of explosions; while within the range of its more immediate activity, embracing a space of three hundred miles around, it produced the most astonishing effects, and excited the most alarming apprehensions. In Java, at the distance of three hundred miles, it seemed to be awfully present. The sky was overcast at noon-day with clouds of ashes; the sun was enveloped in an atmosphere, whose 'palpable' density he was unable to penetrate; showers of ashes covered the houses, the streets, and the fields, to the depth of several inches; and amid this darkness, explosions were heard at intervals, like the report of artillery or the noise of distant thunder. So fully did the resemblance of the noises to the report of cannon impress the minds of some officers, that, from an apprehension of pirates on the coast, vessels were despatched to afford relief. Superstition on the other hand was busily at work on the minds of the natives, and attributed the reports to an artillery of a different description to that of pirates. All conceived that the effects experienced might be caused by eruptions of some of the numerous volcanoes on the island; but no one could have conjectured that the showers of ashes which darkened the air and covered the ground of the eastern districts of Java, could have proceeded from a mountain in Sumbawa, at the distance of several hundred miles."

The lieutenant-governor of Java directed a circular to the different residents, requiring them to transmit to the governor a statement of the facts and circumstances connected with this eruption. The most remarkable circumstance attending this eruption, is the distance at which the explosions were heard in the islands of the Indian Sea. "From Sumbawa, to the part of Sumatra where the sound was noticed, is about nine hundred and seventy geographical miles. From Sumbawa to Ternate, is a distance of about seven hundred and twenty miles. The distance to which the cloud of ashes was carried so thickly as to produce utter darkness was clearly pointed out to be the Island of Celebes, and the district of Grisik in Java; the former two hundred and seventeen nautical miles in a direct line, the latter more than three hundred geographical miles." The greatest distance at which the eruption of any volcano had been previously heard, is six hundred miles: according to M. Humboldt, the explosions from Cotopaxi are sometimes sensibly heard at that distance from the volcano, The eruptions of the Peak of Teneriffe have been very rare during the last two centuries. According to Humboldt, " the long intervals of repose appear to characterize volcanoes highly elevated. Stromboli, which is one of the lowest, is always burning; the eruptions of Vesuvius are rarer, but still more frequent than those of Ætna. The colossal summits of the Andes, Cotopaxi and Tungurahua, scarcely have an eruption once in a century. The Peak of Teneriffe seemed to be extinguished for ninety-two years, when it made its last eruption by a lateral opening in 1798. In this interval Vesuvius had sixteen eruptions." The greatest eruptions of lava from Ætna and Vesuvius are always from the sides of these mountains; but these lateral eruptions finish by an ejection of ashes and flames from the crater at the summit of the mountain. In the Peak of Teneriffe, an eruption of lava from the summit has not taken place for ages; and in the recent great eruption of 1798, the crater remained inactive, nor did its bottom fall in.

The observation of M. Humboldt, that lofty volcanoes have the longest periods of repose, will not be found universally correct. The small volcano of Volcano, one of the Lipari islands, was in a dormant state for thirteen hundred years, while the volcano of Popocatapetl, fourteen leagues from Mexico, which is nearly eighteen thousand feet above the level of the sea, seems to be in a state of constant activity. It was ascended by Lieutenant William Glennie, in 1827. The volcano rises from a country that is 8216 feet above the sea; its sides are thickly wooded with pine forests to the height of nearly 13,000 feet: beyond this altitude vegetation ceased entirely. The ground consisted of loose black sand of considerable depth, in which numerous fragments of pumice and basalt were dispersed; above this were several projecting ridges of loose fragments of basalt, arranged one above another. At the summit, the mercury subsided to 15·63 inches. The crater appeared to extend one mile in diameter; the interior walls consisted of masses of rock, arranged perpendicularly, and marked by numerous vertical channels, in many places filled with black sand. Four horizontal circles of rock, differently coloured, were also noticed within the crater. From the edges of the latter, as well as from its perpendicular walls, several small columns of vapour arise, smelling strongly of sulphur. The noise was incessant, resembling that heard near the sea shore during a storm. At intervals of two or three minutes, the sound increased, followed by an irruption of stones: the larger fell again into the crater, the smaller were projected into the ravine which we had ascended.

The volcano of Popocatapetl is perhaps the loftiest active volcano that has been ascended, and yet, according to Humboldt, it sometimes pours out currents of lava from the summit.

Those who are acquainted with hydrostatics, and know the immense power that would be required to raise even a column of water from the level of the sea to the top of Popocatapetl, Ætna, or Teneriffe, will not be surprised that the lava forces itself out of the sides, and rarely rises to the top of the crater, in lofty volcanic mountains. It has been calculated, that the force required to raise a column of lava to the height of the summit of Teneriffe, (twelve thousand five hundred feet,) would be equal to that of one thousand atmospheres; and M. Daubuisson, who has made the calculation, states, that if an opening were effected in the volcano at the level of the sea, under the above pressure, the lava and stones would be forced out with a velocity equal to two hundred and seventy mètres, or eight hundred feet per second. — Tom. i. p. 173.

The elevation of volcanic craters varying, as Humboldt observes, from six hundred to eighteen thousand feet, must not only influence the frequency of their eruptions, but must modify also the quality of the substances ejected. — " Some volcanoes only eject lava from their sides, like Teneriffe, although it has a crater on its summit; others have lateral eruptions, as I observed at Antisana in Quito, at the height of thirteen thousand feet, and their summit has never been pierced. Others equally hollow in their interior, as many phenomena indicate, act only mechanically on the surrounding country, breaking the strata and changing the surface of the soil. Thus the volcanic mountain of Chimborazo, with its dome of volcanic porphyry (*trachyte*), at the height of twenty-two thousand two hundred feet, has no permanent aperture on its summit or its sides: the small crater by which its eruptions are effected, is placed on the Plain of Calpi. The volcano of Pichinca, fifteen thousand feet high, and which I have particularly studied, has never ejected a current of lava since the excavation of the present valleys. On the contrary, the volcano of Popocatapetl in Mexico, sixteen hundred (according to Lieutenant Glennie near eighteen hundred) feet in height, pours out narrow currents of lava, like those from the smaller volcanoes of Auvergne or Italy."

Submarine volcanoes are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapour, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano rises out of the sea during an eruption. In 1783 a submarine volcano broke out near Iceland, which formed a new island; it raged with great fury for several months. The island afterwards sunk, leaving only a reef of rocks. In December, 1720, a violent earthquake was felt at Tercera, one of the Azores; the next morning a new island nine miles in circumference was seen, from the centre of which rose a column of smoke: it afterwards sunk to a level with the sea. A small island was formed in 1811 by a submarine volcano at a little distance from St. Michael's, one of the Azores: it was a mass of black rock, described by the captain of the Sabrina frigate, who witnessed its formation, to be equal in height to the high Tor at Matlock. A gentleman who visited the Azores in 1813, informs me that it has sunk down and disappeared: there is now eighty fathom water in the place.

Near Santorini, in the Grecian Archipelago, submarine volcanoes have repeatedly burst forth during the last two thousand years, and formed several new islands: three of the ancient eruptions are recorded by Pliny, Strabo, and Seneca. The last eruption was in the year 1767.

So recently as the year 1831, a submarine volcano broke out not far from the island of Sicily, attended with all the phenomena before described. It was visited by some French geologists in September, soon after the eruptions had so far subsided as to allow them to land. Its circumference was found by measurement to be seven hundred and eighty yards, its height about two hundred and twenty feet. It appeared to be composed entirely of scoriæ and loose volcanic fragments; in the centre of these were some hard globular blocks of lava, but they appeared to have been projected from the crater. The borders of the crater were about two hundred feet high on one side, and about forty on the other; the bottom was filled with orange-coloured water, and covered with a thick froth. White vapours issued continually, not only from the surface of the water, which appeared to be in a state of ebullition, but from innumerable fissures in the whole ground, and from the adjacent sea. The black sand on one side of the island, for about fifty or sixty feet, appeared burning. Bubbles of gas or vapour rose apparently from the interior of the earth, and they threw up with a slight detonation volcanic sand and particles. This volcanic island had risen from the depth of about five or six hundred feet below the surface of the sea. M. Prévôt states his belief that this volcano ejected currents of submarine lava; and though the island is composed of scoriæ and fragments thrown out of the crater, which is what the French denominate a *Crater of Eruption*, yet that it was preceded by an upheaving of the soil (*soulèvement*), and that there is a belt of rocks at the base, which are the border of a crater of elevation (*cratère de soulèvement*). M. Prevot anticipated, that owing to the loose materials of which this island is composed, it would not long resist the action of the waves. Indeed the island appeared to have suffered considerable degradation before the French geologists landed, for Captain Senhouse, who visited it the preceding month, August 3. stated its circumference to be about one mile and a quarter. According to Captain Swinburne, who observed some of the earliest eruptions from this volcano on the 19th of July, the external diameter of the crater was estimated at from seventy to eighty yards, it was not then more than about twenty feet above the sea. The agitated water in the crater escaped by an opening on one side: he says, "After the volcano had emitted for some time its usual quantities of white steam, suddenly the whole aperture was filled with an enormous mass of hot cinders and dust, rushing upwards to the height of several hundred feet, with a loud roaring noise; then falling into the sea on all sides with a still louder noise. Renewed explosions of hot cinders and dust were quickly succeeding each other, while forked lightning, accompanied by rattling thunder, darted from all directions within the column now darkened with dust, greatly increased in volume, and distorted by sudden gusts and whirlwinds." The latitude of this island is, or rather was, 37° 11′ north, and longitude east 12° 44′.

At the beginning of January in the following year the top of the island was somewhat below the surface of the sea, and at the latter end of February soundings had been made at different times, which discovered depths of from fifty to one hundred and fifty feet, from the surface of the sea to the cone of the volcano. This sudden sinking down of the volcano must be attributed to the subsidence of the ground beneath it.

The French geologists who visited this submarine volcano describe the island as being a crater of eruption (*cratère d'éruption*), while the base below the sea is supposed to have been formed by the upheaving of solid rocks, or to be a crater of elevation (*cratère de soulèvement*).

Craters of eruption are formed by the accumulation of lava or other volcanic matter around the orifice from whence they flowed, or were projected. Such is, perhaps, the origin of the greater number of volcanic craters. That eminent geologist, Von Buch, however, maintains, that beds of primary, or other rocks, have been sometimes raised from beneath the sea to considerable elevations, before the subterranean fire had opened a passage for the eruption of lava or scoriæ. Suppose successive beds of lava to have been poured through a chasm over the bottom of the ocean, and afterwards consolidated, and the chasm to become covered by an immense mass of solid lava; in a succeeding paroxysm, the volcanic energy being unable to force a passage through the former opening, and thus acting with compressed intensity, might upheave the beds of submarine lava and the subjacent rocks to a considerable height above the sea, before a new passage was opened for a subsequent eruption. This would be a crater of elevation. With the ancient lava, the lower beds of granite or other rocks might also be raised up. This mode of volcanic operation is so analogous to that which has up-heaved mountain masses in every part of the globe, that I am at a loss to conjecture on what principle it has been objected to. Let the reader refer to the position of the beds at Wren's Nest Hill, near Dudley, and their contiguity to basalt (Plate III. fig. 4.); or, what may be more directly to the purpose, let him turn to the section of Crich Cliff (page 41.), in which the strata encircle and cover the hill, like the coats of an onion, and in which there is a mass of toadstone near the centre. Few geologists will deny that the beds have been up-heaved by a power acting from beneath; or that the protrusion of beds of volcanic toadstone was the original cause of the elevation of the strata. If the up-heaving power at Crich Cliff had been increased in intensity, and a passage been opened near the summit, through which streams of lava and showers of scoriæ had been projected, we should have had a crater of elevation, though its structure and mode of formation might have been concealed by volcanic substances covering the original rock. Von Buch and Humboldt have been challenged to discover a single volcanic cone composed exclusively of marine or of freshwater strata; but surely this is overlooking the conditions under which such a cone must be formed: the eruptions from the crater, when once open, would cover a great part of the external cone with lava and volcanic matter. The above eminent geologists might show Crich Cliff and Wren's Nest Hill, as presenting a triumphant confirmation of the theory of elevation; a confirmation not the less satisfactory, because the volcanic action had been arrested precisely at the point, where the truth of the theory was rendered most apparent.

The island called the New Kamenoi, raised near St. Erini during a submarine eruption in the year 1707, was partly composed of limestone, and covered with living shells, which prove that the rock was upraised in a solid mass. Volcanic islands of great elevation have been raised, in the present century, in the group called Aleutian Islands; and as they remain permanent, with little diminution of height, it is supposed by Von Buch that they consist of solid rock.

The marine limestone on the sides of Ætna, offer confirmatory evidence of the truth of the theory of elevation, though the strata may have been subsequently disturbed, and dip in different directions. I have in my possession an enormous marine shell, or gigantic cerithium. According to the notice written upon it by the late Faujas St. Fond, it was obtained from the Peak of Teneriffe, which indicates that this vast volcanic mountain, was originally a crater of elevation raised from the sea.

Some volcanoes in Europe, and many in the Andes, throw out aqueous torrents intermixed with mud and stones; indeed, the American volcanoes more frequently eject mud than lava. Eruptions of water from Ætna and Vesuvius are rare, and some which have been described as flowing from the crater of the former, have beenm erely the torrents of melted water from snow on its summit. The volcano of Macaluba, in Sicily, presents the phenomena of mud, water, and stones thrown out of the crater. Ferrara describes an alarming eruption which took place on the 29th of September, 1777:—"Dreadful noises were heard all round; and from the midst of the plain, in which was formed a vast gulf, an immense column of mud arose to the height of about one hundred feet, which, abandoned by the impulsive force, assumed the appearance of a large tree at the top. In the middle, stones of all kinds and sizes were darted violently and vertically, within the body of the column. This terrible explosion lasted half an hour, when it became quiet; but after a few minutes resumed its course, and with these intermissions continued all the day. During the time of this phenomenon, a pungent odour of sulphuretted hydrogen gas was perceived at a great distance, to the surprise of the inhabitants, who did not dare to approach this spot on account of the horrible noises. But many came the following day, and found that the new great orifice, had ejected several streams of liquid chalk (*creta*), which had covered, with an ashy crust of many feet, all the surrounding space, filling the cavities and chinks. The hard substances ejected were fragments of calcareous tufa, of crystallised gypsum, pebbles of quartz, and iron pyrites, which had lost their lustre, and were broken in pieces. All these substances form the outward circuit at this day. The unpleasant smell of sulphur still continued, and the water which remained in the holes was hot for many months; while a keen smell of burning issued from the numerous orifices around the great gulf, which is now completely filled."

Volcanoes frequently occur in groups, sometimes arranged along a line, as if they had originally been formed over one vast chasm, like the minor volcanoes on the sides of Ætna; sometimes they are dispersed irregularly over the surface, and sometimes they are isolated like Ætna, and the Peak of Teneriffe.

The volcanoes in South America, Humboldt observes, instead of being isolated or dispersed in irregular groups as in Europe, are arranged in rows, like the extinct volcanoes of Auvergne, or the volcanoes of Java; sometimes in one line, and sometimes in two parellel lines. These lines are generally in the same direction, as the chain of the Cordilleras, but sometimes (as in Mexico) they form an angle with it of 70°. The volcanoes of Mexico, he further observes, are placed in a narrow zone, between latitude 18° 59′ and 19° 12′. This he regards as a vast chasm, seven hundred and fifty miles in length, extending from the coast of the Atlantic to that of the Pacific, and to the islands of Revillagiedo in the same direction.

Our knowledge of volcanic geography is at present imperfect, but among the principal volcanic groups and ranges, the following may be briefly enumerated: —

In the Azores, there are no less than forty-two active or dormant volcanoes; and submarine volcanoes not unfrequently break forth in their vicinity. Almost all the other islands in the Atlantic, and many of the West Indian islands, are volcanic. Numerous islands in the Pacific Ocean and the Indian Seas have large volcanoes. In the Island of Java alone, there is a range consisting of thirty-eight large volcanic mountains, some of which are at present in an active state; they are detached from each other, and though some of them are covered by the vegetation of many ages, the indications of their former eruptions are numerous and unequivocal.

Numerous volcanoes exist, near or within the arctic circle, in Kamschatka, in Greenland, and in Iceland. A range of active or dormant volcanoes extends from the southern extremity of America to the northern, along a line of six thousand miles in length. Of the volcanoes in northern Asia, or the interior of Africa, we have little information, and the volcanoes covered by the sea, cannot be estimated; but from the above statement, we are authorised in believing, that volcanic fires are more extensively operative, than many geologists are disposed to admit.

Many facts might be cited to prove the connection which exists between volcanoes at a vast distance from each other. In 1783, when a submarine volcano near Iceland suddenly ceased its eruptions, a volcano broke out two hundred miles distant, in the interior of the island. On the night in which Lima and Callao were destroyed by an earthquake, four new volcanoes broke out in the Andes. The source of volcanic fire is seated deep under the surface of the earth: were it not so, the ground in the vicinity of volcanoes would sink down. Yet Ætna has continued to pour out streams of lava for three thousand years; and Stromboli has had daily eruptions for nearly as long a period.*

There are some instances of volcanoes having been entirely engulfed in the chasms beneath them. The volcano of the Pic in the Island of Timore, one of the Moluccas, is known to have served as a prodigious watch-light, which was seen at sea at the distance of three hundred miles. In the year 1638, the mountain during a violent eruption entirely disappeared, and in its place there is now a lake. Many of the circular lakes in the south of Italy are supposed to have been formed by the sinking down of volcanoes; but the best authenticated account we have of the destruction of a volcanic mountain, is given by Governor Raffles in his History of Java.

"The Papandayang, situated at the western part of the district of Cheribor, in the province of Sukapura, was formerly one of the largest volcanoes in

---

* Since the period of authentic history, no great changes have taken place in the country round Ætna; but it appears from Virgil, as well as from a passage in Strabo before quoted, that an ancient tradition existed of the sudden separation of Sicily from Italy.

> "Hæc loca, vi quondam et vastâ convulsa ruinâ
> Dissiluisse ferunt: cùm protinus utraque tellus
> Una foret, venit medio vi pontus, et undis
> Hesperium Siculo latus abscidit: arvaque et urbes
> Littore diductas angusto interluit æstu." *Æn.* l. iii.

Probably this separation took place when Ætna emerged from the ocean: the occurrence of beds of limestone with shells upon its sides, proves that it was originally a submarine volcano.

the island of Java; but the greatest part of it was swallowed up in the earth, after a short but very severe combustion in the year 1772. The account which has remained of this event asserts, that near midnight, between the 11th and 12th of August there was observed about the mountain an uncommonly luminous cloud, by which it appeared to be completely enveloped. The inhabitants as well about the fort, as on the declivities of the mountain, alarmed by this appearance, betook themselves to flight; but before they could all save themselves, the mountain began to give way, and the greatest part of it actually *fell in*, and disappeared in the earth. At the same time a tremendous noise was heard, resembling the discharge of the heaviest cannon. Immense quantities of volcanic substances, which were thrown out at the same time, and spread in every direction, propagated the effects of the explosion, through the space of many miles."

"It is estimated that an extent of ground of the mountain itself, and its immediate environs, fifteen miles long, and full six broad, was by this commotion swallowed up in the bowels of the earth. Several persons sent to examine the condition of the neighbourhood, made report that they found it impossible to approach the place where the mountain stood, on account of the heat of the substances which covered its circumference, and which were piled on each other; although this was the 24th of September, and thus full six weeks after the catastrophe. It is also mentioned, that forty villages, partly swallowed up by the ground, and partly covered by the substances thrown out, were destroyed on this occasion, and that two thousand nine hundred and fifty-seven of the inhabitants perished. A proportionate number of cattle was also destroyed, and most of the plantations of cotton, indigo, and coffee, in the adjacent districts, were buried under the volcanic matter. The effects of this explosion are still very apparent in the remains of this volcano."

It has been already stated, that the volcanoes in the Andes more frequently throw out water and mud than lava. The damage which these aqueous and muddy eruptions occasion, is often prodigiously great. Sometimes the deluge of water attending a volcanic explosion does not come from the interior of the earth, but from the snow which covers the mountain being rapidly dissolved; but in other instances it proceeds from the crater. Interior cavities of vast extent and depth, containing water, are opened during an eruption, and the water coming into contact with ignited lava, is forcibly driven out, and, according to Humboldt, carries along with it a great quantity of small fishes, which he has denominated *pimelodes Cyclopum.** These fishes are about four inches in length, and are of the same species that inhabit the neighbouring brooks and lakes: the number thrown out is sometimes so great, that their putrefaction contaminates the air, and occasions serious maladies among the inhabitants of the adjacent country.

Though the water ejected from volcanoes may in many instances be regarded as of accidental occurrence, I conceive it to be different with those muddy eruptions, which cover large tracts of country with strata containing bituminous or inflammable matter: these strata are as essentially volcanic products, as the matter thrown out of the volcano of Macaluba in Sicily, which never ejects lava; and we are hence instructed, that one of the substances which promotes volcanic combustion, is bitumen or carbon. The muddy eruptions in the Andes, when first ejected, have little consistence or tenacity; but they soon become hard, and form what is called by the inhabitants *moya;* it is dark coloured and soils the fingers, and is used instead of turf for fuel.

---

* It ought to be stated, that the existence of internal cavities filled with water supplied from the melted snow, is an inference from volcanic phenomena, which, however reasonable it may appear, it is impossible to prove.

Boiling springs, and thermal waters, must be classed with volcanic phenomena; for it can scarcely be doubted, that the geysers in Iceland, which throw up columns of boiling water at intervals, to the height of seventy or eighty feet, are occasioned by the subterranean fires which extend under that island. To the same cause must be ascribed the boiling fountains in the island of St. Michael, one of the Azores. The hot springs in the vicinity of the Pyrenees, in Italy, and in other parts of the world, may with much probability be supposed to have a similar source of heat. The unvaried equality of their temperatures for centuries, proves that this source lies far below the agency of those causes which operate on the surface. It has been remarked, that hot springs are most frequent in volcanic and basaltic countries. Though no active volcano exists in the Pyrenees, M. Dralet, in his *Description des Pyrenées*, says, " that the hot springs and frequent earthquakes in different parts of this chain, offer proofs of the present operation of subterranean fires." I have described the thermal waters of the Alps in the second volume of my "Travels in the Tarentaise," and in Chap. V. p. 99. of the present work.

However powerful the effects of subterranean fire may be in various parts of the globe, we must conclude, from the remains of ancient volcanoes, that in a former period, the action of volcanic fire has been far more extensive and intense than at present.

According to Breislak, an Italian geologist, in a space of twenty miles in length and ten in breadth, between Naples and Cumea, there are no less than sixty craters; some of them are larger than that of Vesuvius. One of them is two miles in diameter. The city of Cumea, founded twelve hundred years before the Christian era, is built in the crater of an ancient volcano.

In other parts of Italy, there are undoubted vestiges of ancient volcanoes. In Sicily, there are a number of extinct volcanoes, beside those connected with

Ætna. Many islands in the Grecian Archipelago are volcanic. There are remains of large volcanic craters in Spain and Portugal; and the extinct volcanic mountains in the middle and southern parts of France, cover several thousand square miles. On the eastern banks of the Rhine, and the environs of Andernach, there are numerous extinct volcanoes.

It is further to be noticed, that the craters of ancient volcanoes, are many of them of far greater size than the present ones. Vesuvius is a comparatively small cone, raised within the crater of a larger volcano. The cone of the Peak of Teneriffe, according to the description of travellers, stands within a volcanic plain, containing twelve square leagues of surface, surrounded by perpendicular precipices and mountains, which were the border of the ancient crater. If the opinion of M. Humboldt be correct, all these craters are diminutive apertures, compared with the immense chasms through which, in remote ages, subterranean fire has forced a passage through the crust of the globe.

"The whole of the mountainous parts of Quito," he says, "may be considered as one immense volcano, occupying more than seven hundred square leagues of surface, and throwing out flames by different cones, known by the denominations of Cotopaxi, Tungurahua, and Pichincha. In like manner," he adds, "the whole group of the Canary Islands is placed as it were on one submarine volcano. The fire forces a passage sometimes through one, and sometimes through another of these islands. Teneriffe alone, contains in its centre an immense pyramid terminated by a crater, throwing out from one century to another lava by its flanks. In the other Canary Islands, the different eruptions take place in various parts, and we nowhere find those isolated mountains, to which volcanic effects are restrained. The basaltic crust formed by ancient volcanoes seems every where undermined; and the currents of lava seen at Lanzerote and Palma remind us," he adds, "by every geological affinity, of the eruption which took place in 1301 at the Isle of Ischia, amid the tufas of Epimeo."

In the preceding part of the present chapter, I have endeavoured to give a succinct account of the most important volcanic phenomena. The only formations of hard crystalline rocks in the present day are volcanic; and if we trace the connection that exists between modern and ancient volcanic rocks, and between the latter and the rocks of trap and porphyry, among the ancient rock-formations, we shall extend the dominion of Pluto over a large portion of the globe.

Many of the ancient volcanic rocks, have not flowed in currents from limited apertures, like modern lavas. "The volcanic porphyries on the back of the Cordilleras," says M. Humboldt, "are undoubtedly of igneous origin; but the mode of their formation is not like that of modern lavas, which have been erupted since the excavation of valleys. The action of volcanic fire by an isolated cone or crater of a modern volcano, differs necessarily from the action of this fire, through the fractured crust of the globe." It has been observed by the same geologist, that the further back we can trace volcanic eruptions, the greater is the similarity between their products, and the rocks which are regarded as the most ancient; — hence the countries that have been the seats of ancient volcanoes, are particularly interesting to the geologist. In Auvergne, and the more southern parts of France, there are extinct volcanoes of different ages, covering with their products several thousand square miles. The most recent of these volcanoes has been extinct or dormant since the records of authentic history, and probably for a longer period. Julius Cæsar, who was encamped on this volcanic soil, and has described the country, makes no allusion to its having been the seat of active volcanoes.*

---

* I visited the extinct volcanoes of France in the spring of 1822, and published an account of them in the 2d volume of my Travels, accompanied with cuts, and a section and outline of the

West of the town of Clermont, there is an extensive granitic plain, rising about sixteen hundred feet above the level of the river Allier. On this plain there are numerous cones, and dome-shaped hills, varying in height from twelve hundred to two thousand feet; some of these cones have well-preserved craters, and the cones themselves are chiefly formed of scoriaceous lava. These are the most recent volcanoes of that country; their products differ in no respect from those of modern volcanoes, except that the lava may often be observed passing to the state of compact basalt, exactly similar to many of the basaltic rocks in Great Britain. That these volcanoes are the most recent, is proved by the lava flowing down from them into the present valleys; and hence we are certain, that the eruptions must have taken place subsequently to the excavation of the valleys. There are other currents of lava from more ancient volcanoes, that have flowed before the valleys were excavated, and form isolated caps on the hills that enclose the present valleys. These currents of lava are composed chiefly of compact basalt: the position of these isolated caps of basalt is similar to that on the hill *b*, (Plate III. fig. 2.) but they are not always columnar. The openings from whence these beds of basalt have flowed cannot be always traced; but as we can observe the change from scoriaceous lava to basalt in the currents of undoubted lava, we cannot hesitate to admit, that the basalt which forms these caps, must have had a similar origin. Under the caps of basalt, there are in many situations thick beds of volcanic tufa, containing bitumen, which will be subsequently noticed. Beside the volcanoes with craters, that have ejected currents of scori-

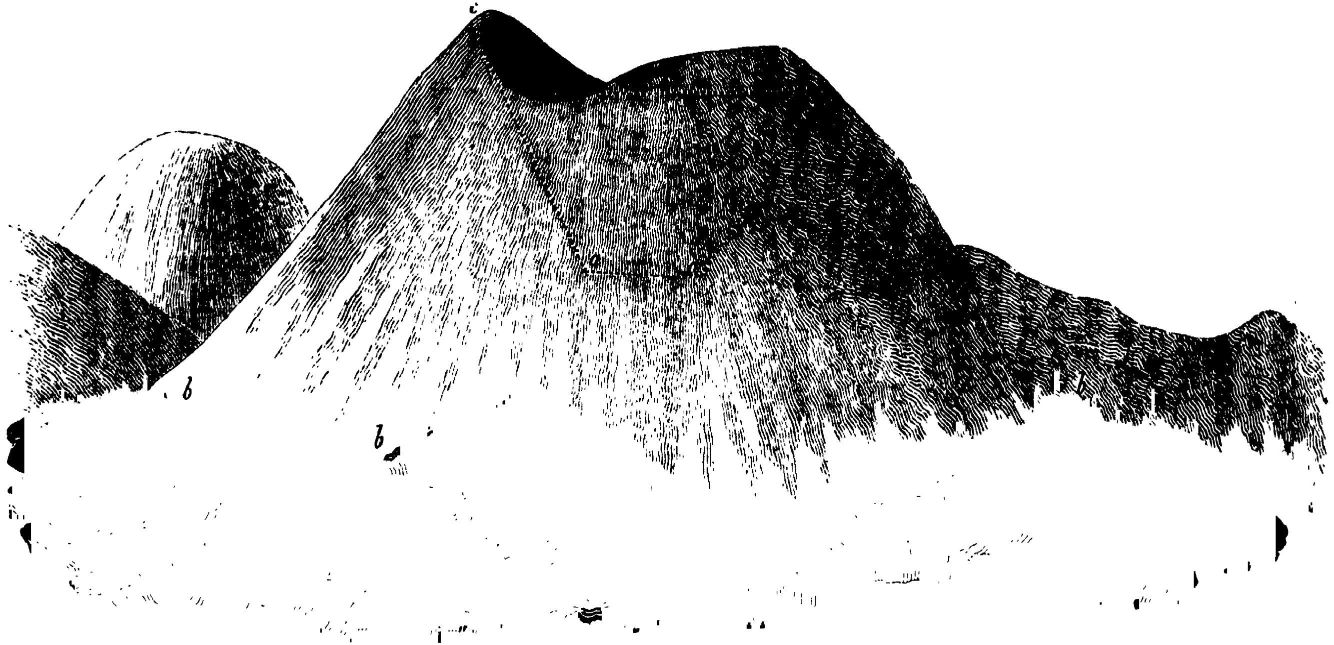
---

country round Clermont, which is, I believe, the first attempt to render in this manner the structure of this volcanic district intelligible to the general reader. Without the aid of sections and diagrams, it is difficult to obtain a distinct notion of the relative position of the different volcanic formations.

aceous lava and basalt, and poured them into the valleys; and beside the more ancient volcanoes, that have formed beds of basalt before the excavation of the valleys, —there are other volcanic mountains, which have rounded summits or domes, without any perforation or crater, and these are chiefly composed of whitish or grey earthy felspar, containing imbedded crystals of felspar: to this rock the name of trachyte has been given, on account of its rough fracture. It may be properly called a volcanic porphyry.

The first, or more recent volcanoes, resemble in every particular the existing volcanoes in various parts of the world; and the currents of lava may be traced from their sides along the granitic plane on which the volcanoes stand, and thence into the adjacent valleys for many miles. The lava appears as fresh as the recent lavas from Vesuvius, though it has been exposed to the action of the atmosphere for some thousand years. The Puy de Pariou is the most perfect of these volcanic cones. The following description of it is taken from the 2d volume of my Travels:—" We were one hour in going from La Barraque, a mountain village, to the foot of the Puy de Pariou, where we left our char, and another hour in ascending to the summit, as we halted several times to rest. As nearly as I could estimate, the summit of this mountain rises about one thousand feet above the plain, and is therefore about three thousand eight hundred feet above the level of the sea. The crater, which is the best preserved of any in Auvergne, is nearly circular. I walked round it, and its circumference is about eight hundred yards. Its shape is that of an inverted cone or funnel quite perfect. The edge or rim of the crater is narrow, from which the descent or slope is very rapid on each side: the depth of the crater from the highest part of the edge (which is on the southern side) to the small plain at the bottom, may be about three hundred and twenty feet; and from the western side, about two hundred and sixty English feet. The lava which flowed from Pariou to La Barraque, and thence towards the plain of Clermont, is generally supposed to have issued from the crater; but had this been the case, the crater would not have been so entire as it is; and I am fully convinced, that the eruption of such a mass of lava must have broken down one of the sides, as at Nugere, which we afterwards visited, and the Puy de Vache. There appears, I think, decisive marks of the lava having flowed from an opening on the north-east side of the mountain, to which it may be traced. Indeed on this side there are the indications of a much larger crater, which has its escarpments turned towards the Puy de Pariou like those of Mount Somma, which are turned towards Vesuvius. The Puy de Pariou was, in all probability, a volcanic cone, formed within the larger crater by its last eruption of scoriæ.

" The annexed cut, from a drawing I made near the foot of the mountain, represents the external shape of the Puy de Pariou, and the dotted lines show the form and the relative depth of the crater, the bottom of which, *a a*, is about three hundred and twenty feet below the highest part of the rim *c*. The current of lava, *b b*, is on the north-east side of the present mountain. The internal shape of Pariou approaches to quadrilateral, or is that of a cone compressed on each side, and somewhat elongated from north to south. The bottom of the crater is nearly flat; there was a little water, from the recent melting of the snow, remaining in some of the hollows: indeed we were told at Clermont that we should find the crater filled with snow. It was early in May: but the snow was gone, and grass was growing in some parts; others were covered with loose masses of scoriæ. Owing to the great porosity of the soil, the crater of Pariou seems doomed to perpetual sterility, — there is no tree or shrub within it; while that of Vesuvius, after a cessation of erup-


c
a
b
b

tions for only four centuries, was covered with large chestnut trees." — Vol. ii. page 307.

In the Puy de Pariou, and many other volcanic mountains of this district, there is nothing particularly remarkable, except, that the lavas which have flowed from them at a remote period, should preserve all the freshness of recent lavas, and that volcanoes so well characterised, both by their forms and mineral products, should have remained unnoticed until the middle of the last century. The round-topped or dome-shaped hill on the left of the Puy de Pariou is called Sarcoui; it belongs to that class of volcanoes that have no craters, which will subsequently be noticed. The more ancient volcanoes, that have poured out the thick beds of basalt that cap many of the valleys round Clermont, cannot always be traced, as the openings from whence it issued may be covered by the lava of more recent eruptions. In order to obtain a more distinct idea of the position of these caps of basalt, it will be necessary to remark, that the granitic plain above Clermont, and the hollows or valleys in its sides, received their present form prior to the most ancient volcanic eruptions; these hollows, or ancient valleys, were probably basins or lakes, in which were deposited a vast thickness of calcareous strata, containing freshwater shells, and the bones of land quadrupeds. Into these lakes, there has flowed a vast mass of volcanic tufa, covering the limestone, and sometimes intermixed with it. The volcanic tufa, and the freshwater strata, appear to have filled up the ancient valleys or lakes; and on this tufa, the basalt was deposited by a subsequent eruption. At a later period, diluvial currents have furrowed excavations or new valleys in the basalt, in the subjacent tufa, and in the freshwater limestone, leaving detached portions or hills, composed of basalt, tufa, and limestone, which once were parts of continuous beds. Into these new valleys, the lava of the most recent volcanoes has flowed. The most remarkable circumstance attending these more ancient eruptions, is the bituminous nature of the tufa, which forms the lowest bed, and covers the fresh-water limestone of Gergovia, Canturges, and the neighbouring hills. This tufa is in some parts more than three hundred feet thick; it consists of earthy basalt or wacke, intermixed with lumps of scoriæ and basalt, and in some places with limestone: it is every where impregnated with bitumen. The tufa of Auvergne bears evident marks of being the product of an aqueous or muddy eruption, intermixed with lava and scoriæ, which increase in quantity in the upper part of the mass, and at length cover it with compact lava or basalt. That the tufa was ejected in an aqueous or muddy state is proved, by the quantity of bitumen which it contains: by any other mode of formation, the bitumen would have been consumed. By some former writers it has been supposed that the tufa is an alluvial bed of sediment and water-worn fragments; but the bituminous nature of this bed excludes the probability of this mode of formation; and at Montadoux, the upper part of the tufa may be clearly seen passing into basalt. In some situations, however, the tufa has been transported from its original situation, and intermixed with fragments of more ancient rocks.

The dome-shaped hills without craters, composed of volcanic porphyry or trachyte, have given rise to much speculation respecting their origin. Some geologists contend that they are only the remains of one vast bed of trachyte, of which the other parts are washed away. Others contend that they are merely portions of the granite on which they rest; and that this granite has been wholly or partially fused, and upheaved, by the expansive force of subterranean fire. This mode of formation is rendered probable, by what may be observed at the Puy de Chopine, which is a mountain standing within a crater; this mountain is partly composed of unaltered granite and sienite, and partly of volcanic trachyte, and appears to have been upheaved, before the fusion of the granite had been effected.

The Puy de Dôme, near the summit, is chiefly composed of whitish trachyte intermixed with unaltered granite; the lower part of the mountain is covered with scoriaceous and compact lava. The dome of this mountain rises 2000 feet above the elevated granitic plain on which it stands, and 4797 feet above the level of the sea: it has no crater or opening on the top; but Dr. Daubeny says, two streams of lava appear to have pierced the sides of the mountain, and to have descended into the valleys. In this respect the Puy de Dôme resembles the enormous dome of trachyte on the summit of Chimborazo, twenty thousand feet above the level of the sea, which, according to Humboldt, acts mechanically on the neighbouring country, fracturing the strata, and changing the surface of the soil; but it has no permanent opening, neither on its summit nor sides. In some of these dome-shaped hills, the action of subterranean heat appears to have been so intense, as to reduce the whole into a spongy pulverulent mass; but, what is remarkable, in the middle of this spongy mass, lumps of scoriaceous lava are sometimes found. It has been objected to the formation of trachyte or volcanic porphyry from granite, that it contains a very small portion of quartz; but in this respect it resembles many granite rocks in Auvergne, in which the quartz is scarcely perceptible.

In the volcanic districts south of Clermont, the porphyry becomes more compact, and assumes the hardest state of that rock; the base of the stone is sometimes green, and the crystals of felspar white: it will receive a fine polish, like the green porphyry of the ancients.

The basaltic rocks also extend south of Clermont, into the districts called the Velay and Viverrais, and cover a great portion of the soil. Near Monpezat, Thueys, and Jaujac, according to M. Faujas

St. Fond, there are small volcanic mountains, with distinct currents of lava, that appear to issue from their feet, and flow into the valleys. The lower part of the lava is scoriaceous, but the upper part is hard sonorous basalt, arranged in columns as perfect as those of Staffa or the Giant's Causeway. We have here a decisive proof of the igneous formation of columnar basaltic rocks. "The basaltic formation extends into the South of France, to the borders of the Mediterranean Sea, where, near to Adge, is the extinct volcano of Saint Loup, the cellular lava of which is employed in the construction of buildings on the canal of Languedoc."—*Daubuisson.**

There are numerous extinct volcanoes in several parts of Germany, particularly in some of the districts bordering the Rhine: these volcanoes, like those of central France, belong to different epochs, but the most recent appear to be more ancient than the earliest periods of authentic history. In the volcanic district of Eyf[illegible]e Rhine and the Moselle, are scatter[illegible] cones and eminences, some with [illegible] of which are filled with water, forming lakes [illegible] meres, without outlets. A German geologist divides these volcanoes into three classes: —

1. Those which have lakes or meres, and have ejected nothing but loose fragments of rock with balls of scoriæ and sand: of these there are eight in that district.
2. Those which have ejected fragments of slag, sometimes loose, and sometimes cemented: of these there are eight.
3. Those which have ejected streams of lava: of these six are enumerated.

---

* In the article "Volcano," which I wrote for Dr. Rees's Cyclopædia, I endeavoured to collect all the most important details of volcanic phenomena then known, and have given an account of different experiments made on lava by Spallanzani and others, which the limits of the present volume will not allow me to notice.

sulphur, iron, and water. In the cliffs of Charmouth, Whitby and Weymouth, we have precisely the same mineral substances combined, that were used in the experiment of Lemery.

The earth itself is in all probability the great laboratory in which, by the aid of subterranean heat, are combined and prepared the mineral substances that compose the hard crystalline crust of the globe. All the minerals which form primary rocks, occur in a perfect state in modern or ancient lava. The substances ejected through fissures in the earth, or volcanoes, belong to the four grand divisions of the mineral kingdom, — the inflammable, saline, metallic, and earthy.

The *inflammable substances* are sulphur, carbon, and hydrogen. The inflammable quality of sulphur prevents its being found in lava in a solid form; during volcanic eruptions it is evolved in a gaseous state combined with hydrogen. It is also sublimed from the fissures of extinct or dormant volcanoes, and forms thick incrustations on the sides of the craters. Almost all the sulphur of commerce in Europe is procured from the craters of dormant volcanoes in the south of Italy, Sicily, and the Lipari Islands. When the combustion of sulphur in volcanoes takes place where there is access to atmospheric air, it forms sulphureous acid gas, and sulphuric acid.

Carbon combined with hydrogen, forming bitumen, is found in volcanic rocks, and also in some basaltic or trap rocks. The volcanic tufa in the vicinity of Clermont, in France, contains so much bitumen, that in warm days it oozes out, and forms streams of bitumen resembling pitch, which is the more remarkable, as this tufa must have been erupted some thousand years. Bitumen has been observed oozing out of the lava of Ætna. The moya erupted from the volcanoes in the Andes in aqueous or muddy eruptions, contains so much bitumen or carbon, as to be inflammable. As bitumen exists in many volcanic rocks, the black smoke which issues during an eruption may proceed from its combustion, though it has generally been supposed to consist of minute volcanic sand, called ashes. Carbon also combines with hydrogen in a gaseous state, and forms carbureted hydrogen gas..

The hydrogen gas evolved from volcanoes, or from chasms in the earth during earthquakes, is generally combined with sulphur or carbon; it is probably formed by the decomposition of water, when it finds access to subterranean fire. Whether phosphorus be a product of volcanoes is unknown: its extreme inflammability prevents it from being discovered in a concrete form; but the dense white clouds, like bales of cotton, which sometimes cover Vesuvius, resemble the fumes produced by the combustion of phosphorus Among the products of volcanoes, only three are combustible at a moderate temperature; — sulphur, hydrogen, and carbon. It has been conjectured by Sir H. Davy, that the earths and alkalies which form lavas, exist in the centre of the globe in a metallic state, and take fire by the access of water. The property of the newly-discovered metals to inflame instantly on the access of water offers an easy explanation of the origin of volcanic fires, could we suppose that substances so extremely inflammable and oxidable have remained for ages in a metallic state. This theory is now abandoned. There may, however, be processes going on in the vast laboratory of the globe, that separate the earths from oxygen, and prepare them for the support of volcanic fires, by which they are thrown upon the surface, and thus establish a communication between the internal and external parts of our planet.

The saline products of volcanoes are not numerous. The sulphureous and sulphuric acids, formed by the combustion of sulphur during eruptions, act upon lavas and rocks, and produce different combinations, of which the most important are alum, sulphate of magnesia, sulphate of iron, or green copperas, and gypsum. Muriate of ammonia, or sal-ammoniac, forms an incrustation on many lavas soon after they cool: muriate of soda, or common salt, and muriate of copper and of iron, are found in the craters of volcanoes. Muriatic acid, in an uncombined state, occurs in some of the spongy lavas in Auvergne.

The *principal metallic substances* in volcanic rocks are iron and titanium; but ores of antimony, copper, and manganese, have sometimes been found in the craters of volcanoes. Tellurium, gold, and mercury are also said to occur in some volcanic rocks. The island of Ischia, which is entirely volcanic, contains a mine of gold.

Iron, in the form of brilliant laminæ, called specular iron, occurs in the cavities and fissures of many lavas. Magnetic iron ore, and oxide of iron, with iron sand and titanium, form a constituent part of nearly all dark-coloured lavas or basalt.

The *earthy products* of volcanoes are either vitreous, or stony, or scoriaceous, or spongy, or in loose grains or powder. Volcanic rocks are composed chiefly of felspar, and the dark-coloured mineral called augite; they contain also hornblende and grains of magnetic iron ore, with titanium and iron sand, and the mineral called olivine. Mica, leucite, iron pyrites, garnets, rubies, and zircon are also found in some volcanic rocks. The different states of lava, whether vitreous, compact, or scoriaceous, depend on the different circumstances under which it has cooled.

Volcanic rocks, being principally composed of the two minerals, felspar and augite, very minutely intermixed, derive their principal characters from the prevalence of one or other of these minerals. Those lavas in which felspar greatly predominates, have generally a whitish or greyish colour, and melt into a white glass. The lavas which contain a large portion of augite, have a dark colour, and melt into a black glass. According to M. Cordier, all volcanic rocks that have flowed as lava, and which appear the most homogeneous, are composed of microscopic crystalline particles, belonging to a small number of minerals, particularly felspar, augite, olivine, and iron sand; and the same intermixture of minerals may be observed in all scoriaceous lava and in basalt. To the white or grey lava, composed principally of felspar, the French have given the name of *trachyte*, from its breaking with a rough surface.

Trachyte. — Common or stony trachyte has generally a whitish or greyish colour, a dull earthy fracture, and is more or less fine-grained; sometimes the grains are very minute, and it has then a compact surface, and sometimes a glistening lustre, in which state it becomes pearlstone. Its hardness is variable; some of the trachytes near Clermont are spongy, and almost friable. Trachyte melts readily into a greyish glass; it generally contains imbedded crystals of vitreous felspar. Acicular or needle-shaped crystals of hornblende, hexagonal crystals of mica, and grains of iron sand, and laminæ of specular iron ore, occur in trachyte. Augite is seldom found in the trachyte of Europe, though it is common in the trachytes of the Andes. The claystone of Braid Hill, near Edinburgh, nearly resembles some of the trachytes in Auvergne; but it is not porphyritic. Trachyte may be regarded as an earthy form of felspar; it is, therefore, unnecessary to speak of its constituent parts. To the variety of trachyte on the Puy de Dôme, M. Von Buch has given the name of *domite*, — a term which the French geologists have properly rejected, as it is only common trachyte, rather whiter than some of the other varieties. It has before been stated, that the trachytes in Auvergne were probably formed by the more or less perfect fusion of granite; like the granite of that district, they contain but a very small portion of quartz.

Trachyte occurs in the Lipari Islands in a perfectly vitreous state, forming obsidian or volcanic glass, which is sometimes colourless, and sometimes black; the black variety, however, forms a white glass when melted. The colouring matter, being fugitive, is probably bitumen: in this respect it differs from obsidian formed from dark lava or basalt: the latter melts into a black glass. Pumice appears to have been formed from felspar or trachyte, exposed to an intense heat, which has reduced it to a fibrous mass.

The island of Lipari contains a mountain entirely formed of white pumice: when seen at a distance, it excites the idea, that it is covered with snow from the summit to the foot. Almost all the pumice-stone employed in commerce is brought from this immense mine. The mountain is not one compact mass, but is composed of balls or globes of pumice aggregated together, but without adhesion. From hence Spallanzani infers, that the pumice was thrown out of a volcano in a state of fusion, and took a globose form in the air. Some of these balls of pumice do not exceed the size of a nut, others are a foot or more in diameter. Many of these pumices are so compact, that no pores or filaments are visible to the eye; when viewed with a lens, they appear like an accumulation of small flakes of ice. Though apparently compact, they swim on water. Other pumices contain pores and cavities, and are composed of shining white filaments. By a long-continued heat, pumice-stone melts into a vitreous semi-transparent mass, in which a number of small crystals of white felspar are seen. Black or dark-coloured pumice is more uncommon. Humboldt says, he has seen black pumice in which augite and hornblende may be recognised; he is inclined to think that such substances owe their origin to basaltic lavas, which have assumed a capillary or fibrous form by intense heat.

Immense quantities of pumice are sometimes thrown up by submarine volcanoes. It has been seen floating upon the sea over a space of three hundred miles, at a great distance from any known volcano: from hence it may be inferred, that submarine volcanoes sometimes break out at such vast depths under the ocean, that none of their products reach the surface, except such as are lighter than water.

Obsidian, or volcanic glass, so nearly resembles lumps of black glass, that they can scarcely be distinguished by the unpractised observer. Its broken surface is smooth, conchoidal, and shining: the most common colour of obsidian is a velvet black. The thinner pieces are translucent. It is harder than glass, and strikes fire with steel. It is common in the neighbourhood of volcanoes, and in some basaltic formations. The obsidian accompanying basalt contains a large portion of augite, and melts into a black glass, as before mentioned; in other respects, its mineral characters are the same as those of obsidian from trachyte. In Lipari, one of the volcanic isles, the mountain de la Castagna, according to Spallanzani, is wholly composed of volcanic glass, which appears to have flowed in successive currents, like streams of water, falling with a rapid descent, and suddenly frozen. This glass is sometimes compact, and sometimes porous and spongy. Numerous veins of obsidian are said to intersect the cone of Mount Vesuvius, and serve as a cement, to keep together the loose materials of which it is composed.

On the elevated plain which surrounds the conical peak of Teneriffe, there are masses of obsidian, which graduates into pitchstone, containing crystals of white felspar. On the south-west side of the peak, there is a stream of vitreous lava or obsidian, several miles in length. Colonel Imrie describes a current of lava in the island of Felicuda, intermixed with obsidian, which had been flowing with it, and now forms part of the congealed stream. " In some parts the obsidian is seen losing its brilliancy, and passing into granular lava, which becomes similar in colour, fracture, and texture, to the other parts of the stream. Where the obsidian appears in a state of perfect glass, it is very near to where it has been first ejected from the side of the crater, and in a situation where it must have undergone a rapid cooling. In some parts of these congealed streams, I could trace a transition of the obsidian into pumice. In these places, the obsidian contained scattered air globules, which were almost always lengthened in the direction of the stream. These globules gradually augmented in number, until the whole substance became a light, fragile, and frothy pumice."[*] Obsidian is found in the crater of Vulcano, one of the Æolian islands, and may be seen forming there at the present time.

Rocks of trachyte sometimes, though rarely, have a columnar structure. Owing to the facility with which trachyte breaks down, it forms beds of conglomerate intermixed with scoriæ and pumice. The more finely comminuted parts of trachyte, intermixed with earthy matter, form beds of tufa. These beds of conglomerate and tufa, frequently environ trachytic mountains, and hide from the view of the geologist their connection with the subjacent rocks.

When trachyte becomes compact and hard, and acquires a laminar or slaty structure, it passes into clinkstone or phonolite, so called on account of its yielding a metallic sound when struck. (See Chap. IX., where it is observed, that dark lava or basalt also passes into clinkstone.) Thus it appears that both the light-coloured lava, or trachyte, and the dark-coloured lava, or basalt, according to the different degrees of heat to which they have been subjected, or the different circumstances under which they have cooled, form volcanic glass, clinkstone, or pumice; and the only difference to be observed in the minerals formed from the trachyte or the basalt, is a difference of colour in the minerals themselves, or in the glass which they yield when melted. Black pumice from basalt is however very rare.[*] Basaltic

---

[*] Memoirs of the Wernerian Society, vol. ii. p. 47.

[†] According to the microscopic and mechanical analysis of light-coloured and dark lavas, by M. Cordier (whether compact or scoriaceous), it appears that the stony lavas which melt into a white glass, contain ninety per cent. of felspar. Those lavas which melt into a bottle-green glass or enamel, contain only from fifty-five to seventy per cent. of felspar; such are the greenish, greyish,

dykes, and the overlying rocks of porphyry, trap, and basalt, described in Chap. IX. ought, I am persuaded, to be classed with ancient volcanic rocks, but their igneous origin is not yet universally admitted, and it is desirable to separate theoretical views from a description of facts. This, however, cannot always be done: circumstances which indicate the mode of rock formations, will deservedly force themselves on our attention; and in stating them fairly, and the inferences which may be drawn from them, we relieve geology from much of its dryness, and stimulate succeeding observers to a strict investigation of nature.

Dark-coloured recent lava does not differ essentially from basalt; it is generally more porous. Probably the compact state of basalt was the result of refrigeration under pressure; it may, however, be frequently observed in Auvergne, passing into the state of scoriaceous lava. Some of the recent lavas from Vesuvius are compact, and have a glistening lustre, but they are more commonly porous. In some volcanic eruptions, lava appears to have acquired the most perfect fluidity. According to Professor Bottis, ho was an eye-witness of the eruption of Vesuvius

or dark-coloured basalt. On a microscopic examination of dark lava or basalt, it appears to consist of minute crystalline grains. The whitish grains belong chiefly to felspar, but in the lava from Vesuvius, to leucite; a small proportion of these grains are chrysolite. The yellowish or greenish grains belong to augite and hornblende: those of augite are rounded and irregular, with a vitreous fracture and splendent lustre. The grains of hornblende are long, and assume a prismatic form; they present indications of a laminar structure, and have little lustre. The perfectly black grains are iron sand, containing iron, combined with titanium; the grains of iron ore (*fer oligiste*) may be known by yielding a red powder when pulverised. Volcanic glass, volcanic scoriæ, and volcanic tufa, are all composed of the same minerals as the most compact lava; and all the most homogeneous dark volcanic rocks are composed of minute microscopic grains, which are chiefly felspar and augite, with a small proportion of olivine and iron sand. M. Cordier informed the author that the microscopic examination of lava was much facilitated by steeping the piece to be examined in dilute muriatic acid.

in 1776, the lava spouted from three small apertures, precisely like water, forming beautiful fountains of fire, which described curves of different dimensions as they fell. In the same year, a current of lava from the summit of Vesuvius flowed with the velocity of a mile and a half in fourteen minutes: it struck upon the lava of 1771, and rebounded into the air, congealing in figures of various shapes. The length of time which currents of lava retain their heat is truly remarkable: the current which flowed from Ætna in 1669 is two miles in breadth, fifteen miles in length, and two hundred feet in depth; it retains a portion of its heat to the present day. Ferrara says, when this lava was perforated at Catania in 1809, flames broke out; and it continued to smoke at the surface after rain, at the beginning of the present century, or 130 years after its eruption.

Stones of enormous size are frequently projected from the craters of volcanoes; but the quantity of matter which they throw out in the state of scoriæ, sand, and powder, often exceeds that erupted in the state of lava, and is spread over distant countries. By the percolation of water it becomes agglutinated, and forms beds of volcanic breccia, and tufa. Sometimes the tufa is sufficiently solid to be used for building-stone; the Roman pepperino is a volcanic tufa. Pozzolana consists of minute particles of scoriæ, which have been partially decomposed: when mixed with lime, it makes a water-setting cement.

Some volcanic rocks decompose rapidly, and form productive soils; others resist the process of decomposition so effectually, that, after the lapse of some thousand years, they present all the freshness of the most recent lavas.

Age of Volcanic Rocks. — Nothing precise can be determined with respect to the relative age of volcanic rocks, except in those districts where they occur together, one covering the other. Humboldt, who has attempted to trace the different ages of volcanic formations, observes, that there are trachytes, clinkstones, and basalts, of different ages; but in proportion as we advance towards the more recent volcanic formations, they appear isolated, superadded, and strangers to the soil in which they are found. The lavas from existing volcanoes vary at different periods of their eruptions; we may, therefore, well conceive, that the volcanic masses which, during thousands of years have been progressively raised to the surface under very different circumstances of pressure and refrigeration, should present striking contrasts and analogies of structure and composition.

OBSERVATIONS.

From the various phenomena which volcanoes present, we may with probability infer, that the internal part of our planet is either wholly or partially in an igneous state, however difficult it may be to explain in what manner this heat is generated and confined. In every department of nature, our enquiries are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun is more inexplicable and surprising, than the constant generation of heat in the centre of our planet; but we cannot refuse our assent to the fact, though it is far beyond the power of the human mind to conceive, by what means the particles of light are propelled through space with such astonishing velocity. We are too apt to measure natural operations by their coincidence with the received systems of philosophy, and to make our own ignorance the standard of truth. Had all the volcanoes in the world been dormant for the last two thousand years, and were we only acquainted with their existence by the writings of ancient historians, we should discredit the fact, and prove its impossibility by an appeal to established chemical principles; we should further accompany the proof with a pathetic lamentation over the credulity of former times. The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt.

Admitting the existence of central fire in the earth, it is not difficult to conceive that there may be determinate causes, by which its intensity is increased or diminished at certain periods. We know little respecting the operation of electric or voltaic energy in the laboratory of nature, but, from the existence of electric light at the poles, we may infer that electric currents are passing through the earth, and are important agents in many subterranean phenomena. Perhaps the different beds of rock which environ the globe may act like a series of plates in the voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat without access to atmospheric air, or even in vacuo; and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, it must be recollected, that its action, when confined beneath the earth, is altogether different from that of fire on the surface, which changes and decomposes almost all substances exposed to its action. It is well known that the most inflammable substances, carbon and sulphur, undergo no change in their weight or properties when subjected to intense heat in vacuo. It is only when air or water obtain access to volcanic fire that it can produce effects analogous to those of combustion on the surface. Indeed, it appears probable that volcanic explosions and eruptions are occasioned by the access of water to subterranean fire. A sudden evolution of steam and vapour thus produced, will force a passage to the surface, in those parts where the incumbent rocks offer the least resistance, and the lava and fragments of rock will be ejected with a force, proportionate to the quantity of steam or air suddenly evolved.

CHAP. XIX.

ON THE REPOSITORIES OF METALLIC ORES.

Metallic Matter disseminated through Rocks. — Masses of Metallic Ore. — Metallic Beds. — Metallic Veins. — Rake Veins. — Flat Veins. — Accumulated Veins. — Cross Courses. — The remarkable Structure of the Botallack Mine worked under the Sea. — On the Formation of Metallic Ores. — Remarkable Phenomena in Mines. — Stream Works. — Gold disseminated in the Sands of Rivers in Africa, and North and South America. — Rocks in which certain Metallic Ores are found.

The rocks and strata, described in the preceding chapters, are composed of earthy minerals, sometimes combined with a portion of metallic matter, which in such instances may be regarded as a constituent part of rocks. The mineral substances to be described in the present chapter, as forming beds or veins, or irregular masses, or grains imbedded in other rocks, consist of metallic matter either pure or in combination with sulphur, oxygen, or acids.

The difference of external character between a pure metal and an earth is so great, that we find some difficulty, at first, in conceiving how metallic matter can form beds interstratified with earthy rocks; but the discoveries of modern chemistry have shown, that metallic and earthy minerals are closely allied. Nothing can appear more essentially different than a piece of polished iron and a piece of marble or slate; yet if iron be exposed to the action of air and water it is converted into rust, and in this state is known as ochre; and between ochre and powdered stone there is little difference of external character; nor would any one unacquainted with chemistry suspect that ochre was a metallic mineral. The ochre can, however, be easily reconverted into metallic iron: but to convert the earths into a metallic substance is a difficult process, — yet it has been effected; and it is further proved, that both earths and alkalies are metallic substances combined with oxygen. The metallic nature of the earths being ascertained, we can no longer be surprised that metallic minerals should be found intermixed with earthy minerals in rocks. Iron is found combined with earths in almost all rocks that are not white; and to the presence of iron they generally owe their colour, whether red, brown, or black.

The other metals rarely occur chemically combined with rocks or strata, but are found either disseminated in grains or irregular pieces, or forming beds between earthy strata, or filling veins that intersect rocks in different directions, as represented Plate IV. fig. 4. *a* and *b*.

The metals, except gold and platina, are rarely found pure, but are generally combined either with sulphur, oxygen, or acids; in this state they are called *ores*. When the metals occur pure, they are called *native metals*: thus we have native gold, native iron, &c.

Metallic ores and native metals are sometimes disseminated in grains through rocks; and when they are abundant, the whole mass of the rock is worked as a mine; but this is seldom the case. Tinstone, or the oxide of tin, is sometimes disseminated in grains in granitic rocks in Cornwall, but it is generally in the vicinity of a vein of tin ore, that disseminated grains of tinstone are found in the rock. At Weal Duchy mine, near Callington, silver ore is obtained, both from a vein which intersects the hill, and from the rock itself, at a considerable distance from the vein. From a section of the mine shown me by the proprietor, it appears that in the rock, which is white killas (a silvery clay slate), the ore is disseminated in various parts, or is collected in bunches. The silver is found native in filaments, or in the state of vitreous silver ore, black silver, and ruby silver. Gold frequently occurs in grains, disseminated through solid rocks, or in the sands of rivers. Considerable masses of metallic ore are sometimes found in rocks, particularly of iron ore; but these masses are generally formed by the meeting of numerous veins, or are parts of metallic beds that are greatly enlarged: — they will be described with beds and veins.

Metallic Beds. — Some metallic ores occur, taking the form of regular strata in the secondary rocks, or of beds in transition and primary rocks. Ironstone in thin strata alternates with coal, coal-shale, and sandstone, and has been described with the coal strata, in Chap. VIII.

Iron ore often forms beds of considerable thickness, interposed between rocks of gneiss, mica-slate, and slate. Metallic ores in beds or strata, may be regarded as constituent parts of the rocks in which they occur, and must be cotemporaneous with them; the metallic and the earthy minerals have been deposited at the same time, and have probably been separated by chemical affinity during the process of consolidation. Sometimes the metallic matter is intermixed with a bed of slate, or of other rocks, in such abundance, that the whole bed is worked as a metallic ore. When a bed of metallic matter swells out irregularly to a considerable thickness, it forms masses of ore, which in some instances attain the magnitude of small mountains; — such are the mountains of iron ore in Sweden and Norway. Metallic beds are, however, of limited extent; they seldom traverse a whole mountain or mountain range, but they gradually or suddenly become narrow and terminate, or in the miners' language *wedge out*. There are few known beds of metallic ores in England; the principal repositories of metallic matter are in veins. I have however ascertained, that the copper mines formerly wrought in the transition rocks of Cumberland, were beds of copper pyrites, interposed between the beds of the mountains in which they were found, and not intersecting them like veins. The beds of rock being highly inclined, the thin metallic beds between them have been mistaken for veins. I believe that several metallic repositories in other counties, which have been described as veins, are in reality beds; the distinction between beds and veins not being well understood, they are both called veins by working miners. The manganese mines at Doddiscombe Leigh, in Devonshire, are irregular beds of oxide of manganese in red sandstone. The iron mine at Dannemora in Sweden is an enormous bed, which has swelled out to the thickness of one hundred and eighty feet of nearly compact ore. Copper pyrites sometimes occurs in beds; mercury has also been found disseminated in beds of clay and sandstone. Black oxide of cobalt is found in beds at Alderly Edge in Cheshire.

Metallic Veins. — Perhaps the reader may obtain a clearer notion of a metallic vein, by first imagining a crack or fissure in the earth, a foot or more in width, and extending east and west on the surface, many hundred yards. Suppose the crack or fissure to descend to an unknown depth, not in a perpendicular direction, but sloping a little to the north or south. Now, let us again suppose each side of the fissure to become coated with mineral matter, of a different kind from the rocks in which the fissure is made, and then the whole fissure to be filled by successive layers of various metallic and mineral substances; we shall thus have a type of a metallic vein. Its course from east to west is called its *direction*, and the dip from the perpendicular line of descent is called the *hading* of the vein, in miners' language. Thus it is said to *hade* or dip to the south or north, &c. Now it is obvious that if the direction of the vein were changed, or its width increased or diminished, and the hade or dip were increased or diminished also, we should still have all the essential conditions of a metallic vein remaining. Let us now proceed to describe existing metallic veins. They appear to have been originally fissures cutting through different beds of rock, that have been subsequently filled with metallic ores, intermixed with other mineral matter, of a different nature from that of the rock which is intersected.

Metallic veins are, therefore, considered to be of posterior formation to the rocks in which they are found: and where a vein cuts through different rocks, it is evident that its formation must have been more recent than that of the rocks which it intersects; but where a vein is found only in one bed of rock, the fissure may have been formed and filled at the period when the rock was consolidated. Metallic veins are principally found in primary and transition rocks, or in the very lowest of the secondary strata: they are often separated from the rocks they intersect, by a thin wall or lining of mineral substances distinct from the rock, and sometimes also by a layer of clay on each side of the vein. The same substance which forms the outer coat of the vein, is also frequently intermixed with the ore, or forms layers alternating with it: this is called the matrix, gangue, or veinstone. It appears as if the ore and the veinstone had been formed over each other, on the sides of the vein, at different times, till they met and filled up the fissure.

Sometimes the ore extends in a compact mass from one side of the vein to the other; but not unfrequently there are hollow spaces in veins, called *druses*, which are lined with crystals; in these cavities the most beautiful and regular crystalline forms are obtained. Metallic veins often divide and unite again, and sometimes they separate into a number of smaller branches, called *strings*. A general idea of the different modes in which metallic veins intersect rocks, and are sometimes intersected by each other, is represented in Plate IV. fig. 4.

To what depth metallic veins descend is not known, nor is it ascertained whether they generally grow wider or narrower in their descent. The opinions of miners on this subject are so various, that it may fairly be inferred that veins differ, in this respect, in different situations. No instances, I believe, have occurred of a vein being absolutely worked-out in depth, though it often grows too poor to repay the labour of working deeper: more frequently the further descent of the miner is stopped, by the difficulty or expense of removing the water. Veins are seldom rich in ore near the surface, but increase in richness as they descend, and at greater depths become poorer again. When Pryce wrote the "Mineralogy of Cornwall," it was believed that the richest state of a mine for copper in that county, was from eighty to one hundred yards deep; and for tin, from forty to one hundred and twenty yards. This account by no means agrees with the present state of the Cornish mines. Copper and tin are procured in considerable quantities at the depth of four hundred and fifty-six yards, in the Dolcoath mine. The Ecton copper mine, in Staffordshire, is now worked at the depth of four hundred and seventy-two yards: it is the deepest mine in England. The deepest mine that has been worked in Europe, or in any part of the world, is one at Truttenberg, in Bohemia, which is one thousand yards below the surface.

Metallic veins frequently contain different ores at various depths. Iron ore, copper ore, cobalt ore, and silver ore, succeed each other in some of the mines in Saxony.

In France there are mines which contain copper ore in the lowest part, silver ore above, and over that iron ore.

In Cornwall, blende, a sulphuret of zinc, frequently abounds in the upper part of veins that become rich in copper as they descend; the blende rarely continuing to any considerable depth. In the same district tin is also commonly found at a small depth, in veins which afterwards prove rich in copper. "Among other instances that might be quoted, are the two deep extensive copper mines called Huel Unity, and Cook's Kitchen, both of which were worked for tin at first. In both the tin was soon extracted; but it should be noted as an uncommon circumstance, that in the latter mine, after working to the depth of one hundred and eighty fathoms, first through tin, and afterwards through copper, tin was found again, and has continued down to its present depth of two hundred and ten fathoms from the surface. It ought however, to be added, that some portion of tin was found in different parts of the vein, which may therefore be said to have prevailed more or less from the surface to the present workings."*

The thickness of veins, and the quantity and quality of the ore they contain, vary in every mine. Some veins are only a few inches wide; others are several feet, and sometimes several yards, in width. Veins are often narrow in one part, and swell out in another. The vein at the Dolcoath mine in Cornwall, varies from two or three feet to forty feet; and in some places it contracts to little more than six inches. The veinstone is quartz, in which are imbedded masses called bunches of copper pyrites, consisting of copper combined with sulphur and iron.

Beside rake veins, there are other mineral repositories, called flat veins, or flat works, and pipe veins. In some instances a rake vein declines from its regular inclination, and has taken the direction of the beds of rock running between them for a greater or less extent, and then resumes its former inclination. In other instances the cavities between beds or strata are filled with metallic ores, lying between an upper and lower stratum, like a seam of coal, and are subject to similar dislocations: but these are not regular strata; they may frequently be traced to a perpendicular or rake vein, from which they appear to be lateral expansions; see Plate VII. fig. 2., in which the regular vein is seen descending, and the flat vein branching off on each side near the bottom.

There is generally what is called a rider, or mass of mineral matter, between the ore of very strong rake veins, and that in the flat veins, at the place of junction. The flat veins that run parallel between the strata, frequently open into large cavities filled with ore and veinstone; these cavities close

---

* Transactions of the Geological Society, vol. ii.

again by the contracting, or what the miners call twitching of the sides, by which the ore is nearly or totally excluded. Such expansions and twitchings are also common to rake veins, as represented at *c c*, Plate IV. fig. 4.

The blue john, or fluor spar mine, near Castleton, is of this kind. The vein which contains this spar is separated from the limestone rock by a lining of cawk or sulphate of barytes, and by a thin layer of unctuous clay; it swells out into large cavities, which contract again, and entirely exclude the ore, leaving nothing but the lining of the vein to conduct the miner to another repository of the spar. The crystallisations and mineral incrustations on the roof and sides of the natural caverns which are passed through in this mine, far exceed in beauty those of any other cavern in England; and were the descriptions of the Grotto of Antiparos translated into the simple language of truth, I am inclined to believe, it would be found inferior in magnificence and splendour of mineral decoration, to the natural caverns in the fluor mine. This mine is rarely visited by travellers: the descent is safe, but, the roof being low in some parts, it is rather difficult of access.

The pipe vein may be described as a tubular mass of ore and veinstone, generally descending in the direction of the beds, and widening and contracting in its course. In reality, the pipe vein is a variety of the flat vein, having the sides closed or twitched in, so as to form a tube or cavity of irregular shape, and of very limited extent along the line of bearing, but descending to a great depth.

One metallic vein often crosses or cuts through another, and displaces it: in such instances it is evident that the vein which is cut through, must be more ancient than that which intersects it. This observation respecting the relative ages of veins was first made by Mr. Pryce in his *Mineralogia Cornubiensis*. The different position of veins is represented in Plate IV. fig. 4., where *a a* is a vein which divides in part of its course and unites again, and finally branches off into small strings. In many instances these strings lead to a further continuation of the vein; perhaps this would be found to be the case in all, were the workings carried on in the same direction. *b b* is another vein which cuts through the former, and has thrown the lower part of the vein *a* out of its course. It is obvious that the vein *a a* was formed before the vein *b b*, which has upheaved the rock on one side, with the lower part of the vein *a*. In Plate VII. fig. 4., a small vein is represented, cut into three parts by the larger veins, *a* and *b*. Sometimes one vein crosses another without changing the direction; and if they both have nearly the same inclination, viz., dip nearly to the same point of the compass, they are generally richer near their junction, as at *b*, Plate VII. fig. 4. When a number of veins cross each other at one place, they sometimes form a cone or mass of ore of vast size, widening as it descends. Such are called accumulated veins. They occur in the metalliferous limestone of Durham and Northumberland. When one vein crosses another in an opposite direction, they often are found poorer in ore near the junction. Fig. 3. shows a ground plan of the veins *b b c c*, cut through nearly at right angles by another vein or cross course: in such instances the veins *b b c c* become poorer; but this is not universally the case.

The direction of rake veins is not very regular. In England the principal veins generally run nearly east and west, and north-east and south-west; but have frequently undulations and deviations from a straight line: the most powerful veins are more regular in their course than smaller ones. Where two veins in the same district have the same direction, or run parallel, it is observed that their contents are similar; but where they run in different directions, the contents vary. Molina, in his interesting History of Chili, mentions a vein of silver at Uspalata, in the Andes, which is nine feet in thickness throughout its whole extent, and has been traced ninety miles. Smaller veins branch off from each side of it, and penetrate the neighbouring mountains to the distance of thirty miles. It is believed that this vein stretches to the distance of three hundred miles. A vein called the Tidswell Rake, in Derbyshire, extends some miles east and west; it is worked from the surface, and may be seen near the roadside, between Great Hucklow and Tidswell. I was informed in Cornwall, that no vein in that county had been traced in length more than two miles; nor had any vein been worked out in depth. The common width of the veins is from one to two feet, but sometimes it exceeds thirty feet.

In Cornwall and Devonshire, and in the mines of Northumberland and Durham, the principal metallic veins range nearly east and west. In the former counties they are called *lodes*, in the latter *right-running veins*. The north and south veins which intersect them are called cross courses: these are seldom productive of ore. Plate VII. fig. 3., the veins *b b c c* are represented as cut through by a cross course. It must be borne in mind that this is a ground plan. The thin cross courses filled with clay are called *fluan*. I was informed by an intelligent proprietor of mines in Cornwall, that these thin cross courses invariably displace the veins, and hold up the water on one side of the vein; but it is most worthy of notice, that a vein which is rich in ore on one side of the fluan, will be poor on the other. Query, *Is this connected with the fluan holding up the water?* In Cornwall the cross courses displace the east and west veins; the displacement is only a few inches in some veins, in others it is several fathoms. On Alston Moor, in Cumberland, a large cross course, called Old Carr's Cross Vein, cuts through two veins, called Goodham Gill Vein, and Grass Field Hill Vein, and has thrown them aside about fifteen or twenty fathoms. When the cross course intersects the east and west veins at right angles, the displacement is generally less, than when it strikes it in an oblique direction. This effect will be more clearly understood by referring to Plate VII. fig. 3.

In Northumberland and Durham, cross courses contain ore, near their junction with powerful veins. In Cornwall, ores of silver and cobalt have been found in some of the cross courses; and at the Botallack mine, north of the Land's End, a powerful cross course, running north and south, is made rich by the junction of east veins, which resemble small rivulets, opening into a river. Their position will be better understood by referring to Plate VII. fig. 6. The direction of the cross course or great vein running north and south, is represented by the letters N, S, the direction of the small veins, rich in ore, which open into it, are represented by *e e e*. The cross course is rich in ore, to the distance of twenty or thirty fathoms, on each side of its junction with a vein; but no veins are found branching from the west side of the cross course. The cross course is worked in those parts, where it is rendered rich by the junction with veins; the small veins are also worked for ore, and are very productive. The rock is what is called a free or soft killas, near the great cross course or vein; but further from it, it becomes a hard blue elvan (*flinty slate*). The width of the vein varies from nine to twelve feet. It contains grey copper ore of a rich quality. Sometimes the sides of the vein are copper ore, and the middle is tin ore, as represented Plate VII. fig. 7. *c c*, which is a vertical section of part of the vein; fig. 6. is a horizontal section of the cross course and veins. The master of the mine furnished me with the above particulars; and under his direction, I made, on the spot, the two rough sections, which will serve to convey a better notion of this singular metallic repository, than can be obtained by a verbal description.

Nor should it be omitted, that the entrance of this mine is at the foot of a precipice more than 200 feet in height, on the border of the Atlantic

Ocean, and the workings of the mine extend two hundred and thirty yards under the sea. From this submarine recess I saw rise up, one of the best-formed and noblest-looking men I ever beheld, — a perfect model for the Apollo of a sculptor.

Particular metallic ores are peculiar to certain rocks. Thus, tin ore occurs in granite and some kinds of slate, but has never been found in limestone. Certain ores are not unfrequently associated together: thus, lead and zinc often occur in the same vein, but in different proportions. The same metal in various combinations is often found in one vein: thus, native copper, sulphuret of copper, carbonate of copper or malachite, sulphate of copper or blue vitriol, and copper combined with lead and iron, frequently occur together in the same mine.

Galena, a sulphuret of lead, is often associated with white lead ore, or carbonate of lead. The latter, though a rich ore containing seventy per cent. of lead, has no metallic appearance, and was mistaken for cawk, and thrown away, by the miners in Derbyshire, until the year 1803 or 1804. The mines of that county have been worked ever since the time of the Emperor Adrian, and the quantity of ore which has been wasted during that period must have been immense.*

In what manner metallic veins were filled with ore has greatly divided the opinions of geologists. Dr. Hutton supposes that both dykes and veins were filled with their contents in a state of fusion by injection from below; the expansive force of the melted matter having cracked the surface, and opened a passage for its reception. (See Chap. IX.) That

---

* In 1810 few of the working miners could distinguish compact white lead ore, from cawk or sulphate of barytes; their specific gravity and appearance are not very different. The following test is of easy application, and will serve to discover the presence of lead: — If a small quantity of flowers of sulphur, mixed with a little potash or soda, be melted on the point of a knife, in a candle, and applied to the moistened surface of the stone, it will make a black spot if the mineral contain white lead ore.

many dykes were so formed I think probable, from circumstances previously stated. Other dykes appear to have been open fissures filled by materials washed from the surface, and contain rounded stones, and sometimes undecayed vegetable matter. From a dyke of clay in a coal mine in Yorkshire, two hundred and fifteen feet deep, I have drawn out long vegetable fibres, apparently roots, the woody part of which was unchanged, and burned like the roots of common weeds. Werner supposes all veins and dykes were first produced by the shrinking of the materials, of which mountains are composed; and that metallic veins have been filled from above by the ores in a state of solution.* This theory has been advanced with much confidence, and warmly supported by many geologists: but I have no hesitation in asserting, that it is demonstratively repugnant to facts: indeed, the implicit credit which has been given to Werner's dogmas on this subject, is one, among numerous instances, of men of distinguished talents resigning their judgment to authority, and supporting the most absurd propositions, when conformable to their favourite hypothesis. If veins were filled by metallic solutions from above, these solutions must have covered the highest mountains over the whole earth; and, instead of finding metallic ores in the present confined repositories, they would fill all the cavities and valleys in every part of the world. As this theory supposes likewise that veins were formed at different times, a number of these metallic solutions would succeed each other, and we should find regular strata of ore in all primary and transition rocks; and the quantity formed by these deep seas of metallic matter, would be inconceivably great.

This theory is decidedly invalidated by the following facts. When a metallic vein passes through different kinds of rock, it is generally observed that

---

* The round pebbles which are sometimes found in veins have been cited to prove that veins were filled from above: they were probably introduced by subterranean currents.

the quality of the ore varies with that of the rock through which it passes; and even some beds of the same rock are more productive than others, and are called by miners *bearing measures.* This is the case in Durham, Derbyshire, Cornwall, and probably in every mining district, in England and Wales.

Not only does the variation in the nature of the rock, occasion a change in the quantity or quality of the ore, but the mineral substance or matrix which accompanies ores, generally varies in different kinds of rock. Quartz and barytes are more frequently the matrix in granite and slate rocks, than calcareous spar; in calcareous mountains, quartz is rarely the prevailing matrix. In the counties of Durham and Northumberland, veins pass through siliceous sandstone, argillaceous shale, and limestone. (See Plate VII. fig. 2.) The ore is more abundant in the limestone than in the sandstone, and in the shale, provincially called *plate*, ore very rarely if ever occurs. In one mine at Welhope the matrix of the vein, as it passes through the sandstone, is cawk or the sulphate of barytes; but when it enters the limestone, it changes to carbonate of barytes in balls, having a radiated diverging structure. What is still more deserving of notice, when the rock on one side of a vein is thrown up or down considerably, so as to bring a stratum of limestone opposite a stratum of sandstone, or when what are called the walls or cheeks of the vein are of two different kinds of stone (see Plate VII. fig. 5.), the vein is never so productive in ore, as when both sides of the vein are of the same kind. In the above figure, different strata are opposite to each other, except where the strata are of great thickness: thus, parts of the lower bed of limestone, *a a*, form the wall on each side of the vein, and in such situations it is rich in ore; but the upper part of the bed, *a*, is brought opposite to a bed of sandstone, *b*, on the left; and in this part of the vein it will become poorer, and the same will be the case when the vein passes through the upper strata; in some it will contain no metallic ore. This fact alone seems sufficient to invalidate the theory of Werner, that veins were filled with metallic solutions, poured in from the upper part. Had this been the case, the nature of the rock could have made no difference in the quality or quantity of the ore.

Werner, in his "Treatise of Veins," states one instance, as if it were extraordinary, of the ore changing its quality, as the vein passed through different rocks; and is inclined to admit that elective affinity for the rock may have contributed to the effect. The circumstance, so far from being extraordinary, is of common occurrence, and known to all working miners. The entire cessation of the ore in one part of a rock, and its re-appearance below, are still more striking.

In Derbyshire the beds of metalliferous limestone are separated by beds of basaltic rock, called toadstone.* When a vein of lead is worked through the first limestone down to the toadstone, it ceases to contain any ore, and often entirely disappears: on sinking through the toadstone to the second limestone, the ore is found again, but is cut off by a lower bed of toadstone, under which it appears again in the third limestone. In strong veins, particles of lead occur in the toadstone, but in very small quantities.

If mineral veins were filled from above by metallic solutions, it is impossible to conceive that the nature of the rock should change the quality of the ore;

---

* The fact of metallic veins being entirely cut off by the beds of toadstone, has recently been doubted; it is supposed that the vein is continued through the toadstone, though it contains no ore: but the fact of veins being cut off by the seams of clay (called *way boards*), if it could be established, would lead to the same conclusion as the separation of the vein by toadstone. — My late visits to Derbyshire have convinced me more fully that Mr. Farey was too hasty in forming his opinions, and that he did not always select his information from the best sources. Neither the beds of clay nor toadstone may contain ore, and yet the vein may pass through them, but, being unproductive, it is not noticed. In some instances, probably, the beds of toadstone were protruded between the beds of limestone, after the formation of metallic veins, as Mr. Whitehurst originally maintained.

much less could the ore disappear in one stratum, and appear again in a stratum below it. Nor could the vein be filled with melted matter ejected from below; for in either case it would be equally impossible, to explain why the ore disappears in the toadstone, though the vein is continued through it. See Plate IV. fig. 5, where *b, b, b* are three beds of limestone divided by beds of toadstone *e e*, and covered by sandstone. When the vein descends to the first bed of toadstone *e*, the ore disappears; but on sinking through to the second bed of limestone it is found again; it disappears a second time at the next bed of toadstone, and reappears in the lower limestone, 3. Another vein, *a a*, is supposed to penetrate the beds of toadstone *e e*, but contains little ore where it passes through them. The upper part of the vein *a*, is represented as penetrating the superincumbent sandstone, which is sometimes the case: in this upper part of the vein the most curious productions of the Odin mine, near Castleton, are discovered. Such facts prove that these veins were not filled from above. Professor Jameson has conjectured that the beds of toadstone and limestone in Derbyshire, with the metallic veins, were all cotemporaneous, and that the toadstone crossed through the veins, at the time of their formation; but the different organic remains in the upper and lower beds of limestone preclude the possibility of their having been formed at the same time. The zoophytes in the lower bed of rock could not be living and co-existent with those in the upper, nor with the vegetable remains occasionally found in the sandstone which frequently covers the whole, and into which the veins sometimes shoot. Cuvier has well observed, that the existence of different organic remains offers incontestable proofs, that the upper and lower strata in which they were found, were formed in succession. As a farther proof of the influence which the position of the rock has upon the vein which intersects it, the miners both in Wales and Derbyshire maintain, that wherever there is a depression in the strata, and they dip on both sides towards the vein (see Plate VII. fig. 9.): in such situations the richest veins occur.

If metallic matter were not poured in from above, nor ejected from below, in what manner did it come into the vein? — The state of chemical science, and the facts at present known, are too limited to furnish a solution to this interesting question. There are, however, certain indications which may serve as a clue to future discovery. The variation of the mineral products in veins, as they pass through different strata, seems to prove, that the strata were efficient causes in producing this variation. Perhaps metallic matter was diffused through different rocks according to their elective affinity, and separated from them by voltaic electricity, the different sides of the vein possessing different states of electricity; or the strata may act like a series of plates in the voltaic pile, separating and secreting metallic matter from its different combinations. Some of the metals and other substances found in veins, are capable of solution in hydrogen gas, and perhaps all of them may be so by natural processes; in this state they may have penetrated the vein, and deposited their contents.

The discovery of the metallic nature of the very earths of which rocks are composed, and the probability that the metals themselves are compound substances of which hydrogen forms a part, open new views respecting the formation of metallic matter by natural processes, which may be within the reach of human power to develope, if not to imitate.

If metallic matter be now forming in mines, the process of its formation is extremely slow; but there are circumstances which appear to prove that it may in some instances be perceived. M. Trebra, director of the mines in Hanover, informed a gentleman of my acquaintance, that he had seen a leather thong suspended from the roof of a mine, coated with silver are: he has also observed native silver, and vitreous silver ore, coating the wooden supports left in a mine called Dreyweiber, in the district of Marienburgh, which had been under water two hundred years, and was opened in 1777.

M. Trebra was led from his own observations on mines to infer, that metallic ores are formed by mineral exhalations, or were once in a gaseous state. Mr. Westgarth Forster, a practical miner in Northumberland, states, that at Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the walls, more than two inches in length.

These and other phenomena observable in mines, may convince us that there are processes going on at present in the great laboratory of the earth, and perhaps there are analogous processes taking place in the atmosphere, which may throw some light on these hidden operations of nature. The formation of saline matter on the surface of walls, is a fact which merits more attention than it has hitherto received. Dr. Kidd, of Oxford, has published some very ingenious observations and experiments on the spontaneous production of nitre on limestone, which may lead to more important results than the learned Professor appears to have anticipated. These experiments show, that neither the alkali nor the acid exists previously in the stone. Nor do they exist ready formed in the moisture of the atmosphere, dry frosty weather being particularly favourable to the rapid production of nitre, and moist weather the contrary.

When a portion of the wall was protected from access to the atmosphere by glass, which projected a little distance from the surface, the formation of nitre went on for a certain time, and then ceased. The saline crystals were better defined, and longer, than on the other parts of the wall. When the wall was coated with paint, crystals of nitre were even formed on the paint. The formation of carbonate of lead on the walls of the mine at Wolfclough, may be analogous to the formation of nitre; and in both instances, the surface of the wall and of the atmosphere, may perhaps be considered as two galvanic plates in action, decomposing and recompounding the elements of metallic or saline matter from the atmosphere, or the gaseous fluids with which it is intermixed. The base of nitre (potassium) is known to be a metal; and could we seize nature in the act of producing a fixed alkali from more simple elements, we might compel her to reveal the process by which she prepares her metallic treasures in the deep recesses of the earth. Nor can the discovery be very remote; for we are already acquainted with the composition of the volatile alkali, and are thereby enabled successfully to imitate nature in its formation.

When the matrix, or the substance which principally fills veins, is a soft unctuous clay, masses and particles of ore are often disseminated through it, varying in size from a pea to that of a large gourd, and are sometimes even of many tons' weight. Masses of veinstone are also imbedded in the same manner; and it is observed that the masses both of ore and veinstone are of no determinate shape, and have generally the appearance of being corroded. Are we to conclude, in such instances, that the hard minerals, and metallic ores, have been formed in the substance of the clay by some peculiar elective affinity, or that they once occupied the cavity of the vein, and have been all subsequently decomposed, except the remaining detached masses? I should be more inclined to adopt the former opinion; but it must be allowed, that there are inexplicable instances of the disappearance of minerals which formerly existed in veins.

The formation of one mineral upon the crystals of another, and the disappearance of the crystal which has served as the mould, is indeed a common phenomenon in many English mines. I have before me a mass of rock crystal from Durham, formed on cubic fluor spar; but the crystals of the latter have entirely disappeared, leaving nothing but the impression of their form. In the mines of Derbyshire, incrustations of calamine are formed on calcareous crystals, taking the shape of the dog-tooth spar; but in these false crystals, no trace of the interior crystal is left. Certain local causes also appear to influence the crystallisation of minerals in different districts, and to dispose them to take peculiar secondary forms, which may be considered as appropriate to the minerals of that district. The pyramidal crystallisation of carbonate of lime, called the dog-tooth spar (*chaux carbonatée metastatique* of Haüy), is abundant in some of the mines of Derbyshire; whilst the same mineral rarely assumes that form in the mines of Northumberland and Durham, but is crystallised in other forms, which are equally rare in the Derbyshire mines. Fluor spar, and sulphate of barytes, have appropriate forms in different districts, from which any deviations may be considered as varieties. The causes which occasion this diversity of secondary forms in minerals, whose constituent parts appear by chemical analysis to be precisely the same, are unknown; nor are we able to explain in what manner the crystals before mentioned have disappeared; but these facts prove, that the powers of nature extend beyond the present limits of science; and it is more consonant with the true spirit of philosophy, frankly to acknowledge our ignorance, than to form systems from imperfect data, which can only serve to perpetuate error.

Metallic ores in rounded fragments, and grains of native metals, are frequently found in the sands of rivers; they have been carried there by torrents or inundations; the rocks in which they were originally formed, having been disintegrated or decomposed. The metals gold, and platina, being indestructible by the action of air, water, or the mineral acids, remain for ages unchanged, in the form of minute grains. The oxide of tin is a very heavy and hard mineral; and it is owing to its weight and indestructibility, that it is found in the sands of rivers, or on the sea shore, where it sometimes occurs in considerable quantities, and is separated from the sand or alluvial soil by directing streams of water over it: hence such works are in Cornwall called Stream Works. With the pebbles of tinstone, there are fragments of granite and other rocks, which serve to indicate from what mountains in the vicinity the stream tin has been washed out. Particles and small pieces of gold are sometimes found with stream tin, in the sands of Cornwall.

Gold being, as before stated, less subject to chemical change than the other metals, is found in the sands of rivers in various parts of the world, particularly in Africa and South America. A considerable part of the gold obtained from Africa is procured by washing the sand of rivers; it is found in small grains called gold dust. It has been remarked, that in certain parts of rivers the sands were rich in gold, which seemed to be renewed after heavy rains, and yet but little gold was found in the sands higher up the river. No satisfactory explanation has been offered, respecting the limitation of the auriferous sands to certain localities. Facts have recently been stated to the author, by a gentleman connected with the gold mine companies in North Carolina, which appear to elucidate the periodical renewal of gold in the African rivers. About the year 1810, gold was found in the beds of several rivers in North Carolina: one mass was obtained weighing 28lbs. Afterwards grains of gold were discovered in the beds of several of the rivers and brooks both of North and South Carolina, and of Georgia. For some years after gold had been discovered in these states, the inhabitants were content with searching for gold in the beds of the brooks and rivers after heavy rains. One of the proprietors of a gold stream, having noticed that it never yielded gold above a certain point, where a small brook entered into it, was induced to trace the brook to its source, and discovered in the adjacent rocks, veins of quartz which were found to contain pieces of native gold, and were subsequently worked as mines. It is highly probable that in Africa the sands in certain parts of rivers become auriferous, by the depositions from rivulets that flow into the main stream.

Mr. Hennah, of Plymouth, has in his collection several pieces of native gold, varying from the size of a bean to that of a hazel-nut; they were found in stream works near St. Austel: he has also a specimen of stream tin, eight or nine inches in length, and five or six in breadth, which was evidently once part of a vein. In the same stream work they could distinguish at different depths, the different veins from which the ore had been washed out. The pebbles of tin ore, have in some situations been washed into the sea, and afterwards covered by beds of clay or gravel. In Mount's Bay, south of the town of Penzance, there was formerly a bed of stream tin worked under the sea. The stream tin covers the killas or slate rock of the country, and is covered by a bed of clay: a perpendicular shaft or tunnel was sunk through the clay, and the bed of stream tin was worked like a bed of coal, the clay forming the roof. See Plate VII. fig. 8. The workings were continued under the sea, but were at length inundated and discontinued.

The bed with pebbles of tinstone, is seen covering the beds of slate; upon this is a thick bed of water-tight clay, over which the tides roll. An iron cylinder was sunk through the clay as a shaft to the tin stone, which was worked like a bed of coal and drawn up the cylinder.

The following is a summary account of the rocks in which the different metallic ores are generally found:

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

Gold and silver are found in primary and transition rocks, in porphyry and sienite, and in the lowest sandstone. Gold has been occasionally discovered in coal, and very abundantly in the sands of rivers, and sometimes in volcanic rocks.

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

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

Iron, in every kind of rock.

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

Lead and zinc, in primary and transition rocks, except trap and serpentine; in porphyry and sienite; in the lowest sandstone, and occasionally in coal strata.

Antimony, in primary and transition mountains, except trap and serpentine; it is also found in porphyry and sienite.

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

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

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

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

CHAP. XX.

ON SUBTERRANEAN RIVERS AND CURRENTS, AND ON CAVERNS.

Occurrence of Subterranean Currents and Rivers in various Parts of the World. — The principal Agents in the Formation of Caverns. — Remarkable Cavern and Cascade in the Speedwell Mine, Derbyshire. — Subterranean Currents and Caverns generally in calcareous Mountains. — The Reason explained. — Subterranean Currents connected with the Surface Water, deposit Animal and Vegetable Remains between ancient Strata, proved by Facts. — Caverns with Bones of extinct Species of Animals in Germany and France, intermixed with Human Bones, and Implements of Industry. — Bones introduced into Caverns by Subterranean Currents and other Causes, and at different Epochs — Cavern at Kirkdale, in Yorkshire. — Bones found in the Clefts and Fissures of Rocks forming Osseous Breccia in various Parts of Europe, and in New Holland. — Epochs of their Deposition supposed to be different in distant Parts of the Globe.

Beside the fissures and spaces filled with metallic matter, that occur in the older rocks, as described in the preceding chapter, there are empty spaces or caverns, that sometimes extend far into the interior of mountains, and sometimes descend to considerable depths. Almost all large caverns occur in limestone rocks, chiefly of the transition and the secondary class. Caverns, in some instances, may have been formed by the upheaving or subsiding of rocks; but they have most frequently been excavated by subterranean currents of water, which have enlarged original fissures, or carried away the beds of soft clay or loose sand that were interposed between hard strata. Many large caverns have streams of water constantly running through them; and after heavy rains they are often gorged with water, which issues with violence from their mouths. This is the case with the great Peak Cavern, near Castleton, in Derbyshire.

The action of subterranean currents of water, has scarcely been attended to by geologists; but were it better understood, it might probably afford a satisfactory explanation of several facts in geology that have been regarded as anomalous, particularly that of the occurrence of bones in caverns which have no opening to the surface. In the third edition of this work I stated some instances of these currents in mountain limestone.

The mountain or transition limestone of Craven, in Yorkshire, forms, in many parts, a nearly flat elevated surface of table land, covered with vegetation, but intersected by numerous fissures or chasms of vast length and depth, varying from a few inches to a foot or more in width. Many of these fissures widen as they descend; and at the bottom, streams of water may be frequently heard running. During snow, it is not uncommon for sheep to be lost in these chasms, and the whole surface is extremely dangerous to traverse in the dark. Limestone plains, intersected by such fissures, may be regarded as natural traps for herbivorous animals, into which they may fall in whole droves, when chased by beasts of prey. Their bones may either stick fast in the fissures, and be afterwards inclosed in calcareous stalactites, or they may be carried by subterranean currents into caverns which have no communication with the surface. Such was the cavern at the Bull's Eye mine, near Worksworth, in Derbyshire, which was opened by mining operations in the year 1663, and contained the entire skeleton of an elephant.

There is a considerable river, called the Pinka, in the cavern at Adlesberg, in Carniola, which forms a subterranean lake, where it appears to be lost; but it emerges again on the north side, and takes the name of the Renz. This cavern is one of the largest in Europe; it extends for several leagues into a calcareous mountain, situated between Laybach and Trieste, and contains the bones of bears and other animals, in the mud that forms the floor of the cavern, or rather series of caverns, that are connected by passages with each other.

There are numerous caverns and grottoes in the vicinity of Adlesberg, and the surface of the country is in various parts broken by depressions from the subsidence of the roofs of these caverns. Doubtless there are subterranean rivulets in all these caverns, which are continually in action, and are undermining and wearing down the rocks that support the strata above them. In Derbyshire, and the district called Craven, in Yorkshire, beside the subterranean rivulets before mentioned, there are currents of water incessantly in action, which are only discovered by mining operations.

The Speedwell mine, near Castleton, in Derbyshire, is a subterranean tunnel and canal, nearly half a mile in length, penetrating into the centre of a mountain composed of metalliferous limestone: the descent to the canal is by a flight of steps, about forty yards in depth. The mountain is intersected by numerous metallic veins, and the proprietors of the mine intended to carry the tunnel and canal through the whole extent, in order to discover the veins, and have ready access to work them, and bring out the ore. The stone was obliged to be excavated by blasting, and before every explosion the miners retired for safety to a considerable distance in the tunnel. When they had proceeded in this manner about eight hundred yards, they were greatly alarmed after a blast, to hear the tremendous roaring of a torrent, and fled towards the entrance of the tunnel. A miner, who was working there at the time, informed the author, that he thought there was no chance of their escaping immediate destruction; however, when they had retreated a considerable distance, they perceived the rushing sound to grow less alarming; they then halted awhile, and took courage to return, when they discovered that the last blast had made an opening into a spacious cavern, and that a torrent of water was falling from a considerable height into a vast chasm on one side of it. The loud roaring of the water was greatly increased by the echoes of the cavern; for in the roof of this cavern there is a wide opening into an upper cavern, the top of which is not visible from below, even with the illumination of fireworks, which those who show the mine generally take with them.

By the ceaseless action of such internal currents of water, falling into original fissures, or descending through soft strata in mountains of compact limestone, it is easy to conceive that caverns of great extent may be excavated. A very few years since, a miner, in driving an adit or passage into the heart of the well-known rock called Matlock High Tor, discovered a large cavern and a lake in the middle of the mountain. Many of the coves or caves in Craven, in Yorkshire, were originally caverns, the roofs of which have fallen in; they have streams of water rushing into them, forming subterranean cascades. The cavern called Weather Coat Cove, and the rocks at Gordale Scar, offer illustrations of the effects of subterranean currents. Where springs of water of considerable magnitude rise at once to the surface, it is obvious that they are not the result of slow percolation through porous strata, but that they are the outlets of internal streams or rivers. The river Air rises at the foot of a perpendicular limestone rock, called Malham Cove, in Craven; it is a broad, powerful, and permanent stream, before it receives any tributary rivulets from the adjacent valleys. It is generally believed that the subterranean stream which gives rise to the river Air, is connected by internal passages with Malham Tarn, a mountain lake, situated at a considerable distance. Perhaps the spring at Holywell, in Flintshire, may be cited as offering a similar proof of underground rivulets.

The reason why subterranean streams of water, and extensive caverns, should chiefly occur in districts where compact transition or mountain limestone is the prevailing rock, will admit of an easy explanation. Slate rocks are almost always intersected by perpendicular fissures, which carry off the water, and prevent its accumulating in large streams; and the secondary strata in England are generally too soft, or too much broken, to form the roofs of extensive caverns, or the beds of subterranean rivers. In the vicinity of the Alps, where the secondary limestones are extremely hard and compact; they contain caverns, and afford a passage for subterranean currents. A considerable cavern has, however, been recently discovered in mica-slate and common slate, in the Isle of Thermia, one of the Cyclades, at the height of 1400 feet above the level of the sea. M. Virlet, who visited the cavern, attributes the excavation to subterranean streams of water, as there is a considerable deposition of mud and bluish clay at the bottom of it. — *Séance du 20 Fév.*, 1832, *de la Société Géologique de France.*

It is admitted by M. Desnoyers, in the report from which this account is extracted, that the existence of such a cavern in rocks of mica-slate and slate, is a new fact in geology. There are several thermal springs in the island, which indicate the action of subterranean heat. This agent may, perhaps, have been, in some manner, the cause of the formation of the cavern; it is, however, supposed by some to have been an excavation formed by mining operations at a remote period.

Instances of rivers of considerable magnitude sinking into the earth, and emerging again at the distance of several miles, have been long known in many countries: it is not the object of the present chapter to enumerate them, but to direct attention to these subterranean streams, that have no apparent connection with the surface. It cannot be doubted, however, that the rivers which run only for a few miles under ground, and emerge without any apparent loss of water, must effect considerable changes in the strata during their subterranean course. In some cases rivers are absorbed into caverns, in others they merely sink into softer strata, as takes place with the river Rhone, about twenty miles from Geneva, at what is called the *Perte du Rhône*. See Travels in the Tarentaise, vol. ii. p. 264.

The subject of subterranean currents has scarcely attracted the attention of English geologists, but it is beginning to excite enquiry in France, where the practice of boring for water is becoming general, and has brought to light some interesting facts. In the report of M. Desnoyers, before referred to, several of these facts are described, but he previously states the observations of MM. Boblet and Virlet, on the closed valleys or gulfs in central Morea, called katavotrons, "into which torrents of water amassed during rainy seasons are precipitated, carrying with them the mud with which they are coloured, the skeletons of animals, with fragments of shells and plants mixed with gravel, which they introduce into subterranean cavities. The water again springs up at a great distance from the sea pure and limpid. This circumstance serves to explain the filling of many caverns; may it not also explain the sinuous passages filled with sand and gravel, between strata which are found at great depths from the surface in the environs of Paris?"

From the borings and sinking for water in different parts of France, it is evident that they occasionally meet with considerable subterranean streams that have somewhere a connection with the surface waters. In a well sunk at Tours, in 1829, in the lower chalk, to the depth of 330 feet, the water rose rapidly for some hours, bringing with it much fine sand, fragments of thorns and seeds of marsh plants, with land and fresh-water shells unchanged. Another fact was recently discovered at Reinke, near Bochum, in Westphalia. A well was sunk to the depth of a hundred and forty-three feet, when the water rose to near the surface, bringing with it small fish from three to four inches in length. The nearest currents of surface water are from two to five leagues distant from the well. How small is the proportion of seeds, shells, or fish, sand or gravel, that came to the surface, compared with these which are arrested in their progress, and *finally fill up the subterranean passages and change the direction of the underground currents!* What a natural explanation does this offer of many facts which have embarassed or deceived geologists! It may be well for the reader to refer to what was stated in Chap. XII. respecting the teeth and bones of small land quadrupeds found in the calcareous slate of Stonesfield. I there observed, that I thought it probable they had been brought into their present situation by subterranean currents, during the tertiary epoch, — and I am inclined to believe that the traces of such subterranean currents would be discovered, could the internal structure of the strata be fully laid open.

The subject of subterranean currents becomes interesting to the geologist when connected with caverns, for caverns themselves would scarcely deserve attention, were it not that they frequently contain skeletons or bones of large mammiferous animals, belonging to species that no longer exist in Europe, and are supposed to be extinct elsewhere. Many of these caverns were closed when first discovered, and some of them have been recently found to contain human skulls and bones, mixed with the bones of extinct species of quadrupeds: hence, we are led to enquire in what manner these bones were introduced into the caverns and at what epoch. The bone caverns in Germany will be first described, and then some notice will be given of the caverns recently discovered in France, containing human skulls and bones: and lastly, we shall notice some of the bone caverns in England.

It has been long known to naturalists and travellers, that there are numerous caverns in the calcareous mountains of Germany and Hungary, the floors of which are covered with clay, enveloping a prodigious quantity of bones and teeth of carnivorous animals. The bones in these caverns are nearly the same, over an extent of more than one hundred leagues. More than three fourths belong to species of bears that are now extinct*; two thirds of the remaining part belong to an unknown species of hyena; a smaller number belong to a species of lion or tiger, or of the wolf or dog; a very few belong to small carnivorous animals, allied to the fox and polecat. The bones are nearly in the same state in all these caverns: they are found scattered and detached, partly broken, but never rounded by attrition, and consequently not brought from a distance by water. They are rather lighter and more fragile than recent bones, but still preserve their true animal matter, containing much gelatine, and are not in the least petrified. The bones are all enveloped in earth which is penetrated with animal matter: except a few bones on the surface, of a different kind, which have been brought there at a later period, and are less decomposed.

The most remarkable of these caverns are those of Gaylenreuth, on the left bank of the river Wiesent, in Bavaria: they vary in height from ten to forty feet, and are connected by narrow low passages. The animal earth intermingled with bones, is in many places more than ten feet deep; and according to the account of a German writer, M. Esper, would fill many hundred waggons. The cavern, or series of caverns, at Adlesberg, in Carniola, is much larger than any in Germany: the caves are of variable dimensions, and are stated to extend more than three leagues in a right line, at which distance there is a lake which prevents further access. The floors of these caverns are covered with indurated clay, enveloping the bones of bears, and other carnivorous animals, similar to those in the caverns of Germany and Hungary. In one part of this cavern, or series of caverns, the entire skeleton of a young bear was discovered, enveloped in clay or mud, between blocks of limestone which lay on one side of the cave. Bones

---

* The most common species of bear in these caverns, the Ursus Spelæus, was the size of a horse. The fossil hyena was one third larger than any known living species.

are found along the cavern, for several miles from the entrance, not only buried in mud, which forms the floor, but among heaps composed of blocks of limestone and yellow mud or clay. This cavern is situated near the great road from Trieste to Laybach.

In many of the caverns in the south of France, and also in Belgium, there are found bones in the mud and gravel which form the floor, but which is sometimes coated with stalagmite.

What has excited great attention is, the intermixture of human bones and rude works of art, with the bones of extinct species of mammiferous quadrupeds. In some instances, the human bones appear to be reduced to what has been called the same fossil state, as that of the animal bones with which they are intermixed. Much more importance has been attached to this circumstance than I think it deserves; for, in the first place, few if any bones of mammiferous land quadrupeds found in caverns, or in diluvial soil, can be properly said to be fossilised, as they retain a part of their original matter; and, secondly, the experiments of Dr. Jenner, stated in p. 27., prove, that when recent bones are immersed in mud containing pyrites or solutions of iron, they become more or less fossilised in a few months. The caverns in the south of France, according to M. Desnoyers, were some of them partly filled with bones of quadrupeds before human bones were introduced into them; others appear to have been empty. He observes, how often may these caverns have served as burial-places to the ancient inhabitants, or, at a more recent period, as places of retreat during religious persecutions, from the persecutions of the Druids to these of the Huguenots. The historian Florus (he adds) expressly informs us, that the inhabitants of Aquitaine, an artful people, retired into caverns, and that Cæsar gave orders to have them closed in their retreats, and left to perish. "Aquitani, callidum genus, in speluncas se recipiebant, jussit includi." — *Flor.* lib. iii. cap. 10.

Add to this, from the known habits of several races of the ancient Celts to live in caverns, of which many are preserved in the provinces bordering the Loire and the Rhone, it may be readily believed that the human bones with pottery, in the caverns of part of ancient Aquitaine and the Narbonnaise, belonged to some of the wretched Gauls, whom Cæsar caused to perish in these caverns.

Where, says M. Desnoyers, the mixture of human bones and those of quadrupeds is more complete, currents of water might have effected a movement and intermixture (*remaniement*) of a more recent date. The hatchets of flint and other rude instruments found in these caves, are such as are found also in the tumuli of the ancient Celts, and were in use in the time of Cæsar.

M. Desnoyers thinks the most ancient of these bones are Gaulic or Celtic: others belong to a more recent epoch. He examined the rich collection of Celtic coins in the Bibliothèque Royale; on many of them he observed figures of animals, such as the boar, the horse, the wild ox, and the stag; and more rarely symbolic or monstrous animals, but no figures of the rhinoceros and other extinct races, which, had they been co-existent with man, there might have been reason to expect.

M. Tournal, who first discovered human bones in the cavern at Bize, maintains a contrary opinion, and he applies the same conclusions to the bones of mammiferous animals in other caverns. The caverns of Bize (Aude) contain bones of the stag, the camel, the roebuck, the antelope, and bear; those of Sommières (Gard) contain bones of the rhinoceros, the ox, the horse, the stag, and the hyena. M. Tournal concludes from the state of the bones, that they are antediluvian, and that before the last general catastrophe (*cataclysme*) southern Gaul was inhabited by man, together with a great number of species of mammiferous animals now extinct.

The cavern of Rancogne, situated three leagues from Angoulême, is one of the largest in France, and has long been celebrated for its quantity of stalactites; but under the stalagmite and alluvial soil on the floor of the cavern, a great quantity of human and quadrupedal bones have been found, mixed with fragments of pottery and with pebbles from the adjoining rocks. A brook still traverses this grotto. The river Tardonère, which runs at a little distance, loses a part of its waters in other gulfs in the country; it often overflows, and has penetrated into the cavern of Rancogne. The traditions of the country preserve the remembrance of the cavern having served the inhabitants as a place of refuge at different periods, and that wolves, which abound in the forest of Braconne, commonly retire into it and carry with them their prey, and human bodies, which they exhume from the neighbouring cemetery.

This mode of filling the cavern (observes M. Desnoyers) differs much indeed from the antediluvian theory of M. Tournal. Some grottoes contain human bones in the upper alluvial soil, over a bed of stalagmite, under which there is a lower bed with bones of quadrupeds.

The cavern of Miallet, near Andure (department of Gard), is situated near the banks of the river Gardon. It occurs in magnesian limestone, about 100 feet above the valley: the lower bed or floor of the grotto is a sandy magnesian limestone, covered with a thin bed of stalagmite, and also in several parts, with a bed of argillaceous mud, about five feet in thickness. In this bed the heads and bones of bears were found in great abundance and in a high state of preservation: they were larger than the common cavern bear (*Ursus spelæus*). A few fragments of bones of the hyena, of ruminating animals, and of birds were also found with them. Under the stalagmite and a thin stratum of sandy mud, a great number of human bones were discovered in different parts of the cavern. Towards the farther end of the cavern, the human bones are incontestably mixed with the bones of bears, which predominate in that part: but near the entrance, human bones predominate, and appear somewhat more recent. Upon the ossiferous or bone mud, and under a projection of the rock, a human skeleton was discovered almost entire; near which was a lamp and a small figure in baked clay, and at a little distance were copper bracelets. In other parts of the cave were found fragments of rude pottery, and instruments of flint, the workmanship of a preceding age. The human heads are stated to present indications of belonging to the Caucasian race, but they have a depression of the skull, which M. Tessier supposes to have been produced artificially.

M. Tessier distinguishes three periods during which this grotto was filled: 1st, An antediluvian epoch — that of the bears, which belong to an extinct species; these he supposes may have lived in the cavern during successive generations, or may have been driven there by some great convulsion. 2d, An epoch of incipient civilisation, that of the ancient Celts; whose bones are intermixed with rude implements of industry. 3d, A Roman epoch, indicated by more perfect works of art. With respect to the mixture of human bones with those of bears, it does not prove that the latter were contemporaneous with man, because it is obvious that they could not have lived together in the same cavern. The mixture may have been effected by the action of water, or by artificial excavations in the original bone bed, for sepulchral purposes.

Perhaps it may yet be regarded as uncertain, whether these human bones were or were not coeval with those of the cavern bear, the rhinoceros, and other animals; for we have no decided evidence when these animals became entirely extinct. I am inclined to believe, that the mastodon of North America existed there much later than is generally admitted; the reason for this opinion will be given in the following chapter. Secondly, we cannot assign a reason why man might not have existed in the tertiary epoch, except that his bones are nowhere discovered in the regular tertiary strata. The country that could give support to the mammoth, or ancient elephant, to the mastodon, and the elk, might, for aught we know to the contrary, be also suited for the residence of man.

It is very different with respect to the secondary strata; for though many of these strata have once been dry land, or in the vicinity of dry land, yet we nowhere find in them the bones of herbivorous mammalian quadrupeds, that could have been with man joint tenants of the globe; nor even do we find bones of carnivorous quadrupeds, that might have preyed upon the former, had they existed.

During the tertiary epoch, however, there is evidence of great revolutions of the surface, by the elevation of mountain ranges, which might, perhaps, render the earth unfit for the continued existence of the human species; and I am inclined to believe, that the occurrence of human bones in caverns, or in diluvial beds of gravel, sand, or mud, has not yet invalidated the position, that the creation of man was posterior to the tertiary epoch.

We come now to the English caverns: they have been more recently the object of attention than the bone caverns of Germany; but their discovery may be said to have given a new impulse to geology, both in this country and on the Continent, for which we are chiefly indebted to the enlightened and indefatigable exertions of Professor Buckland, of Oxford.

Single skeletons of large quadrupeds have formerly been discovered in caverns in this country; but we had no authentic account of the bones of carnivorous animals having been found in any English caves, previously to the year 1821; when some labourers, working in a quarry at Kirkdale, near Kirby Moorside, in Yorkshire, discovered an opening covered over with rubbish and earth, about 100 feet above the neighbouring brook. This was the mouth of a low cavern, extending about 200 feet into the rock. The floor of the cavern was covered with broken bones and teeth of various animals, encased in a stratum of mud about a foot thick. Fortunately this cavern was examined by Professor Buckland, of Oxford, soon after its discovery, who has published a very luminous account of its structure and contents, elucidated by references to the most remarkable caverns in other countries which he has visited, containing the bones of carnivorous animals. The bones in the Kirkdale Cave are broken and gnawed, and some of them preserve the marks of the teeth which have fractured them. Even the excrements of animals, similar to those of the hyena, have been discovered with them. The bones in this cave differ much from those in the caves of Germany, as a great number of them belong to herbivorous animals, and the carnivorous animals whose remains are most abundant are hyenas.

Among these remains, Professor Buckland has ascertained bones of the following orders: —

Carnivorous Quadrupeds. — The hyena, tiger, bear, wolf, fox, and weasel.

Pachydermata. — The elephant, rhinoceros, hippopotamus, and horse.

Rodentia, or Gnawers. — The hare, rabbit, rat, water-rat, and mouse.

Ruminant Animals. — The ox, and fragments and bones of three species of deer.

Birds. — The raven, pigeon, lark, snipe, and a small species of duck.

From the great number of bones of the hyena found in this cave, Professor Buckland infers that it had long been the habitation of these animals. It is their ascertained habit, partly to devour the bones of their prey; they also devour the dead bodies of their own species; like wolves they are gregarious, and hunt in packs. From the habits of the hyena, he explains the occurrence of the remains of large herbivorous quadrupeds, like the elephant, in so low a cave as that of Kirkdale; they have been dragged into it by these voracious animals. Several English caverns have since been explored. In some of them there are bones both of herbivorous and carnivorous animals, similar to those in the Kirkdale Cave. These caves are described in Professor Buckland's valuable work, entitled *Reliquiæ Diluvianæ.*

That the caverns in which the bones of carnivorous animals are found in such prodigious quantities, were the retreats of some of these animals, cannot be doubted. Many circumstances, described in the account of the Kirkdale Cave, can only be explained by admitting it. There are, however, other circumstances, particularly in the caves of Germany, which would imply, that part of the bones belong to animals that had fallen through fissures, which formerly opened into these caverns, or that the bones themselves had been carried by currents of water, through subterranean passages into these caverns, as before explained in the present chapter. In the cave at Gaylenreuth there are rounded fragments of limestone, intermixed with the bones; and the entrance of some of the caverns *is much too small* to have admitted the animals whose bones are found in them. I think it is also probable, that a violent convulsion of nature, as a rising deluge and the fierce war of elements without, might have driven, under the strong impulse of alarm, numerous animals of different species into the same caverns, where they devoured each other, and their bones have been intermixed with those of the former inhabitants. The entrances of many of the caverns, and the caverns themselves, were doubtless formerly more lofty than at present; they have been gradually lowered by the subsidence of the upper strata. Indeed, it is admitted that the caverns and grottoes in the neighbourhood of Adelsberg, have occasioned numerous depressions of the surface. Such an effect must generally take place, in a greater or less degree, with the strata over caverns.

The occurrence of the bones of quadrupeds in the clefts or fissures of rocks, intermixed with fragments of the rock, and cemented with them into a kind of breccia, is very common in many of the calcareous rocks adjoining the Mediterranean sea. The osseous breccia of Gibraltar is well known: the calcareous matter which has been infiltrated into the fissures, and forms the cement, has generally a reddish colour, and contains so much phosphoric acid, from the decomposition of animal matter, as to become luminous in the dark when scraped. The bones in the fissures surrounding the Mediterranean, belong chiefly to herbivorous quadrupeds; but they are sometimes intermixed with marine shells, indicating a great change in the level of the rocks, subsequent to the filling of the fissures.

Osseous breccia, similar to that in Europe, has been recently discovered by Major Mitchel, in the rocks bordering Wellington Valley, in New Holland. The breccia contains bones and fragments of rock, with the same red calcareous cement as the osseous breccia of Gibraltar, &c.

According to the examination of Cuvier and Mr. Pentland, some of the bones belong to different species of the kangaroo, and animals of the same genera that exist in New Holland; but others belong to species hitherto unknown to naturalists. Among these bones there are the remains of a species of elephant: a fact extremely interesting, as it proves that, in the ancient condition of the globe, this part of its surface supported animals more analogous to those of Asia and Africa, than any which existed upon it when first discovered by Europeans. In the report to the Geological Society of France, 1831, it is observed — "Thus we have in New Holland, a deposition of osseous breccia and caverns, similar to those of Europe. *Were these depositions cotemporary?* This is not very probable; at different epochs the analogy has consisted in the mode of formation; many different catastrophes may have destroyed the great animals of the Ohio, of the Irrawadi, of the north and central parts of Europe, and of Australia, and buried their bones in fissures and caverns, or in beds of clay and gravel. But whatever was the epoch of the deposition in New Holland, the organisation of animal life was then, in a great part, the same as at present; since we find in the osseous breccia, the types of that class of animals that are still peculiar to the country, but always accompanied by bones of genera (the mastodon and elephant) which are altogether unknown there."

The depositions of calcareous earth pendant from the roofs of caverns, called *stalactites*, and those upon the floors of caverns, called *stalagmites*, are formed by the evaporation of water, holding calcareous earth in solution. A drop of water, in evaporating, deposits a pellicle of limestone, which is increased by succeeding depositions, until a small protuberance of solid limestone is formed, nearly the shape of a drop of water. This protuberance becomes enlarged by water trickling over it, and takes the shape of an icicle. The water that drops upon the floors of caverns, sometimes deposits a thick coat of limestone over the whole floor; but in those parts where the drops fall most frequently, a more copious deposition of calcareous earth takes place, in the form of tubercles: these are the stalagmites. In some instances the stalactites and stalagmites increase, until they nearly fill the whole cavern.

CHAP. XXI.

ON THE DESTRUCTION OF MOUNTAINS, AND THE FORMATION OF SOILS; AND ON ALLUVIAL AND DILUVIAL DEPOSITIONS.

Erroneous Opinions respecting the Growth of Stones, supported by the Authority of John Locke. — On the Causes in present Operation that wear down Rocks. — Rapid Destruction of Mountains dependent on their Structure. — Fall of Mont Grenier in Savoy. — Breaking down of the Barriers of Mountain Lakes. — Scattered Masses of Rock. — Increase of Land by Alluvial Depositions in Lakes, and the Deltas of large Rivers. — On the Formation of productive Soils. — Recent Strata formed in Lakes. — Peat and Peat Moors. — Inundations of Sand. — Remains of Elephants and other large Animals, found in the Diluvial Beds in England, and the frozen Regions of Europe and Asia.

Few persons can have travelled a hundred miles through any country without having seen beds of gravel, or of rounded stones, or fragments of rock scattered in different directions, which were evidently never brought into their present situation by the labour of man. In some instances these masses of loose stones, or large fragments of rock, occur on the summits of hills, or on elevated ground, and the stones are altogether unlike any rocks or strata in the adjacent districts. Among the hundreds of travellers to whom such objects are familiar, it is surprising how few have ever raised the enquiry—"*How did these masses of rock, or beds of loose stones, come here?*" One great reason for this indifference arises from a cause that may surprise geologists. Many well-educated persons, who possess much information on various subjects, still entertain the belief that stones grow in the places where they are now found: this belief excludes the necessity for further enquiry. They can also refer to the authority of the ablest philosopher this country ever possessed, for a confirmation of their opinion, should it be controverted.

The celebrated John Locke states, in his "Elements of Natural Philosophy," that "*all stones, metals, and minerals, are real vegetables; that is, grow organically from proper seeds, as well as plants.*"

If any one should think it superfluous to notice this extraordinary passage, in the present age of general information, let him enquire among his friends *whether stones grow?* and he will be somewhat surprised by the answers he may receive.

These scattered fragments of rock, or beds of loose stones, together with beds of sand and gravel, present objects of enquiry of the most interesting kind. From what districts were they transported? What were the causes by which they were removed? What was the epoch of their removal?

A farther enquiry also presents itself, as some of the beds of loose stone are rounded, or water-worn, like the shingles on the sea beach, but are now raised many hundred feet above the high-water mark. *By what agents were these beds raised to their present elevation?* Satisfactory solutions to all these enquiries will probably long remain desiderata in geology, though, in some instances, we can now arrive at a high degree of probability, by referring to causes in present operation. These scattered fragments or masses of rock, with beds of loose stones and gravel, or of superficial sand or clay, are comprised by French geologists under the appropriate name of *terreins de transport;* a name, however, which cannot well be introduced into our language. We shall, therefore, divide them into three groups, adopting the names generally received. Scattered blocks of rock; diluvial beds or diluvium; and alluvial beds or alluvium; using the two latter without any reference to theory. *Alluvial beds*, consist of the sand, soil, or stones brought down by rivers, and deposited in their beds, or scattered upon their banks, or carried into the sea or into lakes, forming deltas at the mouths of rivers.

Diluvium, or diluvial beds, comprise both the scattered blocks of rock, and the beds of stone or gravel, that are carried into distant districts. They are called diluvial, on the supposition that they were transported during some great convulsion, by deluges or inundations; or, in other words, that they were removed by causes more powerful than any which are seen in constant operation.

In order to form a more distinct idea of the causes which have transported the beds and fragments of stone into their present situation, we shall first consider the causes that are daily wearing down the loftiest mountains and cliffs, or undermining the solid ground on the sea shore. The disintegration of rocks and mountains is constantly taking place, by the incessant operation of atmospheric causes. The infiltration of water into the fissures of rocks, and its expansion by frost, often produces sudden falls of immense masses of rock. The slow operation of descending currents, excavates the soft beds in the lower parts of mountains; and the upper rocks, being undermined, fall, with a tremendous crash, into the vales below. Instances of this kind have occurred in our own times. By both these causes, the process of disintegration is rapidly going on in the Alps; but such is the immensity of these enormous mountain ranges, that ages pass away, before any diminution of their bulk is perceived.

In Alpine districts of great elevation, there is also another cause, more exposed to observation, which is ever in action during the summer months. The snow upon the mountains below the line of eternal congelation, when it begins to dissolve, forms numerous rivulets, that unite into large streams, and descend in cataracts with impetuous force, excavating deep ravines in the lower rocks. To use the words of Professor Playfair, they are "Nature's saws, incessantly at work, cutting down the mountains."

The vignette in the titlepage of this volume represents the upper part of the valley of Sext, in

Savoy, in which the water, descending from the Alpine snow on the Buet and other mountains, is seen rushing in numerous cascades to the lower valley. But the most powerful effects of these cataracts may be observed during thunder storms, or after an unusually rapid thaw, when the upper rivulets overflow their accustomed boundaries, and carry with them the loose stones or masses of rock they meet in their descent, and dash them with inconceivable violence into the lower waterfalls, breaking down the solid rocks on each side, and deepening and enlarging the ravines into which they fall. The operation of this cause will be again referred to in the following chapter.

We need not indeed travel to the Alps to prove, that the mountains have been, and are still wearing down. The rocky fragments in Borrowdale; the deep ravines made by torrents in the sides of Skiddaw; the immense blocks of granite torn from Wastdale Crag, in Westmoreland, and scattered many miles over the adjacent counties, offer striking proofs of this. The central parts of England have once had a greater elevation than at present; pebbles formed of the Charnwood Forest rocks, are spread all over the midland counties. Masses of the rocks of Cumberland and Wales, more or less water-worn, occur almost every where under the alluvial plains of Cheshire and Lancashire. Beds of flint gravel, formed by the disintegration of chalk rocks in which flints were imbedded, occur in many parts of England at a considerable distance from the sea, or from the chalk districts.

The transportation of these masses of rock, or beds of stones and gravel, cannot have been effected by any thing like the present action of rivers in England, and is generally referred to the more extensive operation of deluges, during great convulsions of the globe; but if we return to the Alps, and view the effects now taking place, we must admit, that it is not always easy to make the distinction between alluvial and diluvial depositions.

Innumerable blocks of granite and other primary rocks, torn from the central range of the Alps, are scattered over the calcareous mountains at a great distance from this range, or are spread in heaps in many of the distant valleys. All the great rivers that issue from the Alps, where the valleys open into the plains, have made deep sections in beds composed of the ruins of the mountains, and exhibit proofs of the vast destruction that has taken place. The river Doire, where it enters the plains of Piedmont, has cut through a mass of fragments more than 1500 feet in depth; these fragments consist of irregular blocks of granite, mica slate, and serpentine, frequently more than thirty cubic yards in extent, covered by smaller fragments, and by earthy matter from the decomposition of the softer rocks: the fragments decrease in size as their distance increases from the parent mountain.

Whoever has ascended the lofty eminences immediately below the highest pinnacles of the Alps, can scarcely fail to have received sensible proofs, of the daily and hourly disintegration of the mountains. Here, placed nearly above the region of vegetable or animal existence, and surrounded by the sublimest objects in nature, the deep silence which prevails around is truly solemn and impressive; but it is broken from time to time, by sounds like the rolling of distant thunder, or by a nearer and louder crash, which is repeated by the echoes from rock to rock. These sounds proceed from the falling of avalanches, or from glaciers splitting and discharging the loose rocks upon their surface, or from éboulements of rock, detached from the bare and exposed sides of the pinnacles and aiguilles. The fragments generally fall into the elevated mountain valleys, and are scattered over the surface of the higher glaciers, which extend from thence into the lower Alpine valleys. As the glaciers in these valleys are gradually melting during summer, the ice above progressively moves downward, bearing with it the cargoes of stones on its surface, which it discharges in heaps at its feet and sides.

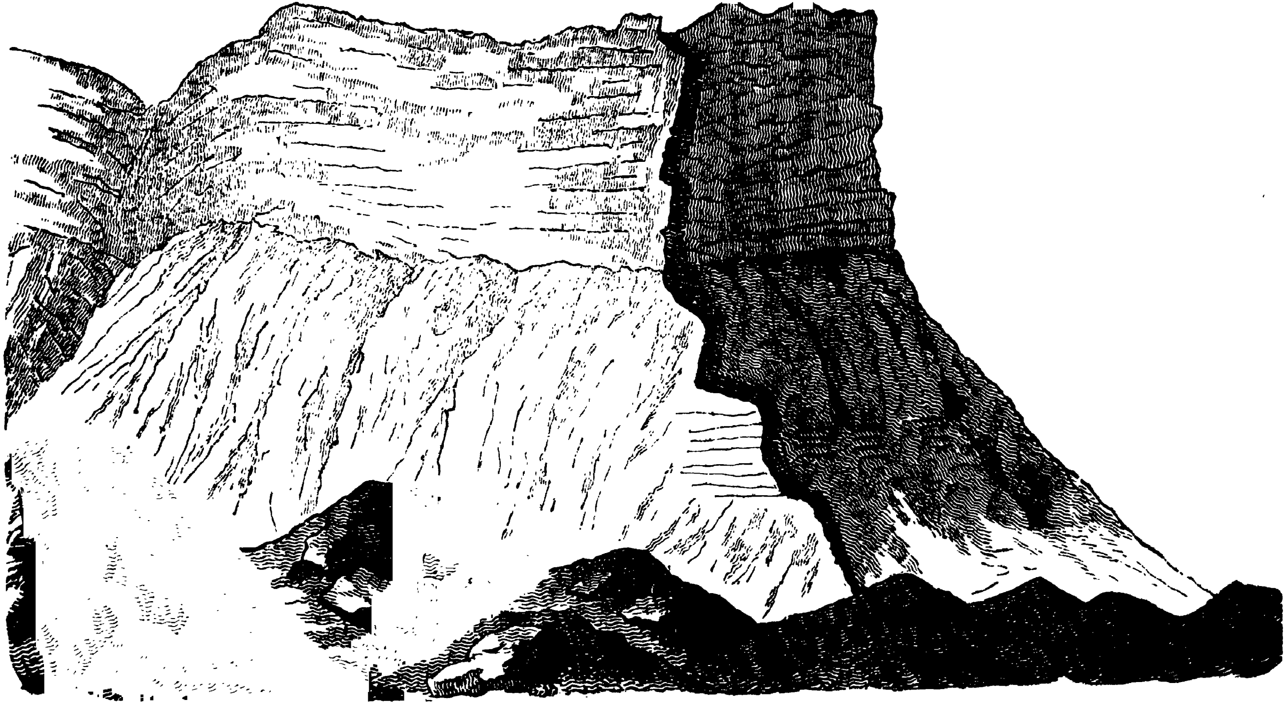
The destruction of the calcareous mountains in the Alps, depends on the peculiar composition and structure of these mountains. In the year 1821, I passed a great part of the summer in examining the calcareous mountains in Savoy, the structure of which was then not generally understood, or at least had not been described, in any geological work that I had met with. It was generally believed that the calcareous mountains were entirely composed of beds of limestone, with lofty mural precipices on the upper part; and that the lower parts, sloping from these precipices, were formed of the débris of the limestone. So far from this being the case, the calcareous mountains of the Alps, which comprise all the English formations, from the magnesian limestone or chalk, alternate, like the English formations, with enormous beds of soft shale and sandstone; and it is to this alternation, they owe the frequent destruction of the upper parts of the mountains.

If all our English secondary formations, were by some powerful cause elevated six or seven thousand feet above their present level, and the beds bent into curves, constituting several ranges of mountains, we should have precisely what is found in the calcareous ranges of the Alps. This arched form of the calcareous mountains is represented, Plate II. fig. 1., and fig. 2. *x*, *y*. Now, if one thick bed of limestone, or a portion of it, be broken off as at *z*, fig. 2, the action of continued rains on the soft bed on which it rests, will undermine it, until other portions of the limestone will fall down; and if this process take place on both sides of the mountain, the whole of the bed of limestone will fall, except the part which rests flat upon the summit: in this manner have been left the enormous caps of limestone, like immense castles, that compose the summits of the calcareous mountains, near the lake of Annecy, and in the Bauges. — Sometimes the mountain caps, which form an extended range in front, present the appearance of a narrow ridge when seen in profile.

The mountain called the Dent d'Alençon, near the Lake of Annecy, offers a remarkable instance of this. See Plate II. fig. 6. The mass of limestone on its summit, — which I found by trigonometrical measurement to rise 3840 feet above the lake, and to be nearly five hundred feet in thickness, — was undoubtedly once a continuous bed, covering the mountain like a mantle, as represented by the dotted lines: in the course of ages, the side *a a* has fallen down, and the action of rain on the soft bed, *c*, on the other side, is undermining the steep escarpment *b*, and preparing for its further destruction. The soft bed *c c*, which forms the talus or slope, being covered with vegetation on the side *b c*, is in some parts protected from rapid disintegration. On the opposite side of the valley, I found that the thick bed which formed the talus or slope under the limestone, was lias clay. I was not able to ascend the Dent d'Alençon, and therefore did not ascertain whether the bed *c* was soft sandstone or lias. In numerous instances, the upper beds of limestone in the mountains of Savoy, may be observed overlapping and overhanging, as at *a a*, Plate II. fig. 1., and are thus prepared to fall, whenever the rain and frost has widened the longitudinal natural fissures in the limestone. In Plate II. fig. 2., the mountain at *y*, which had the arched stratification, has been so broken as to present a steep escarpment: such instances are very common in Savoy. The present state of Mont Grenier, south of Chamberry, and the vast ruins in the plain below, offer a striking illustration of the causes which are in operation, to disintegrate the vast calcareous mountains of Savoy. The following description, with the cut, is taken from the first volume of my Travels:— "A part of Mont Grenier fell down in the year 1248, and entirely buried five parishes, and the town and church of St. André. The ruins spread over an extent of about nine square miles, and are called *les Abymes de Myans*. After a lapse of so many centuries, they still present a singular scene of desolation. The catastrophe must have been most awful when seen from the vicinity; for Mont Grenier is almost isolated, advancing into a broad plain, which extends to the valley of the Isère. It is several miles in length, and is connected with the mountains of the Grand Chartreux, but it is very narrow. Its longitudinal direction is from east to west: near the middle it makes a bend towards the north, forming a kind of bay or concavity on the southern side.

"Mont Grenier rises very abruptly upwards of 4000 feet above the plain. It is capped with an immense mass of limestone strata, not less than 600 feet in thickness, which presents on every side the appearance of a wall. The strata dip gently to the side which fell into the plain. This mass of limestone, rests on a foundation of softer strata, probably molasse, under which are distinctly seen thin strata, alternating with soft strata. The annexed cut represents the east wing of the mountain, and a small part of the Abymes de Myans. There can be little doubt that the catastrophe was caused by the gradual erosion of the soft strata, which undermined the mass of limestone above, and projected it into the plain. It is also probable, that the part which fell, had for some time been nearly detached from the mountain by a shrinking of the southern side, as there is at present a rent at this end, upwards of 2000 feet deep, which seems to have cut off a large section from the eastern end, that now

'Hangs in doubtful ruins round its base,'



H H

as if prepared to renew the catastrophe of 1248. The Abymes de Myans are hills, or rather monticules, of a conical shape, varying in height from twenty to thirty feet; they cover about nine square miles: the monticules are composed of fragments of calcareous strata, some of which are of immense size. They consist of yellowish oolitic limestone, strongly resembling the lower oolites in Gloucestershire; a gray limestone, harder and more crystalline than lias, which, however, it may probably be; and a thin slaty arenaceous limestone, much resembling Stonesfield slate. Fragments of schistose chert were interstratified with some of the limestone.

"The largest masses have evidently fallen from the upper bed of limestone by which Mont Grenier is capped. The velocity they would acquire by falling from so great a height, making due allowance for the resistance of the atmosphere, could not be less than 300 feet per second; and the projectile force they gained by striking against the base of the mountain, or against each other, has spread them far into the plain. In the course of years, the rains or currents of water from dissolving snows, have furrowed channels between the larger masses of stone, and, washing away part of the loose earth, have left the immense number of detached conical hills which are seen at present. So deep and vast was the mass of ruins that covered the town of St. André and the other parishes, that nothing belonging to them has been discovered, except a small bronze statue." — Vol. i. p. 201.

A part of a mountain near Servos, on the road to Chamouny, fell down in the year 1751. The fall continued for many days, and the air was darkened with immense volumes of black dust, which extended for twenty miles, and is still remembered by some of the oldest inhabitants of Chamouny. A continued succession of reports, like those of cannon, announced the successive falling of rocks, day and night. The mountain did not, like that of Mont Grenier, fall at once, for it is composed of a succession of beds of limestone resting on sandstone, and extremely fragile schist, which are even now yielding to the constant action of rain. A deep excavation, which I observed under a precipice of limestone, near the summit, appeared in 1821 to threaten a renewal of the catastrophe of 1751.*

In the Swiss Alps, the great *éboulements*† which have destroyed whole villages, have been caused by the sliding down of highly inclined beds of loose conglomerates, which have been undermined at their bases. This will be better understood by a reference to Plate II. fig. 2., representing the section of a mountain on the Alps: the beds *a a b a b* are highly inclined; and should the outer bed *a* be a soft sandstone or conglomerate, the action of water-courses or heavy rains upon its foot or base tends to destroy and undermine it, and the whole bed, perhaps several hundred feet in thickness, is suddenly precipitated into the valley. In 1806, a part of the mountain of Rosberg, between the lakes of Zug and Laworts, fell down from the cause here mentioned, and buried a considerable part of the valley, and several of the inhabitants.

Where the soil is favourable to vegetation, the débris, or ruins from the fall of mountains, become covered with vineyards and chestnut-trees; of which we have an example in the soil that covers the former

---

* In an Essay *sur les Caractères Zoologiques*, by M. Brongniart, published in 1822, he has given a section of this mountain; and from the fossils in the upper bed, and the green sand intermixed, he has with much probability classed it with the chalk formation. The lower beds of the mountain, containing ammonites, he still classes with transition rocks; but I am persuaded that these lower beds are not more ancient than the English lias, or the blue beds of the magnesian limestone: and in this mountain, (Montagne de Fis,) we have all the upper secondary strata of this part of Savoy in one group.

† The fall of parts of mountains is so common an occurrence in the Alps, that it is expressively called an *éboulement*, from the verb *ébouler*. In Devonshire and Dorsetshire, the fall of the cliffs is called a *rougement*.

town of Pleurs, near Chavennes, and all its noble palaces, belonging to opulent citizens of Milan. On the 26th of August, 1618, "an inhabitant entered the town, and said that he saw the mountains cleaving: he was laughed at for his pains; but in the evening the mountain fell, and buried the town and all its inhabitants. The number destroyed is stated to be 2430, of whom not one escaped, except the person who warned them of their danger."

Where the soil is unfavourable to vegetation, the ruins remain exposed to the action of rains, and of torrents from the sudden melting of snow, which furrow channels through them, and leave detached monticules, as in the *Abymes de Myans;* but it is evident, that by these causes they could not be transported to distant countries, except in the comminuted form of sand or mud.

There are, however, other causes in present activity, which tear down large masses of rock, and carry them many miles from their native sites. The mountain valleys in the higher Alps, on the confines of eternal snow, sometimes become closed by the extension of a lateral glacier across them, which dams in the water from the melting of Alpine snow, and forms a mountain lake, elevated many thousand feet above the lower habitable valleys. During very hot summers, the same cause which increases the waters in the lake, by a more rapid melting of the Alpine snows, diminishes the strength and thickness of the barrier of ice; it is rent asunder, and the whole water of the lake is suddenly precipitated into the lower valleys with tremendous violence, tearing down and bearing along with it all opposing obstacles: the water is seen approaching like a moving wall. In this manner was the village of Martigny in the Valais nearly destroyed in 1818. A similar inundation, in the valley of the Upper Doron in the Tarentaise, took place in the following year. I had an opportunity of observing its effects, which appeared to equal in intensity, but not in extent, those of diluvial action.

Numerous blocks of stone of many tons' weight, were brought down by the torrent, and scattered over a small plain at the mouth of the lateral valley, along which they had descended. These blocks were chiefly quartz rock, intermixed with a few blocks of mica and talc slate.

To proceed to the causes which are in the present time wearing down the surface of islands and continents. — The action of the sea upon the cliffs in England, proves in a striking manner the changes which this important agent can effect in the space of a few centuries, and sometimes in a few years. In Devonshire and Dorsetshire, and on the coasts of Sussex, Kent, and Suffolk, the sea has made great encroachments on the land since, the time of the Norman Conquest; as may be proved both by ancient records, and by what is now taking place; the cliffs being undermined by high tides, large portions of land are yearly falling into the sea.

It may, however, be doubted, whether the surface of dry land is not gradually increasing on the whole globe. The depositions from the sea and from rivers are filling up bays, estuaries, and lakes: all broad flat valleys, and almost all low and fertile plains, were once covered with water. On the eastern side of our own island, though the land is wearing away in some parts, it is increasing more rapidly in others. The flat parts of Lincolnshire, Cambridgeshire, and Holderness in Yorkshire, have been gained from the sea, or from rivers, by depositions of sand and mud at no very remote period; and the process is going on daily. In many parts, the sea, during high tides, is above the present level of the land, and is kept out by embankments.

In Yorkshire, the proprietors contrive to raise the surface of the ground, by what is called *warping*. At the highest spring tides, they open sluices in the embankments, and cover the land with the turbid sea-water, which remains until it has deposited its contents, and is let out at low water. The quantity of earthy matter held in suspension by rivers after heavy rains is prodigiously great. According to Major Rennell, a glass of water taken from the Ganges at the height of its inundations, yields one fourth sediment. Mr. Barrow says, in his account of China, that the quantity of mud brought down by the Yellow River was found, by calculation founded on experiment, to exceed two million solid feet per hour; and that some miles distant from the sea, the river was three quarters of a mile broad, and was running at the rate of seven or eight miles an hour. A great part of the enormous mass of mud, which is perpetually brought down by the Yellow River, is borne by strong currents from the Yellow Sea into the Gulf of Petchelee, where the stillness of the water allows it to subside. Into the same gulf the river of Peking discharges itself; and Mr. Barrow observes, that a great part of the land adjoining this gulf has apparently been formed, by the sand and mud brought into it; for the tide flows inland one hundred and ten miles, and often inundates the whole country, the general level of which is not more than two feet above the level of the river: indeed, the deepest part of the great gulf of Petchelee does not exceed twelve fathoms; and the prodigious number of sandy islands just appearing above the surface, are said to have been formed within the records of history. —*Barrow's China*, p. 492. From the above account, there is every probability that this wide gulf will soon be filled up by alluvial and marine depositions. The Gulf of Mexico, according to Humboldt, is gradually filling by the sand brought into it from the Caribbean Sea on the south side, and from the vast rivers, the Rio del Norte and the Mississippi.

From several sources of information referred to in the "Asiatic Researches," and from the best accounts of the Portuguese, who first visited India, there is much reason to believe, that the whole country of Malabar, between the Gaut Mountains and the sea, has become dry land at no very remote period. Numerous traditions refer to it. There is an ancient book called "Kerul Oofpiette," or the emerging of the country of Kerul, or Malabar. The book was translated by Jonathan Duncan, Esq. In this account, the formation of the land is ascribed to supernatural agency; but it contains many statements that appear highly probable. It was soon inhabited, on account of the fertility of the ground; but the inhabitants were at first driven away by the multitude of serpents, which abounded in the mud and slime of the newly emerged country. In a manuscript account of Malabar, ascribed to the Bishop of Virapli, the seat of a celebrated Roman Catholic seminary, the writer observes, that, by the accounts of the learned natives of that coast, it is little more than 2300 years since the sea came up to the foot of the Jukem or Gaut Mountains; and this he thinks extremely probable, from the nature of the soil, and the quantity of sand, oyster shells, and other fragments, met with on making excavations. It is not unreasonable to believe that the whole coast was elevated by subterranean agency; for so recently as 1805, the bed of part of the sea and of the Indus, was permanently changed by an earthquake, near Cutch, on the coast of Bombay.

The increase of land at the mouth of the Nile, and of many European rivers, is well known. Adria, which was once a port of the Adriatic Sea (to which it gave its name), is now six leagues inland. In lakes, the diminution of the surface, by the gradual increase of land at the mouths of rivers which flow into them, is still more remarkable. The mud and débris brought into the lake of Geneva by the Rhone, and deposited near its entrance, has made the land advance two miles in the space of 1700 years, — the Roman harbour Portus Valesiæ being now that distance from the lake. All the lakes in Savoy and Switzerland, and in our own island, are gradually diminishing by similar causes. To multiply instances of this kind would be incompatible with the limits of the present volume; every attentive observer must have noticed them in the course of his travels.

All the most fertile parts of the globe were formed by alluvial depositions: alluvial agency appears to have been the means employed, in the economy of nature, to prepare the world for the residence of social and civilised man. The most ancient cities of which we have any authentic record, Babylon, Nineveh, and Thebes, were founded in the midst of alluvial soils, deposited by the Euphrates, the Tigris, and the Nile: indeed, it does not appear unreasonable to believe, that the formation of soils for the support of vegetables and animals, is the final end to which all terrestrial changes ultimately refer.

It has been justly observed by Dr. Paley and others, that in the peculiar conformation of the teeth in graminivorous animals, and in the production of grasses which serve them for food, we may trace evident marks of relation, and of a designing intelligent cause. With equal reason must we admit, that the destruction of mountains, and the formation of soils for the support of the vegetable tribes, are provided for by the same cause, and are part of a regular series of operations in the economy of nature. Hence also we may infer, that those grand revolutions of the globe, by which new mountains or continents are elevated from the deep, are parts of the same series, extending through ages of indefinite duration, and connecting all the successive phenomena of the material universe.

By a wise provision of the Author of nature, it is ordained, that those rocks which decompose rapidly, are those which form the most fertile soils; for the quality of soils, depends on the nature of the rocks from which they were formed. Granitic and siliceous rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixed with clays, form marl; but when not covered by other strata, they support a short, but nutritious vegetation.

For the formation of productive soils, an intermixture of the three earths—clay, sand, and lime—is absolutely necessary. The oxide of iron appears also to be a requisite ingredient. The proportion necessary for the formation of good soil, depends much on the nature of the climate, but more on the quality of the sub-soil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which upon a different sub-soil would be exceedingly productive. When this is the case, drainage or irrigation offers the only means of permanent improvement.

Different vegetables also require different admixtures of earth. They require it, first, because it is necessary to their growth that the soil should be sufficiently stiff and deep to keep them firm in their place; and also that it should not be too stiff to permit the expansion and growth of their roots: and, lastly, that it should supply them with a constant quantity of water, neither too abundant nor deficient. Hence we may learn why different degrees of tenacity, depth, and power of retaining or absorbing moisture, are required in soils for different kinds of plants. Thus, in uncultivated countries, we find that certain vegetables affect particular situations in which they flourish spontaneously and exclusively; and it is only by imitating nature, and profiting by the instruction she affords, that we can hope to obtain advantageous results, or acquire certain fixed principles, to guide us in our attempts to bring barren lands into a state of profitable cultivation. When rocks contain in their composition a due proportion of silex, clay, and lime, they furnish soils whose fertility may be said to be permanent. The most fertile districts in England were made so by nature; their original fertility was independent of human operation.

Some small portion of the earths and alkalies is found by chemical analysis in plants: but it would be contrary to fact and analogy, to suppose that the earths, in a concrete state, form any part of the food of plants: the earths and alkalies which they contain, are in all probability formed by the process of vegetation, from more simple elements; for it is now ascertained, that the earths and alkalies are compound substances.

The principal elements found in plants are hydrogen, carbon, and oxygen; and by experiments of Gay Lussac and Thenard*, it appears that the hydrogen and oxygen in starch, gum, vegetable oils, and sugar, exist in precisely the same proportions that form water. Carbon, the other principal elementary substance found in plants, exists both in water and in the atmosphere. Water and the atmosphere contain in themselves, or in solution, all the elements necessary for the support and growth of vegetables. But most soils are either too wet or too dry, too loose or too adhesive, to admit plants to extract these elements, in the proportions necessary for their growth. Manures supply this deficiency, by furnishing in great abundance the hydrogen, carbon, or azote, which they may require. In proportion as soils possess a due degree of tenacity, and power of retaining or absorbing heat and moisture, the necessity for a supply of manure is diminished; and in some instances the earths are so fortunately combined, as to render all supply of artificial manure unnecessary. He who possesses on his estate the three earths, — clay, sand, and lime, — of a good quality, with facilities for drainage or irrigation, has all the materials for permanent improvement; the grand desiderata in agriculture being to render wet lands dry, to supply dry lands with sufficient moisture, to make adhesive soils loose, and loose soils sufficiently adhesive.

The intermixture of soils, where one kind of earth is either redundant or deficient, is practised in some countries with great advantage. Part of Lancashire is situated on the red-sandstone described in the sixth chapter. This rock, being principally composed of siliceous earth and the oxide of iron, forms of

---

* Recherches Physico-Chimiques.

itself very unproductive land: but, fortunately, in many situations, it contains detached beds of calcareous marl near the surface. By an intermixture of this marl with the soil, it is converted into fertile land, and the necessity for manure is superseded. The effect of a good marl applied liberally to this land, lasts for more than twenty years. In some lands, a mixture of light marl which contains scarcely a trace of calcareous earth, is found of great service. The good effect of this appears to depend on its giving to the sandy soil a sufficient degree of tenacity. The sterile and gravelly soils in Wiltshire have been recently rendered productive, by mixing them with chalk; the most liberal application of manure having been found ineffective, or injurious. In stiff clay soils, where lime is at a great distance, the land might frequently be improved by an intermixture with siliceous sand. A proper knowledge of the quality of the sub-soil, and the position of the substrata, is necessary to ascertain the capability of improvement which land may possess. It may frequently happen, that a valuable stratum of marl or stone, which lies at a great depth in one situation, may rise near the surface in an adjoining part of the estate, and might be procured with little expense.

Lime is the only earth which has been generally used to intermix with soils, and has been considered as a manure; but its operation as such is very imperfectly understood. Burnt lime, when caustic, destroys undecomposed vegetable matter, and reduces it to mould, — so far its use is intelligible. It combines also with vegetable or mineral acids in the soil, which might be injurious to vegetation, — here its operation is likewise intelligible: but if we assert, that when burnt lime has absorbed carbonic acid and become mild, it gives out its carbon again to the roots of plants, we assume a fact, which we have neither experiments nor analogies to support. The utility of lime in decomposing vegetable matter and neutralising acids is obvious: but its other uses are not so evident; except we admit that it acts mechanically on the soil, and renders the clay or sand with which it is intermixed, better suited to the proper expansion of the roots, and more disposed to modify the power of retaining or absorbing the requisite degree of heat and moisture, which particular vegetables may demand.

Where earths are properly intermixed, instances are known of land producing a succession of good crops for many years, without fallowing or manure. On the summit of Breedon Hill, in Leicestershire, I have seen a luxuriant crop of barley growing on land, that had borne a succession of twenty preceding crops without manuring. This is more deserving notice, being in an exposed and elevated situation, and upon the very hill of magnesian limestone, which has been so frequently referred to by chemical writers, as peculiarly unfavourable to vegetation. The limestone of this hill contains above 20 per cent. of magnesia.*

The temperature requisite for the growth of plants is influenced by the power of different soils to absorb and retain heat from the solar rays, which depends much on their moisture and tenacity. "It is a well known fact, that the vegetation of perennial grasses in the spring, is at least a fortnight sooner on limestone and sandy soils, if not extremely barren, than on clayey or even in deep rich soils: it is equally true, but perhaps not so well known, that the difference is more than reversed in the autumn." — *Observations on Mildew, by J. Egremont, Esq.* This effect Mr. E. ascribes, with much probability, to the rich or clayey soils absorbing heat slowly, and parting with it again more reluctantly than the calcareous soils, owing to the greater quantity of moisture in the clay, which is an imperfect conductor of heat.

---

* The magnesian lime acts more powerfully in destroying undecomposed vegetable matter than common lime, and its effects on land are more durable: hence it is in reality of greater value in agriculture, as a much smaller quantity will answer the same purpose.

Calcareous soils might frequently be much improved by a mixture of clay, sand, or gravel, which, in many situations, is practicable with little expense, and would well reward the labour of the experimental agriculturist.

Calcareous Tufa. — Beside the new land formed by alluvial depositions, beds of calcareous tufa are sometimes formed in valleys, and at the bottom of lakes, by a process which bears some analogy to chemical formations. Springs containing carbonic acid, that issue from limestone strata, contain particles of carbonate of lime chemically dissolved in the water; but on exposure to air and light, the carbonic acid, which had but a slight affinity for the particles of limestone, separates, and the particles of lime are precipitated and form calcareous incrustations: these in a course of years form thick beds, and are sometimes sufficiently hard to be used for building-stone. The Rock Mill, near Stroud, in Gloucestershire, is built of this stone. In almost all limestone countries, there are instances of calcareous incrustations formed in springs, which have received the name of petrifying wells.

Thermal waters, that contain calcareous earth in solution, deposit beds of tufa very rapidly. Nearly the whole bottom of the valley at Matlock Baths, in Derbyshire, is filled with calcareous tufa, forming a bed not less than fifty feet in thickness, and half a mile in length. It contains fragments of moss, and some land shells. The horns of a stag were found in excavating this tufa; it is deposited by the thermal springs, that every where gush out from the hill behind the baths. Except the depositions from thermal waters, beds of calcareous tufa are seldom formed on land, of any considerable magnitude; but thermal waters have probably been important agents, in the formation of many of the secondary strata at the bottom of the ocean. (See Chap. XV.)

Mr. Lyell, in the first volume of his "Principles of Geology," has described many depositions of calcareous tufa in the volcanic districts of France and Italy.

There are depositions of freshwater limestone slowly forming in some of our present lakes. Mr. Lyell, in "Geological Transactions," 1826, describes a small lake about nine miles west of Forfar, in Scotland. It once extended over two hundred acres, but is now reduced to a peat moss, or swampy hollow in diluvium. The bed of the lake has been in a great part excavated for marl; it contains different strata, of variable thickness. The upper covering is peat, one or two feet thick, under which is shell or rock marl, varying from one to sixteen feet. Quicksand two feet, and lower shell marl of a good quality, from one to two feet thick, resting on a bed of fine sand, of variable thickness. The rock marl consists wholly of carbonate of lime; it is hard and compact, and in some parts crystalline. The lower shell marl rarely contains any distinguishable quantity of shelly matter. In the rock marl are found shells of Helices, the Turbo fontinalis, and the Patella lacustris.

There are remains of land quadrupeds in the shell marl, but not in the rock marl. The rock marl, (it appears from Mr. Lyell's description,) nearly resembles the upper freshwater limestone in the Paris basin, and, like it, is traversed by tubular cavities. Some part of the rock marl is, however, stated to be a tufaceous limestone. This recent formation of freshwater limestone, is in so many respects analogous to the most recent formation of freshwater strata of the ancient world, that all the particular circumstances described by Mr. Lyell, deserve the careful attention of the geologist.

Peat is a substance which has been classed with alluvial soils, though it is obviously a vegetable production. Peat formerly covered extensive tracts in England, but is disappearing before the genius of agricultural improvement, which has no where produced more important effects, than in the conversion of the black and barren peat moors of the northern counties, into valuable land covered with luxuriant herbage, and depastured by numerous flocks. The following description of the peat moors in Scotland, by Mr. Jameson, is an accurate picture of the remaining peat moors in the mountainous parts of Yorkshire, and the adjoining counties: —

" In describing the general appearance of a peat moor, we may conceive an almost entire flat of several miles extent, of a brown colour, here and there marked with tufts of heather, which have taken root, owing to the more complete decomposition of the surface peat; no tree or shrub is to be seen; not a spot of grass to relieve the eye, in wandering over this dreary scene. A nearer examination discovers a wet spongy surface, passable only in the driest seasons, or when all nature is locked in frost. The surface is frequently covered with a slimy black-coloured substance, which is the peat earth so mixed with water, as to render the moor only passable, by leaping from one tuft of heather to another. Sometimes, however, the surface of peat mosses has a different aspect, owing to the greater abundance of heath and other vegetables, as the schœni, scirpi, eriophora, &c.: but this is principally the case with some kinds of what are called muirlands, which contain but little peat, being nearly composed of the interwoven roots of living vegetables. Quick moss (as it is called) is a substance of a more or less brown colour, forms a kneadable compound, and when good, cuts freely and clean with the spade; but when it resists the spade by a degree of elasticity, it is found to be less compact when dried, and is of an inferior quality. The best kinds burn with a clear bright flame, leaving light-coloured ashes; but the more indifferent kinds, in burning, often emit a disagreeable smell, and leave a heavy red-coloured kind of ashes. In digging the peat, we observe that when first taken from the pit it almost immediately changes its colour, which becomes more or less a deep brown or black, and the peat matter becomes much altered, being incapable of forming a kneadable paste with water. When dry and reduced to powder, as it is often by the action of the weather, it forms a blackish coloured powdery matter, capable of supporting vegetation, when calcareous earth is added.

"Peat is found in various situations, often in valleys or plains, where it forms very extensive deep beds, from three to forty feet deep, as those in Aberdeenshire: it also occurs upon the sides of mountains, but even there it is generally in a horizontal situation. The tops of mountains, upwards of two thousand feet high, in the Highlands of Scotland, are covered with peat of an excellent kind.

"It is also found in situations nearly upon a level with the sea: thus, the great moss of Cree in Galloway, lies close upon the sea, on a bed of clay, little higher than the flood marks at spring tides."*

In the first volume of Dr. Macculloch's valuable "History of the Western Islands of Scotland," he has given a luminous description of the formation of peat, which completes the natural history of peat moss. Beside the Sphagnum palustre, he has enurated nearly forty plants which concur to the generation of peat.

The process by which these vegetables are converted into peat, is most clearly seen in the sphagnum. As the lower extremity of the plant dies, the upper sends forth fresh roots like most of the mosses, the individual thus becoming in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter. A similar process, though less distinct, takes place in many of the rushes and grasses, the ancient roots dying together with the outer leaves, while an annual renovation of both, perpetuates the existence of the plant. The growth of peat, necessarily keeps pace with that of the vegetables from which it is formed; hence the necessity of replacing the living turf on the bog where peat has

---

* Jameson's Mineralogy of the Shetland Islands.

been cut, — a condition now required in all leases, in which liberty to cut turf is included. On the conversion of vegetable matter into peat Dr. Macculloch observes: — "Where the living plant is still in contact with peat, the roots of the rushes, and ligneous vegetables, are found vacillating between life and death, in a spongy half decomposed mass. Lower down, the pulverised carbonaceous matter is seen mixed with similar fibres, still resisting decomposition. These gradually disappear, and at length a finely powdered substance alone is found, the process being completed by the total destruction of all the organised bodies." — P. 130. The best peat is that of which the decomposition is most complete, and the specific gravity and compactness the greatest. The quality of peat, Dr. Macculloch observes, is much affected by the wetness or dryness of the soil, and the elevation or other causes, which influence the temperature and moisture of the atmosphere.

For a description of the chemical changes produced in peat by water and fire, I must refer to the first volume of Dr. Macculloch's work before quoted, p. 131. It is only in the first stages of decomposition that peat is soluble, and communicates a dark colour to water.

The rapid formation of peat in many situations, where it is found covering ground that was formerly pastured, admits of an easy explanation, since Dr. Macculloch has so clearly described the mode in which this substance is generated.

The property possessed by peat of preserving animal matter from putrefaction is well deserving notice. It is probably owing to this, that some of the fleshy parts of the mastodon have been so long preserved in peat bogs.

In the *Philosophical Transactions*, 1734, there is a letter from Dr. Balguy, giving an account of the preservation of two human bodies in peat for fifty-nine years. "On January 14, 1675, a farmer and his maid-servant were crossing the peat moors above Hope, near Castleton, in Derbyshire; they were overtaken by a great fall of snow, and both perished: their bodies were not found till the 3d of May, in the same year; and being then offensive, the coroner ordered them to be buried on the spot in the peat. They lay undisturbed twenty-eight years and nine months, when the curiosity of some countrymen induced them to open their graves. The bodies appeared quite fresh, the skin was fair and of its natural colour, and the flesh as soft as that of persons newly dead. They were afterwards frequently exposed as curiosities until in the year 1716, when they were buried by order of the man's descendants. At that time Dr. Bourne, of Chesterfield, who examined the bodies, says the man was perfect, his beard was strong, the hair of his head was short, and his skin hard and of a tanned leather colour, like the liquor he was lying in. The body of the woman was more injured, having been more frequently exposed; the hair was like that of a living person. Mr. Wormwald, the minister of Hope, was present when they were removed: the man's legs, which had never before been uncovered, were quite fair when the stockings were drawn off, and the joints played freely without the least stiffness."

In the beginning of the last century, the perfect body of a man, in the ancient Saxon costume, was discovered in peat, at Hatfield Chase, in Yorkshire: it soon perished on exposure to the air.

Extensive tracts of cultivated ground are sometimes converted into sandy deserts, by the drifting of sea-sand inland. The process by which this is effected, is taking place, at present, in many situations. During very high winds, the sand is driven from the sea-shore to a certain distance, leaving an elevated ridge at the further boundary of the drift. Succeeding winds blow the sand forward, and at the same time bring fresh sand from the shore to supply its place. In the sixth volume of the *Transactions of the Irish Academy*, an account is given of the encroachment of the sand, over some parts of Ireland.

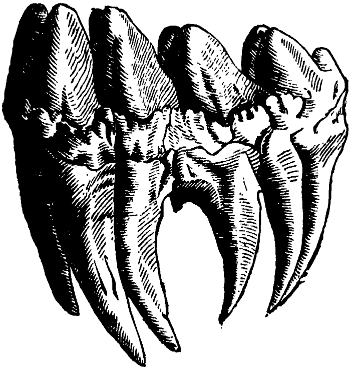
Trees, houses, and even villages, have been surrounded or covered with sand, during the last century. In the vicinity of sandy deserts, the sand is also encroaching on the habitable land. The loose sands of Libya are thus spreading over the valley that borders the Nile, and burying the monuments of art and the vestiges of former cultivation. From a similar cause, the country immediately round Palmyra, that once supplied a crowded population with food, now scarcely affords a few withered plants, to the camel of the wandering Arab.

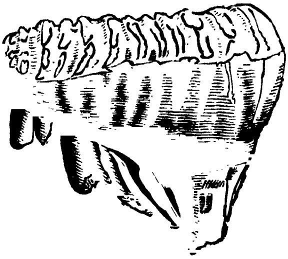
A sandy inundation on the north coast of Cornwall was mentioned Chap. I. p. 22. This sand, which is composed of fragments of shells and coral, is in some parts cemented into sandstone, by water infiltrating from the slate-rocks: it is similar in appearance to the recent sandstone of Guadaloupe, in which human skeletons have been found: the latter is a very common sandstone in the West Indies; it increases rapidly, and the land gained from the sea, which forms some of the plains of St. Domingo, is composed of it. A concreted calcareous sandstone extends on the southern, western, and north western coast of Australasia, for three thousand miles. Some specimens, which I examined with a lens, appear perfectly similar to the recent sandstone from Guadaloupe.

Among the causes in present activity, which are changing the surface of the globe, the labours of madrepores must not be unnoticed. These minute polypi, raise up walls and reefs of coral rock with astonishing rapidity in tropical climates, and encircle the present islands with belts of coral, thus enlarging their coasts. A coral reef of seven hundred miles in length, extends from the north-west of Australasia, towards new Guinea. For a detailed account of coral rocks and reefs, I must refer the reader to the observations of Dr. Forster, and the voyages of Captain Flinders, and of Kotzebue, and of the French naturalists MM. Quoi and Gaimard, but more particularly to the observations of Captain Beechy, made during his voyage to the Southern Pacific. The subject of coral reefs has been before referred to at some length. See Chap. VI.

Organic Remains in Diluvial Beds. — As the remains of the mastodon, the elephant, the rhinoceros, and hippopotamus occur with the bones of other mammalia in diluvial beds, this circumstance proves their great antiquity, and distinguishes them from alluvial depositions. Teeth of the latter animals are not uncommon in English diluvium, and two teeth of the mastodon have been found in the Norfolk Crag.

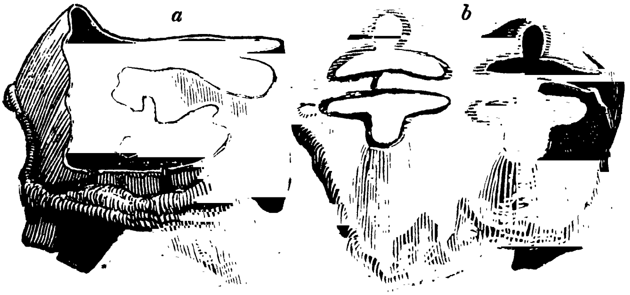
It has been thought desirable to give drawings of the teeth, for the use of the geological student.





The first represents the pointed tooth of the mastodon; the other the flat crowned tooth of the elephant, which is sometimes larger than that of the mastodon.

The following cut represents the molar tooth of



the rhinoceros, *a*, from Kirkdale cavern; *b* is the molar tooth of the hippopotamus, much worn, from the same locality.

The fossil elephant, or mammoth, is the most remarkable of the ancient herbivorous quadrupeds, both from its vast size, and the amazing number of bones of this genus, which are found in the northern parts of Europe, and in America. The mammoth must have existed in herds of hundreds and thousands. According to Pallas, there is scarcely a river, from the Don or the Tanais, to the extremity of the promontory Tchuskoinosa, in the banks of which the bones of the mammoth are not abundant. There are two large islands near the mouth of the river Indigerska, which are said to be entirely composed of the bones of the mammoth, intermixed with ice and sand: the tusks are so perfect, that they are dug out for ivory. With the bones of the mammoth are intermixed those of the elk, the rhinoceros, and other large quadrupeds. The body of a fossil elephant has been found entire, with the flesh preserved, buried in ice: it had a mane along its back, and was covered with coarse red wool, protected by hair of a coarser kind, indicating that it was an inhabitant of cold or temperate climates; indeed, the circumstance of the body being preserved in ice, is a further proof of this; for had it been conveyed from distant regions, the flesh must have been speedily decomposed, before it could have been enveloped in ice. The height of this animal was from fifteen to eighteen feet. Bones and teeth of the mammoth are not unfrequently found in England in beds of diluvial gravel and clay, and in caverns: they are chiefly found in low situations, such as the vale of the Thames, and the vale of the Severn. The mammoth bears a near resemblance to the Indian elephant, but Cuvier regards it as a distinct species.

The rhinoceros, of which there are three large species, and one smaller, appears to have lived with the fossil elephant: their bones are found together;

but it is in Siberia that the bones of the rhinoceros are most numerous, and best preserved. In the year 1771, the entire body of one of these animals, was found in the frozen sands of that country.

Bones and teeth of the hippopotamus are found both in England, France, Germany, and Italy: there are two species, the largest resembles the African hippopotamus, the smaller is the size of the wild boar. Bones and teeth of the large animal, called the mastodon, are found both in Europe and America. The great mastodon had pointed grinders; it was a native of North America, and equalled in size the elephant, which, in many particulars, it resembled. Entire skeletons of the mastodon have been found in salt marshes; but what is more extraordinary, parts of the flesh and the stomach have been found with them. Among the vegetable substances in the stomach, were distinguished the remains of some plants known in Virginia. The Indians believe that this animal is still living north of the Missouri, and the above circumstances render it probable, that this species of mastodon has not been long extinct. Bones of other species of the mastodon are found in Europe and South America; these are probably more ancient. Teeth of a gigantic species of tapir, equal in size to the rhinoceros, have been found in France and Germany*: the bones of horses are also found in great abundance, with the bones of the above-mentioned animals. Bones and horns of the elk, the stag, and of various species of deer, and of oxen, some of which closely resemble existing species, are often intermixed with the bones of elephants, and other ancient animals. With these animal remains, are also

---

* The most perfect tooth of this animal, which is at present known, was found near Grenoble; the enamel is as fresh as that of a recent tooth. This tooth, of which there are models in the principal museums in Europe, is in the author's collection: it was purchased by him, at the sale of the late M. Faujas St. Fond, together with the tooth of a South American mastodon, found in the volcano of Imbabura in the Cordilleras, and the tooth of a European mastodon, found with that of the gigantic tapir, near Grenoble.

found the bones of carnivorous animals of the size of the lion, the tiger, and the hyena; the bones of bears are numerous, particularly in caverns.

The number of bones belonging both to the order of pachydermata, and of ruminant and carnivorous quadrupeds, is so great in various parts of Europe, as to leave no doubt that the animals were inhabitants of northern or temperate climates. In America have been found the bones of two large animals, of extraordinary form. The megatherium is the size of the rhinoceros; it unites part of the structure of the armadillo with that of the sloth; its claws are of vast length and size. The megalonix was nearly similar in form, but smaller.

Bones of the camel have been occasionally found in some parts of Europe, but they are of rare occurrence. For a knowledge of nearly all the above species of fossil mammiferous quadrupeds, we are indebted to the researches of Cuvier. "Their bones," he observes, "are found in that mass of earth, sand, and mud, that diluvium which covers our large plains, fills our caverns, and chokes up the fissures in many of our rocks. They incontestably formed the population of the continents, at the epoch of the great catastrophe which has destroyed their races, and has prepared the soil on which the animals of the present day subsist. Whatever resemblance certain of these species bear to those of existing species, the general mass of this population had a different character; the greater part of the races which composed it have been utterly destroyed. Among all these mammiferous animals, the greater number of which have their congeners living at the present day, there has not been found a single bone or tooth of any species of ape or monkey. Nor is there any trace of man: all the human bones which have been found, along with those of which we have been speaking, have occurred accidentally; and their number besides is exceedingly small, which assuredly would not have been the case, if men had been then settled in the countries which these animals inhabited."* When Cuvier published the first edition of his *Recherches sur les Ossemens fossiles*, he too hastily concluded, that we were already acquainted with all the existing species of large land quadrupeds; and hence he inferred, that it was highly improbable that any of the species of unknown quadrupeds, whose bones are found in diluvial soils, should be still living. Since that time a large species of living tapir has been found in the East Indies; and other discoveries of new quadrupeds have been made: hence we cannot conclude with absolute certainty, that all the species of unknown fossil quadrupeds are extinct, though it seems highly probable that the greater number of the races have perished. The animals whose bones are found in peat bogs and marshes, such as the elk in Ireland, and the great mastodon in Kentucky, may, I conceive, be referred with much probability to a more recent epoch, than that in which the diluvial beds were deposited.

Skeletons, both of the Irish elk and the great American mastodon, have been found erect in peat bogs and marshes, which proves that the surface of the ground has undergone little change since the animals perished; and the further circumstance of the flesh and stomach of the mastodon being found near the surface, not protected, like the bodies of the elephant and rhinoceros found in Siberia, by ice, seems opposed to the general belief in the high antiquity of these animal remains; and it is admitted by Cuvier, that they are in better preservation than any other fossil bones. The quadrupeds whose bones are buried in beds of clay, sand, or gravel, or accumulated in caverns, undoubtedly lived in a very remote period, and under a different condition of our planet to the present one. The northern parts of Europe seem now incapable of supporting the im-

---

* For an account of human bones found in caverns mixed with the bones of extinct species, see the preceding Chapter.

mense number of elephants, which have formerly spread over all the valleys bordering the Frozen Ocean. Were we to admit that the temperature of the earth was then higher than at present, which the remains of palms and other tropical plants found in northern latitudes render highly probable, this would not remove the difficulty; for the fact that entire bodies of elephants have been preserved in ice, and that their skins were covered with a thick coat of wool and hair, proves that these animals were constituted for living in cold climates, and that their remains have not been transported to any great distance from the countries which they inhabited.*

The remains of these large quadrupeds occur in different states of preservation. In the frozen regions of the north the ivory of the tusks is perfect. In beds of clay, the bones and teeth are frequently impregnated with mineral matter; but in gravel they are generally in a loose or friable state, or at least they soon become so, after exposure to the air. In the *Phil. Journal of Edinburgh*, January, 1828, an account is given of numerous bones of the mastodon, rhinoceros, and other animals, having been found on the surface of the ground, near Irrawady River, in Ava. These bones, though exposed to the atmosphere, are stated to be extremely hard; they were mixed with silicified wood, in a deposition of sand or gravel. With the remains of the broad-toothed mastodon, were also found teeth of a new species of mastodon of enormous size, which appears to be intermediate in form, between that of the elephant and of the mastodon: it has hence received the name of *mastodon elephantoides.* Specimens of these teeth are in the museum of the Geological Society, in London.

---

* A friend has suggested, that the Siberian elephants were probably migratory, and passed the winter months in more temperate latitudes. If this were the case, individuals that from lameness or disease were unable to travel, may have been incrusted with ice immediately after death.

CHAP. XXII.

ON THE ELEVATION OF MOUNTAINS AND CONTINENTS.

The Elevation of the Beds of Granite and Slate in England proved by the Author, in 1823, to have taken place at a much earlier Epoch, than the Elevation of the Granite of Mont Blanc. — The Facts on which this Conclusion was founded described and explained. — Application of similar Conclusions to other Mountain Ranges by M. Elie de Beaumont. — The Elevation of Rocks of Granite and Slate, proved to have taken place by a distinct Operation from that which upheaved Continents from the Ocean, and at a different Epoch. — Elevation of the Mountains and Table Land in Central Asia. — Depression of the Surface round the Caspian Sea. — Instances of the Elevation and Submergence of the Earth's Surface in various Parts of the Globe.

THAT granite, or some modification of granite, forms the foundation rock of the present continents, is admitted by geologists. It is also ascertained, that specimens of granite, gneiss, and mica-slate, from the most distant parts of the globe, appear to be identical. It is, therefore, probable that the crust of granite which environs the globe, was all formed or consolidated at the same epoch, though local protrusions of granite have taken place at much later epochs.

If granite be the lowest and most extensive formation of known rocks, yet, in many countries, it is raised in immense ridges, forming the basis of mountain ranges: sometimes the beds of granite are nearly vertical, and constitutes the summit as well as the central base of mountains. An enquiry suggests itself; was the elevation of these mountain ranges co-temporaneous in different countries? The followers of Werner maintained, that granite mountains were crystalline masses, precipitated in a universal ocean impregnated with mineral matter; and that their elevation was coëval with their origin. In the year

1819, M. Daubuisson, who was regarded by the French as an oracle in Géognosie, published his *Traité de Géognosie*, in which, following the steps of Werner on most points, he asserted, that the granite of the Alps attained its present elevation soon after the epoch of its formation. In the years 1820, 1821, and 1822, I had frequent opportunities of ascertaining the error of this opinion; and that the beds of granite were not elevated, till after the deposition of the calcareous beds that rest upon them. I farther ascertained, that many of these calcareous beds were identical with the upper secondary strata in England; hence it followed, that the granite beds in the Alps were not elevated till a late geological epoch, after the deposition of the oolites and chalk. This discovery I published in 1823, in my Travels in the Tarentaise, vol. ii. pp. 17, 18; and I there distinctly stated, *that the elevation of the granite of the Alps, was more recent, than the elevation of the beds of granite and slate in England.* Neither the importance of the discovery, nor its now generally admitted truth, have obtained for it the attention which I think it was justly entitled to, and which it would certainly have received, had it been announced by any tyro in geology, either in France or Germany. At pages 223. and 224., of the present volume, will be found a brief account of this discovery, which was also republished in the 3d edition of this work; but it may be proper to give a more full reference to the sections by which the discovery was illustrated, as they serve, not only to explain from what data the relative age of the elevation of different mountain chains may be ascertained, but to show that M. Elie de Beaumont has been guided by exactly the same data, in forming his recent conclusions respecting the ages of mountain chains in various parts of Europe. See Plate II. fig. 2.: *d*, *d*, *d*, represent the highly inclined beds of granite and primary rocks of Mont Blanc: the dotted lines represent the supposed extent of the beds before they were broken down by causes that are incessantly wearing them away, as described in the preceding chapter: *c c*, are elevated beds of soft slate, which have undergone more disintegration than the harder beds of granite: it is in these depressions, called *cols*, that the passages over the Alps are generally situated.

The beds *b a*, *b a a*, are composed of the secondary formations, from magnesian limestone, to the green sand of the chalk formation. Now, as all these beds rise at nearly the same angle of elevation as the granite, it is evident that they were elevated at the same epoch, which must have been subsequent to the deposition and consolidation of all the secondary beds from *a a* to *b*, that rise up with the granite, and therefore the elevation of the granite of Mont Blanc, was posterior to the secondary epoch. Plate II. fig. 4. shows a section of the low granitic and slate rocks of Charnwood Forest, Leicestershire, considerably elevated *b c*, *c b*. On the top of the elevated beds *c c*, there are a series of nearly horizontal beds of the upper new red sandstone described in Chapter XI. Now as these beds of new red sandstone are of the same age as the lower secondary beds *b b*, in fig. 2., and were obviously deposited, after the beds of granite and slate rock were elevated, it is obvious that this elevation took place prior to the secondary epoch, and therefore long before the elevation of the granite beds of Mont Blanc. The new red sandstone not only fills up depressions in the rocks of slate and granite at Charnwood Forest, but also fills some of the valleys at their feet.

If we admit, what few geologists will deny, that the same secondary formations in different European countries were cotemporaneous, it cannot be controverted, that the elevation of the slate rocks and granite in Charnwood Forest, was long prior to the elevation of the granite of Mont Blanc. This is but repeating what I published in 1823: — a similar position has recently been advanced by M. Elie de Beaumont, much amplified, and illustrated by numerous facts. It would scarcely be possible within the limits allowed for the subject in the present volume, to give a more clear and concise account of M. Elie de Beaumont's views, than by quoting Professor Sedgwick's summary, in his able and truly eloquent address to the Geological Society in 1831. After which, I shall notice some corrections M. Elie de Beaumont has since found necessary to introduce.

"By an incredible number of well-conducted observations of his own, combined with the best attested facts recorded by other observers, M. Elie de Beaumont has proved, that whole mountain chains have been elevated at one geological period, — that great physical regions have partaken of the same movement at the same time, — and that these paroxysms of elevatory force, have come into action at many successive periods.

"Step by step, we have been advancing towards the conclusion, — that different mountain chains had been elevated at several distinct geological periods; and by a long series of independent observations, Humboldt, Von Buch, and other great physical geographers, had proved, — that the mountain chains of Europe might be separated into three or four distinct systems; distinguished from each other (if I may so express myself) by a particular physiognomy, and above all, by the different angles made by the bearings of their component formations, with any assumed meridian. All the subordinate parts of any one system were shown to be parallel; while the different systems (*mountain ranges*) were inclined at various angles to each other.

"By an unlooked for and most felicitous generalisation, M. Elie de Beaumont has now proved, that these two great classes of facts are commensurate to each other; and that each of these great systems of mountain chains, marked on the map of Europe by given parallel lines of direction, has also a given period of elevation, limited and defined by direct geological observations."

Professor Sedgwick then describes four of these systems or mountain chains. "The first includes the higher elevations in eastern France, of the Côte d'Or, and Mount Pilas, and a portion of the Jura chain; it may also be traced in the chain of the Erzgebirge, between Bohemia and Saxony. This system or mountain chain never rises into mountains of the first order, but is marked throughout by many longitudinal ridges and furrows, ranging nearly parallel to each other, in a direction about north-east and south-west. It will appear that this chain has been elevated, after the deposition of the oolitic series, but before that of the chalk formation, for the lower secondary formations, comprising the oolites, wherever they appear are elevated in broken or contorted strata, yet they preserve a parallelism in the general direction of the ridges. On the contrary, wherever beds analogous to chalk or green sand occur, they are found at a dead level, and expand in horizontal planes into the neighbouring mountains, like the sea at the base of a lofty cliff; or if they have undergone any movement, it is shown to have no relation to the bearing of the older ridges, and to have been produced at a later period. Hence it follows, that the action of elevation was violent and of short continuance, for the inclined strata are shattered and contorted, and between them and the horizontal strata there is no intermediate gradation of deposits: it farther proves, that the period of elevation was followed by an immediate change in many of the forms of organic life.

"The next great system includes the whole chain of the Pyrenees, — the northern Apennines, — the calcareous chains to the north-east of the Adriatic, — nearly the whole of the Carpathian chain, and it extends thence through the Hartz mountains, to the plains of northern Germany. Through the whole of these vast regions, the main bearings of the beds range about west-north-west and east-south-east. This system was elevated at a later period than the former, and not till the chalk and green sand had been deposited, for the strata of these formations are every where ruptured and contorted, and often lifted up to the very pinnacles of the mountains: whereas, when any of the tertiary strata approach these ranges, they are stated to be in a position nearly horizontal as the surface of the waters in which they were deposited, unless disturbed by local causes. Hence, it is inferred, that the great parallel ridges and chains of this second system were suddenly and violently elevated, at a period between the deposition of the chalk, and the commencement of the tertiary groups. The corresponding change in organic remains, is still more striking than in the former system.

"The third system embraces a great number of parallel ranges, bearing about north-north-east, and west-south-west; it includes the whole western Alps, from the neighbourhood of Marseilles, to the volcanic ridges near the lake of Constance. It is attempted to be proved, that all these parallel ranges in the western Alps, had their origin after the tertiary molasse, a deposit partaking of all the elevations and contortions of the older strata; that the elevatory movements were sudden and violent, and commenced at a time when tribes of mammalia flourished in many parts of Europe; and that these movements were immediately succeeded by great horizontal deposits of old diluvial gravel at the base of the western Alps, and probably, also, by that vast offshot of Scandinavian rocks, which lie scattered over the plains of Germany.

"The fourth system embraces several considerable chains in Provence, and nearly the whole chain of the eastern Alps, from the great flexure, in the region of Mont Blanc, to the Alps of the states of Austria. The range extends E.N.E. and W.S.W. M. Elie de Beaumont appears to have proved, that there are two distinct deposits of diluvial gravel, near a portion of the western Alps: that the colossal mass of Mont Blanc, and at least a considerable portion of the eastern Alps, were elevated after the deposit of the older diluvium; and that all the newer dilu including the granite blocks scattered over Savoy, rolled off from the regions of the higher Alps, during this last period of their elevation. There are six other supposed periods of elevation. If these generalisations be true, and they seem to be based on an immovable mass of evidence, we must conclude, that there have been, in the history of the earth, long periods of comparative repose, during which the sedimentary deposits went on in regular continuity; and short periods of comparative violence and revolution, during which that continuity was broken; and if we admit that the higher regions of the globe have been raised from the sea by any modification of volcanic force, we must then also admit, that there have been several successive periods of extraordinary volcanic energy. How we are to escape from this conclusion I am unable to comprehend, unless we shut out the evidence of our senses.

"That the system of M. Elie de Beaumont is directly opposed to a fundamental principle of Mr. Lyell, cannot admit of doubt; and I have decided in favour of the former author, because his conclusions are not based upon any *à priori* reasoning, but on the evidence of facts.*"

If we admit that the primary, the transition, the secondary, and the tertiary classes of rock, were formed at different successive epochs, and that the lower beds in each of these classes, are more ancient than the beds which rest upon them, it follows, as a necessary consequence, that the elevation of any of these rocks, must be dated from a later epoch than the period of their formation. The elevation of a range of primary or transition mountains, if they are not covered by any secondary or tertiary formations,

---

* Though I agree with Professor Sedgwick and M. Elie de Beaumont, that the elevation of mountain ranges, where the beds are nearly vertical, was effected by a sudden and violent upheaving, yet I am persuaded, that the elevation of continents, or extensive tracts of country, was (as Mr. Lyell maintains) a long continued process. It may be proved that these operations were distinct from each other, as I shall afterwards state.

may be dated either from an epoch coeval with their consolidation, or from any subsequent epoch; but if they are partly covered by secondary or tertiary beds which are tilted up with them, we have direct evidence that the date of their elevation, was posterior to the secondary or tertiary epoch. So far we may advance on secure ground; but when we infer, that mountains which range in the same direction were all elevated at the same time, we wander into the region of vague hypothesis. It is by no means certain, that the elevation of the outer ranges of the Alps was contemporaneous with that of the principal range. In various parts of Savoy, I observed that the mountains at a certain distance from the central range, had their escarpments turned in a different direction, and frequently took the arched form of stratification, as represented Plate II. fig. 2. *x*, *y*.

Indeed, M. Elie de Beaumont has himself been obliged to modify his generalisations considerably, as will appear from the following extract from the *Bulletin de la Société Géologique de France.* M. Reboul, in a memoir on the structure of the Pyrenees, read to the society in December, 1831, states, that several distinct axes of elevation may be observed in different parts of these extensive mountain ranges, inclined in different directions to each other, and that the lines of bearing of the strata are also different in each. There are, he observes, indications in the Pyrenees, of the elevation of rocks at different epochs, both before and after the most recent secondary depositions, that rise to the summit of Mont Perdu. He also states instances of the tertiary beds of molasse, being elevated near the central range of the Pyrenees, whereas in the Alps they only occupy the central parts of the range, which would imply that the period of elevation of that part of the Pyrenees, was more recent than that of the Alps. It appears however, in the same report, that M. Elie de Beaumont now admits four epochs of elevation in the Pyrenees: the most ancient immediately succeeded the formation of the transition rocks. The second took place between the deposition of the green sand, and that of the upper chalk. The third epoch of elevation was posterior to the chalk formation. The fourth, which gave birth to the serpentines (*ophites*), and to the gypsum with rock salt, is more recent than the tertiary epoch.*

M. Beaumont however contends, that notwithstanding the four different directions of the ranges in the Pyrenees, of which traces may be observed in several of the valleys, the great chain of the Pyrenees, owes its actual elevation and general direction, to the third system or epoch of elevation, which was posterior to the chalk formation; the two former epochs of elevation, discoverable in this chain, having been modified by the great elevation of this third epoch. The fourth epoch of elevation is only perceivable, in the localities where serpentine rocks appear.

I wish to press upon the attention of geologists the consideration, that the arched stratification implies a very limited extent of operation. Where it is confined to one mountain, as at Crich Cliff, (see the cut, p. 140.) the elevating force may be said to act at one point. Where the arched stratification extends through a range, it may be said to act along narrow lines, forming mountain ridges, with valleys between them. From what I observed in the Alps, I was convinced that the explosive force which upheaved Mont Blanc, and the central range of the Alps, did not extend its action very far from the axis of the range on each side; and that this action, being confined within narrow limits, produced a rent or line of fracture on the crust of the globe, along which the beds were suddenly tilted into their present position; and that the outer

---

* The formation of serpentine (which was formerly considered as a primary rock) after the tertiary epoch, will cease to surprise geologists, since the identity of basalt, green stone, and serpentine, has been ascertained by Dr. Macculloch. Serpentine, like basalt and volcanic rocks, may have been formed among any class of rocks. It was stated in Chapter XI., that some of the rock salt deposits in Poland were in tertiary strata.

ranges were raised by similar explosions, acting along lines of fracture of greater or less extent. These upheavings, whether simultaneous or successive, took place under the sea, and must have occasioned an agitation of the water, far exceeding in violence, any thing which modern causes present to our observation.

The vertical, or highly elevated position of certain portions of strata, that were originally horizontal, implies the sudden and violent action of an upheaving force. Where mountains are raised to a considerable elevation, and preserve an unbroken range of nearly horizontal strata, we may infer, that the upheaving force was slow in its operation, or acted on a large segment of the earth's surface.

I now claim the attention of geologists to the following position, which admits of direct and positive proof, though I am not aware that it has been before noticed:—THE ELEVATION OF LARGE CONTINENTS AND ISLANDS, WAS NOT EFFECTED BY THE SAME OPERATION, WHICH UPRAISED THE PRIMARY ROCKS. For instance, the horizontal strata of new red sandstone, that rest on the upraised beds of slate and granite at Charnwood Forest (see Plate II. fig. 4.), were deposited under the ocean; they are evidently sedimentary depositions, composed of fragments of slate and other rocks, intermixed with clay and sand, indurated into sandstone.

Now let us notice the present elevation of these strata of sandstone, which is not less than about 500 feet above the level of the sea, and we shall be compelled to admit, that the rocks of slate and granite, together with their covering of sandstone strata, were raised from the ocean to their present height, at an epoch long posterior to the uptilting of the former beds, or to the deposition of the sandstone that rests upon them. At the same epoch, and by the same upheaving cause, a great extent of the central part of England was also raised from the ocean; for the same beds of slate, sienite, granite and quartz rock, covered with the same beds of new red sandstone, extend into Warwickshire, and, in all probability, are connected with the Malvern range. Should any one suggest a doubt, whether this portion of the new red sandstone was deposited under the sea, it is only necessary to say, that the same new red sandstone, immediately adjacent to the Charnwood range, is covered by beds of the lias formation (see *e* in the same plate), which abound in marine organic remains. The same reasoning will apply to all other situations in which uptilted transition or primary rocks, are covered by horizontal depositions of secondary strata. The elevation of the uptilted beds was a distinct operation from that which raised them, together with the rocks that cover them, above the ocean, and which converted the former bed of the sea into dry land.

I consider it probable, that all large tracts of country or continents emerged slowly from the ocean, forming at first mountainous islands, before the lower countries were raised above the level of the sea. The power which could upheave a continent, or in other words occasion a large portion of the crust of the globe to swell out, must be very different from the force which acted along certain lines, and elevated mountain ranges. This power may be dependent on a more general law of subterranean motion, with which we are at present unacquainted; for I deem it would be the extreme of presumptuous absurdity to maintain, that the causes we observe in present operation, comprise the whole agencies of the material Universe. The discoveries of electric and voltaic energy, and several laws of crystalline and magnetic polarity, have only been made during the lifetime of some of the present generation; shall we then presume to fix limits to the discoveries of other powers and properties of Nature, of whose existence we cannot at present form the most remote conjectures? We might offer many instances in our own island, in which the forces that have broken and lifted up the strata along certain lines, appear to be very different from that which elevated continents or large islands. The elevating force that broke and tilted up the chalk strata, and the tertiary strata, along a line extending east and west through the Isle of Wight into Dorsetshire, does not appear to have produced any considerable change on each side of the line.

In passing from Alum Bay, where the chalk strata are nearly vertical, to the south side of the island, it is truly extraordinary to observe, how little the lower beds beneath the chalk, and adjacent to it, appear to have been disturbed. The force which uptilted the strata is altogether distinct from that mighty upheaving force, which raised the whole chalk hills in the south of England from the ocean, without disturbing the relative position of the strata.

The same conclusions may be formed respecting the Wealden beds (see Chap. XIII.); but in this case the strata have been upheaved and submerged more than once, without any great change in their relative position. The repeated upheaving and submergence of the secondary strata is proved by the occurrence of fresh water strata, or of strata containing freshwater shells and land plants, resting on marine strata, and also covered with a great thickness of marine formations. (See Chap. VIII.) The strata in the great coal formation, were deposited in the freshwater lakes or marshes of an ancient country. The coal is composed of vegetable matter, and sometimes contains cortical impressions of plants. The beds of sandstone and shale that accompany coal, contain trunks and stems of large terrestrial plants, sometimes standing in the position in which they grew. In the greater number of coal fields not a vestige of any marine shells is found, though they frequently contain freshwater shells. In the lower part of some coal formations, indeed, there are beds of limestone, supposed to be marine, and a few marine organic remains. In such situations we must admit, that the lakes or basins in which the coal strata are deposited, were nearly on a level with the sea, and subject to occasional irruptions of salt water; or the relative level of the land and sea may have been changed, by frequent oscillations of the land. The strata of coal and ironstone are much too regularly separated from admixture with other substances, to allow us to suppose, that they were formed by matter drifted into the sea. If the regular coal strata in our English coal fields are not freshwater formations, deposited in marshes or in tranquil water, we can have no evidence for freshwater formations in any part of the world. All the coal basins were either formed in inland marshes or lakes, or were surrounded by dry land; but a great submergence of the land took place, and they were covered in many parts by thick depositions of marine limestone. At a subsequent period, they again emerged from the ocean with a covering of marine secondary strata. (See *Appendix.*) It would not be difficult to accumulate proofs, of the repeated elevation and submersion of portions of the crust of the globe.

The following account is interesting, from the vast extent of surface to which it relates; but it may be said to present rather a description of the present state of the earth's surface, than a direct proof of former changes. M. Humboldt in a recent work, entitled *Fragmens Géologiques sur l'Asie Centrale*, the result of his late travels into Asia, observes, that the high part of central Asia, commonly called *le grand plateau*, is composed of four powerful ranges (*systèmes*) of mountains, directed east and west, and supported by a common base, also raised above the surrounding country. At the foot of this immense system of mountain chains and elevated ground, is an enormous depression, eighteen thousand miles square, and from 150 feet to 300 feet below the level of the ocean. The surface of the Caspian Sea and the level of Astracan is 300 feet lower than the sea, and the course of the Volga is 150 feet lower. M. Humboldt supposes, that this subsidence was the result of the elevation of the Plateau, which supports the Himalaya and Irun mountains, and perhaps those of Caucasus, an enormous mass, the elevation of which can be compared to no geological phenomena of the same order, observed on the other continents.

M. Humboldt notices the existing traces of volcanic agents in central Asia, which may be more or less directly connected with the internal force, that has produced such mighty results.

The epoch of these elevations is not precisely indicated by M. Humboldt, but the discovery of tertiary shells in the higher regions of Caucasus and the Himalaya mountains, analogous to those in the adjacent seas, may lead us to regard the elevation of these mountain chains, as being posterior to the latest tertiary epoch, which would (if established) confirm the conclusion, "that the highest chains of mountains are the most recent." — From the imperfect knowledge at present possessed of the geology of central Asia, and of the structure of the mountains, it would be unwise to draw any general conclusions respecting the elevation of the different mountain chains, or of the elevated plateau from which they rise; but we can scarcely conceive, that the whole of the mountain chains, and this elevated plain in central Asia, were raised by one sudden upheaving force: it seems more probable, that the expansion of so large a portion of the earth's surface, and its depression in other parts, were not effected in a very short period; but still the convulsive intermissions of such an upheaving, while in progress, must have produced tremendous effects. If this elevation of central Asia took place after the tertiary epoch, perhaps it may not have an earlier date than the existence of the human race, and its destructive effects on the surrounding countries, may have given rise to the tradition of an extensive deluge, still preserved among the most ancient eastern nations, and referred to in the writings of Moses.

The elevations of limited portions of the earth's surface, at a distance from any known volcanic agency, are not uncommon. Loose stones or shingles of an ancient sea beach, are found at heights considerably above the present level of the sea, in many parts of England. Beds of gravel and diluvial sand, with marine shells, were recently found on the summit of Moel Tryfane, near Caernarvon, at the height of 1000 feet above the level of the sea: the shells are said to resemble the broken shells on the adjacent beach. On the coast of Norway and Sweden, Von Buch and M. Brongniart discovered deposits of shells at various heights above the level of the sea; this would indicate that the rocks have been elevated at a recent period, though they are chiefly composed of gneiss and primary formations. In countries that are adjacent to volcanic districts, instances of the repeated elevation and submersion of the land are not uncommon. In the first volume of Mr. Lyell's Principles of Geology, many interesting facts of this kind, in Calabria and Sicily are fully stated. The most remarkable elevation of the ground that has been recorded in modern times, is that which took place, in the year 1822 (see Chap. V.), on the coast of Valparaiso, in which the bed of the sea was raised permanently above its surface, over an extent of 100 miles.

It may be truly said that these instances of elevation, present but a feeble resemblance to the mighty upheaving forces which have elevated whole continents; but I before stated, that it is highly probable the emersion of continents from the ocean, was a slow and long continued process. We have fewer recent instances of subsidence on an extensive scale than of elevation; though cities have been ingulfed and their place occupied by lakes, and the bed of the sea near the coast, has been deepened as well as elevated by earthquakes. In addition to this, there are submarine forests on some parts of the English coast, particularly of Yorkshire and Lincolnshire, which may be seen, at low water, extending far into the sea. The trees are broken off near the roots, but their stumps are erect, proving that they are in the position in which they grew: this fact clearly indicates a submersion of that part of the country at no very remote epoch. If ancient traditions could be relied upon with as much certainty, as the records of nature imprinted on the crust of the globe, we might cite the fact of ancient continents having sunk down, since the world was peopled by the human race. Plato, in his dialogue entitled *Timæus*, says, that Solon received an account from the priests of Sais in Egypt, that there was formerly a vast country called the Atlantides, situated beyond the Straits of Gibraltar, the inhabitants of which were highly civilised and flourishing; but the whole country was ingulfed in the ocean, during a violent earthquake.

The upheaving of extensive islands or continents, was probably always accompanied by the depression of other portions of the crust of the globe: the oscillations of the surface may be the result of some general laws of subterranean motion, as regular and definite in their operation, as the laws which regulate the motions of the planetary system. These laws may for ever remain undiscovered by human intelligence, but our ignorance respecting the causes which have repeatedly submerged and elevated various portions of the earth's surface, does not invalidate the fact, that such submersions and elevations have taken place at various epochs. The admission of this fact has been progressively gaining ground, and is supported by a mass of evidence that cannot be refuted.

CHAP. XXIII.

ON THE FORMATION OF VALLEYS, AND THE GEOLOGICAL THEORIES RELATING TO VALLEYS AND DENUDATIONS.

On the Causes that have broken the Surface of the Globe. — Erosive Action of running Water illustrated by the Process called *Hushing*. — Bursting of Lakes. — Some Valleys originally formed by Elevation or Subsidence, and subsequently enlarged by the Action of Water. — Different Theories respecting the Formation of Valleys. — Theory of Werner — of Hutton. — Of Elevation. — Of the retiring Waters of the Ocean. — Theory of Excavation and Denudation by Deluges. — Modification of this Theory by Sir James Hall; its Application to explain Denudations, and Transportation of Blocks of Granite from the Alps. — Particular Phenomena presented by the scattered Blocks in the Vicinity of Geneva. — Denudation of stratified Rocks, effected by the same Causes which have broken the Primary Rocks, and scattered their Fragments into distant Districts.

From what has been stated in the preceding chapter, respecting the elevation and submersion of the earth's surface, the geological student might infer, that such elevations and submergences offer a satisfactory explanation of the formation of valleys, but the inference would be erroneous. There are two distinct causes which have modified the surface of the globe; the one internal, dependent on the earth itself, the other dependent on the atmosphere which surrounds it; beside these, there is the ceaseless flux and reflux of the ocean, dependent on the attractive forces of the sun and moon, and on the earth's diurnal revolution on its axis. The two former causes have been principally concerned in the formation of valleys; and there are few valleys in which the combined effects of both these causes may not be traced. The inequalities of surface produced by the upheaving of mountain ranges, or the emergence of continents from the ocean, must have originally determined the course of the retiring water, or of atmospheric water precipitated in rain. Of the power of atmospheric water to act upon the surface of the globe, we can form but a very feeble idea from what we observe in our own country. In warm climates, as much rain will fall sometimes in one hour, as falls at different times during three months in northern latitudes: added to this, when the rain descends in mountainous regions, the water is suddenly collected into powerful rivers, rushing with incredible violence to the lower valleys. At remote epochs, it is highly probable that many elevated depressions, which are now mountain valleys in alpine regions, upheld the waters and formed lakes, that have subsequently burst their barriers, and have ploughed a passage for the succeeding rivers, when the drainage of the country became more regular.

To enable the reader to form some notion of the force of falling water, carrying with it loose stones that occur in its passage, it may be useful to describe a process called *hushing*, in Westmoreland. The quarrymen, when in search for good beds of slate, where the side of a mountain is covered with stones and vegetation, form a lake or pool near the top of the mountain, by damming up a rivulet where it passes through a depression or small valley. When the water has accumulated in sufficient quantity, they dig a trench near the dam, to direct the current where they wish it to flow, and then break down part of the dam. The water flows first through the trench, and rushing with accelerated velocity down the mountain, carries with it the stones near the surface, and in a very short time ploughs a deep channel in the rocks, exposing every bed to view. Thus in a few hours is effected, what the labour of many men, continued for months could not have accomplished. I have been informed, that in the upper part of the valley of Long Sleddale, when the process of *hushing* takes place, the river Ken, (as it flows by Kendal, twelve miles distant,) is made turbid for some days, by the quantity of débris carried into it. If such an effect can be produced by

Many of the valleys in the Alps have evidently once been lakes. The upper valley of the Rhone, from its source to Martigny, formed one lake: the whole valley of Geneva, between the Alps and the Jura, formed a lower and more extensive lake, before a passage was opened for the water at Porte l'Ecluse. When a fissure was once made by earthquakes or by subsidence, the rushing of water charged with stones would enlarge and deepen the passage, and thus lay dry and reduce the ancient lakes in a comparatively short period. In the year 1819, part of a mountain immediately above the river Isère, and opposite to the city of Moutiers, in the Tarentaise, suddenly fell down into the river, and formed a dam across it, over which persons might pass from one side to the other. When I was there in the year 1821, all this mass of stone had been carried away by the river. The action of rivers in extensive and level valleys, tends rather to fill them with débris, brought from the more elevated countries in which the rivers had their origin, than to excavate them deeper.

The formation of the greater number of valleys cannot be explained by the action of water alone. There are valleys of elevation formed by the raising of the strata on each side — valleys of subsidence, formed by the sinking of the ground, leaving the adjacent rocks unmoved — valleys formed on the line of faults, in which the rocks on one side have been thrown up or depressed — valleys of disruption, where a range of mountains, or an extent of country has been rent by earthquakes or by subsidence. Most of the valleys formed originally by these causes, have been subsequently enlarged or modified by the action of water. There are, indeed, instances of valleys and ravines formed entirely by the continued erosion of water; such is the valley of Niagara, between Queenstown and the Falls. (See the frontispiece to the present volume.) Other instances might be cited, in which the action of water is equally evident. In many cases, however, where water appears to have been the sole agent in excavating rocks, I am inclined to believe, that an original break or fissure has greatly accelerated the process. In many broader valleys, the excavation must often have been effected by more powerful agents than any which we perceive in present operation; and when a broad outlet is once made, the subsequent drainage of a country may work its way to the sea in a very sinuous course; but this sinuous course, does not prove that the valley had been originally formed by the river that flows through it.

Besides the action of mountain torrents, the bursting of lakes, and the regular flowing of rivers, many geologists believe that the excavation of valleys, and the transportation of loose rocks, have been effected by the more powerful agency of the ocean, thrown over the surface of the land by the great convulsions that have upheaved mountain ranges and continents. For the benefit of the geological student, I shall endeavour to give a brief outline of the principal theories that have been maintained respecting the formation of valleys; but the first of these theories is now admitted to be untenable.

The formation of valleys has been ascribed to the following causes: —

1st, To the original unequal deposition of the earth's surface.
2d, To excavation, by the rivers that flow through them.
3d, To the elevation or subsidence of part of the earth's surface.
4th, To excavations, caused by the sudden retreat of the sea from our present continents.
5th, To excavations by inundations or deluges, that have suddenly swept over the surface of different parts of the globe.

I shall notice the leading facts that favour or oppose each of these theories. The disappearance of large portions of strata from districts which they have once evidently covered, is also a phenomenon of frequent occurrence; and its explanation must be sought from some of the same causes, that have excavated valleys. This disappearance of the strata is called a denudation.

The first of the above theories is that of Werner: he supposed that all the matter of which primary, transition, and secondary rocks are formed, was originally held in solution by water, and that the water, so saturated with mineral matter, covered the whole globe. The primary rocks of granite were formed by chemical precipitation, and their peaked summits and declivities were the result of their original deposition. On the steep sides of these primary mountains were subsequently deposited the different schistose rocks, and all the secondary strata. During the time that these rocks were depositing, the water, though nearly saturated with mineral matter, was capable of supporting animal life, and the shells and remains of zoophytes and fish, were enveloped in the strata, at the period of their deposition. According to this theory, when the water retired from the present continents, the mountains and valleys were already formed.

The theory of Werner requires for its support the admission of conditions, which appear in the present state of our experience impossible, and it is at variance with existing phenomena. The vertical position of beds of puddingstone, sandstone, and the tertiary strata in the Alps, could not have been their original one; nor can the bendings and contortions of the strata, so common in Alpine countries, be explained by original deposition. A further account of part of Werner's theory is given, Chap. IX. p. 216. Werner's theory of valleys is altogether distinct from that theory which ascribes the formation of valleys to inequalities of the surface, subsequently enlarged by the erosion of water.

The second theory, that all valleys have been excavated by the rivers that flow through them, was maintained by Dr. Hutton and Professor Playfair: it formed a part of their general theory of the earth; the leading propositions of which are, that the surface of the present continents is wearing down by the action of the atmosphere and by torrents, and that the materials are carried by rivers into the sea, and there deposited. At a future period, these materials will be melted or consolidated by subterranean heat under the pressure of the ocean, and subsequently, by the expansive force of central fire, the bed of the ocean will be elevated, and form new continents. According to this theory, our present continents have been also formed from the ruins of a preceding world, and elevated by a similar cause. It is only with that part of the Huttonian system, which relates to the excavation of valleys, that we have at present any concern.

It is remarkable, that a theory which maintains that the continents were raised from the ocean by subterranean fire, should limit the formation of valleys to the action of the rivers that run through them; for if the land were raised by an expansive power acting from beneath, it seems to follow as a necessary corollary, that the surface would be unequally elevated and broken into inequalities by the same cause; unless we suppose, that every part presented an equal degree of resistance to the moving force. There must, therefore, have been original inequalities or valleys, which determined the direction of the water-courses in the first instance, though the form of these valleys may have been subsequently modified by the action of water. That all valleys have been excavated by the rivers that flow through them, is opposed by many decisive facts. Before their excavation, the water must have had less force than at present, as the fall would be gentle; and the present effect of rivers in large valleys, is not to excavate them deeper, but to fill them with alluvial depositions.

There are numerous deep valleys in the Alps, that are closed at one end by steep mountains or perpendicular walls of rock, and which were originally closed, and are now nearly closed, at the other end also. Such are the valley of Thones, near Annecy, the valley of Chamouni, and, on a larger scale, the valley of Geneva. It is evident that the valley of Thones, and that of Geneva, have once been filled with water, and formed lakes: by an earthquake, or by the erosion of water, a fissure has been made, which has drained the greater part of these valleys; but it is obvious that the valleys could not have been formed by the original lakes, or by the rivers that flowed into them. If valleys were formed by the erosion of rivers, the lakes through which these rivers flow, must have long since been filled up by the materials brought into them. To say that the lakes were once deeper than at present, is giving up the theory; for lakes are only the deeper parts of valleys.

Had the valley of Borrowdale, in Cumberland, been excavated by the water that flows from it, the lake of Keswick, at its entrance, must have received all the materials, and been long since choked up. Or had the valley of the Rhone, ten thousand feet deep and sixty miles in length, been excavated by the Rhone, the quantity of matter brought down by this river, would not only have filled the lake of Geneva, into which it empties itself, but the broad valley in which the lake lies, must also have been filled up, and raised to the height of the Jura. That the Lake of Geneva, and all lakes into which large rivers flow, are gradually filling up, has been before stated; but the valley of the Rhone is not, nor are other valleys becoming deeper. The upper part of this valley, as before stated, has evidently been itself a lake, closed in, or nearly so, by the rocks at Martigny.

The action of torrents in Alpine districts may have been sufficient to widen fissures already made, or to scoop out glens, in the softer beds on the sides of mountains; but they appear inadequate to the original formation of large longitudinal valleys. Water-courses running on the edges of nearly vertical beds, may scoop out a portion of a softer bed, placed between two hard rocks, and thus form small longitudinal valleys. I have observed several instances of such valleys in the Alps, which may probably have been furrowed by mountain torrents in the course of ages. Some vallies, as Les Echelles, near Chambery, are closed at one end by a perpendicular wall of rock; through this rock a tunnel has been cut for the road: but it is impossible to conceive, that any action of water courses could have formed such a valley. There is only a feeble stream that flows from it.* Malham Cove, at the head of the valley of the Aire, in Yorkshire, is a perpendicular wall of limestone 200

---

* For a particular account of the structure of this valley, see Travels in the Tarantaise, vol. i. p. 169. I there ascribe its original formation to subsidence.

feet high: at its feet the river rises; but no conceivable action of the river could have originally formed this valley. Whatever extension we may reasonably grant to the action of rivers, it will not be found sufficient for the excavation of valleys, except in particular situations.

The third theory, which attributes the formation of valleys to the elevation of mountain ranges, appears to assign a cause, that will explain, in a simple manner, the formation of many valleys; but on examination, it will be found inadequate to explain the phenomena of other valleys, without the concurrence of inundations or the action of water.

If the crust of the globe were broken, and raised in parallel ridges, they might form mountain ranges, with valleys between them, like what are observed bordering the central range of the Alps; the arched stratification of many of the calcareous mountains, and the vertical position of the beds, favour this hypothesis.

In some instances, where the beds of a mountain are raised from an horizontal, to a nearly vertical position, they would leave a chasm proportionate to the part that had been raised; and this might form the bed of a lake. The steep escarpments, which the calcareous mountains in Switzerland and Savoy present to the lakes which they border, indicate that the beds of the lakes were formed in the hollows that had been left by the elevation of the mountains. The beds of the mountains on the side opposite to the escarpments, generally slope down to the lakes; hence M. De Luc inferred, that it was these mountains that had sunk down, and left the chasm which forms the bed of the lake. Indeed it is highly probable, that when the beds of rock were broken and elevated in one part, the beds adjoining would sink down, leaving vast chasms, which were soon filled with water, and formed lakes. It seems quite certain, that the lakes in the valleys of mountainous countries, could never have been excavated by the rivers that flow into them.

The great lakes of North America are situated upon a vast extent of table land, about 800 feet above the sea; but the country is so level, that the rivers which flow into the lakes, and those which empty themselves in the gulf of Mexico, are only separated at their sources, by elevations not exceeding a few feet, and when swelled by rain, the northern and southern rivers sometimes interlock. In this plain there are no mountains. These lakes were probably formed by partial subsidences, at the epoch when the whole country was upheaved from the ocean. The efforts of elevation and depression have been described in the preceding chapter.

Transversal vallies, or those which cut through mountain ranges, nearly at right angles to the direction of the ranges they intersect, may have been originally fissures or openings, made either at the period when the ranges were elevated, or subsequently, by the same causes that have rent and displaced the secondary strata. These fissures may have been afterwards widened by the erosion of water.

Geologists seem now generally agreed, that the action of rivers is not sufficient to explain all the phenomena of valleys, and still less to account for the fragments of rocks scattered over extensive plains, at an immense distance from Alpine districts, where rocks similar to these fragments occur. Another phenomenon, of more importance, is altogether inexplicable by the action of rivers. Immense tracts of the secondary strata, several hundred feet in depth, have in some districts been torn off, and the materials entirely removed, except detached patches, which here and there form isolated caps on distant hills; and incontestably prove, that they were once parts of one continuous stratum or formation. Numerous instances of this might be cited in our own island. It is probable that the beds of chalk that form the north and south downs of Sussex, once extended over the Wealden beds. See p. 281. This local disappearance of a stratum or formation, has properly been called

Denudation. The theory advanced by Mr. Farey, to explain these denudations, was, that the surface had been broken and swept away, by the near approach of a comet. But the most rational explanation that can be offered, is that which ascribes the effect to a mighty deluge, sweeping over the surface of the globe, tearing off part of its crust, and transporting the fragments into distant regions, or into the ocean. The case is one which may be truly said to be *dignus vindice nodus*, and the geologist is compelled to call in the aid of Neptune; for none of the causes in present activity (however we may imagine them to be increased in power or magnitude,) will be found adequate to produce the denudation of an extensive district, and the disappearance of the stony materials, by which it was covered.

The fourth theory, which attributes the formation of valleys to the sudden retreat of the sea from our present continents, is founded on the admitted fact, that the sea has once covered them; and whether we suppose that the bed of the ocean was deepened in one part by a sudden subsidence, which drew off the water from another part; or that the continents emerged, by an expansive force acting beneath them, — the effect on the water would be nearly the same. This effect, in scooping out valleys, has been compared to what may be observed in miniature "by the drainage of the retiring tides on muddy shores, especially in confined estuaries, where the fall is considerable and rapid," the water cutting out channels for its passage, as it drains off. The retiring of the ocean suddenly from the present continents, would be a cause sufficient for the excavation of valleys; but I have stated, in the preceding Chapter, the reasons for believing, that continents emerged from the ocean, by the long continued action of an upheaving or expanding force.

The fifth theory, which ascribes the formation of valleys, and the extensive denudations of the strata, to deluges that have suddenly swept over different parts of the globe, has been maintained by Professor Pallas and Sir James Hall. The former conjectured, that the inundations that have covered parts of the Asiatic continent with blocks of stone, beds of gravel, and marine remains, were occasioned by the formation of volcanic islands in the Indian ocean. Within the period of authentic history, extensive inundations have been occasioned by volcanoes and earthquakes, which afford probability to the opinion of Pallas. In the year 1650, a new volcanic island rose from the sea in the Grecian Archipelago; and according to the account of Kircher, a contemporary writer, it occasioned the sea to rise forty-five feet in height, at the distance of eighty miles, and destroyed the galleys of the Grand Signior in the port of Candia. The principal damage done by earthquakes to cities adjoining the sea, is often effected by an enormous wave, the sea, retiring from its bed in the first instance, suddenly returns with a prodigious swell, and in a few moments rushes over the adjacent country.

Sir James Hall has given greater extension and consistency to this speculation. He supposes that the upheaving of a large island, like Sumatra, might take place so suddenly as to drive the ocean with great impetuosity over the summits of the highest mountains, and strip off the glaciers, and transport them into distant countries. Ice being specifically lighter than water, the glaciers would carry away with them, the blocks of stone that had fallen from the impending rocks, and had become incased in ice. This theory of Sir James Hall's would, I conceive, offer a better explanation than any other, for the occurrence of groups of fragments of particular rocks, unmixed with fragments of other rocks. Each glacier, loaded with stones from the rocks above it, may be regarded as a ship freighted with specimens of its native mountains, which it deposits, by thawing, in the place where it ultimately rests. Nor would a wave or swell of the sea, that had covered the highest mountains, suddenly subside; it would sweep repeatedly over the whole surface of the globe, at a lower and lower level each time; breaking down opposing obstacles, opening new passages for the water, and scooping out valleys and cols in the softer beds and strata.* On the whole, the theory of Sir James Hall, affords perhaps the most satisfactory explanation of diluvian agency, that has yet been advanced. But whatever difficulties may oppose the admission of this or any other theory, the fact that the present continents have been subjected to the action of a mighty rush of waters, seems confirmed by many coincident phenomena.

Granting the agency of a deluge, or a succession of deluges, there are still phenomena left, that their action will not satisfactorily explain. In the midland counties of England, for instance, there are beds of gravel, and fragments of rock, scattered over hills, that are not only far distant from the rocks which have supplied the fragments, but which are separated from them by deep valleys, over which it is supposed that the fragments could not have been carried, by any power of diluvian agency; for in England, we have not the glaciers to assist in their transportation. It has been imagined, that these fragments and beds of gravel, were deposited in their present positions before the intervening valleys were scooped out. But any subsequent deluge, sufficiently powerful to scoop out

---

* Those depressions in a range of mountains which offer the easiest access in crossing from one valley to another, are in the Alps called *Cols*. I observed that these cols were all in the softest beds; and their formation admits of an easy explanation by diluvial action. See Plate II. fig. 2. " A range of mountains, with their beds highly elevated, is extended from *a* to *d d*. At *c c* the beds are of very soft slate or shale, which has been excavated so as to offer a passage over the range, though the highest part is several thousand feet above the valley. Such is the Col de Balm above Chamouni. The beds probably extended, at the period of their elevation, in the direction of the dotted lines. These cols could not be formed by rivers, as very little water flows from them. The valley of Derwent (see Plate IV. fig. 1. between the hills 3 and 6,) was evidently formed by the erosion of water, and not by the elevation of its sides; as the beds on each side are the same.

valleys, must have swept away the loose stones on the surface. The local elevation of the surface would appear to offer a more satisfactory explanation. The blocks of granite torn from Mont Blanc and the adjacent granitic range, are scattered over the calcareous mountains, and in the valleys of Savoy to the distance of 60 miles or more, from the parent rocks, and some of these blocks have traversed the Jura into France, a distance of 100 miles. Two hypotheses have recently been formed respecting them: the one, that these blocks of granite were thrown from the mountains by an expulsive force at the period of their elevation; the other, that the calcareous mountains have been subsequently raised with their load of granitic blocks upon them. There are facts opposed to both of these theories, which appear to render them less satisfactory, than that of Sir James Hall before stated.

If any readers of this volume should visit Geneva, I would recommend them to devote a day to visiting the mountains called the Great and Little Saleve, in the immediate vicinity of that city. They present their steep escarpments of limestone to the valley of the Rhone, but slope down on the south side to the valley of the Arve. On this southern side may be seen, not the remains of an ancient temple or city, but the magnificent ruins of mighty mountains, and the monuments of an overwhelming catastrophe, which transported these ruins into their present situation. The snow-clad mountains from which they were torn rise magnificently to the view, though fifty miles distant. On the Little Saleve, at the height of fourteen hundred feet above the valley, are scattered numerous blocks of granite of vast size, not at all water-worn, and almost as fresh as if recently torn from their parent mountains; they are of that kind of granite called Protogine, in which talc or chlorite is one of the component parts, and are identical with the granite of Mont Blanc, while the Saleve on which they lie, and the surrounding mountains are calcareous. On the

Great Saleve adjoining, there is one block of this granite seven feet in length, at the height of 2500 feet above the valley. Saussure has remarked, that these blocks are not broken or shattered, as they would have been, had they been hurled with violence from the Alps ; neither do the limestone strata beneath them present any appearance of having been fractured or indented by their fall : on the contrary the blocks lie upon the surface. Two of these blocks of granite rest upon pedestals of limestone, a few feet above the general level of the ground. The blocks have evidently protected the limestone beneath them from disintegration, and thus would serve as chronometers, to indicate the period when they were deposited, could we ascertain the thickness of surface worn away in a given time.

I observed a few of the blocks were cracked, but this was in all probability effected by the percolation of water, and its expansion by frost. Another circumstance pointed out by Saussure is, that these blocks, in their passage from the Alps, appear to have taken the course of the present valleys, and where they have been carried as far as the Jura chain, they rest at various heights on the sides of that range of mountains, exactly opposite to the mouths of the Alpine valleys. Saussure, however, supposes, and with much probability, that the whole of the valley of Geneva, and the valleys that run from the Alps, and all the lower mountains of Savoy, were covered by the sea at the period when the great catastrophe took place, and that the rocks were torn off, and transported by a sudden rush of waters. He further supposes, that the specific gravity of the blocks being diminished by the medium in which they were borne along, they might be carried to a great distance by the violence of the current, and deposited at considerable altitudes. The floating of Alpine glaciers loaded with fragments of rock, would perhaps better remove the difficulty attending the explanation of these occurrences at the height of fifteen hundred feet and more above the valleys. That these valleys were formed before the transportation of the granite blocks, seems evident from the circumstance before stated, that the blocks occur in groups, opposite to the embouchures of all the Alpine valleys, that open into the great valley of Geneva. These valleys or depressions, were therefore formed before the country emerged from the ocean, not by the erosion of rivers, but by the elevation and fracture of the beds on each side. The summits of the mountains that border the present valleys may have directed the course of the rush of water by which the blocks were transported. The valley of the Arve, in the upper part, has evidently been a lake, or series of lakes, originally formed by elevation and depression: the waters have cut passages through the barriers of these lakes at a subsequent period, and the river Arve has afterwards cut through the deep mass of sand and rounded stones, that fill the bottom of the lower part of the valley, from Bonneville, to the junction of the Arve with the Rhine. The transportation of the granite blocks was posterior not only to the original formation of the Alpine valleys, but also took place at a later period than the deposition of the deep mass of sand and rolled stones, that forms the bed of the lower part of these valleys, for the blocks often rest upon it. Blocks of similar granite may be seen in the lake of Geneva, between that city and Thonon, which indicates that this part of the lake has undergone no great change, since these blocks were deposited. The transportation of the granite blocks appear to have been effected suddenly; but the rounded blocks and sand at the bottom of the valleys, must have been long subjected to the violent agitation of water.

There are numerous instances of transported masses of rock, scattered over our own island, and various parts of the continent, but none of them appear so immediately to elucidate the enquiry respecting the origin of valleys, as the granite blocks in Savoy, and on the Jura. — Seated on the side of a mountain, among a group of these blocks (as on the Saleve, near Geneva); you may see, at the same time, the distant rocks from which they were torn, the valleys or depressions, along which they have been transported, and the original situations on which they were deposited, and where they remain, and may probably continue till another revolution of the globe. By whatever force the granite was torn from the nearly vertical beds of the Alps, the same force acting on the level secondary strata, might tear off a large extent of surface and uncover the lower beds: this is what is understood by a *denudation.*

The geological student is requested to observe, that though I have denominated these transported masses of rock in Savoy, granite blocks, because they are principally granite, yet blocks of the other Alpine rocks are also frequently intermixed with them.

CHAP. XXIV.

ON THE ANCIENT TEMPERATURE OF THE EARTH. —ON CENTRAL HEAT, AND ON ASTRONOMICAL PHENOMENA ILLUSTRATIVE OF GEOLOGICAL THEORIES. — CONCLUSION.

It is now generally admitted by geologists, that the temperature of the earth was at a former epoch much higher than at present, at least that it was so in northern latitudes. The facts on which this opinion is founded are very numerous, but they are chiefly dependent on the organic remains found in a fossil state. The animal remains of the large mammalia, such as the elephant, the rhinoceros, and hippopotamus, are abundant in some of the tertiary and diluvial beds. The bones and teeth of elephants in Siberia, and the borders of the Icy Sea, are so numerous, that it is evident the animals must once have existed in immense multitudes in these high latitudes. On the Oyster Bank, off Hasburgh, on the Norfolk coast, many hundred grinders of elephants have been found, and a vast quantity of their bones. (*S. Woodward's Syn. Tab.*) Teeth of the elephant have also been found in almost every county in England, and in all the northern kingdoms of Europe. Remains of lizards of enormous size occur in many of the English strata: these animals, in a peculiar manner, seem to require a high temperature for their full development.

The fossil remains of vegetables prove the high temperature of the countries in which they flourished, more decidedly than animal remains. Fossil trunks and leaves of the palm tree, the tree-fern, and of gigantic reeds, analogous to what are now growing in equatorial climates, abound in the coal strata of northern latitudes. It may be objected, that the large mammalia (such as the elephant or hippopotamus,) belong to the order of Pachydermata, or thick-skinned animals, and like the pig, which belongs to that order, might be constituted for living both in polar and equatorial regions. Indeed it is known, that some of the fossil elephants had a covering of hair or wool, which must have been intermixed as a defence against cold. A race of elephants with shaggy hair (according to bishop Heber) inhabit the cool regions of the Hummelaya mountains. From the remains of these large mammalia alone, we could not therefore prove the high former temperature of northern latitudes. But these animals would require a constant supply of food throughout the year, which they could scarcely obtain in a frozen climate; and when we farther observe, that the vegetation of the ancient world was analogous to the vegetation of the warm regions which the elephant and the rhinoceros now chiefly inhabit, we can scarcely refuse our assent to the position, that the temperature of the earth at a former period was much higher than at present. In addition to this, we have in our strata, the fossil bones of enormous amphibious reptiles, and the shells of marine animals like the nautili, that exist at present in equatorial seas: we thus obtain an accumulation of evidence, both from the water as well as the land, in proof of the same position. The present temperature of the earth appears to be dependent on two causes, — the radiation of heat from the sun, and internal fire. That the temperature of different latitudes is in a considerable degree dependent on solar radiation will not be disputed: it increases with the increase of the sun's meridian altitude as we advance towards the equator, and it increases and decreases in the same latitude, with the increase and decrease of the sun's altitude in different seasons. The temperature of different countries in the same parallels of latitude is very much modified by various causes: between the tropics, at the height of about fifteen thousand feet, we meet with eternal snow. In the Swiss and Savoy Alps, the

line of perpetual congelation is about seven or eight thousand feet: yet in the canton of the vallais, the upper valley of the Rhine, surrounded by snow-clad mountains, is subjected to an oppressive heat in the summer months. Thus difference of elevation has a certain effect on temperature in all latitudes.

Large elevated continents in high latitudes, greatly decrease the temperature of the air, by presenting a great surface of snow and ice to the atmosphere. On the contrary, near the equator, large continents raise the temperature greatly, by the constant radiation of heat from the ground. The ocean preserves a more uniform temperature at different seasons than the land; hence, islands surrounded by large seas, possess a more equal temperature throughout the year, than continents in the same latitudes. The lines of equal temperature (called isothermal lines) are not parallel to the lines of latitudes, as they would be, were temperature not affected by the causes before stated. Quebec, with its Siberian winter, is nearly in the same parallel of latitude as Rochelle, in France, and is not two degrees north of the latitude of Bordeaux; a difference not greater than between London and Nottingham, which in this country produces scarcely a perceptible effect on the climate. In some countries, where the summer temperature is much greater than that of other countries in the same parallel of latitude, yet the average annual heat, or what is called the mean temperature, as measured by the thermometer, is the same in both; because though the summers may be hotter, the winters are proportionally colder, which reduces the average temperature to an equality. But though the mean temperature may be the same, the greater periodical increase and decrease of temperature in one country than in the other, occasions a considerable difference in the vegetation. If we examine in a good map two situations in the same parallel of latitude, which possess very different degress of temperature, we may generally observe a variation in the relative portion of land and water, which may serve in a considerable degree to explain, why one situation should enjoy more heat than the other.

Mr. Lyell has advanced a theory respecting the former high temperature of northern latitudes, in which, by many local illustrations and ingenious arguments, he attempts to prove, that a great change in the relative position of the land and sea, would be sufficient to account for the excess of the former temperature, over that now enjoyed in northern regions. He states two extreme cases, which, could they ever occur, must produce an important change in the climate of Europe. Were the land between the tropics to be submerged under the ocean, and an equal portion of mountainous land to be raised in the polar circles, the cold of those regions would be much increased, and the heat between the tropics would be very greatly diminished; by the joint operation of these causes the climate of the southern parts of Europe, might become as cold as that of Siberia. On the contrary, were all the land in high latitudes to be submerged, and an equal quantity of land to be raised above the sea, near the equator, the mean temperature of a great part of Europe might be sufficiently increased, to support the vegetation of tropical climates. The theory of Mr. Lyell is entirely original, and throws much light on the causes which affect the climate of various countries in the same parallels of latitude; and could we grant that the change of land and sea had ever been so complete as what he has imagined, the conclusions deduced therefrom would be undeniable: but so many conditions are required to effect such extreme changes, that we must regard their occurrence as merely possible, and La Place, in his "*Essai Philosophique sur les Probabilités*" has shown, that between events which are merely possible, and those which the philosopher should regard as probable, there is an almost immeasurable interval. Nor can the theory of Mr. Lyell be well reconciled with the occurrence of the remains of such immense multitudes of tropical animals and plants, in countries bordering the arctic circle, because, to increase the temperature of Europe in a considerable degree, the theory would require all the land in high northern latitudes to be submerged; but this is precisely the very land on which the elephants flourished.

The cause which has effected a change in the temperature of the earth, must probably be sought for, either in the earth itself, or in some change in its orbit, or in the relative position of its axis. Did the severe laws which analysis and observation have established in astronomy, allow the geologist to admit a slow revolution of the globe, round two opposite points of the present equator, each part of the earth would in succession be brought between the tropics; and if we could suppose the axis of diurnal rotation, to preserve the same inclination to the ecliptic as at present, we should have all the conditions required, for explaining the former high temperature of polar regions. The spheroidal form of the globe appears, however, to preclude the admission of this hypothesis; nor does it derive any support from astronomical observations continued for 2000 years.

Even an increase of the obliquity of the earth's axis to the ecliptic, without any other change, would produce a great effect in the climate of northern latitudes, by increasing the summer heat; but the winters would be colder than at present. There is, indeed, an annual change in the obliquity of the ecliptic, but it appears to be confined within limits too small to produce a sensible effect on the temperature of any part of the globe. The effects that might be produced by a change of the earth's orbit remain to be noticed.

A change in the form of the earth's orbit, if considerable, might change the temperature of the earth, by bringing it nearer to the sun in one part of its course. The orbit of the earth is an ellipsis, approaching nearly to a circle: the distance from the centre of the orbit, to either focus of the ellipsis, is called by astronomers the "*eccentricity of the orbit.*" This eccentricity has been for ages slowly decreasing, or, in other words, the orbit of the earth has been approaching nearer to the form of a perfect circle; after a long period it will again increase, and the possible extent of the variation has not been yet ascertained.* From what is known respecting the orbits of Jupiter and Saturn, it appears highly probable, that the eccentricity of the earth's orbit, is confined within limits, that preclude the belief of any great change in the mean annual temperature of the globe ever having been occasioned by this cause.†

The heat from solar radiation, may possibly have been greater in remote ages than at present. Sir Wm. Herschell inferred, from the variable spots on the sun, that the mean temperature of the earth was increased or decreased in certain years; or, in other words, that the earth received an unequal annual supply of heat from the sun. We have, however, no data from whence to ascertain that there has ever been any considerable change of temperature effected by this cause; to appeal to the high former temperature of the globe in proof of it, would be to substitute vague hypothesis in the place of facts.

Beside solar radiation, it is believed by many philosophers, that there is a source of subterranean heat within the earth itself: this opinion is by no means

---

* Sir J. W. Herschell, in a paper on the subject read to the Geological Society, states that a variation in the eccentricity of the earth's orbit, from the circular form to that of an ellipse, having an eccentricity of one fourth of the major axis, would produce only an increase of 3 per cent. in the mean annual amount of solar radiation.

† Un autre phénomène également remarquable du systême solaire, est le peu d'eccentricité des orbes des planètes, et des satellites, tandis que ceux des comètes sont très-allongés. Nous sommes encore forcés de reconnaître ici l'effet d'une cause régulière, le hazard n'eut point donné une forme presque circulaire aux orbes de toutes les planètes et de leurs satellites."

La Place, sur les Probabilités.

new, but it appears to have received support from numerous observations and experiments made in a comparatively recent period. The evidence by which the theory of central heat is supported, is derived first, from the occurrence of volcanic fires in almost every degree of latitude north or south: secondly, from submarine volcanoes: thirdly, from the occurrence of numerous thermal springs in countries remote from active volcanoes: lastly, from direct experiments made on the temperature of the earth, at various depths in mines, and by sinking and boring into the earth.

Whether there exist a mass of heated matter under the whole surface of the globe may be uncertain; but that there is subterranean fire, under a considerable extent of the surface, can scarcely be doubted. The volcanoes that are thickly scattered over both the northern and southern hemisphere, the long period of their activity, and the connection that appears to subsist between the volcanoes in distant districts (see Chap. XVIII.), prove the depth and extent of the source of volcanic fire. The volcanoes that break out from under the sea, and overcome the vast pressure of the incumbent ocean, farther indicate, that the explosive force is situated at a great depth. Thermal waters, prove the extensive effects of subterranean heat; for though many hot springs rise in volcanic districts, and are properly a part of volcanic phenomena, yet other thermal waters are far removed from any active volcanoes. Some hot springs have flowed without any known diminution of temperature for nearly two thousand years; this is the case with the waters of Bath, which have no volcanoes nearer to them, than those in Iceland and the south of Italy. That thermal waters derive their temperature from a deep-seated internal source of heat, and not from any local cause, or from chemical changes near the surface, is rendered probable by various circumstances. In many of these waters there is scarcely any admixture of saline or mineral matter, which there would be, were the heat derived from chemical decomposition. Most warm springs are situated near to crystallised primary rocks, or to basaltic rocks or dykes, as I observed to be the case in the Alps. Hot springs often rise among the loftiest mountain ranges in Asia and America. The temperature of thermal waters in low situations, is frequently reduced by admixture with cool springs near the surface, and this I believe to be the principal cause why thermal waters so rarely rise in the upper secondary strata, as I have more fully stated in an account of the thermal waters of the Alps. (See *Appendix.*) It could scarcely have been expected, that an enquiry relating to the temperature of the central part of our planet, could be brought within the limits of human observation and experiment, as the depth to which we can explore by boring or by excavation, bears so inconsiderable a proportion to the diameter of the earth; yet from numerous observations on the temperature of the earth in deep mines, and from experiments on the temperature of water at different depths, it would appear, that this temperature increases in a very remarkable degree, as we descend lower from the surface. In France, the subject has been recently investigated with considerable activity, and the practice, which is becoming general in that country, of boring for water, to form what are called Artesian wells, has greatly facilitated the investigation.*

M. Cordier has particularly directed his attention to this subject, and from numerous experiments made by himself and others in mines and Artesian wells, he has drawn the following conclusions: — 1st. that

---

* Boring for Artesian wells has become general in many parts of Italy and Germany. In France, it is found that the average increase of heat, above the mean temperature of the surface, is about one degree of Fahrenheit's thermometer, for every forty-five feet in depth; or one degree of the centigrade scale, for twenty-five metres: but this is liable to variation of increase or decrease in different situations. For a further account of the temperature of mines and wells see Appendix.

there exists a subterranean heat in the terrestrial globe independent of solar radiation, and which increases rapidly with the depth: — 2nd. that the increase of heat, does not follow the same line in all parts of the earth; indeed, he supposes the differences may be twice or three times as great in one country as in another: — 3rd. these differences are not in constant relation with the longitudes and latitudes of places where the experiments have been made: — 4th. that the heat increases with the increase of depth, in a much greater degree than was previously believed. M. Cordier farther maintains, that there is a source of intense heat in the earth, and that the external crust may be from 50 to 100 miles in thickness, and that all within this crust is a mass of melted matter: that originally the whole globe was an entire mass of melted matter before the external crust became solid, by throwing out its heat into space; and that, in this manner, the solid crust is constantly growing thicker, and the internal heat diminishing.

The spheroidal form of the earth indicates an original state of fluidity, and whatever might be the tenacity of the fluid matter, the rapid rotation of the earth on its axis, would swell out the equatorial parts, and form a spheroid of rotation. Intense heat appears to be the only natural agent we are acquainted with, that could retain the mass of the earth in a fluid state: — farther, the granitic crust of the globe most probably owes its crystalline structure to slow refrigeration from a state of igneous fusion. Thus both the form of the earth, and the structure of its crystalline crust, are favourable to the theory of central heat. If this theory can be established, it will offer a satisfactory explanation of the former high temperature of the globe, and of its subsequent progressive refrigeration: — also of another circumstance equally remarkable; for it would appear, from the fossil remains of vegetables in different latitudes, that every part of the globe once enjoyed nearly the same degree of heat; the cause of this equality must have been independent of solar radiation, and derived from the earth itself. There are certainly numerous circumstances that favour the theory of central heat, but it must be confessed, that it is also accompanied with difficulties not easily to be removed.

If the earth be composed of a solid crust or shell surrounding a fluid mass, this internal fluid would be subjected to the attraction of the sun and moon, or, in other words, would have its regular tides. We are not acquainted with any counteracting influence, to prevent the impulse of these tides upon the solid shell. I am, however, fully persuaded, that the internal parts of the earth do not consist of an assemblage of chaotic elements, but that they are arranged with as much wisdom as the parts of the external universe, and that the earth itself is the vast laboratory, in which was prepared, according to definite laws, all the mineral substances found on its surface, and in which are now preparing the elements of future changes. There is one difficulty attending the theory of central heat, noticed by Professor Sedgwick, which it may be proper to state. " If," says he, " during any period the earth has undergone any considerable refrigeration, it must also have undergone a contraction of dimensions; and also, as a necessary consequence of a well-known mechanical law, an acceleration round its axis: but direct astronomical observations prove, that there has been no sensible diurnal acceleration during the last 2000 years; and, therefore, during that long period, there has been no sensible diminution in the mean temperature of the earth. This difficulty does not, however, entirely upset the previous hypothesis; it only proves, that the earth had reached an equilibrium of mean temperature, before the commencement of good astronomical observations."

If the terrestrial globe has ever been a fluid ignited mass, it is obvious that the atmosphere must have undergone great changes during the progress of refrigeration. In the original ignited state of the earth, all the aqueous particles that form the ocean, and all the more volatile mineral substances, would have existed in the form of vapour, and have constituted a nebulous medium of vast extent, resembling the atmosphere of a comet, or the nebulosity surrounding the newly-discovered planets, Juno, Ceres, and Pallas. By progressive refrigeration, the volatile mineral matter would be concreted, and the aqueous particles precipitated, until the constitution of the atmosphere became fitted for the support of animal life. It is not improbable, that the animals of the earliest creation, might have been constituted to breathe a denser atmosphere than the present one. Such an atmosphere would, in a considerable degree, equalise the mean temperature of the earth; and the excess of moisture and of carbonic acid gas, would also be favourable to the rapid development of vegetation.

In stating these hypotheses, my only object has been to suggest to the reader, the various causes which may have affected the former temperature of the globe, and shall leave him to determine how far any of them appear to be supported by analogy and probability.

The original fluidity of the globe appears to be indicated by its present spheroidal form; and in the large planets that compose part of our system, the spheroidal form is more fully displayed, particularly in the planet Jupiter. Now it well deserves attention, that the conditions under which this form was impressed on the earth and planets, cannot recur again by any known causes now in operation, or by any other conceivable cause, except the fiat of the Creator. Thus we are brought at once to a commencement of the series of geological changes, which could not have been the result of any secondary causes, that come within the limit of our present experience. About a century ago it was the fashion among philosophers to explain all the phenomena of nature, even thunder and muscular action, by the operation of known causes; that is, by the established laws of mechanics, and by chemical fermentation. The discoveries of Franklin and others subsequently proved, that there were more things in heaven and earth than had been dreamed of in past philosophy. It would, indeed, be astonishing if, with our limited powers and ephemeral existence, we have now discovered all the causes that have effected changes in the former condition of the globe.

> " One part, one little part, we dimly scan
> Through the dark medium of life's feverish dream."

The senses given us by the Creator, as the inlets of knowledge, are sufficient for all the useful purposes of life on our planet; but it would be extremely rash to infer, that they are adequate to discover or perceive all the properties of matter, or the changes these properties can effect. Some material powers or agents cannot be made perceptible to any of our senses, except by their effects; such are universal gravitation, magnetism, and crystalline polarity; and ages had elapsed, before the existence or operation of such powers was even suspected. If we extend our views to the planetary system, we may discover a state of things which implies that the elementary matter of which they are composed is essentially different from terrestrial matter; and the difference must be such, that it would require an organisation and constitution of the inhabitants (if they be inhabited), altogether so unlike what we are acquainted with, that we are as incapable of forming any distinct idea respecting them, as a blind man is of forming an idea of colours. This may be clearly inferred from the different density of the planets. The density of Saturn is stated by astronomers to be about one tenth that of the earth, or scarcely half the density of pure water. Most of the Saturnian metals and minerals must be lighter than cork wood; and no fluid like water, can exist any where but in the centre of the planet. But Saturn has an atmosphere and variable clouds or belts; it must therefore have a fluid on its surface, that performs the functions of water; yet this fluid must be chemically and essentially different from water, or from any fluid on our earth. The properties of matter, and the laws of definite proportion, cannot be the same on Saturn as upon the earth, and it is highly probable, that different senses would be required to make these properties perceptible. If from the body of Saturn we turn our attention to the double ring by which it is surrounded, we must admit a former condition of that planet, which can never return by any known secondary causes in present operation. Thus both geology and astronomy lead us to acknowledge a first Almighty cause, and a commencement of the present order of things, dependent upon his will.

In offering the preceding remarks, I have not been influenced by a desire to oppose the opinions of others, but to support what appears to me to be the truth.

I shall now take leave of the reader in the words with which the last edition was concluded.

It may be right to advert to an enquiry that has frequently been made — *What advantage can be derived from the study of geology?*

The value of every science must ultimately rest on its utility: but in making the estimate, we ought not to be guided alone by the narrow view of immediate gain. The material universe appears destined to answer two important purposes: the first of which is to provide for the physical wants of its various inhabitants. Now, in relation to this purpose, the science which teaches us the structure of the earth, and where its mineral treasures may be found, can scarcely be deemed devoid of utility, by a nation deriving so much of its comfort and wealth from its mineral resources. But, beside supplying our physical wants, the external universe is destined to answer a nobler purpose; its various objects appear intended to excite our curiosity, and stimulate our intellectual powers, to the discovery of those laws by which the successive events we observe in nature are governed. Without this excitement, man would for ever remain the mere creature of animal sensation, scarcely advanced above the beasts of the forest; and the universe would be to him a mute and unmeaning succession of forms, sounds, and colours, without connection, order, or design. In those sciences which have attained the highest degree of perfection, the skill of the Creator, and the ends and uses of the different parts are most apparent. Geology has not yet made sufficient progress to carry us far in this path of enquiry; but we see enough to discover, that the apparent disorder into which the strata on the surface of the globe are thrown, and the inequalities which it presents, are absolutely necessary to its habitable condition. The distribution of its mineral treasures, and particularly of coal, to the cold and temperate regions of the globe, is well deserving attention, and implies a prospective regard for the wants of civilised man: but a cold-hearted philosophy, under the sanction of a quaint expression of Lord Bacon*, has (to use the words of Dugald Stewart) "made it fashionable to omit the consideration of final causes entirely, as inconsistent with the acknowledged rules of sound philosophising. The effect of this has been to divest the study of Nature of its most attractive charms, and to sacrifice to a false idea of logical rigour, all the moral impressions and pleasures, which physical knowledge is fitted to yield."

Geology discovers to us proofs of the awful revolutions which have in former ages changed the surface of the globe, and overwhelmed all its inhabitants: it reveals to us the forms of strange and unknown animals, and unfolds the might and skill of creative

---

* "Causarum finalium inquisitio sterilis est, et tanquam virgo Deo consecrata nihil parit."

energy, displayed in the ancient world: indeed, there is no science, which presents objects that so powerfully excite our admiration and astonishment. We are led almost irresistibly to speculate on the past and future condition of our planet, and on man its present inhabitant. What various reflections crowd upon the mind, if we carry back our thoughts to the time when the surface of our globe was agitated by conflicting elements, or to the succeeding intervals of repose, when enormous crocodilian animals scoured the surface of the deep, or darted through the air for their prey; — or again, to the state of the ancient continents, when the deep silence of nature was broken by the bellowings of the mammoth and the mastodon, who stalked the lords of the former world, and perished in the last grand revolution, that preceded the creation of man. Such speculations are somewhat humbling to human pride on the one hand, but on the other, they prove our superiority over the rest of the animal creation; for it has been regarded by the wisest philosophers in ancient times, as a proof of the high future destiny of man, that he alone, of all terrestrial animals, is endowed with those powers and faculties, which impel him to speculate on the past, to anticipate the future, and to extend his views and exalt his hopes, beyond this visible diurnal sphere.

The following observations on the study of geology, taken from Professor Sedgwick's truly eloquent address to the Geological Society of London, in 1831, are so just and beautiful, and are so closely related to what I have before stated, that I am certain my readers will be highly gratified by their insertion.

" If I believed that the imagination, the feelings, the active intellectual powers bearing on the business of life, and the highest capacities of our nature were blunted or impaired by the study of our science (Geology), I should then regard it as little better than a moral sepulchre, in which, like the strong man, we were burying ourselves and those around us, in ruins of our own creating. But I believe too firmly in the immutable attributes of that Being, in whom all truth, of whatsoever kind, finds its proper resting place, to think that the principles of physical and moral truth can ever be in lasting collision. And as all the branches of physical science are but different modifications of a few simple laws, and are bound together by the intervention of common objects and common principles; so also, there are links, less visible, indeed, but not less real, by which they are also bound to the most elevated moral speculations.

" Geology lends a great and unexpected aid to the doctrine of final causes; for it has not merely added to the cumulative argument, by the supply of new and striking instances of mechanical structure adjusted to a purpose, and that purpose accomplished; but it has also proved, that the same pervading principle, manifesting its powers in our times, has also manifested its power in times long anterior to the records of our existence."

SUPPLEMENT TO CHAPTER VIII.

ON THE GREAT COAL FORMATION.

Beside what has been already stated respecting the freshwater origin of the coal strata, I wish the reader to bear in mind, that the marine or freshwater character of formations, must be determined by the general assemblage of the organic remains, and not by a few individuals, or a few species of shells, which differ from the general character of the fossils; particularly as we now know, that several species supposed to be marine, are capable of living in fresh water.

In the great coal formation of England, the upper and middle beds, for many hundred feet or yards in thickness, abound in the remains of terrestrial or of marsh plants, with some freshwater shells, but without any admixture of marine species. The whole mass of the coal measures, however, rests on marine limestone; and in some parts of England, the lowest measures alternate with beds of limestone, and also contain some shells supposed to be marine. Though the upper and middle parts of all the English coal fields are freshwater formations, we can have no doubt, that the limestone on which all the coal fields rest was deposited under the ocean; but many circumstances tend to prove, that its elevation was a slow and long-continued process, and that the lower part of the coal measures were deposited when nearly on a level with the sea, or in situations subject to irruptions of marine water; or else the ground was subject to oscillations, which brought it, at different times, below the level of high tides.

The great valley of the Mississippi contains the largest coal field in the known world; and what is now annually taking place in some parts of that valley, appears to confirm in a remarkable manner, the opinions I have advanced (pages 165 to 173) on the formation of coal, and the cause of the frequent recurrence of the same series of strata at different depths, in the same mine; which I attribute to the periodical filling and desiccation of lakes. In the second volume of Mr. Stuart's interesting "Travels in the United States," there is a very instructive account of the Valley of the Mississippi, quoted from an American review. I shall here insert the parts immediately connected with the present subject:—

"What is called the Valley of the Mississippi is not in reality a valley, but an extensive elevated plain, without hills or inequalities deserving notice. It extends west from the western slope of the Alleghany Mountains, to the sand plains near the Missouri, a distance of about 1500 miles, and south from the valley of the northern lakes, to the mouth of the Ohio, about 600 miles. No part of the globe possesses such an extent of uniform fertility. The difference in elevation is only a few feet, as ascertained by actual survey. The general elevation of this plain, is about 800 feet above the sea. It is crossed by the great rivers Missouri, Mississippi, Ohio, and their branches. As we go westerly up the Missouri and Arkanas to the sand plains, we find nearly the same elevation. The great and numerous rivers that cross this plain, instead of forming valleys, do but indent narrow lines or grooves into its surface, hardly sufficient to retain their floods. As the currents of these rivers roll on in their courses, they sink deeper into the plain; hence the large rivers Ohio, Missouri, and others, seem bordered with hills of several hundred feet elevation, towards their mouths; but the tops of these hills are the level of the great plain.

"The base of this whole extent of plain appears to be transition or mountain limestone, in nearly horizontal beds: it has been perforated to the depth of 400 and 600 feet. It contains trilobites, orthoceratites, the productus, and other fossils that characterise the transition limestone. The uppermost stratum of limestone is not many feet below the surface, and supports, nearly over its whole extent, strata of bituminous coal and saline impregnations. The limestone extends under the Alleghany Mountains in the east, and the sand plains on the west, and rests on the granite ridges of Canada on the north.

"This coal field would cover half Europe, having an extent of 900,000 square miles; or 1500 miles in length, by 600 miles in breadth. The coal is pure, and lies above the beds of the rivers, and costs about twenty cents (the fifth part of a dollar) per ton to quarry it. Iron ore abounds generally, but in Missouri there is a mass of this ore 300 feet in height, and five miles in extent, which yields 75 per cent. of fine malleable iron. The lead districts of Missouri and Illinois cover 200 square miles." It is not mentioned in the above account, but there can be no doubt, that the mines are situate in the limestone, which identifies that formation still farther with the mountain limestone of England.

In the geological position and physical structure of this vast coal field, we may, I think, trace, in a satisfactory manner, the mode of its formation. Were the outlet of the waters that drain this large surface to be only partially closed (as we may suppose the mouth of the Mississippi to be) by an earthquake or upheaving of the surface, then in the time of annual periodical inundations, the whole extent of this level plain would be covered with fresh water, and form an inland sea, which would gradually become dry as the inundations subsided. This plain would then become a vast swamp, suited for the rapid development of vegetation. In this manner thick beds of decomposed vegetable matter might every year be formed, and subsequently covered with strata of mud and earthy matter, deposited during the inundation.

Now let us advert to what actually takes place in the lower valley, or plain of the Mississippi, every year. When those mighty rivers, the Mississippi and

Missouri, are inundated, by the melting of the snow near their sources, they pour down immense floods, which fill their banks, and absolutely choke up the mouths of the large secondary rivers that enter them, and throw their waters back for many miles, charged with the mud of the great descending waters. The waters of these secondary rivers in their backward course, overflow their banks, and spread over the lower parts of the level plain, forming lakes of twenty miles or more in length: after some time these lakes are gradually drained by the subsidence of the rivers. The inundations are, however, prolonged by another circumstance. The Missouri and Mississippi rise in different latitudes, and their periodical inundations do not take place at the same time. When one of these mighty streams is inundated, it blocks up the passage of the other, and this reacts on the secondary streams, and prolongs the time of periodical inundation. Thus in these temporary lakes of fresh water, we have the conditions required for the formation of future coal fields — swamps promoting the rapid development and decomposition of vegetables — and periodical inundations of water, charged with sand and mud, to cover the vegetable beds with earthy strata. It is further deserving notice, that over a large part of the plain of the Mississippi, the rapid annual growth of grasses and thistles, exceed any thing of which this part of Europe affords an example: this enormous mass of vegetation perishes every winter.

In the account of the probable duration of the coal of Durham and Northumberland (page 182.), first published in the third edition, I have stated the period of exhaustion to be about 350 years from the present time. In evidence on the subject, given before the House of Commons, the period has been extended to 1727 years; a difference so great as to require some animadversion. In the first place, all evidence given before Parliament, by commercial or public bodies, who have a particular object to establish, must be received with considerable caution. The coal owners in the north were alarmed, lest some restriction should be laid on the unlimited export of coal, if it were known that the coal fields of Northumberland and Durham could only afford a regular supply of fuel for a very limited number of years. It was stated before the House of Commons, that there are 837 square miles of coal strata in Northumberland and Durham, and that only 105 square miles have been worked out. It was assumed, that each workable bed of coal spreads under the whole extent of the coal fields, but this is very far from being the fact. Many of the best and thickest coal beds crop out long before reaching the western termination of the coal field, or are cut off by faults or denudations. The thickness of the beds was also overstated. Professor Buckland estimated the duration of the Northumberland and Durham coal, according to the present rate of consumption, at 400 years, which agrees very nearly with the period of exhaustion I had assigned.

APPENDIX.

AN INDEX OUTLINE OF THE GEOLOGY OF ENGLAND.

THE outline of the geology of England, and the map that accompanied it, given in the first and second editions of this work, presented (the author believes) the first distinct general view of the geology of England that had ever been published; and though several parts of our island have since been more fully examined, the examinations have confirmed the correctness of the leading facts, stated in the editions of 1813 and 1815.

The author has since revisited a considerable part of England and Wales, and collected materials for a more ample detail of their geology; but the limits of the present volume will not admit of their insertion, and it is his intention to publish them in a separate form. This index outline will serve more fully to explain the map and sections, by references to the chapters where the different classes of rock are described.

In tracing the great outlines of the physical geography of continents and islands, we may generally perceive, that they are determined by the ranges of primary and transition mountains that traverse them: these have been compared to the skeletons, on which the other parts of a country are constructed.

The length of Britain is determined by different groups of mountains, which, viewed on a large scale, may be regarded as one mountain range, extending north and south (with its ramifications) along the western side of England and Wales, from Cornwall to Cumberland, and from thence to the northern extremity of Scotland. All the highest mountains in England and Wales are situated in this range, which, in reference to our island, may be called the great Alpine chain. This chain is interrupted by the intervention of the Bristol Channel, and again by the low grounds of Lancashire and Cheshire, which divide it into three groups or ranges; these, for the sake of distinction, may be denominated the Devonian range, the Cambrian range, and the Northern range. They form the

Alpine districts of England (coloured red in the map). The mountains of the great Alpine chain from Cornwall to Cumberland, are composed of primary rocks and of other rocks, which belong chiefly to the class of transition rocks, described in Chaps. V. VI. and VII. Those parts in which the primary rocks chiefly occur, are shaded by lines. In some few parts, east of the Alpine district, the primary and transition rocks also make their appearance, uncovered by the secondary strata. A range of primary and transition mountains appears once to have extended from the Devonian range, in a north-east direction, into Derbyshire; — the transition and basaltic mountains of that county, the Charnwood Forest hills, the sienitic greenstone of Warwickshire, the transition rocks of Dudley, the Malvern Hills, and the trap rocks of Gloucestershire, Somersetshire, and Devonshire, were probably parts of one range, and were much loftier than at present. It may deserve notice, that the granitic rocks, in this range, are closely allied to rocks now generally supposed to be of igneous origin.

It was this range that appears to have determined the extent of our island in that direction, and to have formed the western border of an ancient sea or lake, in which the upper calcareous strata of the midland, eastern, and southern counties were deposited. It also appears to have determined the extent of the upper calcareous strata, that cover the eastern side of England, and are bounded by the line A A A. This boundary marks the direction of a range of calcareous hills, that extends through England in a waving line, from the western extremity of Dorsetshire, to the eastern side of the county of Durham. East of this line, there are no beds of good mineral coal in any part of England. Between the line A A A and the Alpine districts (coloured red), we have the under secondary strata (coloured green). All the principal coal formations in England occur in different parts of this district, which, for the sake of distinction, we shall call the *middle district*: it is however partly covered by beds of red marl and sandstone. *The upper calcareous district*, east of the line A A A (and coloured yellow in the map), is in some parts covered with beds of clay and sand of a more recent formation, belonging to the tertiary strata: they are coloured brown, and are bounded in the map by the lines o o o o. Other low parts of this district are covered by alluvial depositions, and marked 1 1 1.

England and Wales may thus be divided into three geological districts: — the Alpine district, consisting of primary and transition rocks, — the Middle district, comprising the coal formation and the lower secondary strata of new red sandstone,—and the Upper Calcareous district, comprising the lias, the oolite and chalk formations; the latter partly covered by tertiary formations. Each of these districts has its appropriate characters and mineral productions. In order to give the reader a clear idea of the relative position of the rocks and strata of these three divisions, let him take three sheets of paper, and cut out the form of England in each. Let the lower sheet be red; cover this with green paper, cutting out all the parts on the western side, which will leave the parts marked red in the map uncovered, and also the small parts where the Malvern Hills and Charnwood Forest hills are situated. Cut out the third sheet of yellow paper, so that its edge may correspond with the line A A A. Then cut out pieces of darker-coloured paper, and place them over the parts marked 2 2 2, for the tertiary strata; and place dark patches on the parts marked 1 1 1, for alluvial and diluvial depositions; raise the western edge a little, so as to make the sheets of paper incline to the south-east;—and we shall then have a model of the geology of England, which would be more complete, provided we could raise the parts marked red above the level of the green paper. The red paper, which spreads under the whole, and represents the primary and transition rocks of the Alpine districts, may be conceived to extend under the sea, and to rise again in Ireland, France, Sweden, and Germany, and thus to be connected with all the granitic ranges of the old continent. It is scarcely requisite to remark, that, in presenting a general view of the arrangement of the different classes of rocks in this manner, the partial wavings or irregularities of the strata, and the inequality of surface, presented by hills and valleys, must be necessarily disregarded.

The primary rocks of England and Wales are described in various parts of Chaps. V. and VI. in the present volume. The transition rocks, including mountain limestone, are described in Chap. VII. The coal formations in England, within the middle district (coloured green in the map), extend on the eastern side of Northumberland and Durham, from Berwick-on-Tweed to the river Tees; but from thence to the river Air (near Leeds), only the lowest beds of the coal formation occur, which contain but little workable coal. The Yorkshire and Derbyshire coal-field commences a little north of Leeds, and extends in breadth east and west about twenty-five miles, from Halifax to Abberford, and in length about seventy miles, from Leeds to near Nottingham and Derby. The breadth decreases southward, being little more than twelve miles in Derbyshire.

South-west of Derbyshire, there are a few small coal-fields near Ashby-de-la-Zouch, and near Tamworth, Atherstone, and Coventry. The latter coal-field, is the most southern situation in which mineral coal has been discovered in the midland counties.

On the north-west side of England, there is a small coal-field bordering the sea in Cumberland, which extends from Whitehaven to the north of Maryport. This coal-field, though small in extent, contains seven beds of excellent workable coal. From its contiguity to the sea, and its remoteness from other coal-fields, it may be considered, in proportion to its extent, as one of the most valuable coal districts in England. In one mine, the coal is worked at the depth of 298 yards. The workings of some mines have been extended under the sea. The next considerable coal-field is that of Lancashire: it is separated from the Yorkshire coal-field by a range of lofty hills, on the borders of the two counties, extending, on the west side of Colne, to Blackstone Edge, and from thence to Axe Edge, on the border of Derbyshire. These hills are principally composed of millstone grit and shale, but are not covered by coal strata. On the western side of these hills, the coal strata of the Lancashire coal-field commence, dipping westward; but they are broken and deranged by numerous faults. The principal beds of coal are,—one of six feet in thickness, and a lower one called the three-quarter bed. In some parts the sandstone strata are of a deep red colour. The breadth of this coal-field, from Macclesfield to Oldham, does not exceed five or six miles; but from Oldham it extends westward to Prescot, near Liverpool, and from Prescot it extends in a north-east direction to Colne.

Not far from the southern extremity of the Lancashire coal-field, there is a small but valuable coal district, which supplies the potteries near Newcastle in Staffordshire: this may properly be considered as an extension of the Lancashire coal-field. The next important coal-field is that of Dudley and Wolverhampton: it is about twenty miles in length, and varies in width from four to seven miles. It contains the thickest bed of coal in Great Britain. (See page 155.) There is a narrow coal-field on the north-eastern border of Wales, extending from Mostyn in Flintshire, to Chirk in Denbighshire. There are also a few smaller coal-fields on the north-eastern side of Herefordshire, which extend into Shropshire. The Clee Hills, near Ludlow, contain, on their sides, two or three small detached coal basins. The summits of these lofty hills are capped with basalt.

The coal basin of the Forest of Dean, is the next considerable repository of coal: it presents, perhaps, the most perfect model of a coal basin of any in Great Britain; the coal strata occupy a space of about ten miles in length, and six in breadth: the millstone grit and the transition limestone on which they lie, may be distinctly observed cropping out, on its northern and western boundary.

In Somersetshire and Gloucestershire there is a considerable coal-field on each side of the river Avon: its greatest extent is about twenty miles, and its greatest ascertained breadth about eleven miles; but it is covered in many parts by the secondary strata, consisting of red marl and lias. The deepest coal mine in England is in this coal-field; the depth of the pit at Redstock, near Bath, being 409 yards.

The greatest repository of coal in our island is that which extends on the northern side of the Bristol Channel, 100 miles in length, and varying in breadth from five to twenty miles. Further information respecting many of the English coal-fields will be found in Chap. VIII.

A considerable part of the middle district (coloured green in the map), which is not occupied by the coal formations above enumerated, is covered by the red marl and sandstone, described in Chap. XI. As the sandstone of this formation often covers the coal strata, it becomes an object of great interest to landed proprietors in the midland counties, who have estates at no great distance from the coal districts, to ascertain whether coal may not extend under the red marl and sandstone. Some observations on this subject are given (pages 178. and 179.), which the author is persuaded deserve the attention of landed proprietors. The search for coal under the red marl and sandstone in Somersetshire has been eminently successful; and coal has in some instances been found, by sinking through both lias and red sandstone.

The principal repositories of rock salt, and the strongest springs of brine, are situated in the red marl of Cheshire, and near Droitwich, in Worcestershire. (See pages 252. and 253.) In this formation the principal beds of gypsum are found: it is frequently associated with rock salt. (See Chap. XI.)

One of the most remarkable features of the middle district, is the occasional occurrence of various rocks (*in situ*) of granite, slate, and sienite, belonging to the class of primary or transition rocks: they rise through the secondary strata, and appear, from various circumstances, to have once occupied a considerable portion of the midland counties, extending from Leicestershire to Warwickshire, Worcestershire, Gloucestershire, Somersetshire, and Devonshire. The secondary strata of England, from lias to chalk (coloured yellow in the map), are pretty fully described in Chaps. XII., XIII., and XIV. The more recent or tertiary strata (coloured brown in the map, and marked 2 2), are described in Chaps. XVI. and XVII. The basalt dyke of Cleveland, which runs through the North Riding of Yorkshire into Durham, is described, with other basaltic rocks in England, in Chap. IX., and the alluvial beds, marked 1 1 1, are described in Chap. XXI. A description of many of the mining districts of England and Wales will be found in the chapter on metallic veins.

It now remains to notice the sections in different parts of England. A section, to possess much value, should be made as nearly as possible along the true line of the dip and rise of the strata. We possess no true line of dip in England, which passes through all the different classes of rock; and it is only misleading the reader, to represent the succession of rocks out of their true situation. The section of the secondary strata, with a small portion of the tertiary, given at page 234., represents the succession of the different secondary formations, from chalk to the lowest new red sandstone, taken in a line from the chalk hills north-west of London, to the transition rocks south of the Malvern Hills, in Herefordshire. But in this line, the lower red sandstone, and magnesian limestone are wanting.

If we draw another line across England, through Durham and Cumberland, from the German Ocean, near Sunderland, to the Irish Channel (see section, Plate VII.) we may observe the magnesian limestone A forms the uppermost rock of the series; all the secondary strata above this formation are here wanting; it is, however, probable that they may once have extended into the German Ocean, in the order represented at page 234. The magnesian limestone A lies unconformably upon the coal strata, which rise to the west, B B; at X the strata are broken by the Burtreeford Basalt Dyke. C C represents the lower beds of the coal strata, with mountain limestone; they terminate at the mountain called Cross Fell, 5. The lower part of this mountain is composed of mountain limestone and greywacke; a little to the west, the beds are broken, by nearly vertical beds of trap and sienite. In the Vale of Eden is Penrith Beacon, 4. This vale is covered by beds of conglomerate and red sandstone. The lofty mountains, E E, that surround the lakes of Cumberland and Westmoreland, are skirted by beds of mountain limestone; but the higher mountains are chiefly composed of slate, felspar, porphyry, and greywacke. Granite occurs at the base of Skiddaw and Saddleback, and at Coldback Fell. 1, is Sea Fell, the highest mountain in this group; 2, Skiddaw; and 3, Helvellyn. Farther west we come upon the coal strata of Whitehaven, dipping west, and covered by unconformable secondary strata. Some of the more remarkable rocks in the mountains round the lakes are described in Chap. VII. Plate II. fig. 4. represents the arrangement of the strata in the central part of England, passing in a line nearly east and west, though the low granite range at Charnwood Forest, in Leicestershire: *e*, on the right-hand side of the plate, represents lias resting on red marl and sandstone, *a*. The granite and slate rocks are represented, *b b c c*, partly covered by horizontal beds of red marl and sandstone: *d d* are the coal strata, near Whitwick, much elevated as they approach the Forest Hills. A little out of the line of section, are represented the elevated beds of mountain limestone at Breedon and Clouds Hill, part of which limestone is continued to the Forest Hills at Grace Dieu. For a more particular account of this section, see Chaps. X. and XXII.; and for an account of the sections near Dudley, in Staffordshire, see Chap. VII.

This brief sketch of the geology of England, with the references to the map, sections, and chapters in this volume, may suffice to give the reader a general view of the geology of England, and the situation of its principal mineral repositories. I shall subjoin an account of the thermal waters of England, and of a few celebrated thermal waters on the Continent, and a table of the height of mountains.

Temperature of the Thermal Waters in England, and some other Parts of Europe.

	Fahrenheit.
Bristol - - - - - -	74°
Matlock - - - - - -	66
Buxton - - - - - -	82
Bath - - - -	112° and 116
Vichy (Auvergne) - - -	120
Carlsbad (Bohemia) - - -	165
Aix la Chapelle (Flanders) - -	143
Aix les Bains (Savoy) - - -	117
Leuk (in the Haut Valais)	117° to 126
Barèges (South of France) - -	120

For an account of the thermal waters in the Alps, see p. 555.

Height of some of the most remarkable Mountains and Hills in England and Wales.

	Feet.
Arbury Hill, Northamptonshire	804
Arran Fowddy, Merionethshire	2955
Arrenig, Merionethshire	2809
Axedge, Derbyshire	1751
Bagshot Heath, Surrey	463
Beacons, Brecknockshire	2862
Bardon Hill, Leicestershire	853
Beachy Head, Sussex	564
Black Down, Dorsetshire	817
Botley Hill, Surrey	880
Bow Fell, Cumberland	2911
Broadway Beacon, Gloucestershire	1086
Brown Clee Hill, Shropshire	1805
Cader Ferwyn, Merionethshire	2563
Cader Idris, Merionethshire	2914
Caermarthen Vau, Caermarthenshire	2596
Cam Fell, Yorkshire	2245
Capellante, Brecknockshire	2394
Carnedd David, Caernarvonshire	3427
Carnedd Llewellyn, Caernarvonshire	3469
Carraton Hill, Cornwall	1208
Cheviot, Northumberland	2658
Coniston Fell	2577
Cradle Mountain, Brecknockshire	2545
Cross Fell, Cumberland	2901
Crowborough Beacon, Sussex	804
Dichling Beacon, Sussex	858
Dover Castle, Kent	469
Dundry Beacon, Somersetshire	1668
Dunnose, Isle of Wight	792
Dwggan, near Builth, Brecknockshire	2071
Epwell Hill, Oxford	836
Fairlight Down, Sussex	599
Farley Down, near Bath, Gloucestershire	700
Firle Beacon, Sussex	820
Grasmere Fell, Cumberland	2756
Greenwich Observatory, Kent	214
Hampstead Heath, Middlesex	427
Hathersedge, Derbyshire	1377
Hedgehope, Northumberland	2347
Helvellyn, Cumberland	3055
Hensbarrow Beacon, Cornwall	1034
Highclere Beacon, Hampshire	900
High Pike, Cumberland	2101
Holme Moss, Derbyshire	1859
Holyhead Mountain, Anglesea	709
Ingleborough Hill, Yorkshire	2361
Inkpen Beacon, Hampshire	1011
Kit Hill, Cornwall	1067
Leith Hill, Surrey	993
Landinan Mountain, Montgomery	1898
Llangeinor Mountain, Glamorganshire	1859
Long Mount Forest, Shropshire	1674
Long Mountain, Montgomeryshire	1330
Lord's Seat, Derbyshire	1715
Malvern Hill, Worcestershire	1444
Moel Fammau, Denbighshire	1845
Nine Standards, Westmoreland	2136
Orpit Heights, Derbyshire	980
Pendle Hill, Lancashire	1803
Penmaen Maur, Caernarvonshire	1540
Pennigent Hill, Yorkshire	2270
Pillar, Cumberland	2893
Plynlimmon Mountain, Cardiganshire	2463
Radnor Forest, Radnorshire	2163
Rivel Mountain, Caernarvonshire	1866
Rivington Hill, Lancashire	1545
Rodney's Pillar (Base of), Montgomery	1199
Roseberry Topping, Yorkshire	1022
Rumbles Moor, Yorkshire	1308
Saddleback, Cumberland	2787
Sca Fell (High Point), Cumberland	3166
Shooter's Hill, Kent	446
Shunnor Fell, Yorkshire	2329
Skiddaw, Cumberland	3022
Snea Fell, Isle of Man	2004
Snowdon, Caernarvonshire	3571
Stow Hill, Herefordshire	1417
Stow-on-the-Wold, Gloucestershire	883
Tregarron Down, Cardiganshire	1747

	Feet.		Feet.
Wendover Down, Buckinghamshire	905	Whernside, in Kettlewell Dale, Yorkshire	2263
Whernside, in Ingleton Fells, Yorkshire	2384	White Horse Hill, Berkshire	893
		Wrekin, Shropshire	1320

Mountains in Scotland.

Of the height of the mountains in North Britain I believe there have not hitherto been any very accurate admeasurements taken. The following are some of the most considerable, with the heights as given by different writers: —

Arthur's Seat, Edinburgh	810	The most southern of the Paps of Jura	2359
Salisbury Craigs	550	Mount Battock, Kincardineshire	3450
Hartfell, Dumfries-shire (supposed by Mr. Jameson the highest in the south of Scotland)	2800 or 3304	Cairngorum	4050
Goatfield, Island of Arran	2945	Ben-Nevis, Inverness-shire	4380
Benlomond, Stirlingshire	3262	Macdui, in the Grampians, is stated, by late admeasurements, to be 60 feet higher than Ben-Nevis.	
Benlawers, Perthshire	4051		
Ben More, Perthshire	3870		
Schehallien	3281 or 3564		

Highest Mountains in the Pennine Alps.

Mont Blanc	15,534	Aiguille de Géant	13,984
Mont Cervin, or the Matterhorn	15,105	Aiguille d'Argentière	13,370
Monte Rosa	15,410	The Buet	10,112
		Dent du Midi	10,500

Highest Mountains in the Swiss Alps.

The Finsteraarhorn	14,307	The Eiger	12,520
The Jungfrau	13,185	The Monch Eiger	12,900
The Schreckhorn	12,872	The Wetterhorn	12,130

N.B. All these mountains are seen from the churchyard at Berne.

Highest Mountains in other Parts of Europe.

Northern Pyrenees	11,160	Loucyra, in Dauphiné	13,548
Mont Perdu, ditto	10,950	Mont Mézin, the Cevennes, in France	6700
Vigne Male, ditto	10,945	Mont d'Or, ditto	6180
Le Cylindre, ditto	10,880	Cantal, ditto	6150
Ætna, Sicily	10,590	Puy de Dôme, ditto	4750
Le Gran Sasso, in the Apennines	8455	Vesuvius, Naples	3900
Mont Velino, ditto	7860	Mount Athos, in Greece	6780

Very few mountains in Europe, north of the Alps, exceed the height of 6000 feet. Some of the mountains in the chain that separates Norway from Sweden rather exceed that height.

Lowest Line of Eternal Snow.

At the Equator	15,720	In Switzerland	8000
Latitude 20°	15,000	Latitude 65°	4800
——— 45°	8200		

Passages of the Alps which lead from Germany, Switzerland, and France, into Italy.

	Feet.		Feet.
Passage of Mont Cervin (only practicable on foot)	11,200	The Little St. Bernard	7200
Of the Furka	8300	Of St. Gothard	6780
The Grand St. Bernard	8150	Of Mont Cénis	6750
The Col de Ferret	7600	Of the Simplon	6610
		The Col de Tende	5880

Passages in the Pyrenees.

Port d'Or	9850	Port de Cavarnie	7650
Port Viel d'Estambé	8400	Passage de Tourmalet	7130
Port de Pinède	8200		

Passages in Switzerland.

The Wengen Alp	6750	The Sheideck to Meyringen	6500

Mountains in Asia.

The Himmalaya Mountains, in Thibet, are the highest at present known, except two in Upper Peru, which, according to Mr. Pentland, possess an equal altitude. According to Dr. Gerard, in the Valley of Sulei, among the Himmalaya Mountains, there is one village 14,700 feet above the level of the sea. These mountains are pastured by the Thibetian goat. Crops of rye are grown at the elevation of 14,900 feet.

Himmalaya Mountains, from	20,000 to 25,000	Lebanon	9500
Elbourz, in the chain of the Caucasus	18,500	Mount Sinai	5000 to 6000
		Several Islands in the Indian Ocean	10,000 to 13,000

Mountains of Africa.

The geography of Africa is too little known to afford any correct account of its mountains: those of Abyssinia have been estimated to be equal in height to the Alps, and the chain of Mount Atlas to equal the Pyrenees.

The Peak of Teneriffe - - 12,236 feet.

South America.

Chimborazo, Quito	22,700	*Sorate	25,400
Cotopaxi	20,320	Antisana, Peru	20,680
*Illimani	24,350	Pic d'Orizaba, Mexico	17,368

Some very lofty mountains rise on the western coast of North America; but few of the mountains in the Apalachian chain, or the Alleghany on the eastern side, rise 3000 feet above the level of the sea.

Highest habitable Parts of the Globe.

The Farm of Antisana, Peru	13,200	*Titiaco Lake	12,760
City of Micuipamha	11,850	*Post-house of a ti	14,402
City of Quito	9520	City of Mexico	7400
*City of Puno	12,830	Hospice of St. Gothard in the Swiss Alps	6790
*Potosi Town	13,350		
* —— Mines	16,080		

The mountains and towns marked * are situated in a chain of the Andes, in Upper Peru, interior to the great western chain, and distant from the Pacific 350 miles or more. The table land between the two chains is covered with crops of maize, barley, and wheat. In this table land is situated the Lake of Titiaca.

ON THE THERMAL WATERS OF THE ALPS.

This paper was published by the Author in the "Philosophical Magazine and Annals," January 1827; and a nearly similar account was given in his "Travels in the Tarentaise," in 1823. The thermal waters of the Alps had before been regarded as merely local and unconnected phenomena, scarcely deserving the notice of geologists.

When we approach a range of lofty mountains, like that of the Pennine Alps, and observe the calcareous strata on the outer part of the range bent and contorted in various directions; when we further observe beds of limestone and pudding-stone alternating and placed in an elevated position, as we advance to the central part of the range; and that the beds of granite in the central part are frequently vertical; we feel assured that their present contorted or vertical position, is not the original one. The opinions of geologists have been much divided respecting the cause or causes that have elevated mountains, and given a vertical position to beds that once formed the bottom of the ocean. Those who maintain that subterranean heat has expanded and broken the solid crust of the globe, and has raised from vast depths the ancient bed of the ocean, appeal to a cause that is known to exist, and which seems sufficient to explain most of the various appearances which Alpine regions present.

In opposition to this theory, it is asserted that there are no remaining vestiges of the action of subterranean fire in the Alps: but this I am convinced is erroneous. It is true that from near the source of the Rhone, to the foot of the Little St. Bernard, there does not occur any known rock of a volcanic character, with the doubtful exception of some rocks in the valley of Sass, and in the Valorsine. I have examined various parts of this range on the northern side of the highest mountains in the Alps, along a line of one hundred and twenty miles; and though I could discover no indications of the action of subterranean heat in the rocks themselves, I was greatly surprised to observe the numerous thermal springs that are abundantly gushing out at the feet of the primary mountains, near the junction of the mica-slate, or the dark schist passing into the mica-slate, with the lowest calcareous beds of that vast series of limestone strata, which forms the outer ranges of the

Alps. Numerous as these hot springs are on the northern side of the Alps, and not unfrequent on the southern side also, it appeared to me remarkable, that they had hitherto been regarded as isolated phenomena; and that their geological position had not been noticed. It is true, some of the warm springs in the Valais and in Savoy had been long known and visited, but the greater number has been discovered since Saussure published his *Voyages dans les Alpes;* and it appears probable, that they would every where be found near the junction of the primary and secondary rocks, were it not for *éboulements* that have covered them with a heap of ruins, or that torrents from the glaciers have mixed with them, and reduced their temperature. Since I visited Savoy in 1821 and 1822, another considerable warm spring has been discovered near the village of Chamouni, at the foot of a glacier; and in 1820 several thermal springs were discovered in that branch of the Alps which extends to Grenoble.

I shall here briefly enumerate the principal known thermal waters in the Pennine Alps, and add some observations and inferences, which I trust will be acceptable to several of your readers.

NATERS, *in the Haut Valais.*—The warm spring rises under a rock of mica-slate on the north side of the Rhone. The temperature when I visited the place was 86° Fahrenheit; but it is variable, from the intermixture with surface-water. At the time of the great earthquake at Lisbon, in 1755, the mountain above the spring, I was informed, opened, and threw out a considerable quantity of hot water.

LEUK, *in the Haut Valais,* — situated in a deep gorge on the northern side of the Rhone. There are twelve springs, varying in temperature from 117° to 126°. These springs have been long known, and are visited by patients from various parts of Europe.

THE VALLEY OF BAGNES, *in the Bas Valais.* — The warm springs in this valley were buried under a heap of débris from the fall of part of a mountain, which destroyed the baths, the village of Bagnes, and 120 inhabitants, in the year 1545. The name of the valley is obviously derived from the baths. The temperature of the water unknown.

CHAMOUNI.—The thermal waters at this place have been discovered since I visited Chamouni in 1821. I have received no account of the temperature; baths have recently been erected. The situation is near the junction of mica-slate, with the lowest beds of secondary limestone.

ST. GERVAISE,—situated on a deep gorge on the north-east side of Mont Blanc. The thermal water rises near the junction of mica-slate and limestone. The temperature 94° to 98°. This spring was discovered about the year 1806: it is very copious. Baths have lately been erected, and are much frequented.

Aix les Bains, *in Savoy;* — the temperature from 112° to 117°. The thermal waters rise in great abundance from two springs, situated at the foot of a lofty calcareous mountain, and are near the bottom of the great calcareous formation that forms the outer range of the Alps: there are also numerous hot springs in the vicinity, which the Sardinian government will not allow to be opened. Of the mode of douching at these baths, I have given a particular account in the first volume of my *Travels in Savoy, Switzerland, and Auvergne.* The thermal waters of Aix were well known to the Romans.

Moutiers, *in the Tarentaise.*—The thermal waters rise in great abundance from the bottom of a nearly perpendicular mass of limestone. From the position of this rock, and its connection with those on the opposite side of the valley, in which the hot springs rise, I have no doubt that it is the lowest calcareous bed in that part of the Alps; but its junction with mica or talcose slate is not here seen. The thermal waters of Moutiers, contain about two per cent. of saline matter, chiefly common salt. The process of extracting it, I have described in the *Philosophical Magazine*, vol. lxiii. p. 86.

Brida, *in the Tarentaise.*—The thermal waters of Brida were noticed in the ancient records of Savoy, but they were covered during a sudden inundation of the valley, and their situation was concealed for many years. In the summer of 1819, another inundation, occasioned by the breaking down of the side of the glacier, laid open the spring again. The rock from which the spring rises is a greenish talcose slate, passing into mica-slate: it is in junction with limestone. The temperature of the water is from 93° to 97° Fahrenheit. The geological position of this spring, is more obvious than that of any of the other thermal waters which I visited, being situated close to the steep bank of the river Doron, where both the rocks are laid bare. There are some warm springs on the opposite bank of the river, which rise in limestone; but the temperature is lower, owing to an intermixture with common water.

Saute de Pucelle, or *Virgin's Leap.*—There is a very copious thermal spring rising from the bottom of a perpendicular rock near the Isère, between the town of Moutiers and St. Maurice, at the foot of the Little St. Bernard; but, owing to the difficulty of access to it, I did not visit it, to ascertain its temperature.

Beside the above thermal waters in the Pennine Alps, various thermal springs were discovered in the adjacent Alps, near Grenoble, in the year 1820; and it seems probable, that a series of these springs might be found, were proper search made, extending westward to the thermal waters of the Pyrences; for in this line we should approach the southern border of the volcanic district of France. On the Italian side of the Pennine Alps there are also thermal waters: the warm baths of Cormayeur and of St. Didier are situated almost immediately under the southern escarpment of Mont Blanc. I was prevented by the weather, from examining the geological position of these springs: their temperature is stated to be 94° of Fahrenheit.*

The inference that may be drawn from the geological position of these thermal waters near the junction of the calcareous beds with mica-slate, or the dark schist which passes into mica-slate, is, that the waters do not rise from the upper strata, but spring out of the lower or primary rocks; and as they break out near the feet of the highest range of the Alps, that extend from the northern side of the Simplon through the Valais and Savoy into France, we may with much probability infer, that these mountains are situated over or near to one common source of heat, by the agency of which they were originally elevated, and their beds placed in a position nearly vertical. This inference is in some degree supported by the well-attested fact, that the districts where the hot springs are situated, are subject to great and frequent convulsions, particularly in the upper valley of the Rhone. In the year 1755, at Brieg, Naters, and Leuk, the ground was agitated by earthquakes every day from the 1st of November to the 27th of February; some of the shocks were so violent, that the steeples of the churches were thrown down, the walls split, and many houses rendered uninhabitable: many of the springs were dried up, and the waters of the Rhone were observed to boil. At three different times the inhabitants abandoned their houses, and fled for safety into the fields. It has been before mentioned, that the mountain above the warm spring at Naters, opened during the time of the great earth-

---

* Nearly all the thermal waters in the Alps, emit sulphureous vapours, and are slightly saline, except the waters of Leuk, which have the highest temperature, and are inodorous, and free from saline impregnation.

quake at Lisbon, and threw out hot water; at the same period the warm saline springs at Moutiers ceased to flow for forty-eight hours. When the water returned, the quantity was said to be increased, and the saline impregnation was weaker. Former and more formidable agitations of the earth are recorded in the Haut Valais, particularly in the district where the principal hot springs are situated. The last earthquake of consequence in the Valais took place in January, 1803.

I am informed that several of the retired valleys on the Italian side of the Alps, at the foot of the central chain, are subject to earthquakes, during which the ground has opened or sunk down in various parts, though these effects have been too local, to excite attention at a distance. From these facts, it seems as reasonable to infer that the thermal waters of the Alps owe their high temperature to subterranean fire, as that the hot springs in countries that have formerly been volcanic, derive their warmth from an internal, unextinguished, but quiescent, source of heat. No person who has attentively examined the lofty granitic plain to the west of Clermont Ferrand in France, and observed the granite in various parts pierced through by ancient volcanoes that have poured currents of lava over its surface, or seen other parts, where the granite itself has been changed by its contiguity to subterranean fire, or upheaved and intermixed with volcanic rocks; —no one, I say, who has observed this, can doubt that the hot springs of Mont d'Or and Vichy, derive their high temperature from a source of heat situated beneath the granite mountains, though ages have passed away since the volcanoes of that country have been in an active state, and the only proof of the present existence of subterranean fire in Auvergne, is to be found in the hot springs themselves. Nor can any adequate reason be assigned, for attributing the high temperature of the thermal waters in the Alps, to any other cause than to a source of subterranean fire under these mountains,— a cause which is sufficient also to have produced their original elevation. It is, however, proper to state, that in some of the mountains of the Alps, the temperature may be slightly increased by a cause hitherto unnoticed. In the upper part of the secondary formations covering the granite, there are beds of gypsum, and this gypsum is anhydrous; but when exposed to air and moisture, it combines with water, and passes to the state of common gypsum: during this combination we may suppose heat to be evolved; but the process must be extremely slow, and the heat evolved, must be totally inadequate to raise the temperature of powerful streams to 126°. Saussure found the temperature of the water in the lower part of the salt mines of Bex, which are situated in the vicinity of gypsum, to be four degrees of Reaumur higher than the mean temperature of the earth. It is not improbable, though Saussure was not aware of the circumstance, that this small increase of temperature in the mines of Bex, might be partly owing to the combination of water with gypsum: however, an increase of temperature, it is well known, is observed in deep mines, far removed from the gypsum formation.

In reply to what I have advanced respecting the thermal waters in the Pennine Alps, it may be said, that few thermal springs have been yet discovered in the northern range of the Alps which form the Bernese Oberland; but the difference in the geological structure of the two ranges will, I conceive, be sufficient to explain, why hot springs are more rare in the latter than in the southern range. Most of the highest mountains in the Bernese Alps are covered with secondary strata; and the valleys are chiefly excavated in these strata, or in enormous beds of sandstone and conglomerate, that form a thick intervening mass between the surface and the primary rocks, sufficient to obstruct the rise of thermal waters; for it has before been stated, that all the thermal waters in the Pennine Alps, issue from the primary rocks, or near their junction with the lowest calcareous strata.

ON THE TEMPERATURE OF MINES AND WELLS.

It was stated in Chap. XXIV. that the temperature of the water in Artesian wells (or those wells formed by boring) had been found in France to increase about 1° centigrade for 25 metres in depth. But this increase of temperature is sometimes variable in different situations. France has been the seat of active volcanoes at no remote geological epoch; and, in the volcanic districts, there are numerous hot springs remaining: it is, therefore, not improbable that, in the southern and central departments, the increase of temperature with the increase of depth in Artesian wells, may be derived from the remains of volcanic heat. In England, many borings for water have been executed; but I am not aware of any experiments having been made on the water to ascertain the temperature. At Boston, in Lincolnshire, water was bored for to the extraordinary depth of 600 feet: the boring, during the whole depth, was in clay; and the experiment was unsuccessful, no good water being obtained. It is to be regretted that the temperature of the water at that depth had not been ascertained.

Many experiments have been made on the temperature both of the air, the water, and the rocks in mines, at different depths; and the general results of each have indicated a considerable increase of heat with the increase of depth. In Dolcoath copper mine, Mr. Fox found the temperature of the water (at about 480 yards from the surface) to be more than 30° of Fahrenheit above the mean temperature of the country. A thermometer, plunged into the earthy matter, at the bottom of another mine in the same county, 400 yards deep, and which had been inundated for two days, was raised 38° above the mean temperature. I apprehend that in these instances, and in many others that have been stated, one source of error has not been sufficiently attended to, viz. the increase of heat by chemical changes that are taking place in the mineral substances in mines, from access to water or the atmosphere. I was informed by working miners in Cornwall, that they could generally tell when they were approaching to a copper lode, by the increased warmth of the water; but this was not the case when they came to a lode of tin ore. The cause of this warmth seems very intelligible: the copper ore of Cornwall is chiefly a mixture of iron pyrites and copper pyrites; and it is well known that iron pyrites is more or less decomposed by the access of air and water, and that heat is evolved; but this is not the case with tin stone or oxide of tin.

In the preceding article, I have pointed out a probable cause of the increase of temperature in the waters of the salt mines at Bex, in Switzerland, which had not before been noticed.

On the whole, however, making every allowance for errors from various causes, the evidence for a considerable increase of heat with the increase of depth in mines appears to be established, though the amount of that increase remains to be ascertained.

Humboldt states that, from observations made in mines and caves in every zone, it is proved that the heat of the earth is much greater than the mean temperature of the atmosphere at the same places.

ON THE SURFACE OF THE MOON.

Geologists have not hitherto regarded with due attention the physical structure of the moon: it is the only planetary body placed sufficiently near us, to have the inequalities of its surface rendered distinctly visible with the telescope. Attendant on the earth, and having the same quantity of solar light, and nearly the same density, we may reasonably infer that the mineral substances of which it is composed do not differ essentially from those on the surface of our own planet. Astronomers now generally admit that the moon is surrounded with a very clear atmosphere; but which is so low, that it scarcely occasions a sensible refraction of the rays of light when it passes over the fixed stars. Many of the dark parts of the moon, particularly the part called *Mare Crisium*, appear to be covered with a fluid, which may probably be more transparent and less dense than water, as the form of the rocks and craters beneath it are seen, but not so distinctly as in the lighter parts of the moon's surface. To examine the moon with a reference to its external structure, the defining power of the telescope should be of the first quality, sufficient to show the projections of the outer illuminated limb as distinctly as they appear when the moon is passing over the disk of the sun, during a solar eclipse. With such a telescope, and a sufficient degree of light and of magnifying power, almost every part of the moon's surface appears volcanic, containing craters of enormous magnitude and vast depth: the shelving rocks, and the different internal ridges within them, mark the stations at which the lava has stood and formed a floor during different eruptions; while the volcanic cones in some of the craters resemble those formed within the craters of modern volcanoes.

The largest volcanic mountain on the southern limb of the moon (called by some astronomers Tycho, and by others Mount Sinai), like the largest volcanic mountain on the earth, Chimborazo, and like Mont d'Or and the Puy de Dôme in Auvergne, has no deep crater on its summit. There are, indeed, the outlines of the crater, but it is nearly filled up; while, from the foot of this lunar mountain, diverging streams of lava flow in different directions, to the distance of six hundred miles. The largest currents of lava, from lofty volcanoes on the earth, generally issue from their flanks. The longest known current of modern lava is in Iceland — it extends sixty miles; but the volcanoes in that island bear no proportion to the magnitude of the lunar volcanoes.

Geologists who are reluctant to admit the extensive agency of fire on the surface of the terrestrial globe, would have their difficulties removed, were they to study attentively the surface of the moon with a powerful telescope; for there we see the entire hemisphere of a planetary body subjected to the agency of volcanic fire.

Since my return from the extinct volcanoes of Auvergne, I have frequently amused myself in comparing the structure of parts of the moon's surface with that of the volcanic districts in central France; and I could scarcely avoid the conclusion, that the summits of many volcanic mountains in the moon, which reflect so much more light than the other parts, are, like those in Auvergne, composed of rocks analogous to white pumice or trachyte. I have suggested these hints to direct the attention of geologists and astronomers to our attendant planet. *Is it inhabited? Is it passing to a habitable state? or does it present the ruins of a former habitable globe, torn by the powerful agency of volcanic fire?* Its appearance seems most to agree with the latter condition. Perhaps the perfection to which telescopes are advancing on the Continent may enable astronomers, at no distant period, to answer these questions.

ORBICULAR PORPHYRY AND ORBICULAR GRANITE OF CORSICA.

THESE are two of the most rare and beautiful rocks; but little is known respecting their relation with other rocks in that island. According to specimens of considerable size, which I have before me, this porphyry is composed of compact felspar, varying in colour from a greenish to a reddish brown. The globules vary in diameter from one third of an inch to three inches. The most perfectly formed globules have a small globule in the centre of each, from which ranges of minute globules diverge, giving to the large globules the appearance of a radiated diverging structure, more or less regular. In the smaller globules there are concentric circles, which disappear in the larger ones, except near their superficies. The paste in which these globules are imbedded contains also minute globules of lighter-coloured felspar, variously arranged. The larger globules are some of them elongated, as if they had been in fusion. The experiments of Mr. G. Watt on basalt (see page 213.) elucidate the formation of orbicular porphyry.

The globular structure was probably developed during the semiliquefaction of the mass, which formed globules, instead of perfect crystals, as in common porphyry. The globules in the Corsican porphyry can be easily detached from the mass. Common porphyry, in which the imbedded felspar occurs in rounded spots, is called Variolite.

The orbicular granite of Corsica is better known in this country: it is a finely granitic rock, composed of white felspar and blackish green hornblende, with grains of quartz. In this rock are numerous globules composed of concentric coats of hornblende and felspar, varying in diameter from one inch to three or four inches. In the centre of each globule there is a particle of hornblende. The globules appear intimately united with the rock in which they are imbedded, and cannot be detached from it. The orbicular granite takes a more even polish than the porphyry, and is one of the most beautiful granitic rocks.

ON FRESHWATER FORMATIONS.

Dr. Macculloch has claimed the merit of being the first writer who directed the attention of geologists to the circumstance, that some species of marine animals can live when removed into fresh water. But, in the second edition of this work, published in 1815 (p. 461. and 462.), I stated my opinion that the evidence of certain species of shells being marine, or freshwater, rested on too slight a foundation; and that I was informed by Mr. Leckie of a circumstance which proved that marine animals have greater facilities of adaptation than naturalists generally suppose.

"The lake of Lentini in Sicily is stocked with a sea fish called the Cefalo — a species of mullet caught in the Mediterranean, and thrown into the fresh water of the lake, where they not only live, but increase greatly in size and improve in flavour, and are a considerable article of luxury in the island. This lake has no communication with the sea, and is chiefly filled with rain water."

The evidence of certain geological formations being marine or freshwater cannot rest securely upon the occurrence of a few species of marine or freshwater shells, but on the general character of the assemblage of organic remains. If shells belonging to species or genera that are known at present as inhabitants of rivers or lakes, occur with abundant remains of terrestrial animals and vegetables in particular strata, and no marine species are mixed with them, we can have little doubt that such strata were deposited in fresh water: nor would the freshwater origin of the strata be invalidated by the admixture of a few individuals of marine species; because we might with probability infer, either that the animals were capable of living in fresh water, or that they had been drifted by high tides or inundations. The character of the formation must be taken, as before mentioned, from that of the assemblage of organic remains.

FURTHER OBSERVATIONS ON THE INTERMIXTURE OF HUMAN BONES WITH THOSE OF BEARS, IN THE CAVERN OF MIALLET.

The remarkable intermixture of human bones with those of bears, in the cavern of Miallet, in the department of Gard (see p. 450.), has received further elucidation by a subsequent examination of M. Tessier, of which an account was read to the Geological Society of France, November, 1831. The opening of the cavern is situated on the steep declivity of a rock of magnesian limestone, subordinate to lias; it is about 27 feet in height, and 13 feet in breadth. The floor of the cavern, at some distance from the entrance, rises so rapidly to the roof, that it is difficult to stand upon it. The soil is composed of dolomitic sand, more or less intermixed with a greasy mud, and covered in some parts with stalagmite. About 170 feet from the entrance, on the lower part of the ascending floor, under a bed of sandy mud from eight to sixteen inches thick, human bones are found in abundance: they are very fragile and light, and intermixed with fragments of pottery. The grotto divides into several low tunnels (*boyaux*). M. Tessier crawled along some of these descending tunnels, and found numerous bones of bears intermixed with those of men and infants, among dolomitic sand. But the most remarkable circumstance he mentions is, that bones of bears are incrusted with mud, and attached to the roof of the cavern. This proves that the cavern had been filled with bone mud (*limon à ossemens*) by the violent action of water, otherwise the bones of bears that inhabited the cavern would all have been found at the bottom. It is most probable that the cavern was originally inhabited by bears, and afterwards inundated by mud and water; that, at a later epoch, it became the residence or sepulchre of a rude people; but was subjected to a second inundation, which drifted the bones of bears and men into the distant low passages. At a still later period, the cavern had been occasionally used for a sepulchre by the Romans, as a skeleton, with a lamp and bracelets, were discovered on the surface of the floor. M. Tessier says, that the river Gardon, before it had excavated its present deep bed, might have occasionally caused great inundations, which filled the cavern with water. Whatever theory may be adopted respecting the former inhabitants of the cavern of Miallet, the bones attached to the roof prove the agency of water, and sufficiently explain the cause by which the remains of bears and men may have been intermixed.

GLOSSARY.

Some fossils are named in the present volume without any explanation: it has, therefore, been thought desirable, for the benefit of the geological student, to annex a glossary, stating the division or class of animals to which they belong.

The letters P. O. imply that there is a description in the Preliminary Observations; M. L. and T. L. stand for Mountain or Transition Limestone; L. Lias; Oo. Oolite; G. s. Green sand; Ch. Chalk; Tr. Transition; Sec. Secondary; Ter. Tertiary; Rec. Recent; Fos. Fossil.

Alcyonites, fossil alcyonia. Zoophytes nearly allied to sponges, the production or habitation of polypi. Rec. and Fos.

Ammonite. See P. O. Sec.

Ananchytes, a helmet-shaped echinus. Fos. Ch.

Anomia, a bivalve with one valve perforated.

Baculite. See P. O. Fos.

Belemnite. See P. O. Fos. Sec.

Buccinum. See P. O. Rec. and Fos.

Caryophyllia, a branched madrepore with a star at the end of each branch; each star has a mouth and tentacula. M. L. Fos.

Cerithium, a univalve turriculated shell. Ter.

Crinoidea, lily-shaped encrinites.

Dudley fossil, trilobite. Plate 5. Tr.

Echinite fossil, various species. Sec.

Echinus, sea urchin.

Encrinite. See P. O. Tr. and Sec.

Entrochite. See P. O. M. L.

Euomphalus, univalve unchambered shell, involute and compressed. M. L.

Fusus, a spindle-shaped univalve.

Gryphea arcuata, or gryphite, a deeply-curved bivalve shell with a flat lid. L.

G. dilatata, the sides more expanded. Oo. Some species of Gryphea are still living.

Hamite. See P. O. G. s.

Helix, shells of the snail family, terrestrial and aquatic.

Hippurite. See P. O. Ch.

Ianthina. See P. O. Rec.

Inoceramus, a bivalve with an oblique beak. Ch.

Lily encrinite. See p. 240.

Lymnea, a freshwater univalve, Rec. and Fos.: the shells sometimes called Lymnites. Ter.

Madrepores, stony polypi, with concentric lamellæ, resembling stars. In a living state, the stony matter is covered with a skin of living gelatinous matter, fringed with little bunches of tentacula: these are the polypi: the skin and the polypi contract on the slightest touch. — *Cuvier.* Madrepores are sometimes united and sometimes detached: where the laminæ take a serpentine direction, they are called

Meandrina, or brain stone.

Nautilus. See P. O. Rec. and Fos.

Nummulite. See P. O. Fos. Ter.

Orthoceratite. See P. O.

Paludina, a freshwater univalve, nearly resembling the shell of a snail. Wealden.

Patella, the limpet shell. Rec. and Fos.

Pectunculus, an orbicular bivalve. Sec. and Ter.

Planorbis, a discoidal univalve freshwater shell, nearly resembling an ammonite, but without chambers. Ter.

Productus, a nearly semiglobular bivalve, the lid nearly flat. M. L.

Scaphite. See P. O. G. s.

Septaria, stones divided into cells or partitions, common in argillaceous strata; sometimes the cells are empty.

Spatangus, a species of fossil echinus. Ch.

Spirula. See P. O.*

Sponges, living and fossil. The flints in chalk are frequently silicified remains of sponges.

Terebratula, a bivalve with an advanced and curved beak, which is perforated. Numerous species. Rec. and Fos.

Trilobite, a crustaceous fossil animal. See Plate 5. T. L.

Turrilite. See P. O. G. s.

Vegetable fossils. See Chap. II.

---

* In addition to the description of the Spirula in the Preliminary Observations, it may be proper to notice, that, according to Lamarck, the animal, beside the eight arms of the sepia (see fig. 1. plate 8.), has two longer arms or feelers : in this respect it resembles the Calmar, which is common on the coasts of Europe.

INDEX.

THE END.

London:
Printed by A. & R. Spottiswoode,
New-Street-Square.

ERRATUM.

Page 188. line 6. above the note, for “ofter” read “often.’

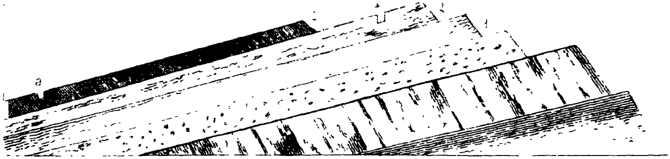


Fig 3

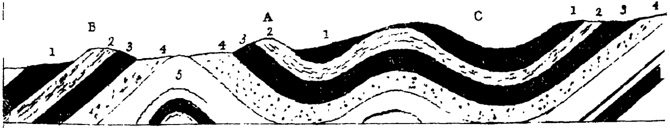


Fig 4

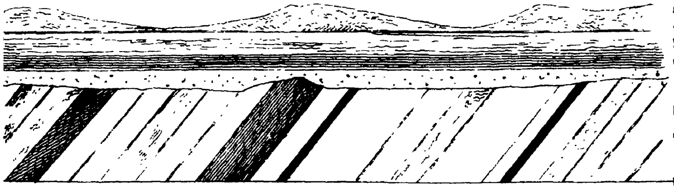


Fig 5

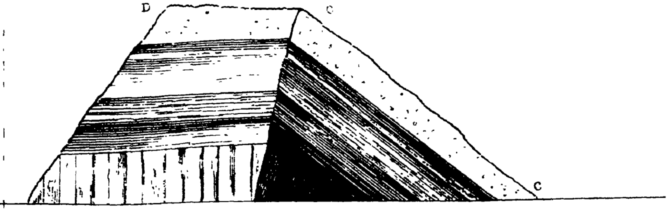
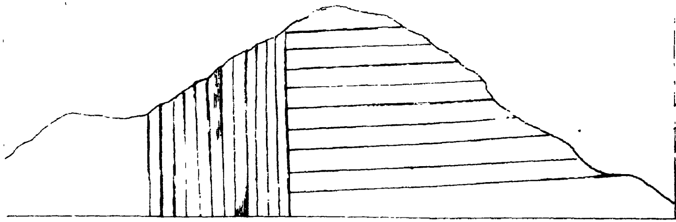


Fig 6



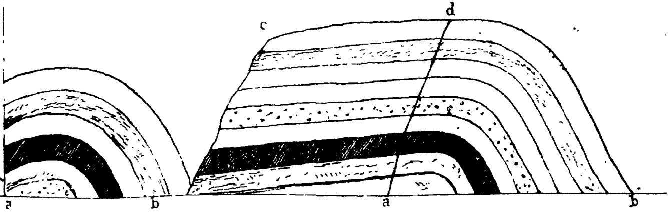


Fig 1

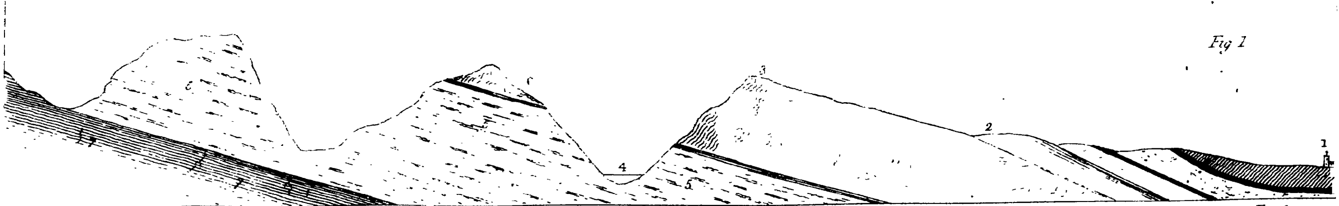


Fig 2

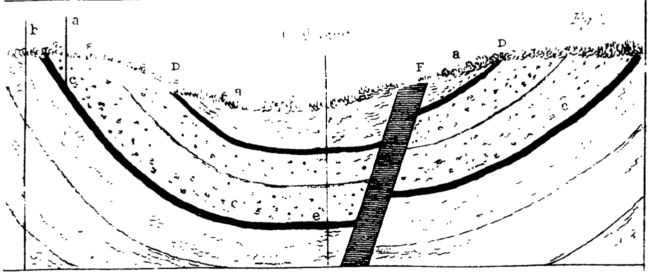


Fig 3

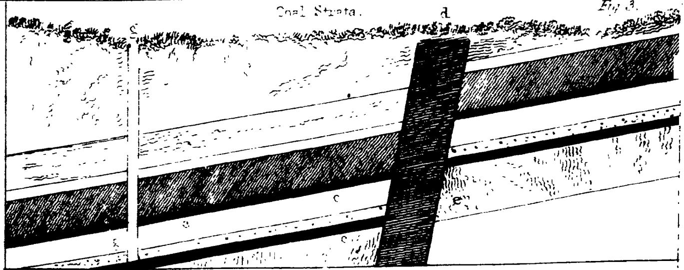


Fig 4

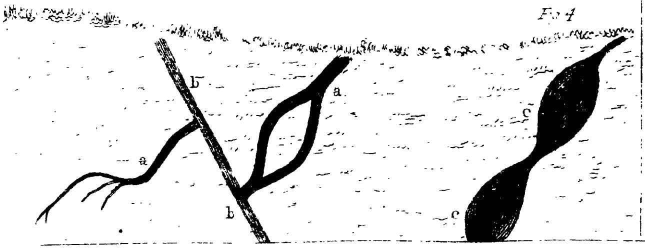


Fig 5

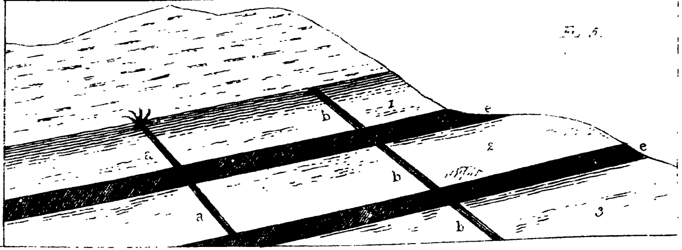


Fig. 1.

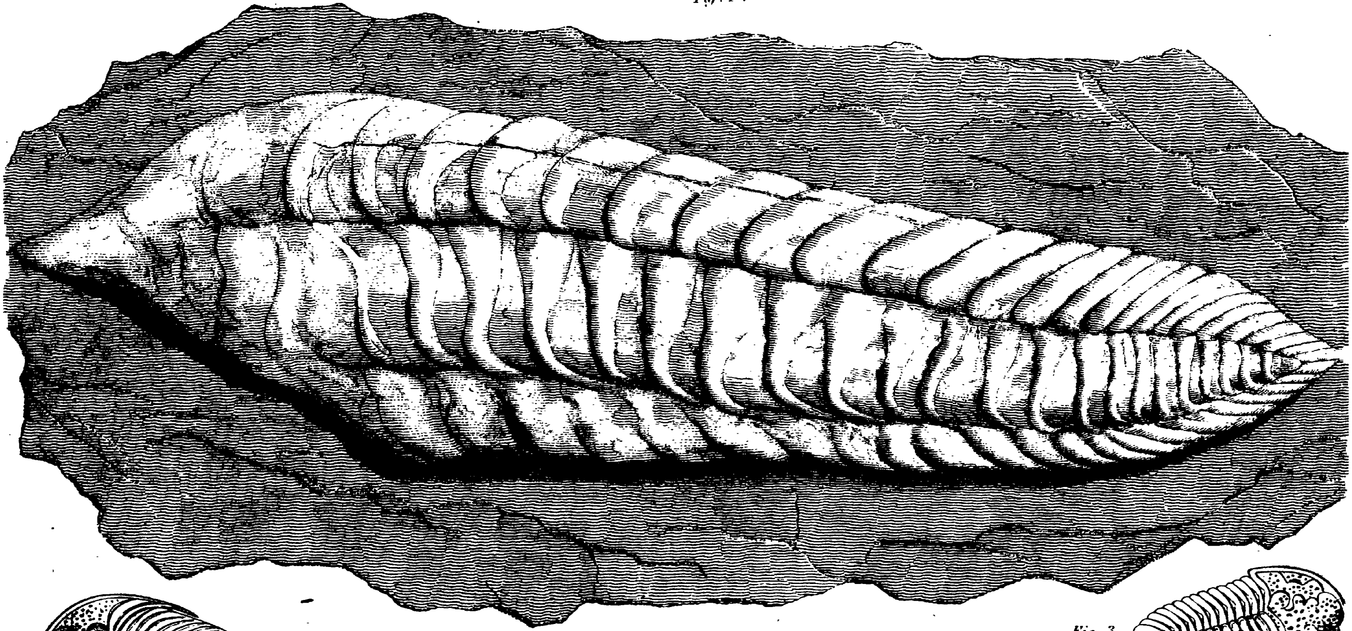
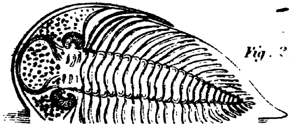


Fig. 2.



THE GIGANTIC TRILOBITE,
drawn the natural Size from a specimen in the Authors Collection.

Fig. 3.