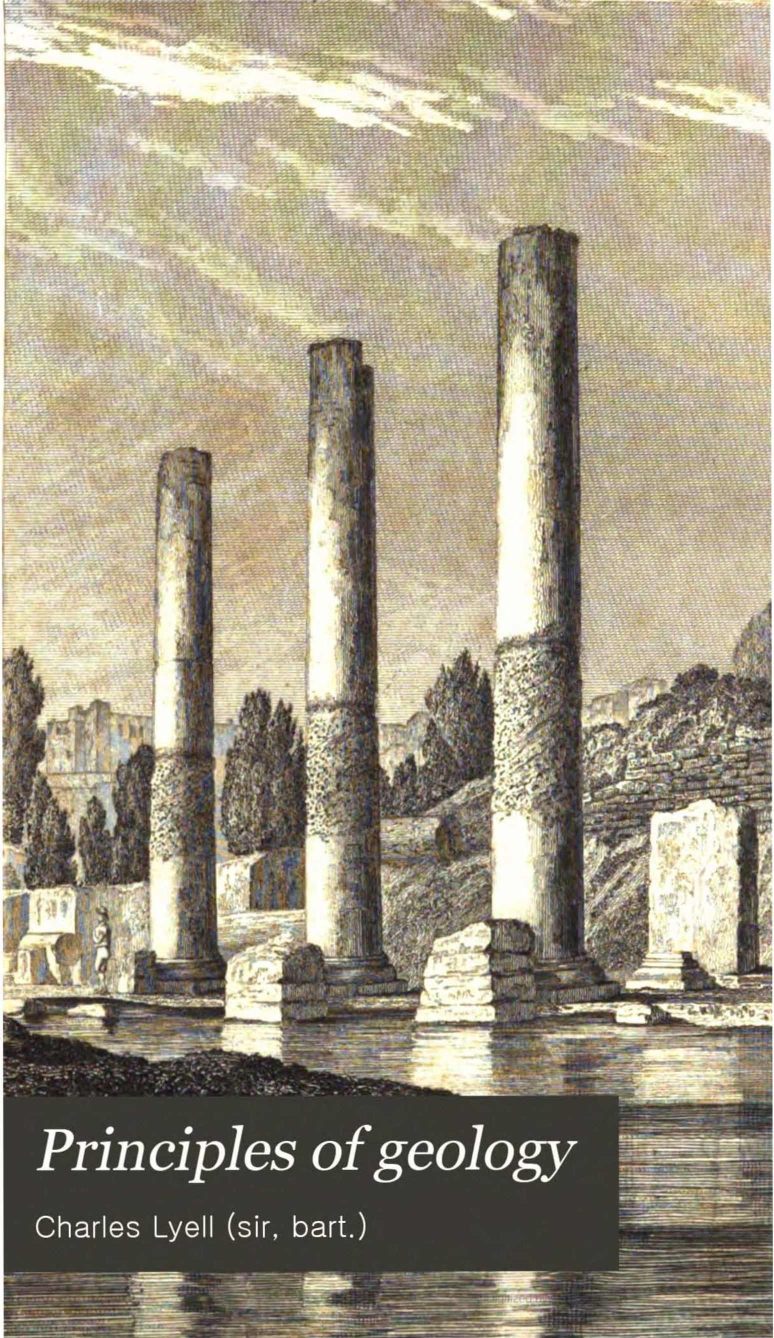

Principles of geology

Charles Lyell (sir, bart.)

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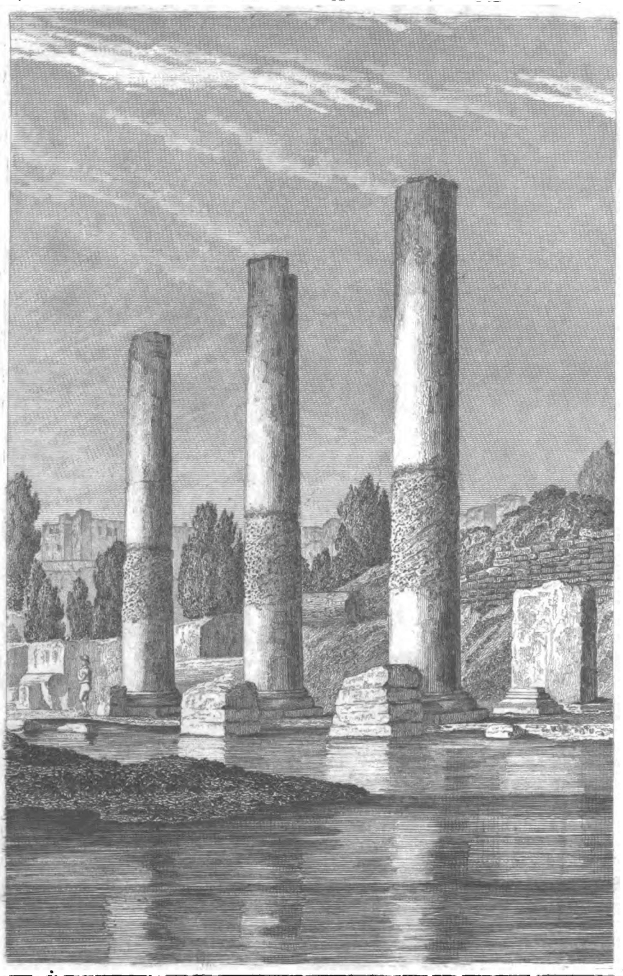

Present state of the Temple of Serapis at Puzzuoli.

London. Published by John Murray, Albemarle Street. April 1834.

PRINCIPLES

OF

GEOLOGY:

BEING

AN INQUIRY HOW FAR THE FORMER CHANGES OF THE EARTH'S SURFACE

ARE REFERABLE TO CAUSES NOW IN OPERATION.

BY

CHARLES LYELL, Esq. F.R.S.

PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON.

"Amid all the revolutions of the globe, the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

PLAYFAIR, *Illustrations of the Huttonian Theory*, § 374.

IN FOUR VOLUMES.

VOL. I.

THE FOURTH EDITION.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1835.

LONDON:
Printed by A. SPOTTISWOODE,
New-Street-Square.

PREFACE.

In the Preface to the last Edition, I gave a list of the places where new matter had been introduced, or where opinions expressed in former Editions had been modified or renounced. I shall now again subjoin a similar list for the sake of those readers who have already studied this work, but who may wish to refer at once to the additions and corrections now made for the first time.

List of the principal Alterations, Additions, and Omissions in the Fourth Edition.

On former occasions I have acknowledged the valuable assistance afforded me by several of my friends in the execution of this work, and have especially alluded to the zealous co-operation of Mr. Murchison, Mr. Broderip, Dr. Fitton, and Mr. Lonsdale. I have now to express my thanks to Capt. Basil Hall for the improvements which he has suggested in the present edition, and for his having visited, at my request, several places in Italy and Sicily, with a view of obtaining for me more exact information on points on which I had entertained doubts.

The original MS. of the Principles of Geology was delivered to the publisher in 1827; but the greater portion of it was then in an unfinished state, the chapters on the early history of Geology and those on "the Inorganic Causes of Change," being the only ones then nearly ready for the press. The work was at that time intended to form two octavo volumes, which were to appear in the course of the year following. Their publication, however, was delayed by various geological tours which I made in the years 1828, 1829, 1830, and 1831, in France, Italy, Sicily, and Germany. The following were the dates when the successive volumes and editions finally appeared:—

1st Vol. in octavo	- -	Jan. 1830.
2d Vol. do.	- -	Jan. 1832.
1st Vol. 2d ed. in octavo	-	1832.
2d Vol. 2d ed. do.	-	Jan. 1833.
3d Vol. 1st ed. do.	-	May, 1833.
New edition of the whole work in 4 vols. 12mo.	-	May, 1834.

Before the spring of 1828 I had been at various times occupied in the inquiry how far it might be possible to explain geological phenomena by reference to changes now going on in the globe; and I had previously made geological tours both in England and France, in company with Professor C. Prevost of Paris, a writer well known to have laboured successfully in the same field of investigation. I had also examined, before I drew up the first outline of my work, the geology of part of Hampshire and Forfarshire, and had given some account of my observations to the Geological Society of London. During the early part of 1827, I was engaged in preparing for publication an article on "Scrope's Geology of Central France," which appeared in the Quarterly Review in the October of that year. I was then led to reflect much on the extent to which one class of geological phenomena, namely, those relating to the igneous rocks, might be solved by the study of the operations of active volcanos. It is but justice to preceding authors to state that the chapters which now appear in my fourth book on Auvergne, Cantal, Velay, and the Vivarais, were in great part written as they now stand before I had visited Central France; so well had I become acquainted with the scenery of those regions of extinct volcanos by studying the beautiful panoramic views which illustrate Mr. Scrope's work, and by reading his graphic descriptions of the country, and those borrowed by him from Montlosier. It will be found also that the speculations in which I have indulged in the article above referred to in the Quarterly Review are in unison with the opinions I now hold.

I have alluded more particularly in the text to the co-operation of several geologists and naturalists who contributed towards the perfecting of different parts of my work, and have mentioned the principal additions which I made subsequently to the spring of 1828. I shall now merely add, that the 3rd book, on the "Changes of the Organic World," which consisted in the original MS. merely of four or five short chapters, was expanded in 1831 into a treatise occupying the 2d volume of my first edition.

Glossary.—Being informed by several readers of my third edition, that they only discovered the Glossary when they arrived at the last volume, I have in this instance appended it to the end of the first volume, in order that it may be conveniently referred to by those who are beginning the work.

If any person, in studying the Principles of Geology, should be lost in the digressions on collateral subjects which are introduced here and there, especially those relating to natural history in the third book, and should be unable to see the bearing of these on the topics which are more strictly geological, they are invited to refer from time to time to the annexed Summary, and to consult in connexion with it the abridged Table of Contents which follows at p. xv.

SUMMARY

OF THE

PRINCIPLES OF GEOLOGY.

After some observations on the nature and objects of Geology (Chap. I. Vol. I.), a sketch is given of the progress of opinion in this science, from the times of the earliest known writers to our own days (Chaps. II. III. IV.). From this historical sketch it appears that the first cultivators of geology indulged in many visionary theories, the errors of which the author refers chiefly to one common source, — a prevailing persuasion that the ancient causes of change were different, both as regards their nature and energy to those now in action; in other words, they supposed that the causes by which the crust of the earth, and its habitable surface, have been modified at remote periods, were almost entirely distinct from the operations by which the surface and crust of the planet are now undergoing a gradual change. The prejudices which led to this assumed discordance of ancient and modern causes are then considered (Chap. V. to p. 122. Vol. I.), and the author contends, that neither the imagined universality of certain sedimentary formations (Chap. V.), nor the different climates which formerly pervaded the northern hemisphere (Chaps. VI. VII. VIII.), nor the alleged progressive development of organic life (Chap. IX.), lend any solid support to the assumption.

The numerous topics of general interest brought under review in discussing this fundamental question are freely enlarged upon, in the hope of stimulating the curiosity of the reader. It is presumed that when he has convinced himself, that the forces formerly employed to remodel the crust of the earth were the same in kind and energy as those now acting, or even if he perceives that the opposite hypothesis is, at least, questionable, he will enter upon the study of the two treatises which follow (on the Changes now in progress in the Organic and Inorganic World, Books II. and III.) with a just sense of the importance of their subject matter, and its direct bearing on Geology.

The first of these treatises, which relates to the changes of the inorganic creation, such as are known to have taken place within the historical era, is divided into two parts. In the first an account is given of the observed effects of aqueous causes, such as rivers, springs, tides, and currents (Book II. Chaps. I. to VIII.); in the second the effects and probable causes of the volcano and earthquake, and all subterranean movements, are considered (Book II. Chaps. IX. to XIX.).

The treatise on the changes of the organic world is also divisible into two parts; the first of which comprehends all questions relating to the variability of species, and the limits assigned to their duration (Chaps. I. to XI.). The second explains the processes by which the remains of animals and plants existing at any particular period may be preserved, or become fossil (Chaps. XII. to XVII.).

Under the first of these divisions, the author defines the term *species*, and combats the notion that one species may be gradually converted into another by insensible modifications in the course of ages (Chaps. I. II. III. and IV.). He also enters into a full examination of the evidence regarded by him as conclusive in favour of the limited durability of species. In proof of this, he argues that the geographical distribution of species being partial, the changes constantly going on in the animate and inanimate world must constantly tend to their extinction (Chaps. V. to X.). Whether new species are substituted for those which die out, is a topic on which no decided opinion is offered; but it is contended that if new species had been introduced from time to time as often as others have been lost, we should have no reason to expect to be able to establish the fact during the limited period of our observation (Chap. XI.).

In the second branch of this treatise, the various circumstances under which aquatic and terrestrial plants and animals, as also man and the works of his hands, become fossil, are examined (Chaps. XIII. to XVII.).

The fourth book is occupied with the description of geological monuments strictly so called, the formations termed tertiary being first more fully examined and classified, the secondary and primary rocks being afterwards more briefly alluded to. In the course of this description, it appears that the rocks which compose the crust of the earth have resulted in part from igneous and partly from aqueous causes; others from the combined influence of these agents, the igneous having operated both upon and far beneath the surface. The bearing of the various phenomena considered in the second book on the interpretation of such monuments cannot fail to be seen.

It is, moreover, shown, that the fossil remains of plants and animals are plentifully included in aqueous rocks of different ages, and that these belong for the most part to species which no longer exist on the earth. It is principally by the aid of such fossils, that the chronological arrangement of rocks is determined; and a careful comparison of the numerous organic remains of the tertiary formations affords some indication of a gradual introduction of the species now living, and a successive extinction of species which previously existed. It is at least clear that during the tertiary epoch entire assemblages of species were not simultaneously swept away from large regions, and others perfectly distinct created in their place. The intimate connection of these phenomena with the subjects investigated in the third book, is sufficiently obvious.

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PRINCIPLES OF GEOLOGY.

BOOK I.

CHAPTER I.

Geology defined — Compared to History — Its relation to other Physical Sciences — Not to be confounded with Cosmogony.

Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature: it inquires into the causes of these changes, and the influence which they have exerted in modifying the surface and external structure of our planet.

By these researches into the state of the earth and its inhabitants at former periods, we acquire a more perfect knowledge of its present condition, and more comprehensive views concerning the laws now governing its animate and inanimate productions. When we study history, we obtain a more profound insight into human nature, by instituting a comparison between the present and former states of society. We trace the long series of events which have gradually led to the actual posture of affairs; and by connecting effects with their causes, we are enabled to classify and retain in the memory a multitude of complicated relations—the various peculiarities of national character — the different degrees of moral and intellectual refinement, and numerous other circumstances, which, without historical associations, would be uninteresting or imperfectly understood. As the present condition of nations is the result of many antecedent changes, some extremely remote and others recent, some gradual, others sudden and violent, so the state of the natural world is the result of a long succession of events; and if we would enlarge our experience of the present economy of nature, we must investigate the effects of her operations in former epochs.

We often discover with surprise, on looking back into the chronicles of nations, how the fortune of some battle has influenced the fate of millions of our contemporaries, when it has long been forgotten by the mass of the population. With this remote event we may find inseparably connected the geographical boundaries of a great state, the language now spoken by the inhabitants, their peculiar manners, laws, and religious opinions. But far more astonishing and unexpected are the connections brought to light, when we carry back our researches into the history of nature. The form of a coast, the configuration of the interior of a country, the existence and extent of lakes, valleys, and mountains, can often be traced to the former prevalence of earthquakes and volcanos in regions which have long been undisturbed. To these remote convulsions the present fertility of some districts, the sterile character of others, the elevation of land above the sea, the climate, and various peculiarities, may be distinctly referred. On the other hand, many distinguishing features of the surface may often be ascribed to the operation at a remote era of slow and tranquil causes — to the gradual deposition of sediment in a lake or in the ocean, or to the prolific increase of testacea and corals.

To select another example, we find in certain localities subterranean deposits of coal, consisting of vegetable matter, formerly drifted into seas and lakes. These seas and lakes have since been filled up, the lands whereon the forests grew have disappeared or changed their form, the rivers and currents which floated the vegetable masses can no longer be traced, and the plants belonged to species which for ages have passed away from the surface of our planet. Yet the commercial prosperity, and numerical strength of a nation, may now be mainly dependent on the local distribution of fuel determined by that ancient state of things.

Geology is intimately related to almost all the physical sciences, as history is to the moral. An historian should, if possible, be at once profoundly acquainted with ethics, politics, jurisprudence, the military art, theology; in a word, with all branches of knowledge, by which any insight into human affairs, or into the moral and intellectual nature of man, can be obtained. It would be no less desirable that a geologist should be well versed in chemistry, natural philosophy, mineralogy, zoology, comparative anatomy, botany; in short, in every science relating to organic and inorganic nature. With these accomplishments, the historian and geologist would rarely fail to draw correct and philosophical conclusions from the various monuments transmitted to them of former occurrences. They would know to what combination of causes analogous effects were referrible, and they would often be enabled to supply, by inference, information concerning many events unrecorded in the defective archives of former ages. But as such extensive acquisitions are scarcely within the reach of any individual, it is necessary that men who have devoted their lives to different departments should unite their efforts; and as the historian receives assistance from the antiquary, and from those who have cultivated different branches of moral and political science, so the geologist should avail himself of the aid of many naturalists, and particularly of those who have studied the fossil remains of lost species of animals and plants.

The analogy, however, of the monuments consulted in geology, and those available in history, extends no farther than to one class of historical monuments, — those which may be said to be *undesignedly* commemorative of former events. The canoes, for example, and stone hatchets found in our peat bogs afford an insight into the rude arts and manners of the earliest inhabitants of our island: the buried coin fixes the date of the reign of some Roman emperor; the ancient encampment indicates the districts once occupied by invading armies, and the former method of constructing military defences: the Egyptian mummies throw light on the art of embalming, the rites of sepulture, or the average stature of the human race in ancient Egypt. This class of memorials yields to no other in authenticity, but it constitutes a small part only of the resources on which the historian relies, whereas in geology it forms the only kind of evidence which is at our command. For this reason we must not expect to obtain a full and connected account of any series of events beyond the reach of history. But the testimony of geological monuments, if frequently imperfect, possesses at least the advantage of being free from all suspicion of misrepresentation. We may be deceived in the inferences which we draw, in the same manner as we often mistake the nature and import of phenomena observed in the daily course of nature, but our liability to err is confined to the interpretation, and, if this be correct, our information is certain.

It was long before the distinct nature and legitimate objects of geology were fully recognized, and it was at first confounded with many other branches of inquiry, just as the limits of history, poetry, and mythology were ill-defined in the infancy of civilization. Even in Werner's time, geology appears to have been regarded as little other than a subordinate department of mineralogy; and Desmarest included it under the head of Physical Geography. But the most common and serious source of confusion arose from the notion that it was the business of geology to discover the mode in which the present system of things originated, or, as some imagined, to study the effects of those cosmological causes which were employed by the Author of Nature to bring this planet out of a nascent and chaotic state into a more perfect and habitable condition. Hutton was the first who endeavoured to draw a strong line of demarcation between his favourite science and cosmogony, for he declared that geology was in nowise concerned "with questions as to the origin of things."

An attempt will be made in the sequel of this work to demonstrate that geology differs as widely from cosmogony, as speculations concerning the mode of the first creation of man differ from history. But, before entering more at large on this controverted question, it will be desirable to trace the progress of opinion on this topic, from the earliest ages to the commencement of the present century.

CHAPTER II.

HISTORICAL SKETCH OF THE PROGRESS OF GEOLOGY.

Oriental Cosmogony — Doctrine of the successive destruction and renovation of the world — Origin of this doctrine — Common to the Egyptians (p. 12.) — Adopted by the Greeks — System of Pythagoras — of Aristotle (p. 19.) — Dogmas concerning the extinction and reproduction of genera and species —Strabo's theory of elevation by earthquakes (p. 23.) — Pliny — Concluding Remarks on the knowledge of the Ancients.

Oriental Cosmogony.— The earliest doctrines of the Indian and Egyptian schools of philosophy agreed in ascribing the first creation of the world to an omnipotent and infinite Being. They concurred also in representing this Being, who had existed from all eternity, as having repeatedly destroyed and reproduced the world and all its inhabitants. In the "Institutes of Menù," the sacred volume of the Hindoos, to which, in its present form, Sir William Jones ascribes an antiquity of at least eight hundred and eighty years before Christ, we find this system of the alternate destruction and renovation of the world, proposed in the following remarkable verses: —

"The Being, whose powers are incomprehensible, having created me (Menù) and this universe, again became absorbed in the supreme spirit, changing the time of energy for the hour of repose.

"When that power awakes, then has this world its full expansion; but when he slumbers with a tranquil spirit, then the whole system fades away. . . . For while he reposes as it were, embodied spirits endowed with principles of action depart from their several acts, and the mind itself becomes inert."

Menù then describes the absorption of all beings into the Supreme essence, and the Divine soul itself is said to slumber, and to remain for a time immersed in "the first idea, or in darkness." He then proceeds (verse fifty-seven), "Thus that immutable power, by waking and reposing alternately, revivifies and destroys, in eternal succession, this whole assemblage of locomotive and immoveable creatures."

It is then declared that there has been a long succession of *manwantaras*, or periods, each of the duration of many thousand ages, and —

"There are creations also, and destructions of worlds innumerable; the Being, supremely exalted, performs all this with as much ease as if in sport, again and again, for the sake of conferring happiness." *

The compilation of the ordinances of Menù was not all the work of one author nor of one period, and to this circumstance some of the remarkable inequalities of style and matter are probably attributable. There are many passages, however, wherein the attributes and acts of the "Infinite and Incomprehensible Being" are spoken of with much grandeur of conception and sublimity of diction, as some of the passages above cited, though sufficiently mysterious, may serve to exemplify. There are at the same time such puerile conceits and monstrous absurdities in this cosmogony, that some may be disposed to impute to mere accident any slight approximation to truth, or apparent coin-

* Institutes of Hindoo Law, or the Ordinances of Menù, from the Sanscrit, translated by Sir William Jones, 1796.

cidence between the oriental dogmas and observed facts. This pretended revelation, however, was not purely an effort of the unassisted imagination, nor invented without regard to the opinions and observations of naturalists. There are introduced into it certain astronomical theories, evidently derived from observation and reasoning. Thus, for instance, it is declared that, at the North Pole, the year was divided into a long day and night, and that their long day was the northern, and their night the southern course of the sun; and to the inhabitants of the moon, it is said, one day is equal in length to one month of mortals.* If such statements cannot be resolved into mere conjectures, we have no right to refer to mere chance the prevailing notion, that the earth and its inhabitants had formerly undergone a succession of revolutions and catastrophes interrupted by long intervals of tranquillity.

Now there are two sources in which such a theory may have originated. The marks of former convulsions on every part of the surface of our planet are obvious and striking. The remains of marine animals imbedded in the solid strata are so abundant, that they may be expected to force themselves on the observation of every people who have made some progress in refinement; and especially where one class of men are expressly set apart from the rest for study and contemplation. If these appearances are once recognized, it seems natural that the mind should conclude in favour, not only of mighty changes in past ages, but of alternate periods of repose and disorder;— of repose, when the fossil animals lived, grew, and

* Menù, Inst. c. i. 66. and 67.

multiplied—of disorder, when the strata in which they were buried became transferred from the sea to the interior of continents, and were uplifted so as to form part of high mountain chains. Those modern writers, who are disposed to disparage the former intellectua advancement and civilization of eastern nations, may concede some foundation of observed facts for the curious theories now under consideration, without indulging in exaggerated opinions of the progress of science; especially as universal catastrophes of the world, and exterminations of organic beings, in the sense in which they were understood by the Brahmin, are untenable doctrines.

We know, that the Egyptian priests were aware, not only that the soil beneath the plains of the Nile, but that also the hills bounding the great valley, contained marine shells*; and it could hardly have escaped the observation of eastern philosophers, that some soils were filled with fossil remains, since so many national works requiring extensive excavations were executed by oriental monarchs in very remote eras. They formed canals and tanks on a magnificent scale, and we know that in more recent times (the fourteenth century of our era) the removal of soil necessary for such undertakings brought to light geological phenomena, which attracted the attention of a people less civilized than were many of the older nations of the East.†

* Herodot. Euterpe, 12.

† This circumstance is mentioned in a Persian MS. copy of the historian Ferishta, in the library of the East India Company, relating to the rise and progress of the Mahomedan empire in India, procured by Colonel Briggs from the library of Tippoo Sultan in 1799; and has been recently referred to at some length

But although the Brahmins, like the priests of Egypt, may have been acquainted with the existence of fossil remains in the strata, it is possible that the doctrine of successive destructions and renovations of the world merely received corroboration from such proofs; and that it may have been originally handed down, like the religious traditions of most nations, from a ruder state of society. The system may have had its source in exaggerated accounts of those partial, but often dreadful, catastrophes, which are sometimes occasioned by particular combinations of natural causes. Floods and volcanic eruptions, the agency of water and fire, are the chief instruments of devastation on our globe. We shall point out in the sequel the extent of many of these calamities, recurring at distant intervals of time, in the present course of nature; and shall only observe here, that they are so peculiarly calculated to inspire a lasting terror, and are so often fatal in their consequences to great multitudes of people, that it scarcely requires the passion for the marvellous, so characteristic of rude and half-civilized nations, still less the exuberant imagination of eastern writers, to augment them into general cataclysms and conflagrations.

Humboldt relates the interesting fact, that after the annihilation of a large part of the inhabitants of

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by Dr. Buckland. — (Geol. Trans. 2d Series, vol. ii. part iii. p. 389.) — It is stated that, in the year 762 (or 1360 of our era), the king employed fifty thousand labourers in cutting through a mound, so as to form a junction between the rivers Selima and Sutluj; and in this mound were found the bones of elephants and men, some of them petrified, and some of them resembling bone. The gigantic dimensions attributed to the human bones show them to have belonged to some of the larger pachydermata.

Cumana, by an earthquake in 1766, a season of extraordinary fertility ensued, in consequence of the great rains which accompanied the subterranean convulsions. "The Indians," he says, "celebrated, after the ideas of an antique superstition, by festivals and dancing, the destruction of the world and the approaching epoch of its regeneration." *

The existence of such rites among the rude nations of South America is most important, for it shows what effects may be produced by great catastrophes of this nature, recurring at distant intervals of time, on the minds of a barbarous and uncultivated race. The superstitions of a savage tribe are transmitted through all the progressive stages of society, till they exert a powerful influence on the mind of the philosopher. He may find, in the monuments of former changes on the earth's surface, an apparent confirmation of tenets handed down through successive generations, from the rude hunter, whose terrified imagination drew a false picture of those awful visitations of floods and earthquakes, whereby the whole earth as known to him was simultaneously devastated.

Egyptian Cosmogony. — Respecting the cosmogony of the Egyptian priests, we gather much information from writers of the Grecian sects, who borrowed almost all their tenets from Egypt, and amongst others that of the former successive destruction and renovation of the world.† We learn from Plutarch, that this was the theme of one of the hymns of Orpheus, so celebrated in the fabulous ages of Greece. It was brought by him from the banks of the Nile; and we even find in his verses, as in the Indian systems, a

* Humboldt et Bonpland, Voy. Relat. Hist. vol. i. p. 30.

† Prichard's Egypt. Mythol. p. 177.

definite period assigned for the duration of each successive world.* The returns of great catastrophes were determined by the period of the Annus Magnus, or great year, — a cycle composed of the revolutions of the sun, moon, and planets, and terminating when these return together to the same sign whence they were supposed at some remote epoch to have set out. The duration of this great cycle was variously estimated. According to Orpheus, it was 120,000 years; according to others, 300,000; and by Cassander it was taken to be 360,000 years.†

We learn particularly from the Timæus of Plato, that the Egyptians believed the world to be subject to occasional conflagrations and deluges, whereby the gods arrested the career of human wickedness, and purified the earth from guilt. After each regeneration, mankind were in a state of virtue and happiness, from which they gradually degenerated again into vice and immorality. From this Egyptian doctrine, the poets derived the fable of the decline from the golden to the iron age. The sect of Stoics adopted most fully the system of catastrophes destined at certain intervals to destroy the world. These they taught were of two kinds; — the Cataclysm, or destruction by deluge, which sweeps away the whole human race, and annihilates all the animal and vegetable productions of nature; and the Ecpyrosis, or conflagration, which dissolves the globe itself. From the Egyptians also they derived the doctrine of the gradual debasement of man from a state of innocence. Towards the termination of each era the gods could no longer bear with the wicked-

* Plut. de Defectu Oraculorum, cap. 12. Censorinus de Die Natali. See also Prichard's Egypt. Mythol. p. 182.

† Prichard's Egypt. Mythol. p. 182.

ness of men, and a shock of the elements or a deluge overwhelmed them; after which calamity, Astrea again descended on the earth, to renew the golden age.*

The connection between the doctrine of successive catastrophes and repeated deteriorations in the moral character of the human race, is more intimate and natural than might at first be imagined. For, in a rude state of society, all great calamities are regarded by the people as judgments of God on the wickedness of man. Thus, in our own time, the priests persuaded a large part of the population of Chili, and perhaps believed themselves, that the fatal earthquake of 1822 was a sign of the wrath of Heaven for the great political revolution just then consummated in South America. In like manner, in the account given to Solon by the Egyptian priests, of the submersion of the island of Atlantis under the waters of the ocean, after repeated shocks of an earthquake, we find that the event happened when Jupiter had seen the moral depravity of the inhabitants.† Now, when the notion had once gained ground, whether from causes before suggested or not, that the earth had been destroyed by several general catastrophes, it would next be inferred that the human race had been as often destroyed and renovated. And since every extermination was assumed to be penal, it could only be reconciled with divine justice, by the supposition that man, at each successive creation, was regenerated in a state of purity and innocence.

A very large portion of Asia, inhabited by the earliest nations whose traditions have come down to us, has been always subject to tremendous earthquakes. Of the geographical boundaries of these, and their

* Prichard's Egypt. Mythol. p. 193. † Plato's Timæus.

effects, I shall speak in the proper place. Egypt has, for the most part, been exempt from this scourge, and the tradition of catastrophes in that country was perhaps derived from the East.

One extraordinary fiction of the Egyptian mythology was the supposed intervention of a masculo-feminine principle, to which was assigned the development of the embryo world, somewhat in the way of incubation. For the doctrine was, that when the first chaotic mass had been produced, in the form of an egg, by a self-dependent and eternal Being, it required the mysterious functions of this masculo-feminine artificer to reduce the component elements into organized forms.

Although it is scarcely possible to recall to mind this conceit without smiling, it does not seem to differ essentially in principle from some cosmological notions of men of great genius and science in modern Europe. The Egyptian philosophers ventured on the perilous task of seeking from among the processes now going on something analogous to the mode of operation employed by the Author of Nature in the first creation of organized beings, and they compared it to that which governs the birth of new individuals by generation. To suppose that some general rules might be observed in the first origin of created beings, or the first introduction of new species into our system, was not absurd, nor inconsistent with any thing known to us in the economy of the universe. But the hypothesis, that there was any analogy between such laws, and those employed in the continual reproduction of species, was purely gratuitous. In like manner, it is not unreasonable, nor derogatory to the attributes of Omnipotence, to imagine that some general laws may be observed in the creation of new worlds; and if man could witness the birth of such worlds, he might reason by induction upon the origin of his own. But in the absence of such data, an attempt has been made to fancy some analogy between the agents now employed to destroy, renovate, and perpetually vary the earth's surface, and those whereby the first chaotic mass was formed, and brought by supposed nascent energy from the embryo to the habitable state.

By how many shades the elaborate systems, constructed on these principles, may differ from the mysteries of the "Mundane Egg" of Egyptian fable, I shall not inquire. It would, perhaps, be dangerous ground, and some of our contemporaries might not sit as patiently as the Athenian audience, when the fiction of the chaotic egg, engrafted by Orpheus upon their own mythology, was turned into ridicule by Aristophanes. That comedian introduced his birds singing, in a solemn hymn, "How sable-plumaged Night conceived in the boundless bosom of Erebus, and laid an egg, from which, in the revolution of ages, sprung Love, resplendent with golden pinions. Love fecundated the dark-winged chaos, and gave origin to the race of birds." *

Pythagorean Doctrines. — Pythagoras, who resided for more than twenty years in Egypt, and, according to Cicero, had visited the East, and conversed with the Persian philosophers, introduced into his own country, on his return, the doctrine of the gradual deterioration of the human race from an original state of virtue and happiness: but if we are to judge of his theory concerning the destruction and renovation of the earth from the sketch given by Ovid, we must concede it to have been far more philosophical than

* Aristophanes, Birds, 694.

any known version of the cosmologies of oriental or Egyptian sects.

Although Pythagoras is introduced by the poet as delivering his doctrine in person, some of the illustrations are derived from natural events which happened after the death of the philosopher. But notwithstanding these anachronisms, we may regard the account as a true picture of the tenets of the Pythagorean school in the Augustan age; and although perhaps partially modified, it must have contained the substance of the original scheme. Thus considered, it is extremely curious and instructive; for we here find a comprehensive and masterly summary of almost all the great causes of change now in activity on the globe, and these adduced in confirmation of a principle of perpetual and gradual revolution inherent in the nature of our terrestrial system. These doctrines, it is true, are not directly applied to the explanation of geological phenomena; or, in other words, no attempt is made to estimate what may have been in past ages, or what may hereafter be, the aggregate amount of change brought about by such never-ending fluctuations. Had this been the case, we might have been called upon to admire so extraordinary an anticipation with no less interest than astronomers, when they endeavour to divine by what means the Samian philosopher came to the knowledge of the Copernican system.

Let us now examine the celebrated passages to which we have been adverting*: —

"Nothing perishes in this world; but things merely vary and change their form. To be born, means simply that a thing begins to be something different from what

* Ovid's Metamor. lib. 15.

it was before: and dying, is ceasing to be the same thing. Yet, although nothing retains long the same image, the sum of the whole remains constant." These general propositions are then confirmed by a series of examples, all derived from natural appearances, except the first, which refers to the golden age giving place to the age of iron. The illustrations are thus consecutively adduced.

1. Solid land has been converted into sea.

2. Sea has been changed into land. Marine shells lie far distant from the deep, and the anchor has been found on the summit of hills.

3. Valleys have been excavated by running water, and floods have washed down hills into the sea.*

4. Marshes have become dry ground.

5. Dry lands have been changed into stagnant pools.

6. During earthquakes some springs have been closed up, and new ones have broken out. Rivers have deserted their channels, and have been re-born elsewhere; as the Erasinus in Greece, and Mysus in Asia.

7. The waters of some rivers, formerly sweet, have become bitter, as those of the Anigris in Greece, &c.†

8. Islands have become connected with the main land, by the growth of deltas and new deposits, as in the case of Antissa joined to Lesbos, Pharos to Egypt, &c.

9. Peninsulas have been divided from the main land, and have become islands, as Leucadia; and according

* Eluvie mons est deductus in æquor, v. 267. The meaning of this last verse is somewhat obscure, but, taken with the context, may be supposed to allude to the abrading power of floods, torrents, and rivers.

† The impregnation from new mineral springs, caused by earthquakes in volcanic countries, is, perhaps, here alluded to.

to tradition Sicily, the sea having carried away the isthmus.

10. Land has been submerged by earthquakes: the Grecian cities of Helice and Buris, for example, are to be seen under the sea, with their walls inclined.

11. Plains have been upheaved into hills by the confined air seeking vent, as at Trœzen in the Peloponnesus.

12. The temperature of some springs varies at different periods. The waters of others are inflammable.*

13. There are streams which have a petrifying power, and convert the substances which they touch into marble.

14. Extraordinary medicinal and deleterious effects are produced by the water of different lakes and springs.†

15. Some rocks and islands, after floating, and having been subject to violent movements, have at length become stationary and immoveable, as Delos, and the Cyanean Isles.‡

* This is probably an allusion to the escape of inflammable gas, like that in the district of Baku, west of the Caspian; at Pietramala, in the Tuscan Apennines; and several other places.

† Many of those described seem fanciful fictions, like the virtues still so commonly attributed to mineral waters.

‡ Raspe, in a learned and judicious essay (De Novis Insulis, cap. 19.), has made it appear extremely probable that all the traditions of certain islands in the Mediterranean having at some former time frequently shifted their positions, and at length become stationary, originated in the great change produced in their form by earthquakes and submarine eruptions, of which there have been modern examples in the new islands raised in the time of history. When the series of convulsions ended, the island was said to become fixed.

16. Volcanic vents shift their position; there was a time when Etna was not a burning mountain, and the time will come when it will cease to burn. Whether it be that some caverns become closed up by the movements of the earth, and others opened, or whether the fuel is finally exhausted, &c. &c.

The various causes of change in the inanimate world having been thus enumerated, the doctrine of equivocal generation is next propounded, as illustrating a corresponding perpetual flux in the animate creation.*

In the Egyptian and Eastern cosmogonies, and in the Greek version of them, no very definite meaning can, in general, be attached to the term "destruction of the world;" for sometimes it would seem almost to imply the annihilation of our planetary system, and at others a mere revolution of the surface of the earth.

Opinions of Aristotle.—From the works now extant of Aristotle, and from the system of Pythagoras, as above exposed, we might certainly infer that these

* It is not inconsistent with the Hindoo mythology to suppose that Pythagoras might have found in the East not only the system of universal and violent catastrophes and periods of repose in endless succession, but also that of periodical revolutions, effected by the continued agency of ordinary causes. For Brahma, Vishnu, and Siva, the first, second, and third persons of the Hindoo triad, severally represented the Creative, the Preserving, and the Destroying powers of the Deity. The co-existence of these three attributes, all in simultaneous operation, might well accord with the notion of perpetual but partial alterations finally bringing about a complete change. But the fiction expressed in the verses before quoted from Menù, of eternal vicissitudes in the vigils and slumbers of the Infinite Being, seems accommodated to the system of great general catastrophes followed by new creations and periods of repose.

philosophers considered the agents of change now operating in nature, as capable of bringing about in the lapse of ages a complete revolution; and the Stagyrite even considers occasional catastrophes, happening at distant intervals of time, as part of the regular and ordinary course of nature. The deluge of Deucalion, he says, affected Greece only, and principally the part called Hellas, and it arose from great inundations of rivers during a rainy winter. But such extraordinary winters, he says, though after a certain period they return, do not always revisit the same places.*

Censorinus quotes it as Aristotle's opinion, that there were general inundations of the globe, and that they alternated with conflagrations, and that the flood constituted the winter of the great year, or astronomical cycle, while the conflagration, or destruction by fire, is the summer or period of greatest heat.† If this passage, as Lipsius supposes, be an amplification, by Censorinus, of what is written in "the Meteorics," it is a gross misrepresentation of the doctrine of the Stagyrite, for the general bearing of his reasoning in that treatise tends clearly in an opposite direction. He refers to many examples of changes now constantly going on, and insists emphatically on the great results which they must produce in the lapse of ages. He instances particular cases of lakes that had dried up, and deserts that had at length become watered by rivers and fertilized. He points to the growth of the Nilotic delta since the time of Homer, to the shallowing of the Palus Mæotis within sixty years from his own time; and although, in the same chapter, he says nothing of earthquakes, yet in

* Meteor. lib. i. cap. 12.

† De Die Nat.

others of the same treatise, he shows himself not unacquainted with their effects.* He alludes, for example, to the upheaving of one of the Eolian islands previous to a volcanic eruption. "The changes of the earth," he says, "are so slow in comparison to the duration of our lives, that they are overlooked (λανθανει); and the migrations of people after great catastrophes, and their removal to other regions, cause the event to be forgotten."†

When we consider the acquaintance displayed by Aristotle, in his various works, with the destroying and renovating powers of Nature, the introductory and concluding passages of the twelfth chapter of his "Meteorics" are certainly very remarkable. In the first sentence he says, "The distribution of land and sea in particular regions does not endure throughout all time, but it becomes sea in those parts where it was land, and again it becomes land where it was sea; and there is reason for thinking that these changes take place according to a certain system, and within a certain period." The concluding observation is as follows:—"As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations, but there is none to time. So also of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but every thing changes in the course of time."

It seems, then, that the Greeks had not only derived

* Lib. ii. cap. 14, 15, and 16. † Ibid.

from preceding nations, but had also, in some slight degree, deduced from their own observations, the theory of periodical revolutions in the inorganic world: there is, however, no ground for imagining that they contemplated former changes in the races of animals and plants. Even the fact, that marine remains were inclosed in solid rocks, although observed by some, and even made the groundwork of geological speculation, never stimulated the industry or guided the inquiries of naturalists. It is not impossible that the theory of equivocal generation might have engendered some indifference on this subject, and that a belief in the spontaneous production of living beings from the earth, or corrupt matter, might have caused the organic world to appear so unstable and fluctuating, that phenomena indicative of former changes would not awaken intense curiosity. The Egyptians, it is true, had taught, and the Stoics had repeated, that the earth had once given birth to some monstrous animals, which existed no longer; but the prevailing opinion seems to have been, that after each great catastrophe the same species of animals were created over again. This tenet is implied in a passage of Seneca, where, speaking of a future deluge, he says, "Every animal shall be generated anew, and man free from guilt shall be given to the earth."*

An old Arabian version of the doctrine of the successive revolutions of the globe, translated by Abraham Ecchellensis†, seems to form a singular exception to

* Omne ex integro animal generabitur, dabiturque terris homo inscius scelerum. — Quæst. Nat. iii. c. 29.

† This author was Regius Professor of Syriac and Arabic at Paris, where, in 1685, he published a Latin translation of many

the general rule, for here we find the idea of different genera and species having been created. The Gerbanites, a sect of astronomers who flourished some centuries before the Christian era, taught as follows:—"That after every period of thirty-six thousand four hundred and twenty-five years, there were produced a pair of *every* species of animal, both male and female, from whom animals might be propagated and inhabit this lower world. But when a circulation of the heavenly orbs was completed, which is finished in that space of years, *other genera and species* of animals are propagated, as also of plants and other things, and the first order is destroyed, and so it goes on for ever and ever."*

Theory of Strabo.—As we learn much of the tenets of the Egyptian and oriental schools in the writings of

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Arabian MSS. on different departments of philosophy. This work has always been considered of high authority.

* Gerbanitæ docebant singulos triginta sex mille annos quadringentos, viginti quinque bina ex singulis animalium speciebus produci, marem scilicet ac feminam, ex quibus animalia propagantur, huncque inferiorem incolunt orbem. Absolutâ autem cœlestium orbium circulatione, quæ illo annorum conficitur spatio, iterum alia producuntur animalium genera et species, quemadmodum et plantarum aliarumque rerum, et primus destruitur ordo, sicque in infinitum producitur. — Histor. Orient. Suppl. per Abrahamum Ecchellensum, Syrum Maronitam, cap. 7. et 8. ad calcem Chronici Oriental. Parisiis, e Typ. regia, 1685. fol.

I have given the punctuation as in the Paris edition, there being no comma after quinque, but, at the suggestion of M. de Schlegel, I have referred the number twenty-five to the period of years, and not to the number of pairs of each species created at one time, as I had done in former editions. Fortis inferred that twenty-five new *species* only were created at a time; a construction which the passage will not admit. Mém. sur l'Hist. Nat. de l'Italie, vol. i. p. 202.

the Greeks, so many speculations of the early Greek authors are made known to us in the works of the Augustan and later ages. Strabo, in particular, enters largely, in the second book of his Geography, into the opinions of Eratosthenes and other Greeks on one of the most difficult problems in geology, viz. by what causes marine shells came to be plentifully buried in the earth at such great elevations and distances from the sea.

He notices, amongst others, the explanation of Xanthus the Lydian, who said that the seas had once been more extensive, and that they had afterwards been partially dried up, as in his own time many lakes, rivers, and wells in Asia had failed during a season of drought. Treating this conjecture with merited disregard, Strabo passes on to the hypothesis of Strato, the natural philosopher, who had observed that the quantity of mud brought down by rivers into the Euxine was so great, that its bed must be gradually raised, while the rivers still continue to pour in an undiminished quantity of water. He therefore conceived that, originally, when the Euxine was an inland sea, its level had by this means become so much elevated that it burst its barrier near Byzantium, and formed a communication with the Propontis; and this partial drainage, he supposed, had already converted the left side into marshy ground, and thus, at last, the whole would be choked up with soil. So, it was argued, the Mediterranean had once opened a passage for itself by the Columns of Hercules into the Atlantic; and perhaps the abundance of sea-shells in Africa, near the Temple of Jupiter Ammon, might also be the deposit of some former inland sea, which had at length forced a passage and escaped.

But Strabo rejects this theory as insufficient to account for all the phenomena, and he proposes one of his own, the profoundness of which modern geologists are only beginning to appreciate. "It is not," he says, "because the lands covered by seas were originally at different altitudes, that the waters have risen, or subsided, or receded from some parts and inundated others. But the reason is, that the same land is sometimes raised up and sometimes depressed, and the sea also is simultaneously raised and depressed, so that it either overflows or returns into its own place again. We must therefore ascribe the cause to the ground, either to that ground which is under the sea, or to that which becomes flooded by it, but rather to that which lies beneath the sea, for this is more moveable, and, on account of its humidity, can be altered with greater celerity.* *It is proper*," he observes in continuation, "*to derive our explanations from things which are obvious, and in some measure of daily occurrence, such as deluges, earthquakes, and volcanic eruptions* †, *and sudden swellings of the land beneath the sea;* for the last raise up the sea also, and when the same lands subside again, they occasion the sea to be let

* "Quod enim hoc attollitur aut subsidit, et vel inundat quædam loca, vel ab iis recedit, ejus rei causa non est, quod alia aliis sola humiliora sint aut altiora; sed quod idem solum modò attollitur modò deprimitur, simulque etiam modò attollitur modò deprimitur mare: itaque vel exundat vel in suum redit locum."

Posteà, p. 88. "Restat, ut causam adscribamus solo, sive quod mari subest sive quod inundatur; potiùs tamen ei quod mari subest. Hoc enim multò est mobilius, et quod ob humiditatem celeriùs mutari possit." — Strabo, Geog. Edit. Almelov. Amst. 1707. lib. i.

† (*Volcanic eruptions*, eruptiones flatuum, in the original Greek, *αναφυσηματα*, gaseous eruptions? or *inflations* of land? — ibid., p. 93.)

down. And it is not merely the small, but the large islands also, and not merely the islands, but the continents, which can be lifted up together with the sea; and both large and small tracts may subside, for habitations and cities, like Bure, Bizona, and many others, have been engulphed by earthquakes."

In another place, this learned geographer, in alluding to the tradition that Sicily had been separated by a convulsion from Italy, remarks, that at present the land near the sea in those parts was rarely shaken by earthquakes, since there were now open orifices whereby fire and ignited matters and waters escape; but formerly, when the volcanos of Etna, the Lipari Islands, Ischia, and others, were closed up, the imprisoned fire and wind might have produced far more vehement movements.* The doctrine, therefore, that volcanos are safety-valves, and that the subterranean convulsions are probably most violent when first the volcanic energy shifts itself to a new quarter, is not modern.

We learn from a passage in Strabo †, that it was a dogma of the Gaulish Druids that the universe was immortal, but destined to survive catastrophes both of fire and water. That this doctrine was communicated to them from the East, with much of their learning, cannot be doubted. Cæsar, it will be remembered, says that they made use of Greek letters in arithmetical computations.‡

Pliny.—This philosopher had no theoretical opinions of his own concerning changes of the earth's surface; and in this department, as in others, he restricted himself to the task of a compiler, without reasoning on the

* Strabo, lib. vi. p. 396.

† Book iv.

‡ L. vi. ch. xiii.

facts stated by him, or attempting to digest them into regular order. But his enumeration of the new islands which had been formed in the Mediterranean, and of other convulsions, shews that the ancients had not been inattentive observers of the changes which had taken place within the memory of man.

Such, then, appear to have been the opinions entertained before the Christian era, concerning the past revolutions of our globe. Although no particular investigations had been made for the express purpose of interpreting the monuments of ancient changes, they were too obvious to be entirely disregarded; and the observation of the present course of nature presented too many proofs of alterations continually in progress on the earth to allow philosophers to believe that nature was in a state of rest, or that the surface had remained, and would continue to remain, unaltered. But they had never compared attentively the results of the destroying and reproductive operations of modern times with those of remote eras, nor had they ever entertained so much as a conjecture concerning the comparative antiquity of the human race, or of living species of animals and plants, with those belonging to former conditions of the organic world. They had studied the movements and positions of the heavenly bodies with laborious industry, and made some progress in investigating the animal, vegetable, and mineral kingdoms; but the ancient history of the globe was to them a sealed book, and, although written in characters of the most striking and imposing kind, they were unconscious even of its existence.

CHAPTER III.

HISTORY OF THE PROGRESS OF GEOLOGY—*continued.*

Arabian writers of the tenth century — Avicenna — Omar — Cosmogony of the Koran — Kazwini — Early Italian writers (p. 33.)—Fracastoro — Controversy as to the real nature of fossils — Attributed to the Mosaic deluge — Palissy — Steno (p. 39.) — Scilla — Quirini — Boyle — Lister — Leibnitz — Hooke's Theory of Elevation by Earthquakes (p. 46.) — Of lost species of animals — Ray — Physico-theological writers — Woodward's Diluvial Theory (p. 53) — Burnet — Whiston — Vallisneri — Lazzaro Moro (p. 59.) — Generelli — Buffon (p. 67.) — His theory condemned by the Sorbonne as unorthodox — His declaration — Targioni — Arduino — Michell — Catcott — Raspe — Fuchsel (p. 75.) — Fortis — Testa — Whitehurst — Pallas — Saussure.

Arabian writers.—After the decline of the Roman empire, the cultivation of physical science was first revived with some success by the Saracens, about the middle of the eighth century of our era. The works of the most eminent classic writers were purchased at great expense from the Christians, and translated into Arabic; and Al Mamûn, son of the famous Harûn-al-Rashid, the contemporary of Charlemagne, received with marks of distinction, at his court at Bagdad, astronomers and men of learning from different countries. This caliph, and some of his successors, encountered much opposition and jealousy from the doctors of the Mahomedan law, who wished the Moslems to confine their studies to the Koran, dreading the effects of the diffusion of a taste for the physical sciences.*

* Mod. Univ. Hist. vol. ii. chap. iv. section iii.

Avicenna.—Almost all the works of the early Arabian writers are lost. Amongst those of the tenth century, of which fragments are now extant, is a short treatise "On the Formation and Classification of Minerals," by Avicenna, a physician, in whose arrangement there is considerable merit. The second chapter, "On the Cause of Mountains," is remarkable; for mountains, he says, are formed, some by essential, others by accidental causes. In illustration of the essential, he instances "a violent earthquake, by which land is elevated, and becomes a mountain;" of the accidental, the principal, he says, is excavation by water, whereby cavities are produced, and adjoining lands made to stand out and form eminences.*

Omar—Cosmogony of the Koran.—In the same century also, Omar, surnamed "El Aalem," or "The Learned," wrote a work on "The Retreat of the Sea." It appears that on comparing the charts of his own time with those made by the Indian and Persian astronomers two thousand years before, he had satisfied himself that important changes had taken place since the times of history in the form of the coasts of Asia, and that the extension of the sea had been greater at some former periods. He was confirmed in this opinion by the numerous salt springs and marshes in the interior of Asia,—a phenomenon from which Pallas, in more recent times, has drawn the same inference.

Von Hoff has suggested, with great probability, that the changes in the level of the Caspian (some of which there is reason to believe have happened within the

* Montes quandóque fiunt ex causa essentiali, quandóque ex causa accidentali. Ex essentiali causa, ut ex vehementi motu terræ elevatur terra, et fit mons. Accidentali, &c. — De Congelatione Lapidum, ed. Gedani, 1682.

historical era), and the geological appearances in that district, indicating the desertion by that sea of its ancient bed, had probably led Omar to his theory of a general subsidence. But whatever may have been the proofs relied on, his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors; to avoid which persecution he went into voluntary banishment from Samarkand.*

The cosmological opinions expressed in the Koran are few, and merely introduced incidentally: so that it is not easy to understand how they could have interfered so seriously with free discussion on the former changes of the globe. The Prophet declares that the earth was created in two days, and the mountains were then placed on it; and during these, and two additional days, the inhabitants of the earth were formed; and in two more, the seven heavens.† There is no

* Von Hoff, Geschichte der Veränderungen der Erdoberfläche, vol. i. p. 406., who cites Delisle, bey Hismann Welt-und Völkergeschichte. Alte Gesch. 1ter Theil. s. 234. — The Arabian persecutions for heretical dogmas in theology were often very sanguinary. In the same ages wherein learning was most in esteem, the Mahometans were divided into two sects, one of whom maintained that the Koran was increate, and had subsisted in the very essence of God from all eternity; and the other, the Motazalites, who, admitting that the Koran was instituted by God, conceived it to have been first made when revealed to the Prophet at Mecca, and accused their opponents of believing in two eternal beings. The opinions of each of these sects were taken up by different caliphs in succession, and the followers of each sometimes submitted to be beheaded, or flogged till at the point of death, rather than renounce their creed. — Mod. Univ. Hist. vol. ii. ch. iv.

† Koran, chap. xli.

more detail of circumstances; and the deluge, which is also mentioned, is discussed with equal brevity. The waters are represented to have poured out of an oven; a strange fable, said to be borrowed from the Persian Magi, who represented them as issuing from the oven of an old woman.* All men were drowned, save Noah and his family; and then God said, "O earth, swallow up thy waters; and thou, O heaven, withhold thy rain;" and immediately the waters abated.†

We may suppose Omar to have represented the desertion of the land by the sea to have been gradual, and that his hypothesis required a greater lapse of ages than was consistent with Moslem orthodoxy; for it is to be inferred from the Koran, that man and this planet were created at the same time; and although Mahomet did not limit expressly the antiquity of the human race, yet he gave an implied sanction to the Mosaic chronology, by the veneration expressed by him for the Hebrew Patriarchs.‡

A manuscript work, entitled the "Wonders of Nature," is preserved in the Royal Library at Paris, by an Arabian writer, Mohammed Kazwini, who flourished in the seventh century of the Hegira, or at the close of the thirteenth century of our era.§ Besides several curious remarks on aerolites, earthquakes, and the successive changes of position which the land and

* Sale's Koran, chap. xi. see note. † Ibid.

‡ Kossa, appointed master to the Caliph Al Mamûd, was author of a book, entitled "The History of the Patriarchs and Prophets, *from the Creation of the World.*"— Mod. Univ. Hist. vol. ii. chap. iv.

§ Translated by MM. Chezy and De Sacy, and cited by M. Elie de Beaumont, Ann. des Sci. Nat. 1832.

sea have undergone, we meet with the following beautiful passage, which is given as the narrative of Khidhz, an allegorical personage:—"I passed one day by a very ancient and wonderfully populous city, and asked one of its inhabitants how long it had been founded. 'It is indeed a mighty city,' replied he, 'we know not how long it has existed, and our ancestors were on this subject as ignorant as ourselves.' Five centuries afterwards, as I passed by the same place, I could not perceive the slightest vestige of the city. I demanded of a peasant who was gathering herbs, upon its former site, how long it had been destroyed. 'In sooth, a strange question!' replied he. 'The ground here has never been different from what you now behold it.'—'Was there not of old,' said I, 'a splendid city here?'—'Never,' answered he, 'so far as we have seen, and never did our fathers speak to us of any such.' On my return there, 500 years afterwards, *I found the sea in the same place*, and on its shores were a party of fishermen, of whom I inquired how long the land had been covered by the waters? 'Is this a question,' said they, 'for a man like you? this spot has always been what it is now.' I again returned, 500 years afterwards, and the sea had disappeared; I inquired of a man who stood alone upon the spot, how long ago this change had taken place, and he gave me the same answer as I had received before. Lastly, on coming back again after an equal lapse of time, I found there a flourishing city, more populous and more rich in beautiful buildings than the city I had seen the first time, and when I would fain have informed myself concerning its origin, the inhabitants answered me, 'Its rise is lost in remote antiquity: we are ignorant how long it has existed, and our fathers were on this subject as ignorant as ourselves.'"

Early Italian writers—Fracastoro, 1517.—It was not till the earlier part of the sixteenth century that geological phenomena began to attract the attention of the Christian nations. At that period a very animated controversy sprung up in Italy, concerning the true nature and origin of marine shells, and other organized fossils, found abundantly in the strata of the peninsula.* The excavations made in 1517, for repairing the city of Verona, brought to light a multitude of curious petrifactions, and furnished matter for speculation to different authors, and among the rest to Fracastoro†, who declared his opinion, that fossil shells had all belonged to living animals, which had formerly lived and multiplied where their exuviæ are now found. He exposed the absurdity of having recourse to a certain "plastic force," which it was said had power to fashion stones into organic forms; and, with no less cogent arguments, demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory obstinately defended by some. That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. His clear exposition of the evidence would have terminated the discussion for ever, if the passions of mankind had not been enlisted in the

* See Brocchi's Discourse on the Progress of the Study of Fossil Conchology in Italy, where some of the following notices on Italian writers will be found more at large.

† Museum Calceol.

dispute; and even though doubts should for a time have remained in some minds, they would speedily have been removed by the fresh information obtained almost immediately afterwards, respecting the structure of fossil remains, and of their living analogues.

But the clear and philosophical views of Fracastoro were disregarded, and the talent and argumentative powers of the learned were doomed for three centuries to be wasted in the discussion of these two simple and preliminary questions: first, whether fossil remains had ever belonged to living creatures; and, secondly, whether, if this be admitted, all the phenomena could not be explained by the Noachian deluge. It had been the general belief of the Christian world down to the period now under consideration, that the origin of this planet was not more remote than a few thousand years; and that since the creation the deluge was the only great catastrophe by which considerable change had been wrought on the earth's surface. On the other hand, the opinion was scarcely less general, that the final dissolution of our system was an event to be looked for at no distant period. The era, it is true, of the expected millennium had passed away; and for five hundred years after the fatal hour, when the annihilation of the planet had been looked for, the monks remained in undisturbed enjoyment of rich grants of land bequeathed to them by pious donors, who, in the preamble of deeds beginning "appropinquante mundi termino"——"appropinquante magno judicii die," left lasting monuments of the popular delusion.*

* In Sicily, in particular, the title-deeds of many valuable grants of land to the monasteries are headed by such preambles,

But although in the sixteenth century it had become necessary to interpret the prophecies more liberally, and to assign a more distant date to the future conflagration of the world, we find, in the speculations of the early geologists, perpetual allusion to such an approaching catastrophe; while in all that regarded the antiquity of the earth, no modification whatever of the opinions of the dark ages had been effected. Considerable alarm was at first excited when the attempt was made to invalidate, by physical proofs, an article of faith so generally received; but there was sufficient spirit of toleration and candour amongst the Italian ecclesiastics, to allow the subject to be canvassed with much freedom. They even entered warmly into the controversy themselves, often favouring different sides of the question; and however much we may deplore the loss of time and labour devoted to the defence of untenable positions, it must be conceded, that they displayed far less polemic bitterness than certain writers who followed them "beyond the Alps," two centuries and a half later.

CONTROVERSY AS TO THE REAL NATURE OF FOSSIL ORGANIC REMAINS.

Mattioli — Falloppio. — The system of scholastic disputations encouraged in the universities of the middle ages had unfortunately trained men to habits of indefinite argumentation; and they often preferred absurd and extravagant propositions, because greater skill was required to maintain them; the end and

composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

object of these intellectual combats being victory, and not truth. No theory could be so far-fetched or fantastical as not to attract some followers, provided it fell in with popular notions; and as cosmogonists were not at all restricted, in building their systems, to the agency of known causes, the opponents of Fracastoro met his arguments by feigning imaginary causes, which differed from each other rather in name than in substance. Andrea Mattioli, for instance, an eminent botanist, the illustrator of Dioscorides, embraced the notion of Agricola, a German miner, that a certain "materia pinguis," or "fatty matter," set into fermentation by heat, gave birth to fossil organic shapes. Yet Mattioli had come to the conclusion, from his own observations, that porous bodies, such as bones and shells, might be converted into stone, as being permeable to what he termed the "lapidifying juice." In like manner, Falloppio of Padua conceived that petrified shells were generated by fermentation in the spots where they are found, or that they had in some cases acquired their form from "the tumultuous movements of terrestrial exhalations." Although celebrated as a professor of anatomy, he taught that certain tusks of elephants dug up in his time at Puglia were mere earthy concretions; and, consistently with these principles, he even went so far as to consider it probable, that the vases of Monte Testaceo at Rome were natural impressions stamped in the soil.* In the same spirit, Mercati, who published, in 1574, faithful figures of the fossil shells preserved by Pope Sixtus V. in the Museum of the Vatican, expressed an opinion that they were mere stones, which had assumed

* De Fossilib. pp. 109. and 176.

their peculiar configuration from the influence of the heavenly bodies; and Olivi of Cremona, who described the fossil remains of a rich Museum at Verona, was satisfied with considering them as mere "sports of nature."

Some of the fanciful notions of those times were deemed less unreasonable, as being somewhat in harmony with the Aristotelian theory of spontaneous generation, then taught in all the schools. For men who had been taught in early youth, that a large proportion of living animals and plants were formed from the fortuitous concourse of atoms, or had sprung from the corruption of organic matter, might easily persuade themselves, that organic shapes, often imperfectly preserved in the interior of solid rocks, owed their existence to causes equally obscure and mysterious.

Cardano, 1552.—But there were not wanting some who, during the progress of this century, expressed more sound and sober opinions. The title of a work of Cardano's, published in 1552, "De Subtilitate" (corresponding to what would now be called Transcendental Philosophy), would lead us to expect, in the chapter on minerals, many far-fetched theories characteristic of that age; but, when treating of petrified shells, he decided that they clearly indicated the former sojourn of the sea upon the mountains.*

Cesalpino—Majoli, 1597.—Cesalpino, a celebrated botanist, conceived that fossil shells had been left on the land by the retiring sea, and had concreted into stone during the consolidation of the soil†; and in the following year (1597), Simeone Majoli‡ went still

* Brocchi, Con. Foss. Subap. Disc. sui Prog. vol. i. p. 5.

† De Metallicis.

‡ Dies Caniculares.

farther; and, coinciding for the most part with the views of Cesalpino, suggested that the shells and submarine matter of the Veronese, and other districts, might have been cast up upon the land by volcanic explosions, like those which gave rise, in 1538, to Monte Nuovo, near Puzzuoli. This hint seems to have been the first imperfect attempt to connect the position of fossil shells with the agency of volcanos, a system afterwards more fully developed by Hooke, Lazzaro Moro, Hutton, and other writers.

Two years afterwards, Imperati advocated the animal origin of fossilized shells, yet admitted that stones could vegetate by force of "an internal principle;" and, as evidence of this, he referred to the teeth of fish, and spines of echini found petrified.*

Palissy, 1580.— Palissy, a French writer on "The Origin of Springs from Rain-water," and of other scientific works, undertook, in 1580, to combat the notions of many of his contemporaries in Italy, that petrified shells had all been deposited by the universal deluge. "He was the first," said Fontenelle, when, in the French Academy, he pronounced his eulogy, nearly a century and a half later, "who dared assert," in Paris, that fossil remains of testacea and fish had once belonged to marine animals.

Fabio Colonna.—To enumerate the multitude of Italian writers, who advanced various hypotheses, all equally fantastical, in the early part of the seventeenth century, would be unprofitably tedious; but Fabio Colonna deserves to be distinguished; for, although he gave way to the dogma, that all fossil remains were to be referred to the Noachian deluge, he resisted the absurd theory of Stelluti, who taught that fossil wood

* Storia Naturale.

and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat; and he pointed out the different states of shells buried in the strata, distinguishing between, first, the mere mould or impression; secondly, the cast or nucleus; and, thirdly, the remains of the shell itself. He had also the merit of being the first to point out, that some of the fossils had belonged to marine, and some to terrestrial, testacea.*

Steno, 1669.—But the most remarkable work of that period was published by Steno, a Dane, once professor of anatomy at Padua, and who afterwards resided many years at the court of the Grand Duke of Tuscany. His treatise bears the quaint title of "De Solido intra Solidum naturaliter contento (1669)," by which the author intended to express, "On Gems, Crystals, and organic petrifactions inclosed within solid Rocks." This work attests the priority of the Italian school in geological research; exemplifying at the same time the powerful obstacles opposed, in that age, to the general reception of enlarged views in the science. It was still a favourite dogma, that the fossil remains of shells and marine creatures were not of animal origin; an opinion adhered to by many from their extreme reluctance to believe, that the earth could have been inhabited by living beings before a great part of the existing mountains were formed. In reference to this controversy, Steno had dissected a shark recently taken from the Mediterranean, and had demonstrated that its teeth and bones were identical with many fossils found in Tuscany. He had also compared the shells discovered in the Italian strata

* Osserv. sugli Animali aquat. e terrest. 1626.

with living species, pointed out their resemblance, and traced the various gradations from shells merely calcined, or which had only lost their animal gluten, to those petrifactions in which there was a perfect substitution of stony matter. In his division of mineral masses, he insisted on the secondary origin of those deposits in which the spoils of animals, or fragments of older rocks were inclosed. He distinguished between marine formations and those of a fluviatile character, the last containing reeds, grasses, or the trunks and branches of trees. He argued in favour of the original horizontality of sedimentary deposits, attributing their present inclined and vertical position sometimes to the escape of subterranean vapours, heaving the crust of the earth from below upwards, and sometimes to the falling in of masses over-lying subterranean cavities.

He declared that he had obtained proof that Tuscany must successively have acquired six distinct configurations, having been twice covered by water, twice laid dry with a level, and twice with an irregular and uneven surface.* He displayed great anxiety to reconcile his new views with Scripture, for which purpose he pointed to certain rocks as having been formed before the existence of animals and plants; selecting unfortunately as examples certain formations of limestone and sandstone in his own country, now known to contain, though sparingly, the remains of animals and plants, — strata which do not even rank as the oldest part of our secondary series. Steno suggested that Moses, when speaking of the loftiest mountains as having been covered by the deluge, meant merely the loftiest of the hills then existing, which may not have been very high.

* Sex itaque distinctas Etruriæ facies agnoscimus, dum bis fluida, bis plana, et sicca, bis aspera fuerit, &c.

The diluvian waters, he supposed, may have issued from the interior of the earth into which they had retired, when in the beginning the land was separated from the sea. These, and other hypotheses on the same subject, are not calculated to enhance the value of the treatise, and could scarcely fail to detract from the authority of those opinions which were sound and legitimate deductions from fact and observation. They have served, nevertheless, as the germs of many popular theories of later times, and in an expanded form have been put forth as original inventions by some of our contemporaries.

Scilla, 1670.—Scilla, a Sicilian painter, published, in 1670, a treatise, in Latin, on the fossils of Calabria, illustrated by good engravings. This work proves the continued ascendency of dogmas often refuted; for we find the wit and eloquence of the author chiefly directed against the obstinate incredulity of naturalists as to the organic nature of fossil shells.* Like many eminent naturalists of his day, Scilla gave way to the popular persuasion, that all fossil shells were the effects and proofs of the Mosaic deluge. It may be doubted whether he was perfectly sincere, and some of his contemporaries who took the same course were certainly not so. But so eager were they to root out what they justly considered an absurd prejudice respecting the nature of organized fossils, that they seem to have been ready to make any concessions, in order to

* Scilla quotes the remark of Cicero on the story that a stone in Chios had been cleft open, and presented the head of Paniscus in relief: — "I believe," said the orator, "that the figure bore some resemblance to Paniscus, but not such that you would have deemed it sculptured by Scopas; for chance never perfectly imitates the truth."

establish this preliminary point. Such a compromising policy was short-sighted, since it was to little purpose that the nature of the documents should at length be correctly understood, if men were to be prevented from deducing fair conclusions from them.

Diluvial Theory.—The theologians who now entered the field in Italy, Germany, France, and England, were innumerable; and henceforward, they who refused to subscribe to the position, that all marine organic remains were proofs of the Mosaic deluge, were exposed to the imputation of disbelieving the whole of the sacred writings. Scarcely any step had been made in approximating to sound theories since the time of Fracastoro, more than a hundred years having been lost, in writing down the dogma that organized fossils were mere sports of nature. An additional period of a century and a half was now destined to be consumed in exploding the hypothesis, that organized fossils had all been buried in the solid strata by the Noachian flood. Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts. In recent times, we may attribute our rapid progress chiefly to the careful determination of the order of succession in mineral masses, by means of their different organic contents, and their regular superposition. But the old diluvialists were induced by their system to confound all the groups of strata together instead of discriminating,—to refer all appearances to one cause and to one brief period, not to a variety of causes acting throughout a long succession of epochs. They saw the phenomena only as they desired to see them, sometimes misrepresenting facts, and at other times deducing false conclusions from correct data. Under the influence of such prejudices, three centuries were of as little avail as a few years in our own times, when we are no longer required to propel the vessel against the force of an adverse current.

It may be well, therefore, to forewarn the reader, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, he must expect to be occupied with accounts of the retardation, as well as of the advance of the science. It will be necessary to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions; and to dwell on futile reasoning and visionary hypothesis, because some of the most extavagant systems were invented or controverted by men of acknowledged talent. In short, a sketch of the progress of geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to one who studies the philosophy of the human mind, is too often barren of instruction to him who searches for truths in physical science.

Quirini, 1676.—Quirini, in 1676*, contended, in opposition to Scilla, that the diluvian waters could not have conveyed heavy bodies to the summit of mountains, since the agitation of the sea never (as Boyle had demonstrated) extended to great depths †; and

* De Testaceis fossilibus Mus. Septaliani.

† The opinions of Boyle, alluded to by Quirini, were published a few years before, in a short article entitled "On the Bottom of the Sea." From observations collected from the divers of the pearl

still less could the testacea, as some pretended, have lived in these diluvian waters; for "the duration of the flood was brief, and *the heavy rains must have destroyed the saltness of the sea!*" He was the first writer who ventured to maintain that the universality of the Noachian cataclysm ought not to be insisted upon. As to the nature of petrified shells, he conceived that as earthy particles united in the sea to form the shells of mollusca, the same crystallizing process might be effected on the land; and that, in the latter case, the germs of the animals might have been disseminated through the substance of the rocks, and afterwards developed by virtue of humidity. Visionary as was this doctrine, it gained many proselytes even amongst the more sober reasoners of Italy and Germany; for it conceded that the position of fossil bodies could not be accounted for by the diluvial theory.

Plot — Lister, 1678. — In the mean time, the doctrine that fossil shells had never belonged to real animals maintained its ground in England, where the agitation of the question began at a much later period. Dr. Plot, in his "Natural History of Oxfordshire" (1677), attributed to a "plastic virtue latent in the earth" the origin of fossil shells and fishes; and Lister, to his accurate account of British shells, in 1678, added the fossil species, under the appellation of

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fishery, Boyle inferred that, when the waves were six or seven feet high above the surface of the water, there were no signs of agitation at the depth of fifteen fathoms; and that even during heavy gales of wind, the motion of the water was exceedingly diminished at the depth of twelve or fifteen feet. He had also learnt from some of his informants, that there were currents running in opposite directions at different depths. — Boyle's Works, vol. iii. p. 110. London, 1744.

turbinated and bivalve stones. "Either," said he "these were terriginous, or, if otherwise, the animals they so exactly represent *have become extinct.*" This writer appears to have been the first who was aware of the continuity over large districts of the principal groups of strata in the British series, and who proposed the construction of regular geological maps.*

Leibnitz, 1680.—The great mathematician Leibnitz published his "Protogœa" in 1680. He imagined this planet to have been originally a burning luminous mass, which ever since its creation has been undergoing refrigeration. When the outer crust had cooled down sufficiently to allow the vapours to be condensed, they fell, and formed a universal ocean, covering the loftiest mountains, and investing the whole globe. The crust as it consolidated from a state of fusion, assumed a vesicular and cavernous structure; and being rent in some places, allowed the water to rush into the subterranean hollows, whereby the level of the primeval ocean was lowered. The breaking in of these vast caverns is supposed to have given rise to the dislocated and deranged position of the strata "which Steno had described," and the same disruptions communicated violent movements to the incumbent waters, whence great inundations ensued. The waters, after they had been thus agitated, deposited their sedimentary matter during intervals of quiescence, and hence the various stony and earthy strata. "We may recognize, therefore," says Leibnitz, "a double origin of primitive masses, the one by refrigeration from igneous fusion, the other by concretion from

* See Mr. Conybeare's excellent Introduction to the "Outlines of the Geology of England and Wales," p. 12.

aqueous solution."* By the repetition of similar causes (the disruption of the crust and consequent floods), alternations of new strata were produced, until at length these causes were reduced to a condition of quiescent equilibrium, and a more permanent state of things was established.†

Hooke, 1688. — The "Posthumous Works of Robert Hooke, M.D.," well known as a great mathematician and natural philosopher, appeared in 1705, containing "A Discourse of Earthquakes," which, we are informed by his editor, was written in 1668, but revised at subsequent periods.‡ Hooke frequently refers to the best Italian and English authors who wrote before his time on geological subjects; but there are no passages in his works implying that he participated in the enlarged views of Steno and Lister, or of his contemporary, Woodward, in regard to the geographical extent of certain groups of strata. His treatise, however, is the most philosophical production of that age, in regard to the causes of former changes in the organic and inorganic kingdoms of nature.

"However trivial a thing," he says, "a rotten shell may appear to some, yet these monuments of nature

* Unde jam duplex origo intelligitur primorum corporum, una, cum ab ignis fusione refrigescerent, altera, cum reconcrescerent ex solutione aquarum.

† Redeunte mox simili causâ strata subinde alia aliis imponerentur, et facies teneri adhuc orbis sæpius novata est. Donec quiescentibus causis, atque æquilibratis, consistentior emergeret rerum status. — For an able analysis of the views of Leibnitz, in his Protogœa, see Mr. Conybeare's Report to the Brit. Assoc. on the Progress of Geological Science, 1832.

‡ Between the year 1688 and his death, in 1703, he read several memoirs to the Royal Society, and delivered lectures on various subjects, relating to fossil remains and the effects of earthquakes.

are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design, as may also books, manuscripts, and inscriptions, as all the learned are now sufficiently satisfied has often been actually practised," &c.; "and though it must be granted that it is very difficult to read them (the records of nature) and *to raise a chronology out of them*, and to state the intervals of the time wherein such or such catastrophes and mutations have happened, yet it is not impossible."*

Respecting the extinction of species, Hooke was aware that the fossil ammonites, nautili, and many other shells and fossil skeletons found in England, were of different species from any then known; but he doubted whether the species had become extinct, observing that the knowledge of naturalists of all the marine species, especially those inhabiting the deep sea, was very deficient. In some parts of his writings, however, he leans to the opinion that species had been lost; and, in speculating on this subject, he even suggests that there might be some connection between the disappearance of certain kinds of animals and plants, and the changes wrought by earthquakes in former ages. Some species, he observes with great sagacity, are "*peculiar to certain places*, and not to be found elsewhere. If, then, such a place had been swallowed up, it is not improbable but that those animate beings may have been destroyed with it; and this may be true both of aërial and aquatic animals: for those animated bodies, whether vegetables or animals, which were naturally nourished or refreshed by the air, would be

* Posth. Works, Lecture, Feb. 29. 1688.

destroyed by the water," &c.* Turtles, he adds, and such large ammonites as are found in Portland, seem to have been the productions of hotter countries; and it is necessary to suppose that England once lay under the sea within the torrid zone! To explain this and similar phenomena, he indulges in a variety of speculations concerning changes in the position of the axis of the earth's rotation, "a shifting of the earth's centre of gravity, analogous to the revolutions of the magnetic pole," &c. None of these conjectures, however, are proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments.

In opposition to the prejudices of his age, we find him arguing against the idea that nature had formed fossil bodies "for no other end than to play the mimic in the mineral kingdom;"—maintaining that figured stones were "really the several bodies they represent, or the mouldings of them petrified," and "not, as some have imagined, 'a lusus naturæ,' sporting herself in the needless formation of useless beings."†

* Posth. Works, p. 327.

† Posth. Works, Lecture, Feb. 15. 1688. Hooke explained, with considerable clearness, the different modes wherein organic substances may become lapidified; and, among other illustrations, he mentions some silicified palm-wood brought from Africa, on which M. de la Hire had read a Memoir to the Royal Academy of France (June, 1692), wherein he had pointed out, not only the tubes running the length of the trunk, but the roots at one extremity. De la Hire, says Hooke, also treated of certain trees found petrified in "the river that passes by Bakan, in the kingdom of *Ava*, and which has for the space of ten leagues the virtue of petrifying wood." It is an interesting fact, that the silicified wood of the Irawadi should have attracted attention more than one hundred years ago. Remarkable discoveries have been recently

It was objected to Hooke, that his doctrine of the extinction of species derogated from the wisdom and power of the Omnipotent Creator; but he answered, that, as individuals die, there may be some termination to the duration of a species; and his opinions, he declared, were not repugnant to Holy Writ: for the Scriptures taught that our system was degenerating, and tending to its final dissolution; "and as, when that shall happen, all the species will be lost, why not some at one time and some at another?"*

But his principal object was to account for the manner in which shells had been conveyed into the higher parts of "the Alps, Apennines, and Pyrenean hills, and the interior of continents in general." These and other appearances, he said, might have been brought about by earthquakes, "which have turned plains into mountains, and mountains into plains, seas into land, and land into seas, made rivers where there were none before, and swallowed up others that formerly were, &c. &c.; and which, since the creation of the world, have wrought many great changes on the superficial parts of the earth, and have been the instruments of placing shells, bones, plants, fishes, and the like, in those places where, with much astonishment, we find them."† This doctrine, it is true, had been laid down in terms almost equally explicit by Strabo, to explain the occurrence of fossil shells in the interior of continents, and to that geographer,

made there of fossil animals and vegetables, by Mr. Crawfurd and Dr. Wallich. — See Geol. Trans. vol. ii. part iii. p. 377. second series. De la Hire cites Father Duchatz, in the second volume of "Observations made in the Indies by the Jesuits."

* Posth. Works, Lecture May 29. 1689. † Posth. Works, p. 312.

and other writers of antiquity, Hooke frequently refers; but the revival and development of the system was an important step in the progress of modern science.

Hooke enumerated all the examples known to him of subterranean disturbance, from "the sad catastrophe of Sodom and Gomorrah" down to the Chilian earthquake of 1646. The elevating of the bottom of the sea, the sinking and submersion of the land, and most of the inequalities of the earth's surface, might, he said, be accounted for by the agency of these subterranean causes. He mentions that the coast near Naples *was raised during the eruption of Monte Nuovo;* and that, in 1591, land rose in the island of St. Michael, during an eruption; and although it would be more difficult, he says, to prove, he does not doubt but that there had been as many earthquakes in the parts of the earth under the ocean, as in the parts of the dry land; in confirmation of which, he mentions the immeasurable depth of the sea near some volcanos. To attest the extent of simultaneous subterranean movements, he refers to an earthquake in the West Indies, in the year 1690, where the space of earth raised, or "struck upwards," by the shock, exceeded, he affirms, the length of the Alps and the Pyrenees.

Hooke's diluvial theory.—As Hooke declared the favourite hypothesis of the day, "that marine fossil bodies were to be referred to Noah's flood," to be wholly untenable, he appears to have felt himself called upon to substitute a diluvial theory of his own, and thus he became involved in countless difficulties and contradictions. "During the great catastrophe," he said, "there might have been a changing of that part which was before dry land into sea by sinking, and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean, in the interval between the creation and the deluge."* Then follows a disquisition on the separation of the land from the waters, mentioned in Genesis: during which operation some places of the shell of the earth were forced outwards, and others pressed downwards or inwards, &c. His diluvial hypothesis very much resembled that of Steno, and was entirely opposed to the fundamental principles professed by him, that he would explain the former changes of the earth *in a more natural manner* than others had done. When, in despite of this declaration, he required a former "crisis of nature," and taught that earthquakes had become debilitated, and that the Alps, Andes, and other chains, had been lifted up in a few months, he was compelled to assume so rapid a rate of change, that his machinery appeared scarcely less extravagant than that of his most fanciful predecessors. For this reason, perhaps, his whole theory of earthquakes met with undeserved neglect.

Ray, 1692.—One of his contemporaries, the celebrated naturalist, Ray, participated in the same desire to explain geological phenomena, by reference to causes less hypothetical than those usually resorted to.† In his essay on "Chaos and Creation," he proposed a system, agreeing in its outline, and in many of its details, with that of Hooke; but his knowledge of

* Post. Works, p. 410.

† Ray's Physico-theological Discourses were of somewhat later date than Hooke's great work on earthquakes. He speaks of Hooke as one "whom for his learning and deep insight into the mysteries of nature he deservedly honoured."—*On the Deluge*, chap. iv.

natural history enabled him to elucidate the subject with various original observations. Earthquakes, he suggested, might have been the second causes employed at the creation, in separating the land from the waters, and in gathering the waters together into one place. He mentions, like Hooke, the earthquake of 1646, which had violently shaken the Andes for some hundreds of leagues, and made many alterations therein. In assigning a cause for the general deluge, he preferred a change in the earth's centre of gravity to the introduction of earthquakes. Some unknown cause, he said, might have forced the subterranean waters outwards, as was, perhaps, indicated by "the breaking up of the fountains of the great deep."

Ray was one of the first of our writers who enlarged upon the effects of running water upon the land, and of the encroachment of the sea upon the shores. So important did he consider the agency of these causes, that he saw in them an indication of the tendency of our system to its final dissolution; and he wondered why the earth did not proceed more rapidly towards a general submersion beneath the sea, when so much matter was carried down by rivers, or undermined in the sea-cliffs. We perceive clearly from his writings, that the gradual decline of our system, and its future consummation by fire, was held to be as necessary an article of faith by the orthodox, as was the recent origin of our planet. His discourses, like those of Hooke, are highly interesting, as attesting the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity. Ray gave an unequivocal proof of the sincerity of his mind, by sacrificing his preferment in the church, rather than take an oath against the Covenanters, which he could not reconcile with his conscience. His reputation, moreover, in the scientific world placed him high above the temptation of courting popularity, by pandering to the physico-theological taste of his age. It is, therefore, curious to meet with so many citations from the Christian fathers and prophets in his essays on physical science—to find him in one page proceeding, by the strict rules of induction, to explain the former changes of the globe, and in the next gravely entertaining the question, whether the sun and stars, and the whole heavens shall be annihilated, together with the earth, at the era of the grand conflagration.

Woodward, 1695.—Among the contemporaries of Hooke and Ray, Woodward, a professor of medicine, had acquired the most extensive information respecting the geological structure of the crust of the earth. He had examined many parts of the British strata with minute attention; and his systematic collection of specimens, bequeathed to the University of Cambridge, and still preserved there as arranged by him, shows how far he had advanced in ascertaining the order of superposition. From the great number of facts collected by him, we might have expected his theoretical views to be more sound and enlarged than those of his contemporaries; but in his anxiety to accommodate all observed phenomena to the scriptural account of the Creation and Deluge, he arrived at most erroneous results. He conceived "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid."* In corroboration of these views, he insisted upon the fact, that "marine bodies are lodged in the strata according

* Essay towards a Natural History of the Earth, 1695. Preface.

to the order of their gravity, the heavier shells in stone, the lighter in chalk, and so of the rest." * Ray immediately exposed the unfounded nature of this assertion, remarking truly, that fossil bodies "are often mingled, heavy with light, in the same stratum;" and he even went so far as to say, that Woodward "must have invented the phenomena for the sake of confirming his bold and strange hypothesis †"—a strong expression from the pen of a contemporary.

Burnet, 1690.—At the same time Burnet published his "Theory of the Earth." ‡ The title is most characteristic of the age,—"The Sacred Theory of the Earth; containing an Account of the Original of the Earth, and of all the general Changes which it hath already undergone, or is to undergo, till the Consummation of all Things." Even Milton had scarcely ventured in his poem to indulge his imagination so freely in painting scenes of the Creation and Deluge, Paradise and Chaos. He explained why the primeval earth enjoyed a perpetual spring before the flood! showed how the crust of the globe was fissured by "the sun's rays," so that it burst, and thus the diluvial waters were let loose from a supposed central abyss. Not satisfied with these themes, he derived from the books of the inspired writers, and even from heathen authorities, prophetic views of the future revolutions of the globe, gave a most terrific description of the general conflagration, and proved that a new heaven and a new earth will rise out of a *second chaos*—after which will follow the blessed millennium.

* Essay towards a Natural History of the Earth, 1695. Preface.

† Consequences of the Deluge, p. 165.

‡ First published in Latin, between the years 1680 and 1690.

The reader should be informed, that, according to the opinion of many respectable writers of that age, there was good scriptural ground for presuming that the garden bestowed upon our first parents was not on the earth itself, but above the clouds, in the middle region between our planet and the moon. Burnet approaches with becoming gravity the discussion of so important a topic. He was willing to concede that the geographical position of Paradise was not in Mesopotamia, yet he maintained that it was upon the earth, and in the southern hemisphere, near the equinoctial line. Butler selected this conceit as a fair mark for his satire, when, amongst the numerous accomplishments of Hudibras, he says,—

> He knew the seat of Paradise,
> Could tell in what degree it lies;
> And, as he was disposed, could prove it
> Below the moon, or else above it.

Yet the same monarch, who is said never to have slept without Butler's poem under his pillow, was so great an admirer and patron of Burnet's book, that he ordered it to be translated from the Latin into English. The style of the "Sacred Theory" was eloquent, and the book displayed powers of invention of no ordinary stamp. It was, in fact, a fine historical romance, as Buffon afterwards declared; but it was treated as a work of profound science in the time of its author, and was panegyrized by Addison in a Latin ode, while Steele praised it in the "Spectator." Towards the end of the last century, Warton, in his "Essay on Pope," discovered that Burnet united the faculty of *judgment* with powers of imagination.

Whiston, 1696.—Another production of the same school, and equally characteristic of the time, was that of Whiston, entitled, "A New Theory of the Earth; wherein the Creation of the World in Six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shewn to be perfectly agreeable to Reason and Philosophy." He was at first a follower of Burnet; but his faith in the infallibility of that writer was shaken by the declared opinion of Newton, that there was every presumption in astronomy against any former change in the inclination of the earth's axis. This was a leading dogma in Burnet's system, though not original, for it was borrowed from an Italian, Alessandro degli Alessandri, who had suggested it in the beginning of the fifteenth century, to account for the former occupation of the present continents by the sea. La Place has since strengthened the arguments of Newton, against the probability of any former revolution of this kind.

The remarkable comet of 1680 was fresh in the memory of every one when Whiston first began his cosmological studies, and the principal novelty of his speculations consisted in attributing the deluge to the near approach to the earth of one of these erratic bodies. Having ascribed an increase of the waters to this source, he adopted Woodward's theory, supposing all stratified deposits to have resulted from the "chaotic sediment of the flood." Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptation, so that the doctrine of the earth having existed long previous to the creation of man might no longer be regarded as unorthodox. He had the art to throw an air of plausibility over the most improbable parts of his theory, and seemed to be proceeding in the most sober manner, and by the aid of mathematical demonstration, to the establishment of his various propositions. Locke pronounced a panegyric on his theory, commending him for having explained so many wonderful and before inexplicable things. His book, as well as Burnet's, was attacked and refuted by Keill.* Like all who introduced purely hypothetical causes to account for natural phenomena, Whiston retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land — on the condensation of the vapours of their tails into water, and other matters equally edifying.

Hutchinson, 1724. — John Hutchinson, who had been employed by Woodward in making his collection of fossils, published afterwards, in 1724, the first part of his "Moses's Principia," wherein he ridiculed Woodward's hypothesis. He and his numerous followers were accustomed to declaim loudly against human learning; and they maintained that the Hebrew scriptures, when rightly translated, comprised a perfect system of natural philosophy, for which reason they objected to the Newtonian theory of gravitation.

Celsius. — Andrea Celsius, the Swedish astronomer, published about this time his remarks on the gradual diminution of the waters in the Baltic, to which I shall have occasion to advert more particularly in the sequel.

Scheuchzer, 1708. — In Germany, in the mean time, Scheuchzer laboured to prove, in a work entitled "The Complaint of the Fishes" (1708), that the earth had been remodelled at the deluge. Pluche also, in 1732, wrote to the same effect; while Holbach, in 1753, after

* An Examination of Dr. Burnet's Theory, &c. 2d ed. 1734.

considering the various attempts to refer all the ancient formations to the Noachian flood, exposed the inadequacy of this cause.

Italian Geologists — Vallisneri. — I return with pleasure to the geologists of Italy, who preceded, as has been already shown, the naturalists of other countries in their investigations into the ancient history of the earth, and who still maintained a decided pre-eminence. They refuted and ridiculed the physico-theological systems of Burnet, Whiston, and Woodward *; while Vallisneri †, in his comments on the Woodwardian theory, remarked how much the interests of religion, as well as those of sound philosophy, had suffered by perpetually mixing up the sacred writings with questions in physical science. The works of this author were rich in original observations. He attempted the first general sketch of the marine deposits of Italy, their geographical extent, and most characteristic organic remains. In his treatise "On the origin of Springs," he explained their dependence on the order and often on the dislocations of the strata, and reasoned philosophically against the opinions of those who regarded the disordered state of the earth's crust as exhibiting signs of the wrath of God for the sins of man. He found himself under the necessity of contending, in his preliminary chapter, against St. Jerome, and four other principal interpreters of Scripture, besides several professors of divinity, "that springs

* Ramazzini even asserted, that the ideas of Burnet were mainly borrowed from a dialogue of one Patrizio; but Brocchi, after reading that dialogue, assures us, that there was scarcely any other correspondence between these systems, except that both were equally whimsical.

† Dei Corpi Marini, Lettere critiche, &c. 1721.

did not flow by subterranean siphons and cavities from the sea upwards, losing their saltness in the passage," for this theory had been made to rest on the infallible testimony of Holy Writ.

Although reluctant to generalize on the rich materials accumulated in his travels, Vallisneri had been so much struck with the remarkable continuity of the more recent marine strata, from one end of Italy to the other, that he came to the conclusion that the ocean formerly extended over the whole earth, and after abiding there for a long time, had gradually subsided. This opinion, however untenable, was a great step beyond Woodward's diluvian hypothesis, against which Vallisneri, and after him all the Tuscan geologists, uniformly contended, while it was warmly supported by the members of the Institute of Bologna.*

Among others of that day, Spada, a priest of Grezzana, in 1737, wrote to prove that the petrified marine bodies near Verona were not diluvian.† Mattani drew a similar inference from the shells of Volterra and other places: while Costantini, on the other hand, whose observations on the valley of the Brenta and other districts were not without value, undertook to vindicate the truth of the deluge, as also to prove that Italy had been peopled by the descendants of Japhet.‡

Moro, 1740.—Lazzaro Moro, in his work (published in 1740) "On the Marine Bodies which are found in the Mountains §," attempted to apply the theory of earthquake as expounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri.||

* Brocchi, p. 28. † Ibid. p. 33. ‡ Ibid. p. 37.

§ Sui Crostacei ed altri Corpi Marini che si trovano sui Monti.

|| Moro does not cite the works of Hooke and Ray; and al-

His attention was awakened to the elevating power of subterranean forces by a remarkable phenomenon which happened in his own time, and which had also been noticed by Vallisneri in his letters. A new island rose in 1707 from a deep part of the sea near Santorino in the Mediterranean, during continued shocks of an earthquake, and, increasing rapidly in size, grew in less than a month to be half a mile in circumference, and about twenty-five feet above high-water mark. It was soon afterwards covered by volcanic ejections, but, when first examined, it was found to be a white rock, bearing on its surface living oysters and crustacea. In order to ridicule the various theories then in vogue, Moro ingeniously supposes the arrival on this new island of a party of naturalists ignorant of its recent origin. One immediately points to the marine shells, as proofs of the universal deluge; another argues that they demonstrate the former residence of the sea upon the mountains; a third dismisses them as mere *sports of nature;* while a fourth affirms, that they were born and nourished within the rock in ancient caverns, into which salt water had been raised in the shape of vapour by the action of subterranean heat.

Moro pointed with great judgment to the *faults* and dislocations of the strata described by Vallisneri, in the Alps and other chains, in confirmation of his doctrine, that the continents had been heaved up by

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though so many of his views were in accordance with theirs, he was probably ignorant of their writings, for they had not been translated. As he always refers to the Latin edition of Burnet, and a French translation of Woodward, we may presume that he did not read English.

subterranean movements. He objected, on solid grounds, to the hypotheses of Burnet and of Woodward; yet he ventured so far to disregard the protest of Vallisneri, as to undertake the adaptation of every part of his own system to the Mosaic account of the creation. On the third day, he said, the globe was every where covered to the same depth by fresh water; and when it pleased the Supreme Being that the dry land should appear, volcanic explosions broke up the smooth and regular surface of the earth composed of primary rocks. These rose in mountain masses above the waves, and allowed melted metals and salts to ascend through fissures. The sea gradually acquired its saltness from volcanic exhalations, and, while it became more circumscribed in area, increased in depth. Sand and ashes ejected by volcanos were regularly disposed along the bottom of the ocean, and formed the secondary strata, which in their turn were lifted up by earthquakes. We need not follow this author in tracing the progress of the creation of vegetables and animals on the other days of creation; but, upon the whole, it may be remarked, that few of the old cosmological theories had been conceived with so little violation of known analogies.

Generelli's illustrations of Moro, 1749.— The style of Moro was extremely prolix, and, like Hutton, who, at a later period, advanced many of the same views, he stood in need of an illustrator. The Scotch geologist was hardly more fortunate in the advocacy of Playfair, than was Moro in numbering amongst his admirers Cirillo Generelli, who, nine years afterwards, delivered at a sitting of Academicians at Cremona a spirited exposition of his theory. This learned Carmelitan friar does not pretend to have been na original observer, but he had studied sufficiently to enable him to confirm the opinions of Moro by arguments from other writers; and his selection of the doctrines then best established is so judicious, that a brief abstract of them cannot fail to be acceptable, as illustrating the state of geology in Europe, and in Italy in particular, before the middle of the last century.

The bowels of the earth, says he, have carefully preserved the memorials of past events, and this truth the marine productions so frequent in the hills attest. From the reflections of Lazzaro Moro, we may assure ourselves that these are the effects of earthquakes in past times, which have changed vast spaces of sea into terra firma, and inhabited lands into seas. In this, more than in any other department of physics, are observations and experiments indispensable, and we must diligently consider facts. The land is known, wherever we make excavations, to be composed of different strata or soils placed one above the other, some of sand, some of rock, some of chalk, others of marl, coal, pumice, gypsum, lime, and the rest. These ingredients are sometimes pure, and sometimes confusedly intermixed. Within are often imprisoned different marine fishes, like dried mummies, and more frequently shells, crustacea, corals, plants, &c. not only in Italy, but in France, Germany, England, Africa, Asia, and America; — sometimes in the lowest, sometimes in the loftiest beds of the earth, some upon the mountains, some in deep mines, others near the sea, and others hundreds of miles distant from it. Woodward conjectured that these marine bodies might be found every where; but there are rocks in which none of them occur, as is sufficiently attested by Vallisneri and Marsilli. The remains of fossil animals consist chiefly of their more solid parts, and the most rocky strata must have been soft when such exuviæ were inclosed in them. Vegetable productions are found in different states of maturity, indicating that they were imbedded in different seasons. Elephants, elks, and other terrestrial quadrupeds, have been found in England and elsewhere, in superficial strata, never covered by the sea. Alternations are rare, yet not without example, of marine strata, and those which contain marshy and terrestrial productions. Marine animals are arranged in the subterraneous beds with admirable order, in distinct groups, oysters here, dentalia or corals there, &c. as now, according to Marsilli *, on the shores of the Adriatic. We must abandon the doctrine, once so popular, which denies that organized fossils were derived from living beings, and we cannot account for their present position by the ancient theory of Strato, nor by that of Leibnitz, nor by the universal deluge, as explained by Woodward and others: "nor is it reasonable to call the Deity capriciously upon the stage, and to make him work miracles for the sake of confirming our preconceived hypotheses."—"I hold in utter abomination, most learned Academicians! those systems which are built with their foundations in the air, and cannot be propped up without a miracle; and I undertake, with the assistance of Moro, to explain to you, how these marine animals were transported into the mountains by natural causes." †

* Saggio fisico intorno alla Storia del Mare, part i. p. 24.

† "Abbomino al sommo qualsivoglia sistema, che sia di pianta fabbricato in aria; massime quando è tale, che non possa sostenersi senza un miracolo," &c. - - De' Crostacei e di altre Produz. del Mare, &c. 1749.

A brief abstract then follows of Moro's theory, by which, says Generelli, we may explain all the phenomena, as Vallisneri so ardently desired, "*without violence, without fictions, without hypotheses, without miracles.*"* The Carmelitan then proceeds to struggle against an obvious objection to Moro's system, considered as a method of explaining the revolutions of the earth, *naturally*. If earthquakes have been the agents of such mighty changes, how does it happen that their effects since the times of history have been so inconsiderable? This same difficulty had, as we have seen, presented itself to Hooke, half a century before, and forced him to resort to a former "crisis of nature:" but Generelli defended his position by shewing how numerous were the accounts of eruptions and earthquakes, of new islands, and of elevations and subsidences of land, and yet how much greater a number of like events must have been unattested and unrecorded during the last six thousand years. He also appealed to Vallisneri as an authority to prove that the mineral masses containing shells bore, upon the whole, but a small proportion to those rocks which were destitute of organic remains; and the latter, says the learned monk, might have been created as they now exist, *in the beginning*.

Generelli then describes the continual waste of mountains and continents, by the action of rivers and torrents, and concludes with these eloquent and original observations:—"Is it possible that this waste should have continued for six thousand, and *perhaps* a greater number of years, and that the mountains should remain so great, unless their ruins have been repaired?

* "Senza violenze, senza finzioni, senza supposti, senza miracoli." De' Crostacei e di altre Produz. del Mare, &c. 1749.

Is it credible that the Author of Nature should have founded the world upon such laws, as that the dry land should for ever be growing smaller, and at last become wholly submerged beneath the waters? Is it credible that, amid so many created things, the mountains alone should daily diminish in number and bulk, without there being any repair of their losses? This would be contrary to that order of Providence which is seen to reign in all other things in the universe. Wherefore I deem it just to conclude, that the same cause which, in the beginning of time, raised mountains from the abyss, has down to the present day, continued to produce others, in order to restore from time to time the losses of all such as sink down in different places, or are rent asunder, or in other way suffer disintegration. If this be admitted, we can easily understand why there should now be found upon many mountains so great a number of crustacea and other marine animals."

In the above extract I have not merely enumerated the opinions and facts which are confirmed by recent observation, suppressing all that has since proved to be erroneous, but have given a faithful abridgment of the entire treatise, with the omission only of Moro's hypothesis, which Generelli adopted, with all its faults and excellencies. The reader will therefore remark, that although this admirable essay embraces so large a portion of the principal objects of geological research, it makes no allusion to the extinction of certain classes of animals; and it is evident that no opinions on this head had, at that time, gained a firm footing in Italy. That Lister and other English naturalists should long before have declared in favour of the loss of species, while Scilla and most of his countrymen hesitated, was perhaps natural, since the Italian museums were filled with fossil shells belonging to species of which a great portion did actually exist in the Mediterranean; whereas the English collectors could obtain no recent species from such of their own strata as were then explored.

The weakest point in Moro's system consisted in deriving *all* the stratified rocks from volcanic ejections; an absurdity which his opponents took care to expose, especially Vito Amici.* Moro seems to have been misled by his anxious desire to represent the formation of secondary rocks as having occupied an extremely short period, while at the same time he wished to employ known agents in nature. To imagine torrents, rivers, currents, partial floods, and all the operations of moving water, to have gone on exerting an energy many thousand times greater than at present, would have appeared preposterous and incredible, and would have required a hundred violent hypotheses; but we are so unacquainted with the true sources of subterranean disturbances, that their former violence may in theory be multiplied indefinitely, without its being possible to prove the same manifest contradiction or absurdity in the conjecture. For this reason, perhaps, Moro preferred to derive the materials of the strata from volcanic ejections, rather than from transportation by running water.

Marsilli.—Marsilli, whose work is alluded to by Generelli, had been prompted to institute inquiries into the bed of the Adriatic, by discovering, in the territory of Parma, (what Spada had observed near Verona, and Schiavo in Sicily,) that fossil shells were not scat-

* Sui Testacei della Sicilia.

tered through the rocks at random, but disposed in regular order, according to certain genera and species.

Vitaliano Donati, 1750.—But with a view of throwing further light upon these questions, Donati, in 1750, undertook a more extensive investigation of the Adriatic, and discovered, by numerous soundings, that deposits of sand, marl, and tufaceous incrustations, most strictly analogous to those of the Subapennine hills, were in the act of accumulating there. He ascertained that there were no shells in some of the submarine tracts, while in other places they lived together in families, particularly the genera Arca, Pecten, Venus, Murex, and some others. He also states that in divers localities he found a mass composed of corals, shells, and crustaceous bodies of different species, confusedly blended with earth, sand, and gravel. At the depth of a foot or more, the organic substances were entirely petrified and reduced to marble; at less than a foot from the surface, they approached nearer to their natural state; while at the surface they were alive, or if dead, in a good state of preservation.

Baldassari.—A contemporary naturalist, Baldassari, had shewn that the organic remains in the tertiary marls of the Siennese territory were grouped in families, in a manner precisely similar to that above alluded to by Donati.

Buffon, 1749.—Buffon first made known his theoretical views concerning the former changes of the earth, in his Natural History, published in 1749. He adopted the theory of an original volcanic nucleus, together with the universal ocean of Leibnitz. By this aqueous envelope the highest mountains were once covered. Marine currents then acted violently, and formed horizontal strata, by washing away solid matter in some parts, and depositing it in others; they also excavated deep submarine valleys. The level of the ocean was then depressed by the entrance of a part of its waters into subterranean caverns, and thus some land was left dry. Buffon seems not to have profited, like Leibnitz and Moro, by the observations of Steno, or he could not have imagined that the strata were generally horizontal, and that those which contain organic remains had never been disturbed since the era of their formation. He was conscious of the great power annually exerted by rivers and marine currents in transporting earthy materials to lower levels, and he even contemplated the period when they would destroy all the present continents. Although in geology he was not an original observer, his genius enabled him to render his hypothesis attractive; and by the eloquence of his style, and the boldness of his speculations, he awakened curiosity, and provoked a spirit of inquiry amongst his countrymen.

Soon after the publication of his "Natural History," in which was included his "Theory of the Earth," he received an official letter (dated January, 1751) from the Sorbonne, or Faculty of Theology in Paris, informing him that fourteen propositions in his works "were reprehensible, and contrary to the creed of the church." The first of these obnoxious passages, and the only one relating to geology, was as follows: — "The waters of the sea have produced the mountains and valleys of the land — the waters of the heavens, reducing all to a level, will at last deliver the whole land over to the sea, and the sea, successively prevailing over the land, will leave dry new continents like those which we inhabit." Buffon was invited by the College, in very courteous terms, to send in an explanation, or rather a recantation, of his unorthodox opinions. To this he submitted; and a general assembly of the Faculty having approved of his "Declaration," he was required to publish it in his next work. The document begins with these words;—"I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and *I abandon every thing in my book respecting the formation of the earth*, and, generally, all which may be contrary to the narration of Moses." *

The grand principle which Buffon was called upon to renounce was simply this,—"that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will in time destroy all the continents, hills, and valleys, and reproduce others like them." Now, whatever may be the defects of many of his views, it is no longer controverted that the present continents are of secondary origin. The doctrine is as firmly established as the earth's rotation on its axis; and that the land now elevated above the level of the sea will not endure for ever, is an opinion which gains ground daily, in proportion as we enlarge our experience of the changes now in progress.

Targioni, 1751.—Targioni, in his voluminous "Travels in Tuscany, 1751 and 1754," laboured to fill up the sketch of the geology of that region left by Steno sixty years before. Notwithstanding a want of arrangement and condensation in his memoirs, they contained a rich store of faithful observations. He has not indulged in many general views, but in regard to the origin of valleys, he was opposed to the theory of Buffon, who attributed them principally to submarine

* Hist. Nat. tom. v. éd. de l'Imp. Royale, Paris, 1769.

currents. The Tuscan naturalist laboured to shew that both the larger and smaller valleys of the Apennines were excavated by rivers and floods, caused by the bursting of the barriers of lakes, after the retreat of the ocean. He also maintained that the elephants and other quadrupeds, so frequent in the lacustrine and alluvial deposits of Italy, had inhabited that peninsula; and had not been transported thither, as some had conceived, by Hannibal or the Romans, nor by what they were pleased to term "a catastrophe of nature."

Lehman, 1756.—In the year 1756 the treatise of Lehman, a German mineralogist, and director of the Prussian mines, appeared, who also divided mountains into three classes: the first, those formed with the world, and prior to the creation of animals, and which contained no fragments of other rocks; the second class, those which resulted from the partial destruction of the primary rocks by a general revolution; and a third class, resulting from local revolutions, and in part from the Noachian deluge.*

A French translation of this work appeared in 1759, in the preface of which the translator displays very enlightened views respecting the operations of earthquakes, as well as of the aqueous causes.

Gesner, 1758.—In this year Gesner, the botanist, of Zurich, published an excellent treatise on petrifactions, and the changes of the earth which they testify.† After a detailed enumeration of the various classes of fossils of the animal and vegetable kingdoms, and remarks on the different states in which they are found petrified, he considers the geological phenomena con-

* Essai d'une Hist. Nat. des Couches de la Terre, 1759.

† John Gesner published at Leyden, in Latin.

nected with them; observing, that some, like those of Œningen, resembled the testacea, fish, and plants indigenous in the neighbouring region *; while some, such as ammonites, gryphites, belemnites, and other shells, are either of unknown species, or found only in the Indian and other distant seas. In order to elucidate the structure of the earth, he gives sections, from Verenius, Buffon, and others, obtained in digging wells; distinguishes between horizontal and inclined strata; and, in speculating on the causes of these appearances, mentions Donati's examination of the bed of the Adriatic; the filling up of lakes and seas by sediment; the imbedding of shells, now in progress; and many known effects of earthquakes, such as the sinking down of districts, or the heaving up of the bed of the sea, so as to form new islands and lay dry strata containing petrifactions. The ocean, he says, deserts its shores in many countries, as on the borders of the Baltic; but the rate of recession has been so slow in the last 2000 years, that to allow the Apennines, whose summits are filled with marine shells, to emerge to their present height, would have required about 80,000 years,—a lapse of time ten times greater, or more, than the age of the universe. We must therefore refer the phenomenon to the command of the Deity, related by Moses, that "the waters should be gathered together in one place, and the dry land appear." Gesner adopted the views of Leibnitz, to account for the retreat of the primeval ocean: his essay displays much erudition; and the opinions of preceding writers of Italy, Germany, and England are commented upon with fairness and discrimination.

Arduino, 1759.—In the year following, Arduino †, in

* Part ii. chap. 9.

† Giornale del Griselini, 1759.

his memoirs on the mountains of Padua, Vicenza, and Verona, deduced, from original observations, the distinction of rocks into primary, secondary, and tertiary, and shewed that in those districts there had been a succession of submarine volcanic eruptions.

Michell, 1760.—In the following year (1760) the Rev. John Michell, Woodwardian Professor of Mineralogy at Cambridge, published, in the Philosophical Transactions, an Essay on the Cause and Phenomena of Earthquakes.* His attention had been drawn to this subject by the great earthquake of Lisbon in 1755. He advanced many original and philosophical views respecting the propagation of subterranean movements, and the caverns and fissures wherein steam might be generated. In order to point out the application of his theory to the structure of the globe, he was led to describe the arrangement and disturbance of the strata, their usual horizontality in low countries, and their contortions and fractured state in the neighbourhood of mountain chains. He also explained, with surprising accuracy, the relations of the central ridges of older rocks to the "long narrow slips of similar earths, stones, and minerals," which are parallel to these ridges. In his generalizations, derived in great part from his own observations on the geological

* See a Sketch of the History of English Geology, by Dr. Fitton, in Edinb. Rev. Feb. 1818, re-edited Lond. and Edinb. Phil. Mag. vol. i. and ii. 1832–33. Some of Michell's Observations anticipate in so remarkable a manner the theories established forty years afterwards, that his writings would probably have formed an era in the science, if his researches had been uninterrupted. He held, however, his professorship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

structure of Yorkshire, he anticipated many of the views more fully developed by later naturalists.

Catcott, 1761.—Michell's papers were entirely free from all physico-theological disquisitions, but some of his contemporaries were still earnestly engaged in defending or impugning the Woodwardian hypothesis. We find many of these writings referred to by Catcott, an Hutchinsonian, who published a "Treatise on the Deluge" in 1761. He laboured particularly to refute an explanation offered by his contemporary, Bishop Clayton, of the Mosaic writings. That prelate had declared that the deluge "could not be literally true, save in respect to that part where Noah lived before the flood." Catcott insisted on the universality of the deluge, and referred to traditions of inundations mentioned by ancient writers, or by travellers in the East Indies, China, South America, and other countries. This part of his book is valuable, although it is not easy to see what bearing the traditions have, if admitted to be authentic, on the Bishop's argument; since no evidence is adduced to prove that the catastrophes were contemporaneous events, while some of them are expressly represented by ancient authors to have occurred in succession.

Fortis—Odoardi, 1761.—The doctrines of Arduino, above adverted to, were afterwards confirmed by Fortis and Desmarest, in their travels in the same country; and they, as well as Baldassari, laboured to complete the history of the Subapennine strata. In the work of Odoardi *, there was also a clear argument in favour of the distinct ages of the older Apennine strata, and the Subapennine formations of more recent

* Sui Corpi Marini del Feltrino, 1761.

origin. He pointed out that the strata of these two groups were *unconformable*, and must have been the deposits of different seas at distant periods of time.

Raspe, 1763. — A history of the new islands by Raspe, an Hanoverian, appeared in 1763, in Latin.* In this work, all the authentic accounts of earthquakes which had produced permanent changes on the solid parts of the earth were collected together and examined with judicious criticism. The best systems which had been proposed concerning the ancient history of the globe, both by ancient and modern writers, are reviewed; and the merits and defects of the doctrines of Hooke, Ray, Moro, Buffon, and others, fairly estimated. Great admiration is expressed for the hypothesis of Hooke, and his explanation of the origin of the strata is shown to have been more correct than Moro's, while their theory of the effects of earthquakes was the same. Raspe had not seen Michell's memoir, and his views concerning the geological structure of the earth were perhaps less enlarged; yet he was able to add many additional arguments in favour of Hooke's theory, and to render it, as he said, a nearer approach to what Hooke would have written had he lived in later times. As to the periods wherein all the earthquakes happened, to which we owe the elevation of various parts of our continents and islands, Raspe says he pretends not to assign their duration, still less to defend Hooke's suggestion, that the convulsions almost all took place during the deluge of Noah. He adverts to the apparent indications of the former tropical heat of the climate of Europe, and

* De Novis e Mari Natis Insulis. Raspe was also the editor of the "Philosophical Works of Leibnitz. Amst. et Leipzig, 1765;" also author of "Tassie's Gems," and "Baron Munchausen's Travels."

the changes in the species of animals and plants, as among the most obscure and difficult problems in geology. In regard to the islands raised from the sea, within the times of history or tradition, he declares that some of them were composed of strata containing organic remains, and that they were not, as Buffon had asserted, made of mere volcanic matter. His work concludes with an eloquent exhortation to naturalists to examine the isles which rose, in 1707, in the Grecian Archipelago, and, in 1720, in the Azores, and not to neglect such splendid opportunities of studying nature "in the act of parturition." That Hooke's writings should have been neglected for more than half a century, was matter of astonishment to Raspe; but it is still more wonderful that his own luminous exposition of that theory should, for more than another half century, have excited so little interest.

Fuchsel, 1762 and 1773. — Fuchsel, a German physician, published, in 1762, a geological description of the country between the Thuringerwald and the Hartz, and a memoir on the environs of Rudelstadt*; and afterwards, in 1773, a theoretical work on the ancient history of the earth and of man.† He had evidently advanced considerably beyond his predecessor Lehman, and was aware of the distinctness, both as to position and fossil contents, of several groups of strata of different ages, corresponding to the secondary formations now recognized by geologists in various parts of Germany. He supposed the European continents to have remained covered by the sea until the formation

* Acta Academiæ Electoralis Maguntinæ, vol. ii. Erfurt.

† This account of Fuchsel is derived from an excellent analysis of his memoirs by M. Keferstein. Journ. de Géologie, tom. ii. Oct. 1830.

of the marine strata called in Germany "muschelkalk," at the same time that the terrestrial plants of many European deposits attested the existence of dry land which bordered the ancient sea; land which, therefore, must have occupied the place of the present ocean. This pre-existing continent had been *gradually* swallowed up by the sea, different parts having subsided in succession into subterranean caverns. All the sedimentary strata were originally horizontal, and their present state of derangement must be referred to subsequent oscillations of the ground.

As there were plants and animals in the ancient periods, so also there must have been men, but they did not all descend from one pair, but were created at various points on the earth's surface; and the number of these distinct birth-places was as great as are the original languages of nations.

In the writings of Fuchsel we see a strong desire manifested to explain geological phenomena as far as possible by reference to the agency of known causes; and although some of his speculations were fanciful, his views coincide much more nearly with those now generally adopted, than the theories afterwards promulgated by Werner and his followers.

Brander, 1766.—Gustavus Brander published, in 1766, his "Fossilia Hantoniensia," containing excellent figures of fossil shells from the more modern marine strata of our island. "Various opinions," he says in the preface, "had been entertained concerning the time when and how these bodies became deposited. Some there are, who conceive that it might have been effected in a wonderful length of time by a gradual changing and shifting of the sea," &c. But the most common cause assigned is that of "the deluge." This conjecture, he says, even if the universality of the flood be not called in question, is purely hypothetical. In his opinion, fossil animals and testacea were, for the most part, of unknown species; and of such as were known, the living analogues now belonged to southern latitudes.

Soldani, 1780. — Soldani applied successfully his knowledge of zoology to illustrate the history of stratified masses. He explained that microscopic testacea and zoophytes inhabited the depths of the Mediterranean; and that the fossil species were, in like manner, found in those deposits wherein the fineness of their particles, and the absence of pebbles, implied that they were accumulated in a deep sea, or far from shore. This author first remarked the alternation of marine and fresh-water strata in the Paris basin.*

Fortis — Testa, 1793. — A lively controversy arose between Fortis and another Italian naturalist, Testa, concerning the fish of Monte Bolca, in 1793. Their letters†, written with great spirit and elegance, show that they were aware that a large proportion of the Subapennine shells were identical with living species, and some of them with species now living in the torrid zone. Fortis proposed a somewhat fanciful conjecture, that when the volcanos of the Vicentin were burning, the waters of the Adriatic had a higher temperature; and in this manner, he said, the shells of warmer regions may once have peopled their own seas. But Testa was disposed to think that these species of testacea were still common to their own and to equinoctial seas: for many, he said, once supposed to be confined to hotter regions, had been afterwards discovered in the Mediterranean. ‡

* Saggio orittografico, &c. 1780, and other Works.

† Lett. sui Pesci Fossili di Bolca. Milan, 1793.

‡ This argument of Testa has been strengthened of late years by

Cortesi — Spallanzani — Wallerius — Whitehurst. — While these Italian naturalists, together with Cortesi and Spallanzani, were busily engaged in pointing out the analogy between the deposits of modern and ancient seas, and the habits and arrangement of their organic inhabitants, and while some progress was making, in the same country, in investigating the ancient and modern volcanic rocks, some of the most original observers among the English and German writers, Whitehurst* and Wallerius, were wasting their strength in contending, according to the old Woodwardian hypothesis, that all the strata were formed by the Noachian deluge. But Whitehurst's description of the rocks of Derbyshire was most faithful; and he atoned for false theoretical views, by providing data for their refutation.

Pallas — Saussure. — Towards the close of the eighteenth century, the idea of distinguishing the mineral masses on our globe into separate groups, and studying their relations, began to be generally diffused. Pallas and Saussure were among the most celebrated whose labours contributed to this end. After an attentive examination of the two great mountain chains

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the discovery, that dealers in shells had long been in the habit of selling Mediterranean species as shells of more southern and distant latitudes, for the sake of enhancing their price. It appears, moreover, from several hundred experiments made by that distinguished hydrographer, Captain Smyth, on the water within eight fathoms of the surface, that the temperature of the Mediterranean is on an average $3\frac{1}{2}°$ of Fahrenheit higher than the western part of the Atlantic ocean; an important fact, which in some degree may help to explain why many species are common to tropical latitudes and to the Mediterranean.

* Inquiry into the Original State and Formation of the Earth. 1778.

of Siberia, Pallas announced the result, that the granitic rocks were in the middle, the schistose at their sides, and the limestones again on the outside of these; and this he conceived would prove a general law in the formation of all chains composed chiefly of primary rocks.*

In his "Travels in Russia," in 1793 and 1794, he made many geological observations on the recent strata near the Wolga and the Caspian, and adduced proofs of the greater extent of the latter sea at no distant era in the earth's history. His memoir on the fossil bones of Siberia attracted attention to some of the most remarkable phenomena in geology. He stated that he had found a rhinoceros entire in the frozen soil, with its skin and flesh: an elephant, found afterwards in a mass of ice on the shore of the North sea, removed all doubt as to the accuracy of so wonderful a discovery.†

The subjects relating to natural history which engaged the attention of Pallas were too multifarious to admit of his devoting a large share of his labours exclusively to geology. Saussure, on the other hand, employed the chief portion of his time in studying the structure of the Alps and Jura, and he provided valuable data for those who followed him. He did not pretend to deduce any general system from his numerous and interesting observations; and the few theoretical opinions which escaped from him, seem, like those of Pallas, to have been chiefly derived from the cosmological speculations of preceding writers.

* Observ. on the Formation of Mountains. Act. Petrop. ann. 1778, part i.

† Nov. comm. Petr. XVII. Cuvier, E'loge de Pallas.

CHAPTER IV.

HISTORY OF THE PROGRESS OF GEOLOGY—*continued.*

Werner's Application of Geology to the Art of Mining — Excursive Character of his Lectures — Enthusiasm of his Pupils — His Authority —His theoretical Errors—Desmarest's Map and Description of Auvergne (p. 85.) — Controversy between the Vulcanists and Neptunists — Intemperance of the rival Sects — Hutton's Theory of the Earth — His Discovery of Granite Veins (p. 90.) — Originality of his Views — Why opposed — Playfair's Illustrations — Influence of Voltaire's Writings on Geology (p. 95.) — Imputations cast on the Huttonians by Williams, Kirwan, and De Luc — Smith's Map of England (p. 101.) — Geological Society of London — Progress of the Science in France — Growing Importance of the Study of Organic Remains.

Werner.—THE art of mining has long been taught in France, Germany, and Hungary, in scientific institutions established for that purpose, where mineralogy has always been a principal branch of instruction.*

Werner was named, in 1775, professor of that science in the "School of Mines," at Freyberg, in Saxony. He directed his attention not merely to the composition and external characters of minerals, but also to what he termed "geognosy," or the natural position of

* Our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any "school of mines," to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner. — See "Prospectus of a School of Mines in Cornwall, by J. Taylor, 1825."

minerals in particular rocks, together with the grouping of those rocks, their geographical distribution, and various relations. The phenomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion: but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically. Werner's mind was at once imaginative and richly stored with miscellaneous knowledge. He associated every thing with his favourite science, and in his excursive lectures he pointed out all the economical uses of minerals, and their application to medicine: the influence of the mineral composition of rocks upon the soil, and of the soil upon the resources, wealth, and civilization of man. The vast sandy plains of Tartary and Africa, he would say, retained their inhabitants in the shape of wandering shepherds; the granitic mountains and the low calcareous and alluvial plains gave rise to different manners, degrees of wealth and intelligence. The history even of languages, and the migrations of tribes, had been determined by the direction of particular strata. The qualities of certain stones used in building would lead him to descant on the architecture of different ages and nations; and the physical geography of a country frequently invited him to treat of military tactics. The charm of his manners and his eloquence kindled enthusiasm in the minds of his pupils; and many, who had intended at first only to acquire a slight knowledge of mineralogy, when they had once heard him, devoted themselves to it as the business of their lives. In a few years, a small school of mines, before unheard of in Europe, was raised to the rank of a great university; and men already distinguished in science studied the German language, and came from the most distant countries to hear the great oracle of geology.*

Werner had a great antipathy to the mechanical labour of writing, and he could never be persuaded to pen more than a few brief memoirs, and those containing no development of his general views. Although the natural modesty of his disposition was excessive, approaching even to timidity, he indulged in the most bold and sweeping generalizations, and he inspired all his scholars with a most implicit faith in his doctrines. Their admiration of his genius, and the feelings of gratitude and friendship which they all felt for him, were not undeserved; but the supreme authority usurped by him over the opinions of his contemporaries, was eventually prejudicial to the progress of the science; so much so, as greatly to counterbalance the advantages which it derived from his exertions. If it be true that delivery be the first, second, and third requisite in a popular orator, it is no less certain that to travel is of first, second, and third importance to those who desire to originate just and comprehensive views concerning the structure of our globe. Now Werner had not travelled to distant countries; he had merely explored a small portion of Germany, and conceived, and persuaded others believe, that the whole surface of our planet, and all the mountain chains in the world, were made after the model of his own province. It became a ruling object of ambition in the minds of his pupils to confirm the generalizations of their great master, and to discover

* Cuvier, Eloge de Werner.

in the most distant parts of the globe his "universal formations," which he supposed had been each in succession simultaneously precipitated over the whole earth from a common menstruum, or "chaotic fluid." It now appears that the Saxon professor had misinterpreted many of the most important appearances even in the immediate neighbourhood of Freyberg. Thus, for example, within a day's journey of his school, the porphyry, called by him primitive, has been found not only to send forth veins or dikes through strata of the coal formation, but to overlie them in mass. The granite of the Hartz mountains, on the other hand, which he supposed to be the nucleus of the chain, is now well known to traverse and breach the other beds, penetrating even into the plain (as near Goslar); and still nearer Freyberg, in the Erzgebirge, the mica slate does not mantle round the granite, as was supposed, but abuts abruptly against it. Fragments, also, of the greywacke slate, containing organic remains, have recently been found entangled in the granite of the Hartz, by M. de Seckendorf.*

The principal merit of Werner's system of instruction consisted in steadily directing the attention of his scholars to the constant relations of superposition of certain mineral groups; but he had been anticipated, as has been shown in the last chapter, in the discovery of this general law, by several geologists in Italy and elsewhere; and his leading divisions of the secondary strata were, at the same time, and independently, made the basis of an arrangement of the British strata by

* I am indebted for this information partly to Messrs. Sedgwick and Murchison, who have investigated the country, and partly to Dr. Hartmann of Blankenburg, the translator of this work into German.

our countryman, William Smith, to whose work I shall presently return.

Controversy between the Vulcanists and Neptunists. —In regard to basalt and other igneous rocks, Werner's theory was original, but it was also extremely erroneous. The basalts of Saxony and Hesse, to which his observations were chiefly confined, consisted of tabular masses capping the hills, and not connected with the levels of existing valleys, like many in Auvergne and the Vivarais. These basalts, and all other rocks of the same family in other countries, were, according to him, chemical precipitates from water. He denied that they were the products of submarine volcanos; and even taught that, in the primeval ages of the world, there were no volcanos. His theory was opposed, in a twofold sense, to the doctrine of the permanent agency of the same causes in nature; for not only did he introduce, without scruple, many imaginary causes supposed to have once effected great revolutions in the earth, and then to have become extinct, but new ones also were feigned to have come into play in modern times; and, above all, that most violent instrument of change, the agency of subterranean fire.

So early as 1768, before Werner had commenced his mineralogical studies, Raspe had truly characterized the basalts of Hesse as of igneous origin. Arduino, as we have already seen, had pointed out numerous varieties of trap-rock in the Vicentin as analogous to volcanic products, and as distinctly referrible to ancient submarine eruptions. Desmarest, as before stated, had, in company with Fortis, examined the Vicentin in 1766, and confirmed Arduino's views. In 1772, Banks, Solander, and Troil compared the columnar basalt of Hecla with that of the Hebrides.

Collini, in 1774, recognized the true nature of the igneous rocks on the Rhine, between Andernach and Bonn. In 1775, Guettard visited the Vivarais, and established the relation of basaltic currents to lavas. Lastly, in 1779, Faujas published his description of the volcanos of the Vivarais and Velay, and showed how the streams of basalt had poured out from craters which still remain in a perfect state.*

Desmarest. — When sound opinions had thus for twenty years prevailed in Europe concerning the true nature of the ancient trap-rocks, Werner by his simple dictum caused a retrograde movement, and not only overturned the true theory, but substituted for it one of the most unphilosophical that can well be imagined. The continued ascendancy of his dogmas on this subject was the more astonishing, because a variety of new and striking facts were daily accumulated in favour of the correct opinions previously entertained. Desmarest, after a careful examination of Auvergne, pointed out, first, the most recent volcanos which had their craters still entire, and their streams of lava conforming to the level of the present river-courses. He then showed that there were others of an intermediate epoch, whose craters were nearly effaced, and whose lavas were less intimately connected with the present valleys; and, lastly, that there were volcanic rocks, still more ancient, without any discernible craters or scoriæ, and bearing the closest analogy to rocks in other parts of Europe, the igneous origin of which was denied by the school of Freyberg.†

* Cuvier, Eloge de Desmarest.

† Journ. de Phys. vol. xiii. p. 115.; and Mém. de l'Inst., Sciences Mathémat. et Phys. vol. vi. p. 219.

Desmarest's map of Auvergne was a work of uncommon merit. He first made a trigonometrical survey of the district, and delineated its physical geography with minute accuracy and admirable graphic power. He contrived, at the same time, to express, without the aid of colours, a vast quantity of geological detail, the different ages, and sometimes even the structure, of the volcanic rocks, distinguishing them from the fresh-water and the granitic. They alone who have carefully studied Auvergne, and traced the different lava-streams from their craters to their termination, — the various isolated basaltic cappings, — the relation of some lavas to the present valleys, — the absence of such relations in others, — can appreciate the extraordinary fidelity of this elaborate work. No other district of equal dimensions in Europe exhibits, perhaps, so beautiful and varied a series of phenomena; and, fortunately, Desmarest possessed at once the mathematical knowledge required for the construction of a map, skill in mineralogy, and a power of original generalization.

Dolomieu—Montlosier.—Dolomieu, another of Werner's contemporaries, had found prismatic basalt among the ancient lavas of Etna; and, in 1784, had observed the alternations of submarine lavas and calcareous strata in the Val di Noto, in Sicily.* In 1790, also, he described similar phenomena in the Vicentin and in the Tyrol.† Montlosier published, in 1788, an essay on the theory of the volcanos of Auvergne, combining accurate local observations with comprehensive views. Notwithstanding this mass of evidence, the scholars of

* Journ. de Phys. tom. xxv. p. 191.

† Ib. tom. xxxvii. part ii. p. 200.

Werner were prepared to support his opinions to their utmost extent; maintaining, in the fulness of their faith, that even obsidian was an aqueous precipitate. As they were blinded by their veneration for the great teacher, they were impatient of opposition, and soon imbibed the spirit of a faction; and their opponents, the Vulcanists, were not long in becoming contaminated with the same intemperate zeal. Ridicule and irony were weapons more frequently employed than argument by the rival sects, till at last the controversy was carried on with a degree of bitterness almost unprecedented in questions of physical science. Desmarest alone, who had long before provided ample materials for refuting such a theory, kept aloof from the strife; and whenever a zealous Neptunist wished to draw the old man into an argument, he was satisfied with replying, "Go and see."*

Hutton, 1788.—It would be contrary to all analogy, in matters of graver import, that a war should rage with such fury on the Continent, and that the inhabitants of our island should not mingle in the affray. Although in England the personal influence of Werner was wanting to stimulate men to the defence of the weaker side of the question, they contrived to find good reason for espousing the Wernerian errors with great enthusiasm. In order to explain the peculiar motives which led many to enter, even with party feeling, into this contest, it will be necessary to present the reader with a sketch of the views unfolded by Hutton, a contemporary of the Saxon geologist. The former naturalist had been educated as a physician, but, declining the practice of medicine, he resolved,

* Cuvier, Eloge de Desmarest.

when young, to remain content with the small independence inherited from his father, and thenceforth to give his undivided attention to scientific pursuits. He resided at Edinburgh, where he enjoyed the society of many men of high attainments, who loved him for the simplicity of his manners and the sincerity of his character. His application was unwearied; and he made frequent tours through different parts of England and Scotland, acquiring considerable skill as a mineralogist, and constantly arriving at grand and comprehensive views in geology. He communicated the results of his observations unreservedly, and with the fearless spirit of one who was conscious that love of truth was the sole stimulus of his exertions. When at length he had matured his views, he published, in 1788, his "Theory of the Earth*," and the same, afterwards more fully developed in a separate work, in 1795. This treatise was the first in which geology was declared to be in no way concerned about "questions as to the origin of things;" the first in which an attempt was made to dispense entirely with all hypothetical causes, and to explain the former changes of the earth's crust by reference exclusively to natural agents. Hutton laboured to give fixed principles to geology, as Newton had succeeded in doing to astronomy: but, in the former science, too little progress had been made towards furnishing the necessary data, to enable any philosopher, however great his genius, to realize so noble a project.

Huttonian theory.—"The ruins of an older world," said Hutton, "are visible in the present structure of our planet; and the strata which now compose our

* Ed. Phil. Trans. 1788.

continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted."

Although Hutton had never explored any region of active volcanos, he had convinced himself that basalt and many other trap-rocks were of igneous origin, and that many of them had been injected in a melted state through fissures in the older strata. The compactness of these rocks, and their different aspect from that of ordinary lava, he attributed to their having cooled down under the pressure of the sea; and in order to remove the objections started against this theory, his friend, Sir James Hall, instituted a most curious and instructive series of chemical experiments, illustrating the crystalline arrangement and texture assumed by melted matter cooled under high pressure.

The absence of stratification in granite, and its analogy in mineral character to rocks which he deemed of igneous origin, led Hutton to conclude that granite also must have been formed from matter in fusion; and this inference he felt could not be fully confirmed, unless he discovered at the contact of granite and other strata a repetition of the phenomena exhibited so constantly by the trap-rocks. Resolved to try his theory by this test, he went to the Grampians, and surveyed the line of junction of the granite and superincumbent stratified masses, until he found in Glen Tilt, in 1785, the most clear and unequivocal proofs in support of his views. Veins of red granite are there seen branching out from the principal mass, and traversing the black micaceous schist and primary limestone. The intersected stratified rocks are so distinct in colour and appearance as to render the example in that locality most striking, and the alteration of the limestone in contact was very analogous to that produced by trap veins on calcareous strata. This verification of his system filled him with delight, and called forth such marks of joy and exultation, that the guides who accompanied him, says his biographer, were convinced that he must have discovered a vein of silver or gold.* He was aware that the same theory would not explain the origin of the primary schists, but these he called primary, rejecting the term primitive, and was disposed to consider them as sedimentary rocks altered by heat, and that they originated in some other form from the waste of previously existing rocks.

By this important discovery of granite veins, to which he had been led by fair induction from an independent class of facts, Hutton prepared the way for the greatest innovation on the systems of his predecessors. Vallisneri had pointed out the general fact that there were certain fundamental rocks which contained no organic remains, and which he supposed to have been formed before the creation of living beings. Moro, Generelli, and other Italian writers, embraced the same doctrine; and Lehman regarded the mountains called by him primitive, as parts of the original nucleus of the globe. The same tenet was an article

* Playfair's Works, vol. iv. p. 75.

of faith in the school of Freyberg; and if any one ventured to doubt the possibility of our being enabled to carry back our researches to the creation of the present order of things, the granitic rocks were triumphantly appealed to. On them seemed written, in legible characters, the memorable inscription—

> Dinanzi a me non fur cose create
> Se non eterne;

and no small sensation was excited when Hutton seemed, with unhallowed hand, desirous to erase characters already regarded by many as sacred. "In the economy of the world," said the Scotch geologist, "I can find no traces of a beginning, no prospect of an end;" a declaration the more startling when coupled with the doctrine, that all past changes on the globe had been brought about by the slow agency of existing causes. The imagination was first fatigued and overpowered by endeavouring to conceive the immensity of time required for the annihilation of whole continents by so insensible a process; and when the thoughts had wandered through these interminable periods, no resting place was assigned in the remotest distance. The oldest rocks were represented to be of a derivative nature, the last of an antecedent series, and that perhaps one of many pre-existing worlds. Such views of the immensity of past time, like those unfolded by the Newtonian philosophy in regard to space, were too vast to awaken ideas of sublimity unmixed with a painful sense of our incapacity to conceive a plan of such infinite extent. Worlds are seen beyond worlds immeasurably distant from each other, and, beyond them all, innumerable other systems are faintly traced on the confines of the visible universe.

The characteristic feature of the Huttonian theory was, as before hinted, the exclusion of all causes not supposed to belong to the present order of nature. But Hutton had made no step beyond Hooke, Moro, and Raspe, in pointing out in what manner the laws now governing subterranean movements might bring about geological changes, if sufficient time be allowed. On the contrary, he seems to have fallen far short of some of their views, especially when he refused to attribute any part of the external configuration of the earth's crust to subsidence. He imagined that the continents were first gradually destroyed by aqueous degradation; and when their ruins had furnished materials for new continents, they were upheaved by violent convulsions. He therefore required alternate periods of general disturbance and repose; and such he believed had been, and would for ever be, the course of nature.

Generelli, in his exposition of Moro's system, had made a far nearer approximation towards reconciling geological appearances with the state of nature as known to us; for while he agreed with Hutton, that the decay and reproduction of rocks were always in progress, proceeding with the utmost uniformity, the learned Carmelite represented the repairs of mountains by elevation from below to be effected by an equally constant and synchronous operation. Neither of these theories, considered singly, satisfies all the conditions of the great problem, which a geologist, who rejects cosmological causes, is called upon to solve; but they probably contain together the germs of a perfect system. There can be no doubt, that periods of disturbance and repose have followed each other in succession in every region of the globe; but it may be equally true, that the energy of the subterranean movements has been always uniform as regards the *whole earth.* The force of earthquakes may for a cycle of years have been invariably confined, as it is now, to large but determinate spaces, and may then have gradually shifted its position, so that another region, which had for ages been at rest, became in its turn the grand theatre of action.

Playfair's illustrations of Hutton.—The explanation proposed by Hutton and by Playfair, the illustrator of his theory, respecting the origin of valleys, and of alluvial accumulations, was also very imperfect. They ascribed none of the inequalities of the earth's surface to movements which accompanied the upheaving of the land, imagining that valleys in general were formed in the course of ages, by the rivers now flowing in them; while they seem not to have reflected on the excavating and transporting power which the waves of the ocean might exert on land during its emergence.

Although Hutton's knowledge of mineralogy and chemistry was considerable, he possessed but little information concerning organic remains; they merely served him, as they did Werner, to characterize certain strata, and to prove their marine origin. The theory of former revolutions in organic life was not yet fully recognized; and without this class of proofs in support of the antiquity of the globe, the indefinite periods demanded by the Huttonian hypothesis appeared visionary to many; and some, who deemed the doctrine inconsistent with revealed truths, indulged very uncharitable suspicions of the motives of its author. They accused him of a deliberate design of reviving the heathen dogma of an "eternal succession," and of denying that this world ever had a beginning. Playfair, in the biography of his friend, has the following comment on this part of their theory: — "In the planetary motions, where geometry has carried the eye so far, both into the future and the past, we discover no mark either of the commencement or termination of the present order. It is unreasonable, indeed, to suppose that such marks should any where exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in His works any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. *He may put an end, as he no doubt gave a beginning*, to the present system, at some determinate period of time; but we may rest assured that this great catastrophe will not be brought about by the laws now existing, and that it is not indicated by any thing which we perceive."*

The party feeling excited against the Huttonian doctrines, and the open disregard of candour and temper in the controversy, will hardly be credited by the reader, unless he recalls to his recollection that the mind of the English public was at that time in a state of feverish excitement. A class of writers in France had been labouring industriously, for many years, to diminish the influence of the clergy, by sapping the foundations of the Christian faith; and their success, and the consequences of the Revolution, had alarmed the most resolute minds, while the imagination of the more timid was continually haunted by dread of innovation, as by the phantom of some fearful dream.

* Playfair's Works, vol. iv. p. 55.

Voltaire.—Voltaire had used the modern discoveries in physics as one of the numerous weapons of attack and ridicule directed by him against the Scriptures. He found that the most popular systems of geology were accommodated to the sacred writings, and that much ingenuity had been employed to make every fact coincide exactly with the Mosaic account of the creation and deluge. It was, therefore, with no friendly feelings that he contemplated the cultivators of geology in general, regarding the science as one which had been successfully enlisted by theologians as an ally in their cause.* He knew that the majority of those who were aware of the abundance of fossil shells in the interior of continents, were still persuaded that they were proofs of the universal deluge; and as the readiest way of shaking this article of faith, he endeavoured to inculcate scepticism as to the real nature of such shells, and to recall from contempt the exploded dogma of the sixteenth century, that they were sports of nature. He also pretended that vegetable impressions were not those of real plants.† Yet he was perfectly convinced that the shells had really belonged to living testacea, as may be seen in his

* In allusion to the theories of Burnet, Woodward, and other physico-theological writers, he declared that they were as fond of changes of scene on the face of the globe, as were the populace at a play. "Every one of them destroys and renovates the earth after his own fashion, as Descartes framed it: for philosophers put themselves without ceremony in the place of God, and think to create a universe with a word."—Dissertation envoyée à l'Académie de Boulogne, sur les Changemens arrivés dans notre Globe. Unfortunately, this and similar ridicule directed against the cosmogonists was too well deserved.

† See the chapter on "Des Pierres figurés."

essay "On the Formation of Mountains."* He would sometimes, in defiance of all consistency, shift his ground when addressing the vulgar; and, admitting the true nature of the shells collected in the Alps and other places, pretend that they were Eastern species, which had fallen from the hats of pilgrims coming from Syria. The numerous essays written by him on geological subjects were all calculated to strengthen prejudices, partly because he was ignorant of the real state of the science, and partly from his bad faith.† On the other hand, they who knew that his attacks were directed by a desire to invalidate Scripture, and who were unacquainted with the true merits of the question, might well deem the old diluvian hypothesis incontrovertible, if Voltaire could adduce no better argument against it than to deny the true nature of organic remains.

It is only by careful attention to impediments originating in extrinsic causes, that we can explain the slow and reluctant adoption of the simplest truths in geology. First, we find many able naturalists adducing the fossil remains of marine animals as proofs of an event related in Scripture. The evidence is deemed

* In that essay he lays it down, "that all naturalists are now agreed that deposits of shells in the midst of the continents are monuments of the continued occupation of these districts by the ocean." In another place also, when speaking of the fossil shells of Touraine, he admits their true origin.

† As an instance of his desire to throw doubt indiscriminately on all geological data, we may recall the passage where he says, that "the bones of a rein-deer and hippopotamus discovered near Etampes did not prove, as some would have it, that Lapland and the Nile were once on a tour from Paris to Orleans, but merely that a lover of curiosities once preserved them in his cabinet."

conclusive by the multitude for a century or more; for it favours opinions which they entertained before, and they are gratified by supposing them confirmed by fresh and unexpected proofs. Many, who see through the fallacy, have no wish to undeceive those who are influenced by it, approving the effect of the delusion, and conniving at it as a pious fraud; until, finally, an opposite party, who are hostile to the sacred writings, labour to explode the erroneous opinion, by substituting for it another dogma which they know to be equally unsound.

The heretical Vulcanists were soon after openly assailed in England, by imputations of the most illiberal kind. We cannot estimate the malevolence of such a persecution, by the pain which similar insinuations might now inflict: for although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement; and it was better, perhaps, for a man's good reception in society, that his moral character should have been traduced, than that he should become a mark for these poisoned weapons.

I shall pass over the works of numerous divines, who may be excused for sensitiveness on points which then excited so much uneasiness in the public mind; and shall say nothing of the amiable poet Cowper*, who could hardly be expected to have inquired into the merit of doctrines in physics. But in the foremost ranks of the intolerant, are found several laymen who had high claims to scientific reputation. Among these appears Williams, a mineral surveyor of Edinburgh, who published a "Natural History of the Mineral

* The Task, book iii. "The Garden."

Kingdom," in 1789; a work of great merit for that day, and of practical utility, as containing the best account of the coal strata. In his preface he misrepresents Hutton's theory altogether, and charges him with considering all rocks to be lavas of different colours and structure; and also with "warping every thing to support the eternity of the world."* He descants on the pernicious influence of such sceptical notions, as leading to downright infidelity and atheism, "and as being nothing less than to depose the Almighty Creator of the universe from his office."†

Kirwan.—De Luc.—Kirwan, president of the Royal Academy of Dublin, a chemist and mineralogist of some merit, but who possessed much greater authority in the scientific world than he was entitled by his talents to enjoy, said, in the introduction to his "Geological Essays, 1799," "that *sound* geology *graduated* into religion, and was required to dispel certain systems of atheism or infidelity, of which they had had recent experience."‡ He was an uncompromising defender of the aqueous theory of all rocks, and was scarcely surpassed by Burnet and Whiston, in his desire to adduce the Mosaic writings in confirmation of his opinions.

De Luc, in the preliminary discourse to his Treatise on Geology§, says, "the weapons have been changed by which revealed religion is attacked; it is now assailed by geology, and the knowledge of this science has become essential to theologians." He imputes the failure of former geological systems to their having been anti-mosaical, and directed against a "sublime tradition." These and similar imputations, reiterated

* P. 577. † P. 59.
‡ Introd. p. 2. § London, 1809.

in the works of De Luc, seem to have been taken for granted by some modern writers: it is therefore necessary to state, in justice to the numerous geologists of different nations, whose works have been considered, that none of them were guilty of endeavouring, by arguments drawn from physics, to invalidate scriptural tenets. On the contrary, the majority of them who were fortunate enough "to discover the true causes of things," rarely deserved another part of the poet's panegyric, "*Atque metus omnes subjecit pedibus.*" The caution, and even timid reserve, of many eminent Italian authors of the earlier period is very apparent: and there can hardly be a doubt, that they subscribed to certain dogmas, and particularly to the first diluvian theory, out of deference to popular prejudices, rather than from conviction. If they were guilty of dissimulation, we may feel regret, but must not blame their want of moral courage, reserving rather our condemnation for the intolerance of the times, and that inquisitorial power which forced Galileo to abjure, and the two Jesuits to disclaim the theory of Newton.*

* In a most able article, by Mr. Drinkwater, on the "Life of Galileo," published in the "Library of Useful Knowledge," it is stated that both Galileo's work, and the book of Copernicus "Nisi corrigatur" (for, with the omission of certain passages, it was sanctioned), were still to be seen on the forbidden list of the Index at Rome in 1828. I was however assured in the same year, by Professor Scarpellini, at Rome, that Pius VII., a pontiff distinguished for his love of science, had procured a repeal of the edicts against Galileo and the Copernican system. He had assembled the Congregation; and the late Cardinal Toriozzi, assessor of the Sacred Office, proposed "that they should wipe off this scandal from the church." The repeal was carried, with the dissentient voice of one Dominican only. Long before that time the Newtonian

Hutton answered Kirwan's attacks with great warmth, and with the indignation justly excited by unmerited reproach. "He had always displayed," says Playfair, "the utmost disposition to admire the beneficent design manifested in the structure of the world; and he contemplated with delight those parts of his theory which made the greatest additions to our knowledge of final causes." We may say with equal truth, that in no scientific works in our language can more eloquent passages be found, concerning the fitness, harmony, and grandeur of all parts of the creation, than in those of Playfair. They are evidently the unaffected expressions of a mind, which contemplated the study of nature, as best calculated to elevate our conceptions of the attributes of the First Cause. At any other time the force and elegance of Playfair's style must have insured popularity to the Huttonian doctrines; but, by a singular coincidence, Neptunianism and orthodoxy were now associated in the same creed; and the tide of prejudice ran so strong, that the majority were carried far away into the chaotic fluid, and other cosmological inventions of Werner. These fictions the Saxon professor had borrowed with little modification, and without any improvement, from his predecessors. They had not the smallest foundation either in Scripture or in common sense, and were probably approved of by many as being so ideal and unsubstantial, that they could never come into violent collision with any preconceived opinions.

theory had been taught in the Sapienza, and all Catholic universities in Europe (with the exception, I am told, of Salamanca); but it was always required of professors, in deference to the decrees of the church, to use the term *hypothesis*, instead of theory. They now speak of the Copernican *theory*.

According to De Luc, the first essential distinction to be made between the various phenomena exhibited on the surface of the earth was, to determine which were the results of causes still in action, and which had been produced by causes that had ceased to act. The form and composition of the mass of our continents, he said, and their existence above the level of the sea, must be ascribed to causes no longer in action. These continents emerged at no very remote period on the sudden retreat of the ocean, the waters of which made their way into subterranean caverns. The formation of the rocks which enter into the crust of the earth began with the precipitation of granite from a primordial liquid, after which other strata containing the remains of organized bodies were deposited, till at last the present sea remained as the residuum of the primordial liquid, and no longer continued to produce mineral strata.*

William Smith, 1790.—While the tenets of the rival schools of Freyberg and Edinburgh were warmly espoused by devoted partisans, the labours of an individual, unassisted by the advantages of wealth or station in society, were almost unheeded. Mr. William Smith, an English surveyor, published his "Tabular View of the British Strata" in 1790, wherein he proposed a classification of the secondary formations in the West of England. Although he had not communicated with Werner, it appeared by this work that he had arrived at the same views respecting the laws of superposition of stratified rocks; that he was aware that the order of succession of different groups was never inverted;

* Elementary Treatise on Geology. London, 1809. Translated by De la Fite.

and that they might be identified at very distant points by their peculiar organized fossils.

From the time of the appearance of the "Tabular View," the author laboured to construct a geological map of the whole of England; and with the greatest disinterestedness of mind, communicated the results of his investigations to all who desired information, giving such publicity to his original views, as to enable his contemporaries almost to compete with him in the race. The execution of his map was completed in 1815, and remains a lasting monument of original talent and extraordinary perseverance; for he had explored the whole country on foot without the guidance of previous observers, or the aid of fellow-labourers, and had succeeded in throwing into natural divisions the whole complicated series of British rocks. D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise to this remarkable performance, observing, that "what many celebrated mineralogists had only accomplished for a small part of Germany in the course of half a century, had been effected by a single individual for the whole of England.*

Werner invented a new language to express his divisions of rocks, and some of his technical terms, such as grauwacke, gneiss, and others, passed current in every country in Europe. Smith adopted for the most part English provincial terms, often of barbarous sound, such as gault, cornbrash, clunch clay; and affixed them to subdivisions of the British series. Many of these still retain their place in our scientific classifications, and attest his priority of arrangement.

* See Dr. Fitton's Memoir, before cited, p. 57.

MODERN PROGRESS OF GEOLOGY.

The contention of the rival factions of the Vulcanists and Neptunists had been carried to such a height, that these names had become terms of reproach; and the two parties had been less occupied in searching for truth, than for such arguments as might strengthen their own cause, or serve to annoy their antagonists. A new school at last arose, who professed the strictest neutrality, and the utmost indifference to the systems of Werner and Hutton, and who resolved diligently to devote their labours to observation. The reaction, provoked by the intemperance of the conflicting parties, now produced a tendency to extreme caution. Speculative views were discountenanced, and, through fear of exposing themselves to the suspicion of a bias towards the dogmas of a party, some geologists became anxious to entertain no opinion whatever on the causes of phenomena, and were inclined to scepticism even where the conclusions deducible from observed facts scarcely admitted of reasonable doubt.

Geological Society of London. — But although the reluctance to theorize was carried somewhat to excess, no measure could be more salutary at such a moment than a suspension of all attempts to form what were termed "theories of the earth." A great body of new data were required; and the Geological Society of London, founded in 1807, conduced greatly to the attainment of this desirable end. To multiply and record observations, and patiently to await the result at some future period, was the object proposed by them; and it was their favourite maxim that the time was not yet come for a general system of geology, but that all must be content for many years to be exclusively engaged in furnishing materials for future generalizations. By acting up to these principles with consistency, they in a few years disarmed all prejudice, and rescued the science from the imputation of being a dangerous, or at best but a visionary pursuit.

A distinguished modern writer has with truth remarked, that the advancement of three of the main divisions of geological inquiry have, during the last half century, been promoted successively by three different nations of Europe,—the Germans, the English, and the French.* We have seen that the systematic study of what may be called mineralogical geology had its origin, and chief point of activity in Germany, where Werner first described with precision the mineral characters of rocks. The classification of the secondary formations, each marked by their peculiar fossils, belongs, in a great measure, to England, where the labours before alluded to of Smith, and those of the most active members of the Geological Society of London, were steadily directed to these objects. The foundation of the third branch, that relating to the tertiary formations, was laid in France by the splendid work of Cuvier and Brongniart, published in 1808, "On the Mineral Geography and Organic Remains of the Neighbourhood of Paris."

We may still trace, in the language of the science and our present methods of arrangement, the various countries where the growth of these several departments of geology was at different times promoted. Many names of simple minerals and rocks remain to this day German; while the European divisions of the secondary strata are in great part English, and are, in-

* Whewell, British Critic, No. xvii. p. 187. 1831.

deed, often founded too exclusively on English types. Lastly, the subdivisions first established of the succession of strata in the Paris basin have served as normal groups, to which other tertiary deposits throughout Europe have been compared, even in cases where this standard, as will afterwards be shewn, was wholly inapplicable.*

No period could have been more fortunate for the discovery, in the immediate neighbourhood of Paris, of a rich store of well-preserved fossils, than the commencement of the present century; for at no former era had Natural History been cultivated with such enthusiasm in the French metropolis. The labours of Cuvier in comparative osteology, and of Lamarck in recent and fossil shells, had raised these departments of study to a rank of which they had never previously been deemed susceptible. Their investigations had eventually a powerful effect in dispelling the illusion which had long prevailed concerning the absence of analogy between the ancient and modern state of our planet. A close comparison of the recent and fossil species, and the inferences drawn in regard to their habits, accustomed the geologist to contemplate the earth as having been at successive periods the dwelling-place of animals and plants of different races, some terrestrial, and others aquatic — some fitted to live in seas, others in the waters of lakes and rivers. By the consideration of these topics, the mind was slowly and insensibly withdrawn from imaginary pictures of catastrophes and chaotic confusion, such as haunted the imagination of the early cosmogonists. Numerous proofs were discovered of the tranquil deposition of

* Book iv. chap. ii.

sedimentary matter, and the slow development of organic life. If many writers, and Cuvier himself in the number, still continued to maintain, that, "the thread of induction was broken *," yet, in reasoning by the strict rules of induction from recent to fossil species, they in a great measure disclaimed the dogma which in theory they professed. The adoption of the same generic, and in some cases, even of the same specific, names for the exuviæ of fossil animals and their living analogues, was an important step towards familiarizing the mind with the idea of the identity and unity of the system in distant eras. It was an acknowledgment, as it were, that part at least of the ancient memorials of nature were written in a living language. The growing importance, then, of the natural history of organic remains may be pointed out as the characteristic feature of the progress of the science during the present century. This branch of knowledge has already become an instrument of great utility in geological classification, and is continuing daily to unfold new data for grand and enlarged views respecting the former changes of the earth.

When we compare the result of observations in the last thirty years with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the

* Discours sur les Révol. &c.

astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never-ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy: to trace the same system through various transformations—to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer were measured the regions of space, and the relative distances of the heavenly bodies—by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events—a succession of phenomena in the animate and inanimate worlds—signs which convey to our minds more definite ideas than figures can do of the immensity of time.

Whether our investigation of the earth's history and structure will eventually be productive of as great practical benefits to mankind, as a knowledge of the distant heavens, must remain for the decision of posterity. It was not till astronomy had been enriched by the observations of many centuries, and had made its way against popular prejudices to the establishment of a sound theory, that its application to the useful arts was most conspicuous. The cultivation of geology began at a later period; and in every step which it has hitherto made towards sound theoretical principles, it has had to contend against more violent prepossessions. The practical advantages already derived from it have not been inconsiderable: but our generalizations are yet imperfect, and they who come after us may be expected to reap the most valuable fruits of our labour. Meanwhile the charm of first discovery is our own; and, as we explore this magnificent field of inquiry, the sentiment of a great historian of our times may continually be present to our minds, that "he who calls what has vanished back again into being, enjoys a bliss like that of creating." *

* Niebuhr's Hist. of Rome, vol. i. p. 5. Hare and Thirlwall's translation.

CHAPTER V.

CAUSES WHICH HAVE RETARDED THE PROGRESS OF GEOLOGY.

Effects of prepossessions in regard to the duration of past time — Of prejudices arising from our peculiar position as inhabitants of the land (p. 118.) — Of those occasioned by our not seeing subterranean changes now in progress — All these causes combine to make the former course of Nature appear different from the present. — Several objections to the assumption, that existing causes have produced the former changes of the earth's surface, removed by modern discoveries (p. 122.).

If we reflect on the history of the progress of geology, as explained in the preceding chapters, we perceive that there have been great fluctuations of opinion respecting the nature of the causes to which all former changes of the earth's surface are referrible. The first observers conceived the monuments which the geologist endeavours to decipher to relate to an original state of the earth, or to a period when there were causes in activity, distinct, in kind and degree, from those now constituting the economy of nature. These views were gradually modified, and some of them entirely abandoned in proportion as observations were multiplied, and the signs of former mutations more skilfully interpreted. Many appearances, which had for a long time been regarded as indicating mysterious and extraordinary agency, were finally recognized as the necessary result of the laws now governing the material world; and the discovery of this unlooked-for conformity has at length induced some philosophers to infer, that, during the ages contemplated in geology, there has never been any interruption to the agency of the same uniform laws of change. The same assemblage of general causes, they conceive, may have been sufficient to produce, by their various combinations, the endless diversity of effects, of which the shell of the earth has preserved the memorials; and, consistently with these principles, the recurrence of analogous changes is expected by them in time to come.

Whether we coincide or not in this doctrine, we must admit that the gradual progress of opinion concerning the succession of phenomena in very remote eras, resembles, in a singular manner, that which has accompanied the growing intelligence of every people, in regard to the economy of nature in their own times. In an early stage of advancement, when a great number of natural appearances are unintelligible, an eclipse, an earthquake, a flood, or the approach of a comet, with many other occurrences afterwards found to belong to the regular course of events, are regarded as prodigies. The same delusion prevails as to moral phenomena, and many of these are ascribed to the intervention of demons, ghosts, witches, and other immaterial and supernatural agents. By degrees, many of the enigmas of the moral and physical world are explained, and, instead of being due to extrinsic and irregular causes, they are found to depend on fixed and invariable laws. The philosopher at last becomes convinced of the undeviating uniformity of secondary causes; and, guided by his faith in this principle, he determines the probability of accounts transmitted to him of former occurrences, and often rejects the fabulous tales of former times, on the ground of their being irreconcilable with the experience of more enlightened ages.

Prepossessions in regard to the duration of past time.—As a belief in the want of conformity in the causes by which the earth's crust has been modified in ancient and modern periods was, for a long time, universally prevalent, and that, too, amongst men who have been convinced that the order of nature is *now* uniform, and that it has continued so for several thousand years, every circumstance which could have influenced their minds and given an undue bias to their opinions deserves particular attention. Now the reader may easily satisfy himself, that, however undeviating the course of nature may have been from the earliest epochs, it was impossible for the first cultivators of geology to come to such a conclusion, so long as they were under a delusion as to the age of the world, and the date of the first creation of animate beings. However fantastical some theories of the sixteenth century may now appear to us,—however unworthy of men of great talent and sound judgment,—we may rest assured that, if the same misconception now prevailed in regard to the memorials of human transactions, it would give rise to a similar train of absurdities. Let us imagine, for example, that Champollion, and the French and Tuscan literati lately engaged in exploring the antiquities of Egypt, had visited that country with a firm belief that the banks of the Nile were never peopled by the human race before the beginning of the nineteenth century, and that their faith in this dogma was as difficult to shake as the opinion of our ancestors, that the earth was never the abode of living beings until the creation of the present continents, and of the species now existing,—it is easy to perceive what extravagant systems they would frame, while under the influence of this delusion, to account for the monuments discovered in Egypt. The sight of the pyramids, obelisks, colossal statues, and ruined temples, would fill them with such astonishment, that for a time they would be as men spell-bound—wholly incapable of reasoning with sobriety. They might incline at first to refer the construction of such stupendous works to some superhuman powers of a primeval world. A system might be invented resembling that so gravely advanced by Manetho, who relates that a dynasty of gods originally ruled in Egypt, of whom Vulcan, the first monarch, reigned nine thousand years; after whom came Hercules and other demigods, who were at last succeeded by human kings.

When some fanciful speculations of this kind had amused their imaginations for a time, some vast repository of mummies would be discovered, and would immediately undeceive those antiquaries who enjoyed an opportunity of personally examining them; but the prejudices of others at a distance, who were not eyewitnesses of the whole phenomena, would not be so easily overcome. The concurrent report of many travellers would, indeed, render it necessary for them to accommodate ancient theories to some of the new facts, and much wit and ingenuity would be required to modify and defend their old positions. Each new invention would violate a greater number of known analogies; for if a theory be required to embrace some false principle, it becomes more visionary in proportion as facts are multiplied, as would be the case if geometers were now required to form an astronomical system on the assumption of the immobility of the earth.

Amongst other fanciful conjectures concerning the history of Egypt, we may suppose some of the following to be started. "As the banks of the Nile have been so recently colonized for the first time, the curious substances called mummies could never in reality have belonged to men. They may have been generated by some *plastic virtue* residing in the interior of the earth, or they may be abortions of nature produced by her incipient efforts in the work of creation. For if deformed beings are sometimes born even now, when the scheme of the universe is fully developed, many more may have been 'sent before their time, scarce half made up,' when the planet itself was in the embryo state. But if these notions appear to derogate from the perfection of the Divine attributes, and if these mummies be in all their parts true representations of the human form, may we not refer them to the future rather than the past? May we not be looking into the womb of Nature, and not her grave? May not these images be like the shades of the unborn in Virgil's Elysium—the archetypes of men not yet called into existence?"

These speculations, if advocated by eloquent writers, would not fail to attract many zealous votaries, for they would relieve men from the painful necessity of renouncing preconceived opinions. Incredible as such scepticism may appear, it has been rivalled by many systems of the sixteenth and seventeenth centuries, and among others by that of the learned Falloppio, who regarded the tusks of fossil elephants as earthy concretions, and the pottery or fragments of vases in the Monte Testaceo, near Rome, as works of nature, and not of art. But when one generation had passed away, and another, not compromised to the support of antiquated dogmas had succeeded, they would review the evidence afforded by mummies more impartially, and would no longer controvert the preliminary question, that human beings had lived in Egypt before the nineteenth century: so that when a hundred years perhaps had been lost, the industry and talents of the philosopher would be at last directed to the elucidation of points of real historical importance.

But the above arguments are aimed against one only of many prejudices with which the earlier geologists had to contend. Even when they conceded that the earth had been peopled with animate beings at an earlier period than was at first supposed, they had no conception that the quantity of time bore so great a proportion to the historical era as is now generally conceded. How fatal every error as to the quantity of time must prove to the introduction of rational views concerning the state of things in former ages, may be conceived by supposing the annals of the civil and military transactions of a great nation to be perused under the impression that they occurred in a period of one hundred instead of two thousand years. Such a portion of history would immediately assume the air of a romance; the events would seem devoid of credibility, and inconsistent with the present course of human affairs. A crowd of incidents would follow each other in thick succession. Armies and fleets would appear to be assembled only to be destroyed, and cities built merely to fall in ruins. There would be the most violent transitions from foreign or intestine war to periods of profound peace, and the works effected during the years of disorder or tranquillity would appear alike superhuman in magnitude.

He who should study the monuments of the natural world under the influence of a similar infatuation, must draw a no less exaggerated picture of the energy and violence of causes, and must experience the same insurmountable difficulty in reconciling the former and present state of nature. If we could behold in one view all the volcanic cones thrown up in Iceland, Italy, Sicily, and other parts of Europe, during the last five thousand years, and could see the lavas which have flowed during the same period; the dislocations, subsidences, and elevations caused by earthquakes; the lands added to various deltas, or devoured by the sea, together with the effects of devastation by floods, and imagine that all these events had happened in one year, we must form most exalted ideas of the activity of the agents, and the suddenness of the revolutions. Were an equal amount of change to pass before our eyes in the next year, could we avoid the conclusion that some great crisis of nature was at hand? If geologists, therefore, have misinterpreted the signs of a succession of events, so as to conclude that centuries were implied where the characters imported thousands of years, and thousands of years where the language of nature signified millions, they could not, if they reasoned logically from such false premises, come to any other conclusion than that the system of the natural world had undergone a complete revolution.

We should be warranted in ascribing the erection of the great pyramid to superhuman power, if we were convinced that it was raised in one day; and if we imagine, in the same manner, a mountain-chain to have been elevated, during an equally small fraction of the time which was really occupied in upheaving it, we might then be justified in inferring, that the subterranean movements were once far more energetic than in our own times. We know that one earthquake may raise the coast of Chili for a hundred miles to the average height of about five feet. A repetition of two thousand shocks, of equal violence, might produce a mountain-chain one hundred miles long, and ten thousand feet high. Now, should one only of these convulsions happen in a century, it would be consistent with the order of events experienced by the Chilians from the earliest times; but if the whole of them were to occur in the next hundred years, the entire district must be depopulated, scarcely any animals or plants could survive, and the surface would be one confused heap of ruin and desolation.

One consequence of undervaluing greatly the quantity of past time, is the apparent coincidence which it occasions of events necessarily disconnected, or which are so unusual, that it would be inconsistent with all calculation of chances to suppose them to happen at one and the same time. When the unlooked-for association of such rare phenomena is witnessed in the present course of nature, it scarcely ever fails to excite a suspicion of the preternatural in those minds which are not firmly convinced of the uniform agency of secondary causes;—as if the death of some individual in whose fate they are interested happens to be accompanied by the appearance of a luminous meteor, or a comet, or the shock of an earthquake. It would be only necessary to multiply such coincidences indefinitely, and the mind of every philosopher would be disturbed. Now it would be difficult to exaggerate the number of physical events, many of them most rare and unconnected in their nature, which were imagined by the Woodwardian hypothesis to have happened in the course of a few months: and numerous other examples might be found of popular geological theories, which require us to imagine that a long succession of events happened in a brief and almost momentary period.

Another liability to error, very nearly allied to the former, arises from the frequent contact of geological monuments referring to very distant periods of time. We often behold, at one glance, the effects of causes which have happened at times incalculably remote, and yet there may be no striking circumstances to mark the occurrence of a great chasm in the chronological series of Nature's archives. In the vast interval of time which may really have elapsed between the results of operations thus compared, the physical condition of the earth may, by slow and insensible modifications, have become entirely altered; one or more races of organic beings may have passed away, and yet have left behind, in the particular region under contemplation, no trace of their existence.

To a mind unconscious of these intermediate events, the passage from one state of things to another must appear so violent, that the idea of revolutions in the system inevitably suggests itself. The imagination is as much perplexed by the deception, as it might be if two distant points in space were suddenly brought into immediate proximity. Let us suppose, for a moment, that a philosopher should lie down to sleep in some arctic wilderness, and then be transferred by a power, such as we read of in tales of enchantment, to a valley in a tropical country, where, on awaking, he might find himself surrounded by birds of brilliant plumage, and all the luxuriance of animal and vegetable forms of which Nature is so prodigal in those regions. The most reasonable supposition, perhaps, which he could make, if by the necromancer's art he was placed in such a situation, would be, that he was dreaming; and if a geologist form theories under a similar delusion, we cannot expect him to preserve more consistency in his speculations, than in the train of ideas in an ordinary dream.

The sources of prejudice hitherto considered may be deemed peculiar for the most part to the infancy of the science, but others are common to the first cultivators of geology and to ourselves, and are all singularly calculated to produce the same deception, and to strengthen our belief that the course of nature in the earlier ages differed widely from that now established. Although these circumstances cannot be fully explained without assuming some things as proved, which it will be the object of another part of this work to demonstrate, it may be well to allude to them briefly in this place.

Prejudices arising from our peculiar position as inhabitants of the land. — The first and greatest difficulty, then, consists in an habitual unconsciousness that our position as observers is essentially unfavourable, when we endeavour to estimate the magnitude of the changes now in progress. In consequence of our inattention to this subject, we are liable to serious mistakes in contrasting the present with former states of the globe. As dwellers on the land, we inhabit about a fourth part of the surface; and that portion is almost exclusively a theatre of decay, and not of reproduction. We know, indeed, that new deposits are annually formed in seas and lakes, and that every year some new igneous rocks are produced in the bowels of the earth, but we cannot watch the progress of their formation; and as they are only present to our minds by the aid of reflection, it requires an effort both of the reason and the imagination to appreciate duly their importance. It is, therefore, not surprising that we estimate very imperfectly the result of operations thus invisible to us; and that, when analogous results of former epochs are presented to our inspection, we cannot immediately recognize the analogy. He who has observed the quarrying of stone from a rock, and has seen it shipped for some distant port, and then endeavours to conceive what kind of edifice will be raised by the materials, is in the same predicament as a geologist, who, while he is confined to the land, sees the decomposition of rocks, and the transportation of matter by rivers to the sea, and then endeavours to picture to himself the new strata which Nature is building beneath the waters.

Prejudices arising from our not seeing subterranean changes.—Nor is his position less unfavourable when, beholding a volcanic eruption, he tries to conceive what changes the column of lava has produced, in its passage upwards, on the intersected strata; or what form the melted matter may assume at great depths on cooling; or what may be the extent of the subterranean rivers and reservoirs of liquid matter far beneath the surface. It should, therefore, be remembered, that the task imposed on those who study the earth's history requires no ordinary share of discretion; for we are precluded from collating the corresponding parts of the system of things as it exists now, and as it existed at former periods. If we were inhabitants of another element—if the great ocean were our domain, instead of the narrow limits of the land, our difficulties would be considerably lessened; while, on the other hand, there can be little doubt, although the reader may, perhaps, smile at the bare suggestion of such an idea, that an amphibious being, who should possess our faculties, would still more easily arrive at sound theoretical opinions in geology, since he might behold, on the one hand, the decomposition of rocks in the atmosphere, or the transportation of matter by running water; and, on the other, examine the deposition of sediment in the sea, and the imbedding of animal and vegetable remains in new strata. He might ascertain, by direct observation, the action of a mountain torrent, as well as of a marine current; might compare the products of volcanos poured out upon the land with those ejected beneath the waters; and might mark, on the one hand, the growth of the forest, and on the other that of the coral reef. Yet, even with these advantages, he would be liable to fall into the greatest errors when endeavouring to reason on rocks of subterranean origin. He would seek in vain, within the sphere of his observation, for any direct analogy to the process of their formation, and would therefore be in danger of attributing them, wherever they are upraised to view, to some "primeval state of nature."

But if we may be allowed so far to indulge the imagination, as to suppose a being entirely confined to the nether world — some "dusky melancholy sprite," like Umbriel, who could "flit on sooty pinions to the central earth," but who was never permitted to "sully the fair face of light," and emerge into the regions of water and of air; and if this being should busy himself in investigating the structure of the globe, he might frame theories the exact converse of those usually adopted by human philosophers. He might infer that the stratified rocks, containing shells and other organic remains, were the oldest of created things, belonging to some original and nascent state of the planet. "Of these masses," he might say, "whether they consist of loose incoherent sand, soft clay, or solid stone, none have been formed in modern times. Every year some part of them are broken and shattered by earthquakes, or melted by volcanic fire; and, when they cool down slowly from a state of fusion, they assume a new and more crystalline form, no longer exhibiting that stratified disposition, and those curious impressions and fantastic markings, by which they were previously characterized. This process cannot have been carried on for an indefinite time, for in that case all the stratified rocks would long ere this have been fused and crystallized. It is therefore probable that the whole planet once consisted of these mysterious and curiously bedded formations at a time when the volcanic fire had not yet been brought into activity. Since that period there seems to have been a gradual development of heat; and this augmentation we may expect to continue till the whole globe shall be in a state of fluidity and incandescence."

Such might be the system of the Gnome at the very time that the followers of Leibnitz, reasoning on what they saw on the outer surface, might be teaching the opposite doctrine of gradual refrigeration, and averring that the earth had begun its career as a fiery comet, and might be destined hereafter to become a frozen mass. The tenets of the schools of the nether and of the upper world would be directly opposed to each other, for both would partake of the prejudices inevitably resulting from the continual contemplation of one class of phenomena to the exclusion of another. Man observes the annual decomposition of crystalline and igneous rocks, and may sometimes see their conversion into stratified deposits; but he cannot witness the reconversion of the sedimentary into the crystalline by subterranean fire. He is in the habit of regarding all the sedimentary rocks as more recent than the unstratified, for the same reason that we may suppose him to fall into the opposite error if he saw the origin of the igneous class only.

ASSUMPTION OF THE DISCORDANCE OF THE ANCIENT AND EXISTING CAUSES OF CHANGE UNPHILOSOPHICAL.

It is only by becoming sensible of our natural disadvantages that we shall be roused to exertion, and prompted to seek out opportunities of observing such of the operations now in progress, as do not present themselves readily to view. We are called upon, in our researches into the state of the earth, as in our endeavours to comprehend the mechanism of the heavens, to invent means for overcoming the limited range of our vision. We are perpetually required to bring, as far as possible, within the sphere of observation, things to which the eye, unassisted by art, could never obtain access.

It was not an impossible contingency, that astronomers might have been placed at some period in a situation much resembling that in which the geologist seems to stand at present. If the Italians, for example, in the early part of the twelfth century, had discovered at Amalfi, instead of the pandects of Justinian, some ancient manuscripts filled with astronomical observations relating to a period of three thousand years, and made by some ancient geometers who possessed optical instruments as perfect as any in modern Europe, they would probably, on consulting these memorials, have come to a conclusion that there had been a great revolution in the solar and sidereal systems. "Many primary and secondary planets," they might say, "are enumerated in these tables, which exist no longer. Their positions are assigned with such precision, that we may assure ourselves that there is nothing in their place at present but the blue ether. Where one star is visible to us, these documents represent several thousands. Some of those which are now single, consisted then of two separate bodies, often distinguished by different colours, and revolving periodically round a common centre of gravity. There is nothing analogous to them in the universe at present; for they were neither fixed stars nor planets, but seem to have stood in the mutual relation of sun and planet to each other. We must conclude, therefore, that there has occurred, at no distant period, a tremendous catastrophe, whereby thousands of worlds have been annihiliated at once, and some heavenly bodies absorbed into the substance of others." When such doctrines had prevailed for ages, the discovery of one of the worlds, supposed to have been lost, by aid of the first rude telescope invented after the revival of science, would not dissipate the delusion, for the whole burden of proof would now be thrown on those who insisted on the stability of the system from a remote period, and these philosophers would be required to demonstrate the existence of *all* the worlds said to have been annihilated.

Such popular prejudices would be most unfavourable to the advancement of astronomy; for, instead of persevering in the attempt to improve their instruments, and laboriously to make and record observations, the greater number would despair of verifying the continued existence of the heavenly bodies not visible to the naked eye. Instead of confessing the extent of their ignorance, and striving to remove it by bringing to light new facts, they would indulge in the more easy and indolent employment of framing imaginary theories concerning catastrophes and mighty revolutions in the system of the universe.

For more than two centuries the shelly strata of the Subapennine hills afforded matter of speculation to the early geologists of Italy, and few of them had any suspicion that similar deposits were then forming in the neighbouring sea. They were as unconscious of the continued action of causes still producing similar effects, as the astronomers, in the case above supposed, of the existence of certain heavenly bodies still giving and reflecting light, and performing their movements as of old. Some imagined that the strata, so rich in organic remains, instead of being due to secondary agents, had been so created in the beginning of things by the fiat of the Almighty; and others ascribed the imbedded fossil bodies to some plastic power which resided in the earth in the early ages of the world. At length Donati explored the bed of the Adriatic, and found the closest resemblance between the new deposits there forming, and those which constituted hills above a thousand feet high in various parts of the Italian peninsula. He ascertained that certain genera of living testacea were grouped together at the bottom of the sea, in precisely the same manner as were their fossil analogues in the strata of the hills, and that some species were common to the recent and fossil world. Beds of shells, moreover, in the Adriatic, were becoming incrusted with calcareous rock: and others were recently inclosed in deposits of sand and clay, precisely as fossil shells were found in the hills. This splendid discovery of the identity of modern and ancient submarine operations was not made without the aid of artificial instruments, which, like the telescope, brought phenomena into view not otherwise within the sphere of human observation.

In like manner, in the Vicentin, a great series of volcanic and marine sedimentary rocks was examined in the early part of the last century; but no geologists suspected, before the time of Arduino, that these were partly composed of ancient submarine lavas. If, when these inquiries were first made, geologists had been told that the mode of formation of such rocks might be fully elucidated by the study of processes then going on in certain parts of the Mediterranean, they would have been as incredulous as geometers would have been before the time of Newton, if any one had informed them that, by making experiments on the motion of bodies on the earth, they might discover the laws which regulated the movements of distant planets.

The establishment, from time to time, of numerous points of identification, drew at length from geologists a reluctant admission, that there was more correspondence between the physical constitution of the globe, and more uniformity in the laws regulating the changes of its surface, from the most remote eras to the present, than they at first imagined. If, in this state of the science, they still despaired of reconciling every class of geological phenomena to the operations of ordinary causes, even by straining analogy to the utmost limits of credibility, we might have expected, at least, that the balance of probability would now have been presumed to incline towards the identity of the causes. But, after repeated experience of the failure of attempts to speculate on different classes of geological phenomena, as belonging to a distinct order of things, each new sect persevered systematically in the principles adopted by their predecessors. They invariably began, as each new problem presented itself, whether relating to the animate or inanimate world, to assume in their theories, that the economy of nature was formerly governed by rules for the most part independent of those now established. Whether they endeavoured to account for the origin of certain igneous rocks, or to explain the forces which elevated hills or excavated valleys, or the causes which led to the extinction of certain races of animals, they first presupposed an original and dissimilar order of nature; and when at length they approximated, or entirely came round to an opposite opinion, it was always with the feeling, that they conceded what they were justified *à priori* in deeming improbable. In a word, the same men who, as natural philosophers; would have been most incredulous respecting any extraordinary deviations from the known course of nature, if reported to have happened *in their own time*, were equally disposed, as geologists, to expect the proofs of such deviations at every period of the past.

I shall now proceed to enumerate some of the principal difficulties still opposed to the theory of the uniformity of the causes which have worked successive changes in the crust of the earth, and in the condition of its living inhabitants. The discussion of so important a question on the present occasion may appear premature, but it is one which naturally arises out of a review of the former history of the science. It is, of course, impossible to enter fully into such speculative topics, without occasionally carrying the novice beyond his depth, and appealing to facts and conclusions with which he must as yet be unacquainted; but his curiosity cannot fail to be excited by having his attention at once called to some of the principal points in controversy, and after reading the second, third, and fourth books, he may return again to these preliminary essays with increased interest and profit.

First, then, it is undeniable, that many objections to the doctrine of the uniform agency of geological causes have been partially or entirely removed by the progress of the science during the last forty years. It was objected, for example, to those who endeavoured to explain the formation of sedimentary strata by causes now in diurnal action, that they must take for granted incalculable periods of time. Now the time which they required has since become equally requisite to account for another class of phenomena brought to light by more recent investigations. It must always have been evident to unbiassed minds, that successive strata, containing, in regular order of superposition, distinct shells and corals, arranged in families as they grow at the bottom of the sea, could only have been formed by slow and insensible degrees in a great lapse of ages: yet, until organic remains were minutely examined and specifically determined, it was rarely possible to prove that the series of deposits met with in one country was not formed simultaneously with that found in another. But we are now able to determine, in numerous instances, the relative dates of sedimentary rocks in distant regions, and to show, by their organic remains, that they were not of contemporary origin, but formed in succession. We often find, that where an interruption in the consecutive formations in one district is indicated by a sudden transition, from one assemblage of fossil species to another, the chasm is filled up, in some other district, by important groups of strata.*

The more attentively we study the European continent, the greater we find the extension of the whole series of geological formations. No sooner does the calendar appear to be completed, and the signs of a succession of physical events arranged in chronological order, than we are called upon to intercalate, as it were, some new period of vast duration. A geologist, whose observations have been confined to England, is accustomed to consider the superior and newer groups of marine strata in our island as modern,—and such they are, comparatively speaking; but when he has travelled through the Italian peninsula and Sicily, and has seen strata of more recent origin forming mountains several thousand feet high, and has marked a long series both of volcanic and submarine operations, all newer than any of the regular strata which enter largely into the physical structure of Great Britain, he returns with more exalted conceptions of the antiquity of some of our modern deposits than he before entertained of the oldest of the British series.

We cannot reflect on the concessions thus extorted from us, in regard to the duration of past time, without foreseeing that the period may arrive when part of the Huttonian theory will be combated on the ground of

* See Book iv. chap. iii.

its departing too far from the analogy of the present course of nature. On a closer investigation of extinct volcanos, we find proofs that they broke out at successive eras, and that the eruptions of one group were often concluded long before others had commenced their activity. Some were burning when one class of organic beings were in existence, others came into action when a different and new race of animals and plants existed:—it is more than probable, therefore, that the convulsions caused by subterranean movements, which seem to be merely another portion of the volcanic phenomena, have also occurred in succession; and their effects must be divided into separate sums, and assigned to separate periods of time. Nor is this all: when we examine the volcanic products, whether they be lavas which flowed out under water, or upon dry land, we find that intervals of time, often of great length, intervened between their formation, and that the effects of single eruptions were not greater in amount than those which now result from ordinary volcanic convulsions. The accompanying or preceding earthquakes, therefore, may be considered to have been also successive, often interrupted by long intervals of time, and not to have exceeded in violence those now experienced in the ordinary course of nature.

Already, therefore, may we regard the doctrine of the sudden elevation of whole continents by paroxysmal eruptions as invalidated; and there was the greatest inconsistency in the adoption of such a tenet by the Huttonians, who were anxious to reconcile former changes to the present economy of the world. It was contrary to analogy to suppose, that Nature had been at any former epoch parsimonious of time and prodigal of violence — to imagine that one district was not at rest, while another was convulsed—that the disturbing forces were not kept under subjection, so as never to carry simultaneous havoc and desolation over the whole earth, or even over one great region. If it could have been shown, that a certain combination of circumstances would at some future period produce a crisis in the subterranean action, we should certainly have had no right to oppose our experience for the last three thousand years as an argument against the probability of such occurrences in past ages; but it is not pretended that such a combination can be foreseen.

In speculating on catastrophes by water, we may certainly anticipate great floods in future; and we may therefore presume that they have happened again and again in past times. The existence of enormous seas of fresh water, such as the North American lakes, the surface of the largest of which is elevated more than six hundred feet above the level of the ocean, and is in parts twelve hundred feet deep, is alone sufficient to assure us, that the time may come, however distant, when a deluge may lay waste a considerable part of the American continent. The depression, moreover, of part of Asia, bordering the Caspian Sea, to a depth of from one to three hundred feet below the level of the ocean, might easily give rise to a similar catastrophe.* No hypothetical agency is required to cause the sudden escape of the waters. Such changes of level, and opening of fissures, as have accompanied earthquakes since the commencement of the present century, or such excavation of ravines as the receding cataract of Niagara is now effecting, might breach the barriers. Notwithstanding, therefore, that we have

* See Book iv.

not witnessed within the last three thousand years the devastation by deluge of a large continent, yet, as we may predict the future occurrence of such catastrophes, we are authorized to regard them as part of the present order of Nature; and they may be introduced into geological speculations respecting the past, provided we do not imagine them to have been more frequent or general than we expect them to be in time to come.

The great contrast in the aspect of the older and newer rocks, in texture, structure, and the derangement of the strata, appeared formerly one of the strongest grounds for presuming that the causes to which they owed their origin were perfectly dissimilar from those now in operation. But this incongruity may be the result of subsequent modifications, since the difference of relative age is demonstrated to have been immense, so that, however slow and insensible the change, it must have become important in the course of so many ages. In addition to the influence of volcanic heat, we must allow for the effect of mechanical pressure, of chemical affinity, of percolation by mineral waters, of permeation by elastic fluids, and the action, perhaps, of many other forces less understood, such as electricity and magnetism. The extreme of alteration which may thus be effected, is probably exemplified in the highly crystalline, or granitiform, strata, to which the name of primary is usually given; but the theory of their origin must be postponed to the concluding chapters of the fourth Book.

In regard to the signs of the upraising, sinking, fracture, and contortion of rocks, it is evident that newer strata cannot be shaken by earthquakes, unless the subjacent rocks are also affected; so that the contrast in the relative degree of disturbance in the more ancient and the newer strata, is one of many proofs that the convulsions have happened in different eras, and the fact confirms the uniformity of the action of subterranean forces, instead of their greater violence in the primeval ages.

Doctrine of Universal Formations. — The popular doctrine of universal formations, or the unlimited geographical extent of strata, distinguished by similar mineral characters, appeared for a long time to present insurmountable objections to the supposition, that the earth's crust had been formed by causes now acting. If it had merely been assumed, that rocks originating from fusion by subterranean fire presented in all parts of the globe a perfect correspondence in their mineral composition, the assumption would not have been extravagant; for, as the elementary substances that enter largely into the composition of rocks are few in number, they may be expected to arrange themselves invariably in the same forms, whenever the elementary particles are freely exposed to the action of chemical affinities. But when it was imagined that sedimentary mixtures, including animal and vegetable remains, and evidently formed in the beds of ancient lakes and seas, were of a homogeneous nature throughout a whole hemisphere, the dogma precluded at once all hope of recognizing the slightest analogy betwen the ancient and modern causes of decay and reproduction. We know that existing rivers carry down from different mountain chains sediment of distinct colours and composition: where the chains are near the sea, coarse sand and gravel is swept in; where they are distant, the finest mud.

We know, also, that the matter introduced by springs into lakes and seas is very diversified in mineral composition; in short, *contemporaneous* strata now in the progress of formation are greatly varied in their composition, and could never afford formations of homogeneous mineral ingredients co-extensive with the greater part of the earth's surface.

This theory, however, is in truth as inapplicable to the geological monuments found in the earth's crust, as to the effects of existing causes. The first investigators of sedimentary rocks had never reflected on the great areas occupied by the modern deltas of large rivers; still less on the much greater areas over which marine currents, preying alike on river-deltas, and continuous lines of sea-coast, diffuse homogeneous mixtures. They were ignorant of the vast spaces over which calcareous and other mineral springs abound upon the land and in the sea, especially in and near volcanic regions, and of the quantity of matter discharged by them. When, therefore, they ascertained the extent of the geographical distribution of certain groups of ancient strata—when they traced them continuously from one extremity of Europe to the other, and found them flanking, throughout their entire range, great mountain chains, they were astonished at so unexpected a discovery; and, considering themselves at liberty to disregard all modern analogy, they indulged in the sweeping generalization, that the law of continuity prevailed throughout strata of contemporaneous origin over the whole planet. The difficulty of dissipating this delusion was extreme, because some rocks, formed under similar circumstances at different epochs, present the same external characters, and often the same internal composition; and all these were assumed to be contemporaneous until the contrary could be shown, which, in the absence of evidence derived from direct superposition, and in the scarcity of organic remains, was often impossible.

Innumerable other false generalizations have been derived from the same source; such, for instance, as the former universality of the ocean, now disproved by the discovery of the remains of terrestrial vegetation in strata of every age, even the most ancient. But I shall dwell no longer on exploded errors, but proceed at once to contend against weightier objections, which will require more attentive consideration.

CHAPTER VI.

FURTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Proofs that the climate of the Northern Hemisphere was formerly hotter — Direct proofs from the organic remains of the Sicilian and Italian strata — Proofs from analogy derived from extinct Quadrupeds — Imbedding of animals in Icebergs — Siberian Mammoths (p. 141.) — Evidence in regard to temperature, from the fossils of tertiary and secondary rocks (p. 153.) — From the Plants of the Coal formation — Northern limit of these fossils — Whether such plants could endure the long continuance of an arctic night (p. 155.).

Climate of the Northern Hemisphere formerly hotter. — THAT the climate of the Northern hemisphere has undergone an important change, and that its mean annual temperature must once have resembled that now experienced within the tropics, was the opinion of some of the first naturalists who investigated the contents of the ancient strata. Their conjecture became more probable when the shells and corals of the secondary rocks were more carefully examined; for these organic remains were found to be intimately connected by generic affinity with species now living in warmer latitudes. At a later period, many reptiles, such as turtles, tortoises, and large saurian animals, were discovered in European formations in great abundance; and they supplied new and powerful arguments, from analogy, in support of the doctrine, that the heat of the climate had been great when our secondary strata were deposited. Lastly, when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation; for the flora of a country is peculiarly influenced by temperature: and the ancient vegetation of the earth might, more readily than the forms of animals, have afforded conflicting proofs, had the popular theory been without foundation. When the examination of animal and vegetable remains was extended to rocks in the most northern parts of Europe and North America, and even to the Arctic regions, indications of the same revolution in climate were discovered.

It cannot be said, that in this, as in many other departments of geology, we have investigated the phenomena of former eras, and neglected those of the present state of things. On the contrary, since the first agitation of this interesting question, the accessions to our knowledge of living animals and plants have been immense, and have far surpassed all the data previously obtained for generalizing, concerning the relation of certain types of organization to particular climates. The tropical and temperate zones of South America and of Australia have been explored; and, on close comparison, it has been found, that scarcely any of the species of the animate creation in these extensive continents are identical with those inhabiting the old world. Yet the zoologist and botanist, well acquainted with the geographical distribution of organic beings in other parts of the globe, would have been able, if distinct groups of species had been presented to them from these regions, to recognize those which had been collected from latitudes within, and those which were brought from without the tropics.

Before I attempt to explain the probable causes of great vicissitudes of temperature on the earth's surface, I shall take a rapid view of some of the principal data which appear to support the popular opinions now entertained on the subject. To insist on the soundness of these inferences, is the more necessary, because some zoologists have of late undertaken to vindicate the uniformity of the laws of nature, not by accounting for former fluctuations in climate, but by denying the value of the evidence in their favour.*

Direct proofs from the fossil remains of living species. — It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of Europe; there are direct proofs in confirmation of the same doctrine, in the only countries hitherto investigated by expert geologists where we could expect to meet with such proofs. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata where the organic remains belong to extinct species, but where living species abound in a fossil state, that a theory of climate can be subjected to the experimentum crucis. In Sicily, Ischia, and Calabria, where the fossil testacea of the more recent strata belong almost entirely to species now inhabiting the Mediterranean, the conchologist remarks, that individuals in the inland deposits often exceed in their average size their living analogues, as if the circum-

* See two articles by the Rev. Dr. Fleming, in the Edinburgh New Phil. Journ. No. xii. p. 277., April, 1829; and No. xv. p. 65., Jan. 1830.

stances under which they formerly lived were more favourable to their development. Yet no doubt can be entertained of their specific identity on the ground of such difference in their dimensions; because living individuals of many of these species still attain, in warmer latitudes, the average size of the fossils.

I collected several hundred species of shells in Sicily, at different elevations, sometimes from one thousand to three thousand feet above the level of the sea; and forty species or more in Ischia, partly from an elevation of above one thousand feet, and these were carefully compared with recent shells procured by Professor O. G. Costa, from the Neapolitan seas. Not only were the fossil species for the most part identical with those now living, but the relative abundance in which different species occur in the strata and in the sea corresponds in a remarkable manner. Yet the larger average size of the fossil individuals of many species was very striking. A comparison of the fossil shells of the more modern strata of Calabria and Otranto, in the collection of Professor Costa, afforded similar results.

As we proceed northwards in the Italian peninsula, and pass from the region of active to that of extinct volcanos, we find the assemblage of fossil shells, in the modern (Subapennine) strata, to depart somewhat more widely from the type of the neighbouring seas. 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. Although occurring in localities which are removed several degrees farther from the equator (as at Sienna, Parma, Asti, &c.), the shells yield clear indications of a hotter climate. Many of them are common to the Subapennine hills, to the Mediterranean, and to the Indian Ocean. Those in the fossil state, and their living analogues from the tropics, correspond in size; whereas the individuals of the same species from the Mediterranean are dwarfish and appear degenerate, and stunted in their growth, for want of conditions which the Indian Ocean still supplies.*

This evidence is of great weight, and is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to arctic regions. Whenever any of the fossil shells are identified with living species foreign to the Mediterranean, it is not in the Northern Ocean, but between the tropics, that they must be sought †: on the other hand,

* Professors Guidotti of Parma, and Bonelli of Turin, pointed out to me, in 1828, many examples in confirmation of this point. Among others, I may mention that Bulla lignaria, a very common shell, is invariably found fossil in the north of Italy of the same magnitude as it now reaches in the Indian sea, and much smaller in a living state in the Mediterranean. Individuals, however, of this great size are said to have been found at La Rochelle. The common Orthoceras of the Mediterranean, O. raphanista, attains larger average dimensions in a fossil, than in a recent state.

† Thus, for example, Rostellaria curvirostris, found fossil by Signor Bonelli near Turin, is only known at present as an Indian shell. Murex cornutus, fossil at Asti, is now only known recent in warmer latitudes, the only localities given by Linnæus and Lamarck being the African and Great Indian Oceans. Senegal is the principal known habitat at present. Conus antediluvianus cannot be distinguished from a shell now brought from Owhyhee. Among other familiar instances mentioned to me by Italian naturalists, in confirmation of the same point, Buccinum

the associated unknown species belong, for the most part, to *genera* which are now most largely developed in equinoctial regions, as, for example, the genera Pleurotoma and Cypræa.*

On comparing the fossils of the tertiary deposits of Paris and London with those of Bordeaux, and these again with the more modern strata of Sicily, we should at first expect that they would each indicate a higher temperature in proportion as they are situated farther to the south. But the contrary is true; many shells are common to all these groups, and some of them, both freshwater and marine, are of species still living. Those found in the older, or Eocene deposits of Paris and London, although 6° or 7° N. of the Miocene strata at Bordeaux, afford evidence of a warmer climate; while those of Bordeaux imply that the sea in which they lived was of a higher temperature than that of Sicily, where the shelly strata were formed six or seven degrees nearer to the equator. In these cases the greater antiquity of the several formations (the Parisian being the oldest and the Sicilian the newest) has more than counterbalanced the influence which latitude would otherwise exert, and this phe-

clathratum, Lam., was cited; but Professor Costa assured me that this shell, although extremely rare, still occurs in the Mediterranean. M. Deshayes informs me that he has received it from the Indies.

* Of the genus Pleurotoma a very few living representatives have yet been found in the Mediterranean; yet no less than twenty-five species are now to be seen in the museum at Turin, all procured by Professor Bonelli from the Subapennine strata of northern Italy. The genus Cypræa is represented by many large fossil species in the Subapennine hills, with which are associated one small and two or three minute species of the same genus, now found in the Mediterranean.

nomena clearly points to a gradual refrigeration of climate.

Siberian Mammoths.—In the superficial deposits of sand, gravel, and loam, strewed very generally over all parts of Europe, the remains of extinct species of land quadrupeds have been found, especially in places where the alluvial matter appears to have been washed into small lakes, or into depressions in the plains bordering ancient rivers. Similar deposits have also been lodged in rents and caverns of rocks where they may have been swept in by land floods, or introduced by engulphed rivers during changes in the physical geography of countries. The various circumstances under which the bones of animals have been thus preserved will be more fully considered hereafter *; I shall only state here, that among the extinct mammalia thus entombed, we find species of the elephant, rhinoceros, hippopotamus, bear, hyæna, lion, tiger, and many others; consisting for the most part of genera now confined to warmer regions.

It has been inferred that the same change of climate which has caused certain Indian species of testacea to become rare, or to degenerate in size, or to disappear from the Mediterranean,—and certain genera of the Subapennine hills, now exclusively tropical, to retain no longer any representatives in the adjoining seas,—may also have contributed to the annihilation of the mammiferous genera which formerly inhabited the continents. It is certainly probable that, when these animals abounded in Europe, the climate was milder than that now experienced, but they by no means

* Book iii. chaps. 14, 15, &c.

appear to have required a tropical heat. The hippopotamus is now only met with in rivers where the temperature of the water is warm and nearly uniform, but the great fossil species of the same genus (*H. major*, Cuv.) certainly inhabited England when the testacea of our country were nearly the same as those now existing, and when the climate cannot be supposed to have been very hot. The bones of this animal have lately been found by Mr. Strickland, together with those of a bear and other mammalia, at Cropthorn, near Evesham, in Worcestershire, in alluvial sand, together with twenty-three species of terrestrial and freshwater shells, all, with two exceptions, of British species. The bed of sand, containing the shells and bones, reposes on lias, and is covered with alternating strata of gravel, sand and loam.*

The mammoth also appears to have existed in England when the temperature of our latitudes could not have been very different from that which now prevails; for remains of this animal have been found at North Cliff, in the county of York, in a lacustrine formation, in which all the land and freshwater shells, thirteen in number, can be identified with species and varieties now existing in that county. Bones of the bison also, an animal now inhabiting a cold or temperate climate, have been found in the same place. That these quadrupeds, and the indigenous species of testacea associated with them, were all contemporary inhabitants of Yorkshire, has been established by unequivocal proof. The Rev. W. V. Vernon Harcourt caused a pit to be sunk to the depth of twenty-two feet through undisturbed strata, in which the remains of the mammoth

* Geol. Proceedings, No. 36. June, 1834.

were found imbedded, together with the shells, in a deposit which had evidently resulted from tranquil waters.*

When reasoning on these phenomena, the reader must always bear in mind that the fossil individuals belonged to *species* of elephant, rhinoceros, hippopotamus, bear, tiger, and hyæna, distinct from those which now dwell within or near the tropics. Dr. Fleming, in a discussion on this subject, has well remarked that a near resemblance in form and osteological structure is not always followed, in the existing creation, by a similarity of geographical distribution; and we must therefore be on our guard against deciding too confidently, from mere analogy of anatomical structure, respecting the habits and physiological peculiarities of *species*, now no more. "The zebra delights to roam over the tropical plains, to which it is in a great measure restricted; while the horse can maintain its existence throughout an Iceland winter. The buffalo, like the zebra, prefers a high temperature, and cannot thrive even where the common ox prospers. The musk ox, on the other hand, though nearly resembling the buffalo, prefers the stinted herbage of the arctic regions, and is able, by its periodical migrations, to outlive a northern winter. The jackal (*Canis aureus*) inhabits Africa, the warmer parts of Asia, and Greece; while the isatis (*Canis lagopus*) resides in the arctic regions. The African hare and the polar hare have their geographical distribution expressed in their trivial names†;" and different species of bears thrive in tropical, temperate, and arctic latitudes.

* Phil. Mag., Sept. 1829 and Jan. 1830.

† Fleming, Ed. New Phil. Journ., No. 12. p. 282. 1829.

Recent investigations have placed beyond all doubt the important fact that a species of tiger, identical with that of Bengal, is common in the neighbourhood of Lake Aral, near Sussac, in the forty-fifth degree of north latitude; and from time to time this animal is now seen in Siberia, in a latitude as far north as the parallel of Berlin and Hamburgh.* Humboldt remarks that the part of southern Asia now inhabited by this Indian species of tiger is separated from the Himalaya by two great chains of mountains, each covered with perpetual snow,—the chain of Kuenlun, lat. 35° N., and that of Mouztagh, lat. 42°,—so that it is impossible that these animals should merely have made excursions from India, so as to have penetrated in summer to the forty-eighth and fifty-third degrees of north latitude. They must remain all the winter north of the Mouztagh, or Celestial Mountains. The last tiger killed, in 1828, on the Lena, in lat. 52¼°, was in a climate colder than that of Petersburgh and Stockholm.†

We learn from Mr. Hodgson's account of the mammalia of Nepal, that the tiger is sometimes found at the very edge of perpetual snow in the Himalaya‡; and Pennant mentions that it is found among the snows of Mount Ararat in Armenia.

A new species also of panther (*Felis irbis*), covered with long hair, has been discovered in Siberia, evidently inhabiting, like the tiger, a region north of the Celestial Mountains, which are in lat. 42°.§

The two-horned African rhinoceros occurs without the tropics at the Cape of Good Hope, in lat. 34°

* Humboldt, Fragmens de Géologie, &c., tome ii. p. 388. Ehrenberg, Ann. des Sci. Nat., tome xxi. p. 387.

† Ehrenberg, ibid. p. 390.

‡ Journ. of Asiat. Soc., vol. i. p. 240.

§ Ehrenberg, ibid.

29′ S., where it is accompanied by the elephant, hippopotamus, and hyæna. Here the migration of all these species towards the south is arrested by the ocean; but, if the continent had been prolonged still farther, and the land had been of moderate elevation, it is very probable that they might have extended their range to a greater distance from the tropics.

Now, if the Indian tiger can range in our own times to the southern borders of Siberia, or skirt the snows of the Himalaya, we may easily imagine that large species of the same genus may once have inhabited our temperate climates. The mammoth (*E. primigenius*), already alluded to as occurring fossil in England, was decidedly different from the two existing species of elephants, one of which is limited to Asia, south of the 31° of N. lat., the other to Africa, where it extends, as before stated, as far south as the Cape of Good Hope. The bones of the great fossil species are very widely spread over Europe and North America; but are nowhere in such profusion as in Siberia, particularly near the shores of the frozen ocean. Are we, then, to conclude that this animal preferred a polar climate? If so, by what food was it sustained, and why does it not still survive near the arctic circle?

Pallas and other writers describe the bones of the mammoth as abounding throughout all the Lowland of Siberia, stretching in a direction west and east, from the borders of Europe to the extreme point nearest America, and south and north, from the base of the mountains of central Asia to the shores of the arctic sea. Within this space, scarcely inferior in area to the whole of Europe, fossil ivory has been collected almost every where, on the banks of the Irtish, Oby, Yenesei, Lena, and other rivers. The elephantime remains do not occur in the marshes and low plains, but where the banks of the rivers present lofty precipices of sand and clay; from which circumstance Pallas very justly inferred that, if sections could be obtained, similar bones might be found in all the elevated lands intervening between the great rivers. Strahlenberg, indeed, had stated, before the time of Pallas, that wherever any of the great rivers overflowed and cut out fresh channels during floods, more fossil remains of the same kind were invariably disclosed.

As to the position of the bones, Pallas found them in some places imbedded together with marine remains; in others, simply with fossil wood, or lignite, such, as he says, might have been derived from carbonized peat. On the banks of the Yenesei, below the city of Krasnojarsk, in lat. 56°, he observed grinders, and bones of elephants, in strata of yellow and red loam, alternating with coarse sand and gravel, in which was also much petrified wood of the willow and other trees. Neither here nor in the neighbouring country were there any marine shells, but merely layers of black coal.* But grinders of the mammoth were collected much farther down the same river, near the sea, in lat. 70°, mixed with *marine* petrifactions.† Many other places in Siberia are cited by Pallas, where sea shells and fishes' teeth accompany the bones of the mammoth, rhinoceros, and Siberian buffalo, or bison (*Bos priscus*). But it is not on the Oby nor the Yenesei, but on the Lena, farther to the east, where, in the same parallels of latitude, the cold is far more intense, that fossil remains have been found in the most wonderful state of preservation. In 1772, Pallas obtained from Wiljuiskoi, in lat. 64°, from the banks of

* Pallas, Reise in Russ. Reiche, pp. 409, 410.

† Nov. Com. Petrop. vol. 17. p. 584.

the Wiljui, a tributary of the Lena, the carcass of a rhinoceros (*R. tichorhinus*), taken from the sand in which it must have remained congealed for ages, the soil of that region being always frozen to within a slight depth of the surface. This carcass was compared to a natural mummy, and emitted an odour like putrid flesh, part of the skin being still covered with black and gray hairs. So great, indeed, was the quantity of hair on the foot and head conveyed to St. Petersburg, that Pallas asked whether the rhinoceros of the Lena might not have been an inhabitant of the temperate regions of middle Asia, its clothing being so much warmer than that of the African rhinoceros.* After more than 30 years, the entire carcass of a mammoth was obtained in 1803, by Mr. Adams, much farther to the north. It fell from a mass of ice, in which it had been encased, on the banks of the Lena, in lat. 70°; and so perfectly had the soft parts of the carcass been preserved, that the flesh, as it lay, was devoured by wolves and bears. This skeleton is still in the museum of St. Petersburg, the head retaining its integument and many of the ligaments entire. The skin of the animal was covered, first, with black bristles, thicker than horse hair, from twelve to sixteen inches in length; secondly, with hair of a reddish brown colour, about four inches long; and thirdly, with wool of the same colour as the hair, about an inch in length. Of the fur, upwards of thirty pounds' weight were gathered from the wet sand-bank. The individual was nine feet high, and sixteen feet long, without reckoning the large curved tusks; a size rarely surpassed by the largest living male elephants.†

* Nov. Com. Petrop. vol. 17. p. 591.

† Journal du Nord, St. Petersburg, 1807.

It is evident, then, that the mammoth, instead of being naked, like the living Indian and African elephants was enveloped in a thick shaggy covering of fur, probably as impenetrable to rain and cold as that of the musk ox.* The species may have been fitted by nature to withstand the vicissitudes of a northern climate; and it is certain that, from the moment when the carcasses, both of the rhinoceros and elephant, above described, were buried in Siberia, in latitudes 64° and 70° N., the soil must have remained frozen, and the atmosphere nearly as cold as at this day.

* Fleming, Ed. New Phil. Journ., No. xii., p. 285.

Bishop Heber informs us (Narr. of a Journey through the Upper Provinces of India, vol. ii. p. 166—219.), that in the lower range of the Himalaya mountains, in the north-eastern borders of the Delhi territory, between lat. 29° and 30°, he saw an Indian elephant of a small size, covered with shaggy hair. But this variety must be exceedingly rare; for Mr. Royle (late superintendant of the East India Company's Botanic Garden at Saharunpore) has assured me, that being in India when Heber's Journal appeared, and having never seen or heard of such elephants, he made the strictest inquiries respecting the fact, and was never able to obtain any evidence in corroboration. Mr. Royle resided at Saharunpore, lat. 30° N., upon *the extreme northern limit* of the range of the elephant. Mr. Everest also declares that he has been equally unsuccessful in finding any one aware of the existence of such a variety or breed of the animal, though one solitary individual was mentioned to him as having been seen at Delhi, with a good deal of long hair upon it. The greatest elevation, says Mr. E., at which the wild elephant is found in the mountains to the north of Bengal, is at a place called Nahun, about 4000 feet above the level of the sea, and in the 31st degree of N. lat., where the mean yearly temperature may be about 64° Fahrenheit, and the difference between winter and summer very great, equal to about 36° F., the month of January averaging 45°, and June, the hottest month, 81° F. (Everest on Climate of Foss. Eleph., Journ. of Asiat. Soc., No. 25, p. 21.)

So fresh is the ivory throughout northern Russia, that, according to Tilesius, thousands of fossil tusks have been collected and used in turning; yet others are still procured and sold in great plenty. He declares his belief that the bones still left in northern Russia must greatly exceed in number all the elephants now living on the globe.

We are as yet ignorant of the entire geographical range of this fossil mammoth; but its remains have recently been collected from cliffs of frozen mud and ice on the east side of Behring's Straits, in Eschscholtz's Bay, in Russian America, lat. 66° N. As the cliffs waste away by the thawing of the ice, tusks and bones fall out, and a strong odour of animal matter is exhaled from the mud.*

On considering all the facts above enumerated, it seems reasonable to imagine that a large region in central Asia, including, perhaps, the southern half of Siberia, enjoyed, at no very remote period in the earth's history, a temperate climate, sufficiently mild to afford food for large herds of elephants and rhinoceroses, *of species distinct from those now living.* At the time to which these speculations refer, the Lowland of Siberia was probably less extensive towards the north than it is now; but the existing rivers, though of inferior length, may have flowed from south to north, as at present, and, during inundations, may have swept the carcasses of drowned animals into lakes, or the sea, as do the Nile, Ganges, and other rivers in our own time.†

In Siberia all the principal rivers are liable, like the

* See Dr. Buckland's description of these bones, Appen. to Beechey's Voy.

† See Book iii. chaps. xv. and xvi.

Mackenzie, in North America, to remarkable floods, in consequence of flowing in a direction from south to north; for they are filled with running water in their upper course when completely frozen over for several hundred miles near their mouths. Here they remain blocked up by ice for six months in every year, and the descending waters, finding no open channel, rush over the ice; often changing their direction; and sweeping along forests and prodigious quantities of soil and gravel mixed with ice. The rivers of this great country are among the largest in the world, the Yenesei having a course of 2500, the Lena of 2000 miles; so that we may easily conceive that the bodies of animals which fall into their waters may be transported to vast distances towards the arctic sea, and, before arriving there, may be stranded upon thick ice, and afterwards, when the ice breaks up, be floated still farther towards the ocean, until at length they become buried in fluviatile and submarine deposits near the mouths of rivers.

It would doubtless be impossible for herds of mammoths and rhinoceroses to obtain subsistence at present, even in the southern part of Siberia, covered as it is during a great part of the year with snow: but there is no difficulty in supposing a vegetation capable of nourishing these great quadrupeds to have once flourished between the latitudes 40° and 60° N., resembling perhaps that of England; for we have seen that there are proofs of the mammoth having coexisted with a large proportion of the living species of British testacea.

It has been well observed by Dr. Fleming, that "the kind of food which the existing species of elephant prefers will not enable us to determine, or even to offer a probable conjecture, concerning that of the extinct species. No one acquainted with the gramineous character of the food of our fallow-deer, stag, or roe, would have assigned a lichen to the reindeer."

Travellers mention that, even now, when the climate of eastern Asia is so much colder than the same parallels of latitude farther west, there are woods not only of fir, but of birch, poplar, and alder on the banks of the Lena as far north as latitude 60°. Formerly, when the arctic lands were less extensive, the temperature of the winter and summer may have been more nearly equalized, and the increasing severity of the winters, rather than a diminution of the mean annual temperature, may have been the chief cause of the extermination of the mammoth. It is probable that the refrigeration of the climate of north-eastern Asia was accompanied, and in a great measure caused, by changes in its physical geography. The whole country, from the mountains to the sea, may have been upraised by a movement similar to that which is now experienced in part of Sweden; and as the shores of the Gulf of Bothnia are extended not only by the influx of sediment brought down by rivers, but also by the elevation and consequent drying up of the bed of the sea, so a similar combination of causes may have extended the low tract of land where marine shells and fossil bones now occur in Siberia.

It has been suggested, that as, in our own times, the northern animals migrate, so the Siberian elephant and rhinoceros may have wandered towards the north in summer. The musk oxen annually desert their winter quarters in the south, and cross the sea upon the ice, to graze for four months, from May to September, on the rich pasturage of Melville Island, in lat. 75°. The mammoths, without passing so far beyond the arctic circle, may nevertheless have made excursions, during the heat of a brief northern summer, from the central or temperate parts of Asia to the sixtieth parallel of latitude; in which case the carcasses of such as were drowned, or overwhelmed by drift snow, may have been hurried down into the polar sea, and imbedded in the deposits there accumulating.

I have been informed by Dr. Richardson, that in the northern parts of America, comprising regions now inhabited by many herbivorous quadrupeds, the drift snow is often converted into permanent glaciers. It is commonly blown over the edges of steep cliffs, so as to form an inclined talus hundreds of feet high; and when a thaw commences, torrents rush from the land, and throw down from the top of the cliff alluvial soil and gravel. This new soil soon becomes covered with vegetation, and protects the foundation of snow from the rays of the sun. Water occasionally penetrates into the crevices and pores of the snow; but, as it soon freezes again, it serves the more rapidly to consolidate the mass into a compact iceberg. It may sometimes happen that cattle grazing in a valley at the base of such cliffs, on the borders of a sea or river, may be overwhelmed, and at length enclosed in solid ice, and then transported towards the polar regions.

The result of these investigations, therefore, may lead us to conclude that the mammoth, and some other extinct quadrupeds fitted to live in high latitudes, were inhabitants of northern Asia at a time when the climate was milder, and more uniform, than at present. Their extirmination was probably connected with changes in the physical geography of the arctic regions, of which I shall consider the effects in the next chapter.

Change of climate proved by fossils in older strata.—If we pass from the consideration of these more modern deposits, whether of marine or continental origin, in which existing species are abundantly intermixed with the extinct, to the older tertiary strata, we can only reason from analogy; since none of the species of vertebrated animals, and scarcely any of the testacea of those formations, are identifiable with species now in being. In the deposits of that more remote period, we find the remains of many animals analogous to those of hot climates, such as the crocodile, turtle, and tortoise, together with many large shells of the genus nautilus, and plants indicating such a temperature as is now found along the southern borders of the Mediterranean.

A great interval of time appears to have elapsed between the formation of the secondary strata, which constitute the principal portion of the elevated land in Europe, and the origin of the last-mentioned Eocene deposits. In that great series of secondary rocks, many distinct assemblages of organized fossils are entombed, all of unknown species, and many of them referrible to genera and families now most abundant between the tropics. Among the most remarkable are many gigantic reptiles, some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmer parts of the earth. Coral reefs also were evidently numerous in the seas of the same periods, and composed of species belonging to genera now characteristic of a tropical climate. The number of very large chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the Cycadeæ constituting the most numerous family.

But it is from the more ancient coal deposits that the most extraordinary evidence has been supplied in proof of the former existence of an extremely hot climate in those latitudes which are now the temperate and colder regions of the globe. It appears from the fossils of the carboniferous period, that the flora consisted almost exclusively of large vascular cryptogamic plants. We learn, from the labours of M. Ad. Brongniart, that there existed at that epoch Equiseta upwards of ten feet high, and from five to six inches in diameter; tree ferns, or plants allied to them, from forty to fifty feet in height, and arborescent Lycopodiaceæ, from sixty to seventy feet high.* Of the above classes of vegetables, the species are all small at present in cold climates; while in tropical regions there occur, together with small species, many of a much greater size, but their development, even in the hottest parts of the globe, is now inferior to that indicated by the petrified forms of the coal formation. An elevated and uniform temperature, and great humidity in the air, are the causes most favourable to the numerical predominance and the great size of these plants within the torrid zone at present. It is true that, as the fossil flora consists of such plants as may accidentally have been floated into seas, lakes, or estuaries, it may very commonly give a false representation of the numerical relations of families then living on the land. Yet, after

* Consid. Générales sur la Nature de la Végétation, &c. Ann. des Sci. Nat., Nov. 1828.

allowing for liability to error on these grounds, the argument founded on the comparative numbers of the fossil plants of the carboniferous strata is very strong.

"In regard to the geographical extent of the ancient vegetation, it was not confined," says M. Brongniart, "to a small space, as to Europe, for example; for the same forms are met with again at great distances. Thus, the coal plants of North America are, for the most part, identical with those of Europe, and all belong to the same genera. Some specimens, also, from Greenland, are referrible to ferns, analogous to those of our European coal mines." *

The fossil plants brought from Melville Island, although in a very imperfect state, have been supposed to warrant similar conclusions †; and assuming that they agree with those of Baffin's Bay, mentioned by M. Brongniart, how shall we explain the manner in which such a vegetation lived through an arctic night of several months' duration? ‡

This point has of late been dwelt upon by Professor Lindley, as one of considerable difficulty §; and he is even inclined to resort again to the favourite hypothesis of earlier theorists — a derangement in the position of

* Prodrome d'une Hist. des Végét. Foss. p. 179.

† König, Journ. of Sci. vol. xv. p. 20. Mr. König informs me, that he no longer believes any of these fossils to be tree ferns, as he at first stated, but that they agree with tropical forms of plants in our English coal-beds. The Melville Island specimens, now in the British Museum, are very obscure impressions.

‡ Fossil Flora of Great Britain, by John Lindley and William Hutton, Esqrs. No. IV.

§ Fossil Flora, No. IV.; and in his Lectures. Mr. Lindley tells me, however, that he has not yet (Oct. 1833) had opportunities of examining the fossil plants of high latitudes.

the earth's axis of rotation. But all astronomers are agreed that speculations on such a change are inadmissible, as being incompatible with the laws of equilibrium. Even if a catastrophe, such as the collision of a comet, be called in, and admitted as adequate to alter the obliquity of the axis, the problem is by no means solved; for in that case the seas would have all rushed to the new equator, and would probably still be insufficient to restore equilibrium.*

It may seem premature to discuss the question now raised, until the true nature of the fossil flora of the arctic regions has been more accurately determined; yet, as the question has attracted some attention, let us assume for a moment, that the coal plants of Melville Island are strictly analogous to those of Northumberland — would such a fact present an inexplicable enigma to the vegetable physiologist?

Plants, it is affirmed, cannot remain in darkness, even for a week, without serious injury, unless in a torpid state; and if exposed to heat and moisture they cannot remain torpid, but will grow, and must therefore perish. If, then, in the latitude of Melville Island, 75° N., a high temperature, and consequent humidity, prevailed at that period when we know the arctic seas were filled with corals and large multilocular shells, how could plants of tropical forms have flourished? Is not the bright light of equatorial regions as indispensable a condition of their well-being as the sultry heat of the same countries? and how could they annually endure a night prolonged for three months? †

Now, we must bear in mind, in the first place, that,

* Mrs. Somerville's Mech. of Heavens, Prel. Disc. p. 38.

† Fossil Flora, No. IV.

so far as experiments have been made, there is every reason to conclude, that the range of intensity of light to which living plants can accommodate themselves is far wider than that of heat. No palms or tree ferns can live in our temperate latitudes without protection from the cold; but when placed in hot-houses they grow luxuriantly, even under a cloudy sky, and where much light is intercepted by the glass and frame-work. At St. Petersburg, in lat. 60° N., these plants have been successfully cultivated in hot-houses, although there they must exchange the perpetual equinox of their native regions for days and nights which are alternately protracted to nineteen hours and shortened to five. How much farther towards the pole they might continue to live, provided a due quantity of heat and moisture were supplied, has not yet been determined; but St. Petersburg is probably not the utmost limit, and we should expect that in lat. 65° at least, where they would never remain twenty-four hours without enjoying the sun's light, they might still exist.

Nor must we forget that we are always speaking of *living* species formed to inhabit within or near the tropics. The coal plants were of perfectly distinct species, and may have been endowed with a different constitution, enabling them to bear a greater variation of circumstances in regard to light. We find that particular species of palms and tree ferns require at present different degrees of heat; and that some species can thrive only in the immediate neighbourhood of the equator, others only at a distance from it. In the same manner the *minimum of light*, sufficient for the now existing species, cannot be taken as the standard for all analogous tribes that may ever have flourished on the globe.

But granting that the extreme northern point to which a flora like that of the carboniferous era could ever reach may be somewhere between the latitudes of 65° and 70°, we should still have to inquire whether the vegetable remains might not have been drifted from thence, by rivers and currents, to the parallel of Melville Island, or still farther. In the northern hemisphere, at present, we see that the materials for future beds of lignite and coal are becoming amassed in high latitudes, far from the districts where the forests grew, and on shores where scarcely a stunted shrub can now exist. The Mackenzie, and other rivers of North America, carry pines with their roots attached for many hundred miles towards the north, into the arctic sea, where they are imbedded in deltas, and some of them drifted still farther by currents towards the pole.

Some of the appearances of our English coal fields seem to prove that the plants were not floated from great distances; for the outline of the stems of succulent species preserve their sharp angles, and others have their surfaces marked with the most delicate lines and streaks. Long leaves, also, are attached in many instances to the trunks or branches*; and leaves we know, in general, are soon destroyed when steeped in water, although ferns will retain their forms after an immersion of several months.† It seems fair to presume that the coal plants may have grown upon the same land, the destruction of which provided materials for the sandstones and conglomerates of the group of

* Fossil Flora, No. X.

† This has been proved by Mr. Lindley, who is now conducting a series of experiments on the subject.

strata in which they are imbedded; especially as the coarseness of the particles of many of these rocks attests that they were not borne from very remote localities.

Before we are entitled to enlarge farther on this question of transportation, we must obtain more precise information respecting the state of the various fossils which have been found principally in the coal sandstones of high latitudes, and we must learn whether they bear the marks of friction and decay previous to their fossilization.

To return, therefore, from this digression, the uninjured corals and chambered univalves of Igloolik (lat. 69⅓° N.), Melville Island, and other high latitudes, sufficiently prove that, during the carboniferous period, there was an elevated temperature even in northern regions bordering on the arctic circle. The heat and humidity of the air, and the uniformity of climate, appear to have been most remarkable when the oldest strata hitherto discovered were formed. The approximation to a climate similar to that now enjoyed in these latitudes does not commence till the era of the formations termed tertiary; and while the different tertiary rocks were deposited in succession, the temperature seems to have been still further lowered, and to have continued to diminish gradually, even after the appearance upon the earth of a great portion of the existing species.

CHAPTER VII.

FARTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

On the causes of vicissitudes in climate — Remarks on the present diffusion of heat over the globe — On the dependence of the mean temperature on the relative position of land and sea — Isothermal lines — Currents from equatorial regions (p. 165). — Drifting of icebergs — Different temperature of Northern and Southern hemispheres — Combination of causes which might produce the extreme cold of which the earth's surface is susceptible (p. 181). — Conditions necessary for the production of the extreme of heat, and its probable effects on organic life (p. 189).

Causes of vicissitudes in Climate. — As the proofs enumerated in the last chapter indicate that the earth's surface has experienced great changes of climate since the deposition of the older sedimentary strata, we have next to inquire, how such vicissitudes can be reconciled with the existing order of nature. The cosmogonist has availed himself of this, as of every obscure problem in geology, to confirm his views concerning a period when the laws of the animate and inanimate world differed essentially from those now established; and he has in this, as in many other cases, succeeded so far, as to divert attention from that class of facts, which, if fully understood, might probably lead to an explanation of the phenomena. At first it was imagined that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a perpetual equinox, and uniformity of seasons throughout the year;—that the planet enjoyed this 'paradisiacal' state until the era of the great flood; but in that catastrophe, whether by the shock of a comet, or some other convulsion, it lost its equal poise, and hence the obliquity of its axis, and with that the varied seasons of the temperate zone, and the long nights and days of the polar circles.

When the progress of astronomical science had exploded this theory, it was assumed, that the earth at its creation was in a state of fluidity, and red hot, and that ever since that era it had been cooling down, contracting its dimensions, and acquiring a solid crust,—an hypothesis hardly less arbitrary, but more calculated for lasting popularity, because, by referring the mind directly to the beginning of things, it requires no support from observation, nor from any ulterior hypothesis. They who are satisfied with this solution are relieved from all necessity of inquiry into the present laws which regulate the diffusion of heat over the surface; for, however well these may be ascertained, they cannot possibly afford a full and exact elucidation of the internal changes of an embryo world.

But if, instead of forming vague conjectures as to what might have been the state of the planet at the era of its creation, we fix our thoughts on the connexion at present existing between climate and the distribution of land and sea; and then consider what influence former fluctuations in the physical geography of the earth must have had on superficial temperature, we may perhaps approximate to a true theory. If doubts and obscurities still remain, they should be ascribed to our limited acquaintance with the laws of Nature, not to revolutions in her economy;—they should stimulate us to further research, not tempt us to indulge our fancies in framing imaginary systems for the government of infant worlds.

Diffusion of heat over the globe.—In considering the laws which regulate the diffusion of heat over the globe, we must be careful, as Humboldt well remarks, not to regard the climate of Europe as a type of the temperature which all countries placed under the same latitude enjoy. The physical sciences, observes this philosopher, always bear the impress of the places where they began to be cultivated; and as, in geology, an attempt was at first made to refer all the volcanic phenomena to those of the volcanos in Italy, so, in meteorology, a small part of the old world, the centre of the primitive civilization of Europe, was for a long time considered a type to which the climate of all corresponding latitudes might be referred. But this region, constituting only one seventh of the whole globe, proved eventually to be the exception to the general rule. For the same reason, we may warn the geologist to be on his guard, and not hastily to assume that the temperature of the earth in the present era is a type of that which most usually obtains, since he contemplates far mightier alterations in the position of land and sea, at different epochs, than those which now cause the climate of Europe to differ from that of other countries in the same parallels.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other.* It is also known that the *mean* annual

* We are indebted to Baron Alex. Humboldt for collecting together, in a beautiful essay, the scattered data on which he

temperature may be the same in two places which enjoy very different climates, for the seasons may be nearly uniform, or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat, or isothermal lines. The deviations of all these lines from the same parallel of latitude are determined by a multitude of circumstances, among the principal of which are the position, direction, and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

On comparing the two continents of Europe and America, it is found that places in the same latitudes have sometimes a mean difference of temperature amounting to 11°, or even in a few cases to 17° Fahr.; and some places on the two continents, which have the same mean temperature, differ from 7° to 13° in latitude.† The principal cause of greater intensity of cold in corresponding latitudes of North America and Europe, is the connexion of North America with the polar circle, by a large tract of land, some of which is from three to five thousand feet in height, and, on the other hand, the separation of Europe from the arctic circle by an ocean. The ocean has a tendency to preserve every where a mean temperature, which it communicates to the contiguous land, so that it tempers the climate, moderating alike an excess of heat or cold.

founded an approximation to a true theory of the distribution of heat over the globe. Many of these data are derived from the author's own observations, and many from the works of M. Pierre Prevost, of Geneva, on the radiation of heat, and other writers.—See Humboldt on Isothermal Lines, Mémoires d'Arcueil, tom. iii. translated in the Edin. Phil. Journ. vol. iii. July, 1820.

† Humboldt's tables, Essay on Isothermal Lines, &c.

The elevated land, on the other hand, rising to the colder regions of the atmosphere, becomes a great reservoir of ice and snow, arrests, condenses, and congeals vapour, and communicates its cold to the adjoining country. For this reason, Greenland, forming part of a continent which stretches northward to the 82d degree of latitude, experiences under the 60th parallel a more rigorous climate than Lapland under the 72d parallel.

But if land be situated between the 40th parallel and the equator, it produces, unless it be of extreme height, exactly the opposite effect; for it then warms the tracts of land or sea that intervene between it and the polar circle. For the surface being in this case exposed to the vertical, or nearly vertical rays of the sun, absorbs a large quantity of heat, which it diffuses by radiation into the atmosphere. For this reason, the western parts of the old continent derive warmth from Africa, "which, like an immense furnace, distributes its heat to Arabia, to Turkey in Asia, and to Europe." * On the contrary, the north-eastern extremity of Asia experiences in the same latitude extreme cold; for it has land on the north between the 60th and 70th parallel, while to the south it is separated from the equator by the North Pacific.

In consequence of the more equal temperature of the waters of the ocean, the climate of islands and of coasts differs essentially from that of the interior of continents, the more maritime climates being characterized by mild winters and more temperate summers; for the sea breezes moderate the cold of winter, as well as the heat of summer. When, therefore, we

* Malte-Brun. Phys. Geog. book xvii.

trace round the globe those belts in which the mean annual temperature is the same, we often find great differences in climate; for there are *insular* climates in which the seasons are nearly equalized, and *excessive* climates, as they have been termed, where the temperature of winter and summer is strongly contrasted. The whole of Europe, compared with the eastern parts of America and Asia, has an insular climate. The northern part of China, and the Atlantic region of the United States, exhibit "excessive climates." We find at New York, says Humboldt, the summer of Rome and the winter of Copenhagen; at Quebec, the summer of Paris and the winter of Petersburg. At Pekin, in China, where the mean temperature of the year is that of the coasts of Brittany, the scorching heats of summer are greater than at Cairo, and the winters as rigorous as at Upsala.*

If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much farther than the lines of equal mean annual heat. The lines of equal winter in Europe, for example, are often curved so as to reach parallels of latitude 9° or 10° distant from each other, whereas the isothermal lines, or those passing through places having the same mean annual temperature, differ only from 4° to 5°.

Influence of currents on temperature.—Among other influential causes, both of remarkable diversity in the mean annual heat, and of unequal division of heat in the different seasons, are the direction of currents and the accumulation and drifting of ice in high latitudes. The temperature of the Lagullas current is 10° or 12°

* On Isothermal Lines, &c.

Fahr. above that of the sea at the Cape of Good Hope; for the greater part of its waters flow through the Mozambique channel, down the south-east coast of Africa, and are derived from regions in the Indian Ocean much nearer the line, and much hotter than the Cape.* An opposite effect is produced by the "equatorial" current, which crosses the Atlantic from Africa to Brazil, having a breadth varying from 160 to 450 nautical miles. Its waters are cooler by 3° or 4° Fahr. than those of the ocean under the line, so that it moderates the heat of the tropics.†

But the effects of the Gulf stream on the climate of the north Atlantic Ocean are far more remarkable. This most powerful of known currents has its source in the Gulf or Sea of Mexico, which, like the Mediterranean and other close seas in temperate or low latitudes, is warmer than the open ocean in the same parallels. The temperature of the Mexican sea in summer is, according to Rennell, 86° Fahr. or at least 7° above that of the Atlantic in the same latitude.‡ From this great reservoir or caldron of warm water, a constant current pours forth through the straits of Bahama at the rate of 3 or 4 miles an hour; it crosses the ocean in a north-easterly direction, skirting the great bank of Newfoundland, where it still retains a temperature of 8° above that of the surrounding sea. It reaches the Azores in about 78 days, after flowing nearly 3000 geographical miles, and from thence it sometimes extends its course a thousand miles further, so as to reach the Bay of Biscay, still retaining an excess of 5° above the mean temperature of that sea. As it has been known to

* Rennell on Currents, p. 96. London, 1832.

† Ibid. p. 153.

‡ Ibid. p. 25.

arrive there in the months of November and January, it may tend greatly to moderate the cold of winter in countries on the west of Europe.

There is a large tract in the centre of the North Atlantic, between the parallels of 33° and 35° N. lat. which Rennell calls the "recipient of the gulf water." A great part of it is covered by the weed called sargasso, which the current floats in abundance from the Gulf of Mexico. This mass of water is nearly stagnant, is warmer by 7° or 10° than the waters of the Atlantic, and may be compared to the fresh water of a river overflowing the heavier salt water of the sea. Rennell estimates the area of the "recipient," together with that covered by the main current, as being 2000 miles in length from E. to W., and 350 in breadth from N. to S., which, he remarks, is a larger area than that of the Mediterranean. The heat of this great body of water is kept up by the incessant and quick arrival of fresh supplies of warm water from the south, and there can be no doubt that the general climate of parts of Europe and America are materially affected by this cause.

It is considered probable by Scoresby, that the influence of the gulf stream extends even to the sea, near Spitzbergen, where its waters may pass under those of melted ice; for it has been found that, in the neighbourhood of Spitzbergen, the water is warmer by 6° or 7° at the depth of one hundred and two hundred fathoms than at the surface. This might arise from the known law that fresh water passes the point of greatest density when cooled down below 40°, and between that and the freezing point expands again. The water of melted ice might be lighter, both as being fresh (having lost its salt in the decomposing process of freezing), and because its temperature is nearer the freezing point than the inferior water of the gulf stream.*

The great glaciers generated in the valleys of Spitzbergen, in the 79° of north latitude, are almost all cut off at the beach, being melted by the feeble remnant of heat still retained by the gulf stream. In Baffin's Bay, on the contrary, on the west coast of Old Greenland, where the temperature of the sea is not mitigated by the same cause, and where there is no warmer under-current, the glaciers stretch out from the shore, and furnish repeated crops of mountainous masses of ice which float off into the ocean.† The number and dimensions of these bergs is prodigious. Captain Ross saw several of them together in Baffin's Bay aground in water fifteen hundred feet deep! Many of them are driven down into Hudson's Bay, and accumulating there, diffuse excessive cold over the neighbouring continent; so that Captain Franklin reports, that at the mouth of Hayes river, which lies in the same latitude as the north of Prussia or the south of Scot-

* When Scoresby wrote in 1820 (Arctic Regions, vol. i. p. 210.), he doubted whether salt water expanded like fresh water when freezing. Since that time Erman (Poggendorf's Annalen, 1828, vol. xii. p. 483.) has proved by experiment that sea-water does not follow the same law as fresh water, as De Luc, Rumford, and Marcet had supposed. On the contrary, it appears that salt water of sp. gr. 1·027 (which according to Berzelius is the mean density of sea water) has *no maximum of density* so long as it remains fluid; and even when ice begins to form in it, the remaining fluid part always increases in density in proportion to the degree of refrigeration.

† Scoresby's Arctic Regions, vol. i. p. 208.—Dr. Latta's Observations on the Glaciers of Spitzbergen, &c. Edin. New Phil. Journ. vol. iii. p. 97.

land, ice is found every where in digging wells, in summer, at the depth of four feet! Other bergs are occasionally met with, in a state of rapid thaw, as far south as lat. 40°, off the eastern coast of Greenland, where they cool the water sensibly to the distance of forty or fifty miles around, the thermometer sinking sometimes 17°, or even 18°, Fahrenheit in their neighbourhood.*

Difference of climate of the Northern and Southern hemispheres. — When we compare the climate of the northern and southern hemispheres, we obtain still more instruction in regard to the influence of the distribution of land and sea on climate. The dry land in the southern hemisphere is to that of the northern in the ratio only of one to three, excluding from our consideration that part which lies between the pole and the 74° of south latitude, which has hitherto proved inaccessible. And whereas, in the northern hemisphere, between the pole and the thirtieth parallel of north latitude, the land and sea occupy nearly equal areas, the ocean in the southern hemisphere covers no less than fifteen parts in sixteen of the entire space included between the antarctic circle and the thirtieth parallel of south latitude.

This great extent of sea gives a particular character to climates south of the equator, the winters being mild and the summers cool. Thus, in Van Diemen's land, corresponding nearly in latitude to Rome, the winters are more mild than at Naples, and the summers not warmer than those at Paris, which is 7° farther from the equator.† The effect on vegetation is very

* Rennell on Currents, p. 95.

† Humboldt on Isothermal Lines.

remarkable:—tree-ferns, for instance, which require abundance of moisture, and an equalization of the seasons, are found in Van Diemen's land, in latitude 42° S.; and in New Zealand in south latitude 45°. The orchideous parasites also advance to the 38° and 42° of south latitude. Humboldt observes that it is in the *mountainous, temperate, humid,* and *shady* parts of the equatorial regions, that the family of ferns produces the greatest number of species. As we know, therefore, that elevation often compensates for the effect of latitude in the geographical distribution of plants, we may easily understand that a class of vegetables, which grow at a certain height in the torrid zone, would flourish on the plains at greater distances from the equator, if the temperature, moisture, and other necessary conditions, were equally uniform throughout the year.

It has long been supposed that the general temperature of the southern hemisphere was considerably lower than that of the northern, and that the difference amounted to at least 10° Fahrenheit. Baron Humboldt, after collecting and comparing a great number of observations, came to the conclusion that even a much larger difference existed, but that none was to be observed within the tropics, and only a small difference as far as the thirty-fifth and fortieth parallel. Captain Cook was of opinion that the ice of the antarctic predominated greatly over that of the arctic region, that encircling the southern pole coming nearer to the equator by 10° than the ice around the north pole. But the recent voyages of Weddell and Biscoe have shewn that on certain meridians it is possible to approach the south pole nearer by several degrees than Cook had penetrated; and even in the seventy-third and seventy-fourth degrees of south latitude, they found the sea open and with few ice-floes.*

Nevertheless, the greater cold of high southern latitudes is confirmed by the description given both by ancient and modern navigators of the lands in this hemisphere. In Sandwich land, according to Cook, in 59° of south latitude, the perpetual snow and ice reach to the sea beach; and what is still more astonishing, in the island of Georgia, which is in the 54° south latitude, or the same parallel as Yorkshire, the line of perpetual snow descends to the level of the ocean. When we consider this fact, and then recollect that the summit of the highest mountains in Scotland, four degrees farther to the north, do not attain the limit of perpetual snow on our side of the equator, we learn that latitude is one only of many powerful causes, which determine the climate of particular regions of the globe. The permanence of snow in the southern hemisphere, is in this instance partly due to the floating ice, which chills the atmosphere and condenses the vapour, so that in summer the sun cannot pierce through the foggy air. But besides the abundance of ice which covers the sea to the south of Georgia and Sandwich land, we may also, as Humboldt

* Captain Weddell, in 1823, advanced 3° farther than Captain Cook, and arrived at lat. 74° 15′ south, long. 34° 17′ west. After having passed through a sea strewed with numerous ice islands, he arrived, in that high latitude, at an open ocean; but even if he had sailed 6° farther south, he would not have penetrated to higher latitudes than Captain Parry in the arctic circle, who reached lat. 81° 12′ 51″ north. Captain Biscoe, in 1831 and 1832, discovered Graham's Land between 64° and 68° S. lat., to the southward of New South Shetland, and Enderby's Land in the same latitude, on the meridian of Madagascar. Journ. of Roy. Geograph. Soc. of London, 1833, p. 105.

suggests, ascribe the cold of those countries in part to the absence of land between them and the tropics.

If Africa and New Holland extended farther to the south, a diminution of ice would take place in consequence of the radiation of heat from these continents during summer, which would warm the contiguous sea and rarefy the air. The heated aerial currents would then ascend and flow more rapidly towards the south pole, and moderate the winter. In confirmation of these views, it is stated that the ice, which extends as far as the 68° and 71° of south latitude, advances more towards the equator whenever it meets an open sea; that is, where the extremities of the present continents are not opposite to it; and this circumstance seems explicable only on the principle above alluded to, of the radiation of heat from the lands so situated.

The cold of the antarctic regions was conjectured by Cook to be due to the existence of a large tract of land between the seventieth degree of south latitude and the pole; and it is worthy of observation, that even now, after the most recent voyages, the area of land still unexplored within the antarctic circle is far more than double the area of Europe.* Some geographers think that the late discovery of Graham's and Enderby's Lands (between lat. 64° and 68° S.), both of which Captain Biscoe believes to be of great extent, has strengthened the probability of Cook's conjecture. These newly observed countries, although placed in latitudes in which herds of wild herbivorous

* Mr. Gardner informs me that the surface of Europe contains about 2,793,000 square geographical miles, the unexplored antarctic region about 7,620,000.

animals are met with in the northern hemisphere, nay, where man himself exists, and where there are ports and villages, are described as most wintery in their aspect, almost entirely covered, even in summer, with ice and snow, and nearly destitute of animal life.

The distance to which icebergs float from the polar regions on the opposite sides of the line is, as might have been anticipated, very different. Their extreme limit in the northern hemisphere is lat. 40°, as before mentioned, off the eastern coast of Greenland; to which point, as also to the Azores, lat. 42° N., they are sometimes drifted from Baffin's Bay. But in the other hemisphere they have been seen, within the last few years, at different points off the Cape of Good Hope, between latitude 36° and 39°.* One of these was two miles in circumference, and 150 feet high.† Others rose from 250 to 300 feet above the level of the sea, and were therefore of great volume below; since it is ascertained, by experiments on the buoyancy of ice floating in sea-water, that for every solid foot seen above, there must at least be eight feet below water.‡ If ice islands from the north polar regions floated as far, they might reach Cape St. Vincent, and there, being drawn by the current that always sets in from the Atlantic through the Straits of Gibraltar, be drifted into the Mediterranean, so that the serene sky of that delightful region might soon be deformed by clouds and mists.

Before the amount of difference between the temperature of the two hemispheres was ascertained, it

* On Icebergs in low Latitudes, by Captain Horsburgh; read to the Royal Society, February, 1830.

† Edin. New Phil. Journ. No. xv. p. 193.; January, 1830.

‡ Scoresby's Arctic Regions, vol. i. p. 234.

was referred by many astronomers to the acceleration of the earth's motion in its perihelium; in consequence of which the spring and summer of the southern hemisphere are shorter, by nearly eight days, than those seasons north of the equator. But Sir J. Herschel reminds us that the excess of eight days in the duration of the sun's presence in the northern hemisphere is not productive of an excess of annual light and heat; since, according to the laws of elliptic motion, it is demonstrable that whatever be the ellipticity of the earth's orbit, the two hemispheres must receive *equal absolute quantities* of light and heat per annum, the proximity of the sun in perigee exactly compensating the effect of its swifter motion.* Humboldt, however, observes, that the accumulation of heat in the southern hemisphere must be less on account of the greater emission of radiant heat, which continues during a winter longer by eight days than that on the other side of the equator.†

Perhaps no very sensible effect may be produced by this source of disturbance, yet the geologist should bear in mind that to a certain extent it operates alternately on each of the two hemispheres for a period of upwards of 10,000 years, dividing unequally the times during which the annual supply of solar light and heat is received. This cause may sometimes tend to counter-

* This follows, observes Herschel, from a very simple theorem, which may be thus stated: — "The amount of heat received by the earth from the sun, while describing any part of its orbit, is proportional to the angle described round the sun's centre." So that if the orbit be divided into two portions by a line drawn *in any direction* through the sun's centre, the heat received in describing the two unequal segments of the ellipse so produced will be equal. Geol. Trans. vol. iii. part ii. p. 298.; second series.

† On Isothermal Lines.

balance inequalities of temperature resulting from other far more influential circumstances; but, on the other hand, it must sometimes tend to increase the extreme of deviation arising from certain combinations of causes.

But whatever may be at present the inferiority of heat in the temperate and frigid zones south of the line, it is quite evident that the cold would be far more intense if there happened, instead of open sea, to be tracts of elevated land between the 55th and 70th parallel; and on the other hand, the cold would be moderated if there was more land between the line and the forty-fifth degree of south latitude.

Changes in the position of land and sea may give rise to vicissitudes in climate. — Having offered these brief remarks on the diffusion of heat over the globe in the present state of the surface, I shall now proceed to speculate on the vicissitudes of climate, which must attend those endless variations in the geographical features of our planet which are contemplated in geology. That our speculations may be confined within the strict limits of analogy, I shall assume, 1st, That the proportion of dry land to sea continues always the same. 2dly, That the volume of the land rising above the level of the sea is a constant quantity; and not only that its mean, but that its extreme height, are liable only to trifling variations. 3dly, That both the mean and extreme depth of the sea are invariable; and, 4thly, It may be consistent with due caution to assume that the grouping together of the land in great continents is a necessary part of the economy of nature; for it is possible that the laws which govern the subterranean forces, and which act simultaneously along certain lines, cannot but produce, at every epoch, continuous mountain-chains; so that the subdivision of the whole land into innumerable islands may be precluded.

If it be objected, that the maximum of elevation of land and depth of sea are probably not constant, nor the gathering together of all the land in certain parts, nor even perhaps the relative extent of land and water, I reply, that the arguments about to be adduced will be strengthened, if, in these peculiarities of the surface, there be considerable deviations from the present type. If, for example, all other circumstances being the same, the land is at one time more divided into islands than at another, a greater uniformity of climate might be produced, the mean temperature remaining unaltered: or if, at another era, there were mountains higher than the Himalaya, these, when placed in high latitudes, would cause a greater excess of cold. Or, if we suppose that at certain periods no chain of hills in the world rose beyond the height of 10,000 feet, a greater heat might then have prevailed than is compatible with the existence of mountains thrice that elevation.

However constant may be the relative proportion of sea and land, we know that there is annually some small variation in their respective geographical positions, and that in every century the land is in some parts raised, and in others depressed by earthquakes; and so likewise is the bed of the sea. By these and other ceaseless changes, the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth, after it had once become the habitation of living creatures; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant if we consider how slightly the highest mountain-chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet in diameter, by a grain of sand less than one-twentieth of an inch in thickness.*

The superficial inequalities of the earth, then, may be deemed minute in quantity, and their distribution at any particular epoch must be regarded in geology as temporary peculiarities, like the height and outline of the cone of Vesuvius in the interval between two eruptions. But although, in reference to the magnitude of the globe, the unevenness of the surface is so unimportant, it is on the position and direction of these small inequalities that the state of the atmosphere, and both the local and general climate, are mainly dependent.

Before considering the effect which a material change in the distribution of land and sea must occasion, it may be well to remark, how greatly organic life may be affected by those minor variations, which need not in the least degree alter the general temperature. Thus, for example, if we suppose, by a series of convulsions, a certain part of Greenland to become sea, and, in compensation, a tract of land to rise and connect Spitzbergen with Lapland, — an accession not greater in amount than one which the geologist can prove to have occurred in certain districts bordering the Mediterranean, within a comparatively modern period, — this altered form of the

* Malte-Brun's System of Geography, book i. p. 6.

land might cause an interchange between the climate of certain parts of North America and of Europe, which lie in corresponding latitudes. Many European species of plants and animals would probably perish in consequence, because the mean temperature would be greatly lowered; and others would fail in America, because it would there be raised. On the other hand, in places where the mean annual heat remained unaltered, some species which flourish in Europe, where the seasons are more uniform, would be unable to resist the greater heat of the North American summer, or the intenser cold of the winter; while others, now fitted by their habits for the great contrast of the American seasons, would not be fitted for the *insular* climate of Europe. The vine, for example, according to Humboldt, can be cultivated with advantage 10° farther north in Europe than in North America. Many plants endure severe frost, but cannot ripen their seeds without a certain intensity of summer heat and a certain quantity of light; others cannot endure a similar intensity either of heat or cold.

It is now established that many of the existing species of animals have survived great changes in the physical geography of the globe. If such species be termed modern, in comparison to races which preceded them, their remains, nevertheless, enter into submarine deposits many hundred miles in length, and which have since been raised from the deep to no inconsiderable altitude. When, therefore, it is shown that changes in the temperature of the atmosphere may be the consequence of such physical revolutions of the surface, we ought no longer to wonder that we find the distribution of existing species to be *local*, in regard to *longitude* as well as latitude. If all species were now, by an exertion of creative power, to be diffused uniformly throughout those zones where there is an equal degree of heat, and in all respects a similarity of climate, they would begin from this moment to depart more and more from their original distribution. Aquatic and terrestrial species would be displaced, as Hooke long ago observed, so often as land and water exchanged places; and there would also, by the formation of new mountains and other changes, be transpositions of climate, contributing, in the manner before alluded to, to the local extermination of species.*

If we now proceed to consider the circumstances required for a *general* change of temperature, it will appear, from the facts and principles already laid down, that whenever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there is more sea between or near the tropics; while, on the contrary, so often as the above conditions are reversed, the heat will be greater. (See Map, Pl. I.) If this be admitted, it will follow, that unless the superficial inequalities of the earth be fixed and permanent, there must be never-ending fluctuations in the mean temperature of every zone; and that the climate of one era can no more be a type of every other, than is one of our four seasons of all the rest.

It has been well said, that the earth is covered by an ocean, in the midst of which are two great islands, and many smaller ones; for the whole of the continents and islands occupy an area scarcely exceeding one fourth of the whole superficies of the spheroid.

* A full consideration of the effect of changes in physical geography on the distribution and extinction of species, is given in book iii.

Now, on a fair estimate of probability, we may reasonably assume that there will not, at any given epoch, be more than about one fourth dry land in a particular region; such, for example, as within the arctic and antarctic circles. If, therefore, at present there should happen, in the only one of these regions which we can explore, to be much *more* than this average proportion of land, and some of it above five thousand feet in height, this alone affords ground for concluding that, in the present state of things, the mean heat of the climate is below that which the earth's surface, in its more ordinary state, would enjoy. This presumption would be heightened, were we to assume that the mean depth of the Atlantic and Pacific oceans is as great as some astronomers have imagined*; for then

* See Young's Nat. Phil. Lect. xlvii.; Mrs. Somerville's Connex. of Phys. Sci., sect. 14. p. 110. Laplace, endeavouring to estimate the probable depth of the sea from some of the phenomena of the tides, says of the ocean generally, "que sa profondeur moyenne est du même ordre que la hauteur moyenne des continens et des îles au-dessus de son niveau, hauteur qui ne surpasse pas mille mètres (3280 ft.)." Mec. Céleste, Bk. xi. et Syst. du Monde, p. 254. The expression "du même ordre" admits, in mathematical language, of considerable latitude of signification, and does not mean that the depth of the water below the level of the sea corresponds exactly to the height of the land above it. I have endeavoured, in vain, after consulting several eminent mathematicians, among others, Professor Airy, Mr. Lubbock, and Mr. Whewell, to arrive at some conclusion as to the absolute depth of the ocean. My informants all agree in declaring that the hypothetical data on which the calculations of Laplace necessarily proceeded, cannot give even an approximation to a solution of the problem. Neither does Mr. Whewell believe in the alleged approach to uniformity in the depth of the ocean, which some have wished to deduce from the supposed smallness of the difference of the two tides occurring on the same day. (London, March, 1835).

we might look not only for more than two thirds sea in the frigid zones, but for water of great depth, which could not readily be reduced to the freezing point. The same opinion is confirmed, when we compare the quantity of land lying between the poles and the 30th parallels of north and south latitude, with the quantity placed between those parallels and the equator; for, it is clear, that we have at present not only more than the usual degree of cold in the polar regions, but also less than the average quantity of heat within the tropics.

Position of land and sea which might produce the extreme of cold of which the earth's surface is susceptible. — To simplify our view of the various changes in climate, which different combinations of geographical circumstances may produce, we shall first consider the conditions necessary for bringing about the extreme of cold, or what may be termed the winter of the "great year," or geological cycle, and afterwards, the conditions requisite to produce the maximum of heat, or the summer of the same year.

To begin with the northern hemisphere. Let us suppose those hills of the Italian peninsula and of Sicily, which are of comparatively modern origin, and contain many fossil shells identical with living species, to subside again into the sea, from which they have been raised, and that an extent of land of equal area and height (varying from one to three thousand feet) should rise up in the Arctic Ocean between Siberia and the north pole. In speaking of such changes, I shall not allude to the manner in which I conceive it possible that they may be brought about, nor of the time required for their accomplishment—reserving for a future occasion, not only the proofs that revolutions of equal magnitude have taken place, but that analogous operations are still in gradual progress. The alteration now supposed in the physical geography of the northern regions would cause additional snow and ice to accumulate where now there is usually an open sea; and the temperature of the greater part of Europe would be somewhat lowered, so as to resemble more nearly that of corresponding latitudes of North America: or, in other words, it might be necessary to travel about 10° farther south in order to meet with the same climate which we now enjoy. No compensation would be derived from the disappearance of land in the Mediterranean countries; but the contrary, since the mean heat of the soil in those latitudes is probably far above that which would belong to the sea, by which we imagine it to be replaced.

But let the configuration of the surface be still further varied, and let some large district within or near the tropics, such as Mexico, with its mountains rising to the height of twelve thousand feet and upwards, be converted into sea, while lands of equal elevation and extent rise up in the arctic circle. From this change there would, in the first place, result a sensible diminution of temperature near the tropic, for the soil of Mexico would no longer be heated by the sun; so that the atmosphere would be less warm, as also the neighbouring Atlantic. On the other hand, the whole of Europe, Northern Asia, and North America, would be chilled by the enormous quantity of ice and snow, thus generated at vast heights on the new arctic continent. If, as we have already seen, there are now some points in the southern hemisphere where snow is perpetual down to the level of the sea, in latitudes as low as central England, such might assuredly be the case throughout a great part of Europe, under the change of circumstances above supposed; and if at present the extreme range of drifted icebergs is the Azores, they might easily reach the equator after the assumed alteration. But to pursue the subject still farther, let the Himalaya mountains, with the whole of Hindostan, sink down, and their place be occupied by the Indian ocean, while an equal extent of territory and mountains, of the same vast height, rise up between North Greenland and the Orkney islands. It seems difficult to exaggerate the amount to which the climate of the northern hemisphere would then be cooled.

But the refrigeration brought about at the same time in the southern hemisphere, would be nearly equal, and the difference of temperature between the arctic and equatorial latitudes would not be much greater than at present; for no important disturbance can occur in the climate of a particular region, without its immediately affecting all other latitudes, however remote. The heat and cold which surround the globe are in a state of constant and universal flux and reflux. The heated and rarefied air is always rising and flowing from the equator towards the poles in the higher regions of the atmosphere; while in the lower, the colder air is flowing back to restore the equilibrium. That this circulation is constantly going on in the aërial currents is not disputed; it is often proved by the opposite course of the clouds at different heights, and the fact was farther illustrated in a striking manner by an event which happened during the present century. The trade wind continually blows with great force from the island of Barbadoes to that of St. Vincent's; notwithstanding which, during the eruption of the volcano in the island of St. Vincent, in 1812, ashes fell in profusion from a great height in the atmosphere upon Barbadoes. This apparent transportation of matter against the wind, confirmed the opinion of the existence of a counter-current in the higher regions, which had previously rested on theoretical conclusions only.*

That a corresponding interchange takes place in the seas, is demonstrated, according to Humboldt, by the cold which is found to exist at great depths between the tropics; and, among other proofs, may be mentioned the mass of warmer water which the Gulf stream is constantly bearing northwards, while a cooler current flows *from* the north along the coast of Greenland and Labrador, and helps to restore the equilibrium.†

Currents of heavier and colder water pass from the poles towards the equator, which cool the inferior parts of the ocean‡; so that the heat of the torrid zone and the cold of the polar circle balance each other. The refrigeration, therefore, of the polar regions, resulting from the supposed alteration in the distribution of land and sea, would be immediately communicated to the tropics, and from them its influence would extend to the antarctic circle, where the atmosphere and the ocean would be cooled, so that ice and snow

* Daniell's Meteorological Essays, p. 103.

† In speaking of the circulation of air and water in this chapter, no allusion is made to the trade winds, or to irregularities in the direction of currents, caused by the rotatory motion of the earth. These causes prevent the movements from being direct from north to south, or from south to north, but they do not affect the theory of a constant circulation.

‡ See note, p. 168., on the increasing density of sea-water in proportion to the degree of cold.

would augment. Although the mean temperature of higher latitudes in the southern hemisphere is, as before stated, for the most part lower than that of the same parallels in the northern, yet, for a considerable space on each side of the line, the mean annual heat of the waters is found to be the same in corresponding parallels. If, therefore, by the new position of the land, the formation of icebergs had become of common occurrence in the northern temperate zone, and if these were frequently drifted as far as the equator, the same degree of cold which they generated would immediately be communicated as far as the tropic of Capricorn, and from thence to the lands or ocean to the south.

The freedom, then, of the circulation of heat and cold from pole to pole being duly considered, it will be evident that the mean temperature which may prevail at the same point at two distinct periods, may differ far more widely than that of any two points in the same parallels of latitude, at one and the same period. For the range of temperature, or, in other words, the curvature of the isothermal lines in a given zone, and at a given period, must always be circumscribed within narrow limits, the climate of each place in that zone being controlled by the combined influence of the geographical peculiarities of all other parts of the earth. Whereas, if we compare the state of things at two distinct and somewhat distant epochs, a particular zone may at one time be under the influence of one class of disturbing causes, and at another time may be affected by an opposite combination. The lands, for example, to the north of Greenland cause the present climate of North America to be colder than that of Europe in the same latitudes; but the excess of cold is not so great as it would have been if the western hemisphere had been entirely isolated, or separated from the eastern like a distinct planet. For not only does the refrigeration produced by Greenland chill to a certain extent the atmosphere of northern and western Europe, but the mild climate of Europe reacts also upon North America, and moderates the chilling influence of the adjoining polar lands.

To return to the state of the earth after the changes above supposed, we must not omit to dwell on the important effects to which a wide expanse of perpetual snow would give rise. It is probable that nearly the whole sea, from the poles to the parallels of 45°, would be frozen over; for it is well known that the immediate proximity of land is not essential to the formation and increase of field ice, provided there be in some part of the same zone a sufficient quantity of glaciers generated on or near the land, to cool down the sea. Captain Scoresby, in his account of the arctic regions, observes, that when the sun's rays "fall upon the snow-clad surface of the ice or land, they are in a great measure reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other."*

Now field ice is almost always covered with snow†; and thus not only land as extensive as our existing continents, but immense tracts of sea in the frigid and temperate zones, might present a solid surface covered with snow, and reflecting the sun's rays for the greater part of the year. Within the tropics, moreover, where

* See Scoresby's Arctic Regions, vol. i. p. 378. † Ib. p. 320.

the ocean now predominates, the sky would no longer be serene and clear, as in the present era; but masses of floating ice would cause quick condensations of vapour, so that fogs and clouds would deprive the vertical rays of the sun of half their power. The whole planet, therefore, would receive annually a smaller proportion of the solar influence, and the external crust would part, by radiation, with some of the heat which had been accumulated in it, during a different state of the surface. This heat would be dissipated in the spaces surrounding our atmosphere, which, according to the calculations of M. Fourier, have a temperature much inferior to that of freezing water.

After the geographical revolution above assumed, the climate of equinoctial lands might be brought at last to resemble that of the present temperate zone, or perhaps be far more wintery. They who should then inhabit such small isles and coral reefs as are now seen in the Indian ocean and South Pacific, would wonder that zoophytes of large dimensions had once been so prolific in their seas; or if, perchance, they found the wood and fruit of the cocoa-nut tree or the palm silicified by the waters of some ancient mineral spring, or incrusted with calcareous matter, they would muse on the revolutions which had annihilated such genera, and replaced them by the oak, the chestnut, and the pine. With equal admiration would they compare the skeletons of their small lizards with the bones of fossil alligators and crocodiles more than twenty feet in length, which, at a former epoch, had multiplied between the tropics: and when they saw a pine included in an iceberg, drifted from latitudes which we now call temperate, they would be astonished at the proof thus afforded, that forests had once grown where nothing could be seen in their own times but wilderness of snow.

If the reader hesitate to suppose so extensive a alteration of temperature as the probable consequenc of geographical changes, confined to one hemispher he should remember how great are the local anomali in climate now resulting from the peculiar distributio of land and sea in certain regions. Thus, in the islan of South Georgia, before mentioned (p. 171.), Captai Cook found the everlasting snows descending to th level of the sea, between lat. 54° and 55° S.; no tree or shrubs were to be seen, and in summer a few rock only, after a partial melting of the ice and snow, wer scantily covered with moss and tufts of grass. If suc a climate can now exist at the level of the sea in latitude corresponding to that of Yorkshire, in spite o all those equalizing causes before enumerated, b which the mixture of the temperatures of distan regions is facilitated throughout the globe, wha rigours might we not anticipate in a winter generate by the transfer of the mountains of India to our arcti circle!

But we have still to contemplate the addition refrigeration which might be effected by changes i the relative position of land and sea in the souther hemisphere. If the remaining continents were trans ferred from the equatorial and contiguous latitudes t the south polar regions, the intensity of cold produce might, perhaps, render the globe uninhabitable. W are too ignorant of the laws governing the direction subterranean forces, to determine whether such a cris be within the limits of possibility. At the same tim it may be observed, that no distribution of land ca well be imagined more irregular, or, as it were, capr

Plate 1.

MAPS

shewing the position

OF LAND AND SEA

which might produce the extremes of

HEAT AND COLD

in the Climates *of the*

GLOBE

Observations. *These Maps are intended to shew that Continents & Islands having the same shape and relative dimensions as those now existing might be placed so as to occupy either the equatorial or polar regions*

In Fig. N.º 1 scarcely any of the land extends from the Equator towards the poles beyond the 30th. parallel of Latitude and in Fig. 2. a very small proportion of it extends from the poles towards the Equator beyond the 40th. parallel of Latitude.

cious, than that which now prevails; for at present, by drawing a line in a particular direction, the globe may be divided into two equal parts, in such a manner, that one hemisphere shall be entirely covered with water, with the exception of some promontories and islands, while the other shall contain less water than land; and, what is still more extraordinary, on comparing the extratropical lands in the northern and southern hemispheres, the lands in the northern are found to be to those in the southern in the proportion of thirteen to one!* To imagine all the lands, therefore, in high, and all the sea in low latitudes, as delineated in the annexed plate (Pl. I.), would scarcely be a more anomalous state of the surface.

Position of land and sea which might give rise to the extreme of heat.—Let us now turn from the contemplation of the winter of the "great year," and consider the opposite train of circumstances which would bring on the spring and summer. To imagine all the lands to be collected together in equatorial latitudes, and a few promontories only to project beyond the thirtieth parallel, as represented in the annexed map (fig. 1. Pl. I.), would be undoubtedly to suppose an extreme result of geological change. But if we consider a mere approximation to such a state of things, it would be sufficient to cause a general elevation of temperature. Nor can it be regarded as a visionary idea, that, amidst the revolutions of the earth's surface, the quantity of land should, at certain periods, have been simultaneously lessened in the vicinity of both the poles, and increased within the tropics. We must recollect that even now it is necessary to ascend to the

* Humboldt on Isothermal Lines.

height of fifteen thousand feet in the Andes under the line, and in the Himalaya mountains, which are without the tropic, to seventeen thousand feet, before we reach the limit of perpetual snow. On the northern slope, indeed, of the Himalaya range, where the heat radiated from a great continent moderates the cold, there are meadows and cultivated land at an elevation equal to the height of Mont Blanc.* If then there were no arctic lands to chill the atmosphere, and freeze the sea, and if the loftiest chains were near the line, it seems reasonable to imagine that the highest mountains might be clothed with a rich vegetation to their summits, and that nearly all signs of frost would disappear from the earth.

When the absorption of the solar rays was in no region impeded, even in winter, by a coat of snow, the mean heat of the earth's crust would augment to considerable depths, and springs, which we know to be in general an index of the mean temperature of the climate, would be warmer in all latitudes. The waters of lakes, therefore, and rivers, would be much hotter in winter, and would be never chilled in summer by melted snow and ice. A remarkable uniformity of climate would prevail amid the archipelagos of the temperate and polar oceans, where the tepid waters of equatorial currents would freely circulate. The general humidity of the atmosphere would far exceed that of the present period, for increased heat would promote evaporation in all parts of the globe. The winds would be first heated in their passage over the tropical plains, and would then gather moisture from the surface of the deep, till, charged with vapour,

* Humboldt, Tableaux de la Nature, tom. i. p. 112.

they arrived at extreme northern and southern regions, and there encountering a cooler atmosphere, discharged their burden in warm rain. If, during the long night of a polar winter, the snows should whiten the summit of some arctic islands, they would be dissolved as rapidly by the returning sun, as are the snows of Etna by the blasts of the sirocco.

We learn from those who have studied the geographical distribution of plants, that in very low latitudes, at present, the vegetation of small islands remote from continents has a peculiar character; the ferns and allied families, in particular, bearing a great proportion to the total number of other plants. Other circumstances being the same, the more remote the isles are from the continents, the greater does this proportion become. Thus, in the continent of India, and the tropical parts of New Holland, the proportion of ferns to the phænogamous plants is only as one to twenty-six; whereas, in the South-Sea Islands, it is as one to four, or even as one to three.*

We might expect, therefore, in the summer of the "great year," which we are now considering, that there would be a predominance of tree-ferns and plants allied to palms and arborescent grasses in the islands of the wide ocean, while the dicotyledonous plants and other forms now most common in temperate regions would almost disappear from the earth. Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sciences Nat. Nov. 1828.

the pterodactyle might flit again through umbrageous groves of tree-ferns. Coral reefs might be prolonged once more beyond the arctic circle, where the whale and the narwal now abound; and turtles might again be found in regions now inhabited by the walrus and the seal.

But, not to indulge too far in these speculations, I may observe, in conclusion, that however great, during the lapse of ages, may be the vicissitudes of temperature in every zone, it accords with this theory that the general climate should not experience any sensible change in the course of a few thousand years; because that period is insufficient to affect the leading features of the physical geography of the globe. Notwithstanding the apparent uncertainty of the seasons, it is found that the mean temperature of particular localities is very constant, when observations made for a sufficient series of years are compared.

Yet, there must be exceptions to this rule, and even the labours of man have, by the drainage of lakes and marshes, and the felling of extensive forests, caused such changes in the atmosphere as greatly to raise our conception of the more important influence of those forces to which, in certain latitudes, even the existence of land or water, hill or valley, lake or sea, must be ascribed. If we possessed accurate information of the amount of *local* fluctuation in climate in the course of twenty centuries, it would often, undoubtedly, be considerable. Certain tracts, for example, on the coast of Holland and of England consisted of cultivated land in the time of the Romans, which the sea, by gradual encroachments, has at length occupied. Here, at least, a slight alteration has been effected; for neither the distribution of heat in the different seasons, nor the mean annual temperature of the atmosphere investing the sea, is precisely the same as that which rests upon the land.

In those countries, also, where earthquakes and volcanos are in full activity, a much shorter period may produce a sensible variation. The climate of the once fertile plain of Malpais in Mexico must differ materially from that which prevailed before the middle of the last century; for, since that time, six mountains, the highest of them rising sixteen hundred feet above the plateau, have been thrown up by volcanic eruptions. It is by the repetition of an indefinite number of such local revolutions, and by slow movements extending simultaneously over wider areas, as will be afterwards shewn, that a general change of climate may finally be brought about.

CHAPTER VIII.

FARTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Whether the geographical features of the northern hemisphere, at the period of the deposition of the oldest fossiliferous strata, were such as might have given rise to an extremely hot climate — State of the surface when the greywacké, or transition formations, originated — State of the same when the mountain limestone, coal-sandstones, and coal were deposited (p. 199.) — Changes in physical geography, between the carboniferous period and the chalk — Abrupt transition from the secondary to the tertiary fossils (p. 202.) — Accession of land, and elevation of mountain chains, after the consolidation of the secondary rocks — Explanation of Map, shewing the area covered by sea, since the commencement of the tertiary period (p.209.) — Remarks on the theory of the diminution of central heat (p. 216.) — Astronomical causes of fluctuations in climate (p. 219.).

Whether the geographical features of the northern hemisphere, at the period of the deposition of the oldest fossiliferous strata, were such as might have given rise to an extremely hot climate.—In the sixth chapter, I stated the arguments derived from organic remains for concluding that the mean annual temperature of the northern hemisphere was considerably more elevated when the ancient carboniferous strata were deposited than it is at present; as also that the climate had been modified more than once since that epoch, and that it had been reduced by successive changes more and more nearly to that now prevailing in the same latitudes. Farther, I endeavoured, in the last chapter, to prove that vicissitudes in climate of no less importance may be expected to recur in future, if it be admitted that causes now active in nature have power, in the lapse of ages, to produce considerable variations in the relative position of land and sea. It remains to inquire whether the alterations, which the geologist can prove to have *actually taken place* at former periods, in the geographical features of the northern hemisphere, coincide in their nature, and in the time of their occurrence, with such revolutions in climate as would naturally have resulted, according to the meteorological principles already explained.

The oldest system of rocks which afford by their organic remains any decisive evidence as to climate, or the former position of land and sea, are those generally known as the *transition*, or *greywacké*, formations. These have been found in England, France, Germany, Sweden, Russia, and other parts of central and northern Europe, as also in the great Lake district of Canada and the United States; and they appear to have been deposited in a sea of considerable extent. The fossils have been regarded by many naturalists as indicating a greater uniformity in the species of marine animals inhabiting the sea at that early period than would now be found to prevail in a similar extent of ocean. The number and magnitude of the multilocular or chambered univalves, and of the corals, obtained from the limestones of this group, recall the forms now most largely developed in tropical seas. Hitherto few vegetable remains have been noticed, but such as are mentioned are said to agree more nearly with the plants of the carboniferous era than any other, and would therefore imply a tropical and humid atmosphere.*

Carboniferous group.—This group comes next in the order of succession, and one of its principal members, the mountain limestone, was evidently a marine formation, as is shewn by the shells and corals which it contains. That the ocean of that period was of considerable extent in our latitudes, we may infer from the continuity of these calcareous strata over large areas. The same group appears also to have been traced not only through different parts of Europe, but also in North America, towards the borders of the arctic sea.†

The coal itself is admitted to be of vegetable origin,

* Mr. Murchison, during his investigations of the English and Welsh transition rocks, has not met with any vegetable remains of land plants; but MM. Elie de Beaumont, Virlet, and De la Beche have pointed out places where they occur in members of that series. Mr. Weaver also formerly supposed that the coal and coal-plants of Munster, in Ireland, belonged to the transition rocks; but he has lately retracted this opinion, and believes that the coal and plants alluded to occur in the carboniferous series.

† It appears from the observations of Dr. Richardson, made during the expedition under the command of Captain Franklin to the north-west coast of America, and from the specimens presented by him to the Geological Society of London, that, between the parallels of 60° and 70° north latitude, there is a great calcareous formation, stretching towards the mouth of the Mackenzie river, in which are included corallines, productæ, terebratulæ, &c. having a close affinity in generic character to those of our mountain limestone, of which the group has been considered the equivalent. There is also in the same region a newer series of strata, in which are shales with impressions of ferns, lepidodendrons, and other vegetables, and also ammonites. — *Proceedings of Geol. Soc.* No. 7, p. 68 *March* 1828.

and the state of the plants, and the beautiful preservation of their leaves in the accompanying shales, precludes the idea of their having been floated from great distances. As the species were evidently terrestrial, we must suppose that some dry land was not far distant; and this opinion is confirmed by the shells found in some strata of the Newcastle and Shropshire coal-fields.* These shells, which are chiefly found in the upper coal-measures, are referrible to freshwater genera, and lived, perhaps, in lakes or small estuaries. There are some regions in the northern parts of England and Scotland where the marine mountain limestone alternates with strata containing coal. Such an arrangement of the beds may possibly have been produced by the alternate rising and sinking of large tracts, which were first laid dry, and then submerged again. The land of that period appears to have consisted in part of granitic rocks, the waste of which may have produced the coarse sandstones, such, for example, as the millstone-grit. Volcanic rocks, however, were not wanting, as in Scotland, for example, in the present basins of the Forth and Tay, where they seem to have been poured out on the bottom of the sea during the accumulation of the carboniferous strata.

The arrangement of the sandstones and shales in this group has been thought by some geologists, as by MM. Sternberg, Boué, and Adolphe Brongniart, to favour the hypothesis of the strata having resulted from the waste of small islands placed in rows, and forming the highest points of submarine mountain chains. The disintegration of such clusters of islands

* See Mr. W. Hutton, Foss. Flora of Great Brit. Preface, and Mr. Murchison's papers on Shropshire, &c.

might produce around and between them detached deposits, which, when subsequently raised above the waters, might resemble the strata formed in a chain of lakes; for the boundary heights of such apparent lake-basins would be formed of the rocks once constituting the islands, and they might still continue, after their elevation, to preserve their relative superiority of height, and to surround the newer strata on several sides.*

This idea is also confirmed by the opinion of many botanists who have studied with care the vegetation of the carboniferous period, and who declare that it possesses the character of an insular flora, such as might be looked for in islands scattered through a wide ocean in a tropical and humid climate.

There is, as yet, no well-authenticated instance of the remains of a saurian animal having been found in a member of the carboniferous series.† Now the larger oviparous reptiles usually inhabit rivers of considerable size in warm latitudes; and had crocodiles and other animals of that class been abundant in a fossil state, as in some of the newer secondary formations, we must have inferred the existence of rivers, which could only have drained large tracts of land. Nor have the bones of any terrestrial mammalia rewarded our investigations. Their absence may be regarded by some geologists as corroborating the theory of the non-existence of the higher orders of animals in the earlier ages: but the circumstance may, perhaps, be connected with the

* See some ingenious speculations to this effect, in the work of M. Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c., Ann. des Sci. Nat., Nov. 1828.

† The supposed saurian teeth found by Dr. Hibbert in the carboniferous limestone of Burdie House, near Edinburgh, have since been clearly referred by Dr. Agassiz to sauroidal fish.

geographical condition of the northern hemisphere at that time; for it is a general character of small islands remote from continents, to be altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by man. Kerguelen's land, which is of no inconsiderable size, placed in lat. 49° 20′ S., a parallel corresponding to that of the Scilly islands, may be cited as an example, as may all the groups of fertile islands in the Pacific Ocean between the tropics, where no quadrupeds have been found, except the dog, the hog, and the rat, which have probably been brought to them by the natives, and also bats, which may have made their way along the chain of islands extending from the shores of New Guinea far into the southern Pacific.* Even the islands of New Zealand, which may be compared to Ireland and Scotland in dimensions, appear to possess no indigenous quadrupeds, except the bat; and this becomes the more striking, when we recollect that the northern extremity of New Zealand stretches to latitude 34°, where the warmth of the climate must greatly favour the prolific development of organic life.

So far then the examination of the phenomena exhibited by the greywacké and carboniferous groups accord well with the prevalence of such a state of physical geography in the northern hemisphere as would have given rise to a hot and uniform climate. The subaqueous aspect of the igneous products, — the continuity of marine deposits over vast spaces — the basin-shaped disposition of the fragmentary rocks — the insular character of the flora — the absence of large fluviatile reptiles and of land quadrupeds, — all concur

* Prichard's Phys. Hist. of Man., vol. i. p. 75.

to establish the fact of the northern hemisphere having been pervaded by a great ocean, interspersed, like the south Pacific, with small islets or lands of moderate dimensions, and with insular or submarine volcanos.

Changes in physical geography between the formation of the carboniferous strata and the chalk.— We have evidence in England that the strata of the ancient carboniferous group, already adverted to, were, in many instances, fractured and contorted, and often thrown into a vertical position before the deposition of some of the newer secondary rocks, such as the new red sandstone.

Fragments of the older formations are sometimes included in the conglomerates of the more modern; and some of these fragments still retain their fossil shells and corals, so as to enable us to determine the parent rocks from whence they were derived.* There are other proofs of the disturbance at successive epochs of different secondary rocks before the deposition of others; and satisfactory evidence that, during these reiterated convulsions, the geographical features of the northern hemisphere were frequently modified, and that from time to time new lands emerged from the deep. The vegetation during some parts of the period

* Thus, for example, on the banks of the Avon, in the Bristol coal-field, the dolomitic conglomerate, a rock of an age intermediate between the carboniferous series and the lias, rests on the truncated edges of the coal and mountain limestone, and contains rolled and angular fragments of that limestone, in which its characteristic mountain-limestone fossils are seen. For accurate sections illustrating the disturbances which rocks of the carboniferous series underwent before the newer red sandstone was formed, the reader should consult the admirable memoir of the south-western coal district of England, by Dr. Buckland and Mr. Conybeare, Geol. Trans. vol. i. second series.

in question (from the lias to the chalk inclusive), appears to have approached to that of the larger islands of the equatorial zone; such, for example, as we now find in the West Indian archipelago.* These islands appear to have been drained by rivers of considerable size, which were inhabited by crocodiles and gigantic oviparous reptiles, both herbivorous and carnivorous, belonging for the most part to extinct genera. Of the contemporary inhabitants of the land we have as yet acquired but scanty information, but we know that there were flying reptiles, insects, and small mammifera, allied to the opossum.

When describing the Wealden, one of the upper members of the great secondary series, and evidently of freshwater origin, I shall point out the reasons which incline me to believe that, when those strata originated, a large continent advanced very near to the space now occupied by the south-eastern extremity of England. A river, equal, perhaps, in size to the Ganges or the Indus, seems to have continued to pour its turbid waters for ages into the sea in those latitudes at the period referred to. †

It might at first appear, that the position of a continent so far to the north, as the counties of Surrey and Sussex, at a time when the mean temperature of the climate is supposed to have been much hotter than at present, is inconsistent with the theory before explained, that the heat was caused by the gathering together of all the great masses of land in low latitudes, while the polar regions were almost entirely sea. But provided that none of the land was arctic or

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sci. Nat., Nov. 1828

† See Book iv. chap. xxiii.

antarctic, and a large part of the continents intra-tropical, considerable elevation of temperature may be presumed to result, even when large continental tracts were prolonged from the equatorial to the temperate zone.

Changes during the tertiary periods. — It will be seen hereafter* that the Maestricht beds are classed as the newest of the secondary series; and the fossils of that group, including the remains of gigantic reptiles, indicate the prevalence of a very hot climate. Between this uppermost member of the secondary series, and the oldest of the newer class of formations called tertiary, there is a remarkable discordance as to *species* of organic remains, none having yet been found common to both. This abrupt transition from one set of fossils to another, is also accompanied by evident signs of a change of climate; the older tertiary species having a far less tropical aspect than those found fossil in the newest secondary group.

Nor are there wanting signs of a decided coincidence between this alteration of climate, and geographical changes which occurred between the formation of the cretaceous series and that of the older tertiary group.† On comparing the tertiary formations of different ages, we may trace a gradual approximation in the imbedded fossils from an assemblage in which extinct species predominate, to one where the species agree for the most part with those now existing. In other words, we find a gradual increase of animals and plants fitted for our present climates, in proportion as the strata which we examine are more modern. Now,

* See Book iv. chap. xxiii.

† See chaps. xxi. and xxii. B. iv. on the period of the elevation of the chalk of the S. E. of England.

during all these successive tertiary periods, there are signs of a great increase of land in European latitudes. By reference to the map (Pl. II.), and its description, p. 209., the reader will see how great have been the physical revolutions which have occurred since the commencement of the tertiary period.

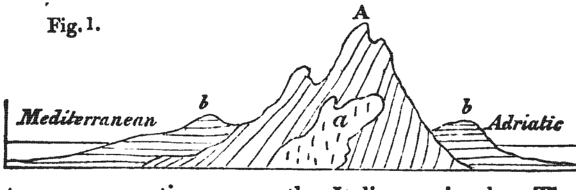
In the present state of Europe, the chalk and associated strata, are of considerable extent, and sometimes rise to the summits of lofty mountains. As all the members of this group contain almost exclusively marine remains, it follows that every tract which they now occupy has, since their origin, been converted from sea into land, and, in some cases, from deep sea to mountains of great altitude. We cannot doubt that part of the changes alluded to happened before the older tertiary strata originated; because these last consist, in a great degree, of the ruins of the newer secondary rocks; which must therefore have been raised and exposed to aqueous erosion before the derivative beds were formed. It will moreover be seen, in the fourth book, (chap. iii.,) that the secondary and tertiary formations, considered generally, may be contrasted as having very different characters; the one appearing to have been deposited in open seas, the other in regions where dry land, lakes, bays, and perhaps inland seas, abounded. The secondary series is almost exclusively marine; the tertiary, even the oldest part, contains lacustrine strata, and not unfrequently freshwater and marine beds alternating.

Now, the facts depicted in the map (Pl. II. p. 209.), demonstrate that about two thirds of the present European lands have emerged since the earliest of these tertiary groups originated. Nor is this the only change which the same region has undergone within this comparatively modern period; some tracts, which were previously land, having gained in altitude, or, on the contrary, having sunk below their former level, within the period alluded to.

The evidence that this rise of land did not take place all at the same time, is most striking. Several Italian geologists, even before the time of Brocchi, had justly inferred that the Apennines were elevated several thousand feet above the level of the Mediterranean, before the deposition of the recent Subapennine beds which flank them on either side. What now constitutes the central calcareous chain of the Apennines must for a long time have been a narrow ridgy peninsula, branching off, at its northern extremity, from the Alps near Savona. This peninsula has since been raised from one to two thousand feet, by which movement the ancient shores, and, for a certain extent, the bed of the contiguous sea, have been laid dry, both on the side of the Mediterranean and the Adriatic.

The nature of these vicissitudes will be explained by the accompanying diagram, which represents a

Fig. 1.



transverse section across the Italian peninsula. The inclined strata A are the disturbed formations of the Apennines into which the ancient igneous rocks *a* are supposed to have intruded themselves. At a lower level on each flank of the chain are the more recent shelly beds *b b*, which often contain rounded pebbles derived from the waste of contiguous parts of the older Apennine limestone. These, it will be seen, are horizontal, and lie in what is termed "unconformable stratification" on the more ancient series. They now constitute a line of hills of moderate elevation between the sea and the Apennines, but never penetrate to the higher and more ancient valleys of that chain.

The same phenomena are exhibited in the Alps on a much grander scale; those mountains being composed in some even of their higher regions of newer secondary formations, while they are encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria, and at their eastern termination towards Styria and Hungary.* This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand feet deep, and wherein masses of strata accumulated, some single groups of which seem scarcely inferior in thickness to the whole of our secondary formations in England. These marine tertiary strata have been raised to the height of from two to four thousand feet, and consist of formations of different ages, characterized by different assemblages of organized fossils. The older tertiary groups generally rise to the greatest heights, and form interior zones nearest to the central

* See a Memoir on the Alps, by Professor Sedgwick and Mr. Murchison. Trans. of Geol. Soc. second ser. vol. iii. accompanied by a map.

ridges of the Alps. Although we have not yet ascertained the number of different periods at which the Alps gained accessions to their height and width, yet we can affirm, that the last series of movements occurred when the seas were inhabited by many existing species of animals.

We may imagine some future series of convulsions once more to heave up this stupendous chain, together with the adjoining bed of the sea, so that the mountains of Europe may rival the Andes in elevation; in which case the deltas of the Po, Adige, and Brenta, now encroaching upon the Adriatic, might be uplifted so as to form another exterior belt of considerable height around the south-eastern flank of the Alps.

The Pyrenees, also, have acquired the whole of their present altitude, which in Mont Perdu exceeds eleven thousand feet, since the origin of some of the newer members of our secondary series. The granitic axis of that chain only attains about the same height as a ridge formed by marine calcareous beds, the organic remains of which shew them to be the equivalents of our chalk and green-sand series.* The tertiary strata at the base of the chain are raised to the height of only a few hundred feet above the sea, and retain a horizontal position, without partaking in general in the disturbances to which the older series has been subjected; so that the great barrier between France and Spain was almost entirely upheaved in the interval between the deposition of the chalk and certain tertiary strata. The Jura, also, owes a great part of its present elevation to subterranean convulsions which

* This observation, first made by M. Boué, has been since confirmed by M. Dufrénoy.

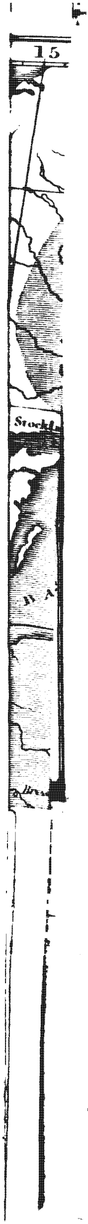
happened after the deposition of certain tertiary groups.*

The remarkable break above alluded to, between the most modern of the known secondary rocks and the oldest tertiary, may be in some measure apparent only, and ascribable to the present deficiency of our information†; in which case the signs of the intermediate steps, by which a passage was effected from one state of things to another, may hereafter be discovered. Nevertheless, it is far from impossible that the interval between the chalk and tertiary formations constituted an era in the earth's history, when the transition from one class of organic beings to another was, comparatively speaking, rapid. For if the doctrines above explained in regard to vicissitudes of temperature are sound, it will follow that changes of equal magnitude in the geographical features of the globe, may at different periods produce very unequal effects on climate; and, so far as the existence of certain animals and plants depends on climate, the duration of species would be shortened or protracted, according to the rate at which the change of temperature proceeded.

Even if we assume that the intensity of the subterranean disturbing forces is uniform and capable of producing nearly equal amounts of alteration on the surface of the planet, during equal periods of time, still the rate of alteration in climate would be by no means uniform. Let us imagine the quantity of land between the equator and the tropic in one hemisphere to be to that in the other as thirteen to one, which, as

* M. Elie de Beaumont. Ann. des Sci. Nat., Dec. 1829, p. 346.
† See Book iv. chap. 23.

before stated, represents the unequal proportion of the extra-tropical lands in the two hemispheres at present. Then let the first geographical change consist in the shifting of this preponderance of land from one side of the line to the other, from the southern hemisphere, for example, to the northern. Now this need not affect the *general* temperature of the earth. But if, at another epoch, we suppose a continuance of the same agency to transfer an equal volume of land from the torrid zone to the temperate and arctic regions of the northern and southern hemisphere, or into one of them, there might be so great a refrigeration of the mean temperature *in all latitudes*, that scarcely any of the pre-existing races of animals would survive, and, unless it pleased the Author of Nature that the planet should be uninhabited, new species would then be substituted in the room of the extinct. We ought not, therefore, to infer, that equal periods of time are always attended by an equal amount of change in organic life, since a great fluctuation in the mean temperature of the earth, the most influential cause which can be conceived in exterminating whole races of animals and plants, must, in different epochs, require unequal portions of time for its completion.


15

showing the extent of surface in Europe which has been covered water since the commencement of the deposition of the older Eocene Tertiary strata. (Strata of the Paris and London asins, &c.) *

is map will enable the reader to perceive at a ce the great extent of change in the physical graphy of Europe, which can be proved to have en place since some of the older tertiary strata an to be deposited. The proofs of submergence, ing some part or other of this period, in all the dis-cts distinguished by ruled lines, are of a most un-uivocal character; for the area thus described is w covered by deposits containing the fossil remains animals which could only have lived under water. he most ancient part of the period referred to can-ot be deemed very remote, considered geologically; ecause the deposits of the Paris and London basins, f Auvergne, and many other districts belonging to e older tertiary epoch, are newer than the greater rt of the sedimentary rocks, commonly called se-ndary and transition, of which the crust of the globe composed. The species, moreover, of marine and esh water testacea, of which the remains are found these older tertiary formations, are not entirely dis-nct from such as now live; a proportion of more than hree in a hundred of the fossils having been identified with species now living.† Yet, notwithstanding the

* Constructed chiefly from M. Ami Boué's Geological Map of Europe.

† See Book iv. ch. 5.

comparatively recent epoch to which the retrospect is carried, the variations in the distribution of land and sea depicted on the map form only a part of those which must have taken place during the period under consideration. Some approximation has merely been made to an estimate of the amount of *sea converted into land* in part of Europe best known to geologists; but we cannot determine how much land has become sea during the same period; and there may have been repeated interchanges of land and water in the same places, changes of which no account is taken in the map, and respecting the amount of which little accurate information can ever be obtained.

I have extended the sea in two or three instances beyond the limits of the land now covered by tertiary formations, because other geological data have been obtained for inferring the submergence of these tracts after the deposition of the tertiary strata had begun. Thus I shall explain, in the 4th Book*, my reasons for concluding that part of the chalk of England (the north and south downs, for example, together with the intervening secondary tracts) continued beneath the sea until the Eocene or earliest tertiary beds had begun to accumulate.

It is possible also that a considerable part of Caernarvonshire might with propriety have been represented as sea, if our information respecting the geology of that county had been more complete; for marine shells have been found in sand and gravel at the height of one thousand feet above the level of the sea, on the summit of Moel Tryfane, between Snowdon and the Menai Straits. The species, so far as

* Ch. xxi. and xxii.

they can be recognized by the fragments hitherto collected, are recent, and the formation appears to be newer than the crag.*

The introduction of a small bay where the river Ribble enters into the sea in Lancashire is warranted by a newly discovered deposit of tertiary shells covering an area of about thirty miles square in that region.†

A portion also of the primary district in Brittany is divided into islands, because it has been long known to be covered with patches of marine tertiary strata; and when I examined the disposition of these, in company with my friend, Captain S. E. Cook, R. N., in 1830, I was convinced that the sea must have covered much larger areas than are now occupied by these small and detached deposits.

The former connexion of the White Sea and the Gulf of Finland is proved by the fact that a broad band of tertiary strata extends throughout part of the intervening space. The channel, it is true, is represented as somewhat broader than the tract now occupied by the tertiary formation; because the latter is bordered on the north-west by a part of Finland, which is extremely low, and so thickly interspersed with lakes as to be nearly half covered with fresh water.

Certain portions of the western shores of Norway and Sweden have been left blank, because the discovery by Von Buch, Brongniart, and others, of deposits of recent shells along the coasts of those countries,

* J. Trimmer, Esq. Proceedings Geol. Soc. London, No. 22. 1831.

† See memoir by Mr. Murchison, Proceedings of York Meeting, 1831.

at several places and at various heights above the level of the sea, attest the comparatively recent date of the elevation of part of the gneiss and other primary rocks in that country, although we are unable as yet to determine how far the sea may have extended.

On the other hand, a considerable space of low land along the shores on both sides of the Gulf of Bothnia, in the Baltic, is represented as sea, because the gradual rise of the land and the shoaling of the water on that coast, known to have taken place during the historical era, leave no room for doubt that the boundaries of the gulf must have been greatly contracted within a comparatively modern period. Beds of sand and clay are also found far inland in these parts, containing fossil shells of species now inhabiting the neighbouring seas. A portion of Scania, and other tracts in the south of Sweden, have also been marked with ruled lines, because they are covered with clay, sand, and erratic blocks, which appeared to me, after examining the district, to be tertiary. If the space overspread by such formations were more accurately known, the area represented as land in this part of Europe, would, doubtless, be much more circumscribed.

I was anxious, even in the title of this map, to guard the reader against the supposition that it was intended to represent the state of the physical geography of part of Europe at any *one point of time.* The difficulty, or rather the impossibility, of restoring the geography of the globe as it may have existed at any former period, especially a remote one, consists in this, that we can only point out where part of the sea has been turned into land, and are almost always unable to determine what land may have become sea. All maps, therefore, pretending to represent the geography of remote geological epochs must be ideal. The map under consideration is not a restoration of a former state of things, at any particular moment of time, but a synoptical view of a certain amount of one kind of change (the conversion of sea into land) known to have been brought about within a given period.

It may be stated that the movements of earthquakes occasion the subsidence as well as the upraising of the surface; and that, by the alternate rising and sinking of particular spaces, at successive periods, a great area may have been entirely covered with marine deposits, although the whole may never have been beneath the waters at one time; nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period. I believe, however, that since the commencement of the tertiary period, the dry land in the northern hemisphere has been continually on the increase, both because it is now greatly in excess beyond the average proportion which land generally bears to water on the globe, and because a comparison of the secondary and tertiary strata affords indications, as I shall endeavour to shew hereafter, of a passage from the condition of an ocean interspersed with islands to that of a large continent.*

But supposing it were possible to represent all the vicissitudes in the distribution of land and sea that have occurred during the tertiary period, and to exhibit not only the actual existence of land where there was once sea, but also the extent of surface now submerged which may once have been land, the map would still fail to express all the important revolutions in physical geography which have taken place within

* See Book iv. chap. iii.

the epoch under consideration. For the oscillations of level, as was before stated, have not merely been such as to lift up the land from below the waters, but in some cases to occasion a rise of several thousand feet above the sea. Thus the Alps have acquired an additional altitude of from 2000 to 4000 feet, and even in some places still more; and the Apennines owe a considerable part of their height (from 1000 to 2000 feet and upwards) to subterranean convulsions which have happened within the tertiary epoch.

On the other hand, some mountain chains may have been lowered during the same series of ages, in an equal degree, and shoals may have been converted into deep abysses.*

Concluding remarks on changes in physical geography.—These observations, it may be said, are confined to Europe, and therefore to a space which constitutes but a small portion of the northern hemisphere; but it appeared from the remarks offered in the preceding chapter, that the great Lowland of Siberia, lying chiefly between the latitudes 55° and 75° N. (an area nearly equal to all Europe) is covered for the most part by marine strata, which, from the account given by Pallas, and other writers, may be considered as of tertiary formation.

Upon a review of all the phenomena above enumerated, there appear grounds for inferring that the eras of the principal alterations in climate, as deduced from fossil remains, were coincident with the periods of the most remarkable changes in the former position

* It may be observed, that the facts and inferences exhibited in this map bear not merely on the theory of climate above proposed, but serve also to illustrate the views explained in the third book respecting the migrations of animals and plants, and the gradual extinction of species.

of sea and land. A wide expanse of ocean interspersed with islands, seems to have pervaded the northern hemisphere at the periods when the transition and carboniferous rocks were formed, and the temperature was then hottest and most uniform. Subsequent modifications in climate accompanied the deposition of the secondary formations, when repeated changes were effected in the physical geography of our northern latitudes. Lastly, the refrigeration became most decided, and the climate most nearly assimilated to that now enjoyed, when the lands in Europe and northern Asia had attained their full extension, and the mountain chains their actual height.

It has been objected to this theory of climate, that there are no geological proofs of the prevalence at any former period of a temperature *lower* than that now enjoyed; whereas, if the causes above assigned were the true ones, it might reasonably have been expected that fossil remains would sometimes indicate colder as well as hotter climates than those now established.* In answer to this objection, I may suggest, that our present climates are probably far more distant from the extreme of possible heat than from its opposite extreme of cold. A glance at the map (Pl. I. fig. 1.) will shew that all the existing lands might be placed in the zone intervening between the 30th parallels of latitude on each side of the equator, and that even then they would by no means fill that space. In no other position would they give rise to so high a temperature. But in the present geographical condition

* Allgemeine Literatur Zeitung, No. cxxxix. July, 1833. Since the last edition was published, I have learnt, that I was misinformed in imputing this criticism to Count Sternberg.

of the earth, the land excluded from this zone, and lying between the poles and the parallels of 30°, is in great excess; so much so that, instead of being to the sea in the proportion of 1 to 3, which is as near as possible the average general ratio throughout the globe, it is as 9 to 23.* Hence it ought not to surprise us if, in our geological retrospect, embracing, perhaps, a small part only of a complete cycle of change in the terrestrial climates we should happen, to discover every where the signs of a higher temperature. The strata hitherto examined may have originated when the quantity of equatorial land was always decreasing, and the land in regions nearer the poles augmenting in height and area, until at length it attained its present excess in high latitudes. There is nothing improbable in supposing that the geographical revolutions immediately preceding our times had this tendency; and in that case the refrigeration must have been constant, although, for reasons before explained, the rate of cooling may not have been uniform.

Theory of Central Heat. — The gradual diminution of the supposed central heat of the globe has been resorted to by many geologists as the principal cause

* In this estimate, the space within the antarctic circle, of which nothing certain is known, is not taken into account: if included, it would probably add to the excess of dry land; for the great accumulation of ice in the antarctic region seems to imply the presence of a certain quantity of terra firma. The number of square miles on the surface of the globe, are 148,522,000, the part occupied by the sea being 110,849,000, and that by land, 37,673,000; so that the land is very nearly to the sea as 1 part in 4. I am informed by Mr. Gardner, that, according to a rough approximation, the land between the 30° N. lat. and the pole occupies a space *about equal to that of the sea*, and the land between the 30° S. lat. and the antarctic circle about $\frac{1}{16}$ of that zone.

of alterations of climate. The matter of our planet is imagined, according to the conjecture of Leibnitz, to have been originally in an intensely heated state, and to have been parting ever since with portions of its heat, at the same time that it has contracted its dimensions. There are, undoubtedly, some grounds for inferring, from recent observation and experiment, that the temperature of the earth increases as we descend from the surface to that slight depth to which man can penetrate; but there are no proofs of a secular decrease of heat accompanied by contraction. On the contrary, La Place has shown, by reference to astronomical observations made in the time of Hipparchus, that in the last two thousand years there has been no sensible contraction of the globe by cooling; for had this been the case, even to an extremely small amount, the day would have been shortened, whereas its length has certainly not diminished during that period by $\frac{1}{300}$th of a second. Baron Fourier, after making a curious series of experiments on the cooling of incandescent bodies, has endeavoured, by profound mathematical calculations, to prove that the actual distribution of heat in the earth's envelope is precisely that which would have taken place if the globe had been formed in a medium of a very high temperature, and had afterwards been constantly cooled.*

Now this conclusion is appealed to by many as corroborating the theory of secular refrigeration, although the phenomenon might perhaps be ascribed, with equal propriety, to the action of volcanic heat, which we

* See a Memoir on the Temperature of the Terrestrial Globe, and the Planetary Spaces, Ann. de Chimie et Phys. tom. xxvii. p. 136. Oct. 1824.

know has, in former ages, shifted its points of chief development over every part of the earth's crust.

M. Cordier announces, as the result of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth; but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences are not in constant relation either with the latitudes or longitudes of places.* All this is precisely what we should have expected to arise from variations in the intensity of volcanic heat, and from that change of position, which the principal theatres of volcanic action can be proved to have undergone.

But the advocates of the doctrine of central heat contend, that although no contraction can be demonstrated to have taken place within the historical period (the operation being slow and the time of observation limited), yet it is no less certain that heat is annually passing out by radiation from the interior of the globe into the planetary spaces. Fourier even undertook to demonstrate that the quantity of heat thus transmitted into space in the course of every century, through every square metre of the earth's surface, would suffice to melt a column of ice having a square metre for its base, and being three metres (or 9 feet 10 inches) high. On the other hand, it is said, there is no assignable mode in which this heat can be again restored to the earth.

Streams of incandescent lava rise up from unknown depths, flow out upon the surface, and before they

* See M. Cordier's Memoir on the Temperature of the Interior of the Earth, read to the Academy of Sciences, 4th June, 1827. — Edin. New Phil. Journal, No. viii. p. 273.

consolidate emit much light and heat. In what manner does the igneous and luminous matter thus withdrawn from our planet return again from the celestial spaces? or, if lost, does it not imply a continual cooling of the central parts of the earth?

This argument may appear plausible, until we reflect how ignorant we are of the sources of volcanic heat, or indeed of the nature of light and heat in general. It is doubtless true, that light and heat are continually emanating from the earth; but, in the same manner, it may be said that they escape without intermission from the sun, and we know not whether there be any compensating causes which again restore them to that luminary.—"It is a mystery," says Herschel, speaking of the sun, "to conceive how so enormous a conflagration (if such it be) can be kept up. Every discovery in chemical science here leaves us completely at a loss, or rather seems to remove farther the prospect of probable explanation. May not," he adds, "a continual current of electric matter be constantly circulating in the sun's immediate neighbourhood, or traversing the planetary spaces?" &c. &c.*

Astronomical causes of fluctuations in climate. — Sir John Herschel has lately inquired, whether there are any astronomical causes which may offer a possible explanation of the difference between the actual climates of the earth's surface, and those which formerly appear to have prevailed. He has entered upon this subject, he says, "impressed with the magnificence of that view of geological revolutions, which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes, regulated by no laws,

* Treatise on Astronomy, § 337.

and reducible to no fixed principles." Geometers, he adds, have demonstrated the absolute invariability of the mean distance of the earth from the sun; whence it would at first seem to follow, that the mean annual supply of light and heat derived from that luminary would be alike invariable: but a closer consideration of the subject will show, that this would not be a legitimate conclusion; but that, on the contrary, the *mean* amount of solar radiation is dependent on the excentricity of the earth's orbit, and therefore liable to variation.*

Now, the excentricity of the orbit, he continues, is actually diminishing, and has been so for ages beyond the records of history. In consequence, the ellipse is in a state of approach to a circle, and the annual average of solar heat radiated to the earth is actually on the *decrease*. So far this is in accordance with geological evidence, which indicates a general refrigeration of climate; but the question remains, whether the amount of diminution which the excentricity may have ever undergone, can be supposed sufficient to account for any sensible refrigeration. The calculations necessary to determine this point, though practicable, have never yet been made, and would be extremely laborious; for they must embrace all the perturbations which the most influential planets, Venus, Mars, Jupiter, and

* The theorem is thus stated: — "The excentricity of the orbit varying, the total quantity of heat received by the earth from the sun in one revolution is inversely proportional to the minor axis of the orbit. The major axis is invariable, and therefore, of course, the absolute length of the year: hence it follows that the mean annual average of heat will also be in the same inverse ratio of the minor axis." — Geol. Trans. second series, vol. iii. p. 295.

Saturn, would cause in the earth's orbit, and in each other's movements round the sun.

The problem is also very complicated, inasmuch as it depends not merely on the ellipticity of the earth's orbit, but on the assumed temperature of the celestial spaces beyond the earth's atmosphere; a matter still open to discussion, and on which MM. Fourier and Herschel have arrived at very different opinions. But if, says Herschel, we suppose an extreme case, as if the earth's orbit should ever become as excentric as that of the planet Juno, or Pallas, a great change of climate might be conceived to result, the winter and summer temperatures being sometimes mitigated, and at others exaggerated, in the same latitudes.

It is much to be desired that the calculations alluded to were executed, as even, if they should demonstrate, as M. Arago thinks highly probable*, that the mean amount of solar radiation can never be materially affected by irregularities in the earth's motion, it would still be satisfactory to ascertain the point. Such inquiries, however, can never supersede the necessity of investigating the consequences of the varying position of continents, shifted as we know them to have been during successive epochs, from one part of the globe to the other.

* Ann. du Bur. des Long. 1834.

CHAPTER IX.

FARTHER DISCUSSION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Theory of the progressive development of organic life — Evidence in its support inconclusive — Vertebrated animals, and plants of the most perfect organization in strata of very high antiquity (p. 227.) — Differences between the organic remains of successive formations — Remarks on the comparatively modern origin of the human race (p. 239.) — The popular doctrine of successive development not confirmed by the admission that man is of modern origin — Introduction of man, to what extent a change in the system (p. 243.)

Progressive development of organic life. — In the preceding chapters I have considered many of the most popular grounds of opposition to the doctrine, that all former changes of the organic and inorganic creation are referrible to one uninterrupted succession of physical events, governed by the laws of Nature now in operation.

As the principles of our science must always remain unsettled so long as no fixed opinions are entertained on this fundamental question, I shall proceed to examine other objections which have been urged against the assumption of the identity of the ancient and modern causes of change. A late distinguished writer has formally advanced some of the most popular of these objections. "It is impossible," he affirms, "to defend the proposition, that the present order of things is the ancient and constant order of nature, only modified by existing laws: in those strata which are deepest, and which must, consequently, be supposed to be the earliest deposited, forms even of vegetable life are rare; shells and vegetable remains are found in the next order; the bones of fishes and oviparous reptiles exist in the following class; the remains of birds, with those of the same genera mentioned before, in the next order; those of quadrupeds of extinct species in a still more recent class; and it is only in the loose and slightly consolidated strata of gravel and sand, and which are usually called diluvian formations, that the remains of animals such as now people the globe are found, with others belonging to extinct species. But, in none of these formations, whether called secondary, tertiary, or diluvial, have the remains of man, or any of his works, been discovered; and whoever dwells upon this subject must be convinced, that the present order of things, and the comparatively recent existence of man as the master of the globe, is as certain as the destruction of a former and a different order, and the extinction of a number of living forms which have no types in being. In the oldest secondary strata there are no remains of such animals as now belong to the surface; and in the rocks, which may be regarded as more recently deposited, these remains occur but rarely, and with abundance of extinct species; — there seems, as it were, a gradual approach to the present system of things, and a succession of destructions and creations preparatory to the existence of man."*

* Sir H. Davy, Consolations in Travel, Dialogue III. "The Unknown."

In the above passages, the author deduces two important conclusions from geological data: first, that in the successive groups of strata, from the oldest to the most recent, there is a progressive development of organic life, from the simplest to the most complicated forms;—secondly, that man is of comparatively recent origin. It will be easy to show that the first of these propositions, though very generally received, has but a slender foundation in fact. The second, on the contrary, is indisputable; and it is important, therefore, to consider how far its admission is inconsistent with the doctrine, that the system of the natural world may have been uniform from the beginning, or rather from the era when the oldest rocks hitherto discovered were formed.

First, then, let us consider the geological proofs appealed to in support of the theory of the successive development of animal and vegetable life, and their progressive advancement to a more perfect state. No geologists who are in possession of all the data now established respecting fossil remains, will for a moment contend for the doctrine in all its detail, as laid down by the great chemist to whose opinions we have referred; but naturalists, who are not unacquainted with recent discoveries, continue to defend it in a modified form. They say that, in the first period of the world, (by which they mean the earliest of which we have yet procured any memorials,) the vegetation consisted almost entirely of cryptogamic plants, while the animals which co-existed were almost entirely confined to zoophytes, testacea, and a few fish. Plants of a less simple structure succeeded in the next epoch, when oviparous reptiles began also to abound. Lastly, the terrestrial flora became most diversified and most perfect when the highest orders of animals, the mammifera and birds, were called into existence.

Now, in the first place, it may observed, that many naturalists are guilty of no small inconsistency in endeavouring to connect the phenomena of the earliest vegetation with a nascent condition of organic life, and at the same time to deduce from the numerical predominance of certain types of form, the greater heat of the ancient climate. The arguments in favour of the latter conclusion are without any force, unless we can assume that the rules followed by the Author of Nature in the creation and distribution of organic beings were the same formerly as now; and that, as certain families of animals and plants are now most abundant, or exclusively confined, to regions where there is a certain temperature, a certain degree of humidity, a certain intensity of light, and other conditions, so also the same phenomena were exhibited at every former era.

If this postulate be denied, and the prevalence of particular families be declared to depend on a certain order of precedence in the introduction of different classes into the earth, and if it be maintained that the standard of organization was raised successively, we must then ascribe the numerical preponderance in the earlier ages of plants of simpler structure, *not to the heat*, but to those different laws which regulate organic life in newly created worlds. If, according to the laws of progressive development, cryptogamic plants always flourish for ages before the dicotyledonous order can be established, then is the small proportion of the latter fully explained; for in this case, whatever may have been the mildness or severity of the climate, they could not make their appearance.

Before we can infer an elevated temperature in high latitudes, from the presence of arborescent Ferns, Lycopodiaceæ, and plants of other allied families, we must be permitted to assume, that at all times, past, present, and future, a heated and moist atmosphere pervading the northern hemisphere has a tendency to produce in the vegetation a predominance of analogous types of form.

In the ancient strata of the carboniferous era, between 200 and 300 species of plants have been found. In these, say the authors of the "Fossil Flora*," no traces have been as yet discovered of the simplest forms of flowerless vegetation, such as Fungi, Lichens, Hepaticæ, or Mosses; while, on the contrary, there appear in their room Ferns, Lycopodiaceæ, and supposed Equisetaceæ, the most perfectly organized cryptogamic plants. In regard to the remains of monocotyledons of the same strata, they consist of palms and plants analogous to Dracænas, Bananas, and the Arrow Root tribe, which are the most highly developed tribes of that class. Among the dicotyledons of the same period coniferous trees were abundant, while the fossil Stigmariæ, which accompany them, belonged probably to the most perfectly organized plants of that class, being allied to the Cacteæ, or Euphorbiaceæ. "But supposing," continue the same authors, "that it could be demonstrated, that neither Coniferæ nor any other dicotyledonous plants

* Fossil Flora of Great Britain, by John Lindley and William Hutton, Esquires. London, 1832. Preface.

existed in the first geological age of land plants, still the theory of progressive development would be untenable; because it would be necessary to show that monocotyledons are inferior in dignity, or, to use a more intelligible expression, are less perfectly formed than dicotyledons. So far is this from being the case, that if the exact equality of the two classes were not admitted, it would be a question whether monocotyledons are not the more highly organized of the two; whether palms are not of greater dignity than oaks, and cerealia than nettles."

Animal remains in the transition, or greywacké, and carboniferous strata.—By far the largest part of the organic remains found in the earth's crust consist of corals and testacea, the bones of vertebrated animals being comparatively rare. When these occur, they belong much more frequently to fish than to reptiles, and but seldom to terrestrial mammalia. This might, perhaps, have been anticipated as the general result of investigation, since all are now agreed that the greater number of fossiliferous strata were deposited beneath the sea, and that the ocean probably occupied in ancient times, as now, the greater part of the earth's surface. We must not, however, too hastily infer from the absence of fossil bones of mammalia in the older rocks, that the highest class of vertebrated animals did not exist in the remoter ages. There are regions at present, in the Indian and Pacific oceans, co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals, without obtaining one bone of a land quadruped. Suppose our mariners were to report, that on sounding in the Indian Ocean near some coral reefs, and at some distance from the land, they drew up on hooks attached to their line portions of a leopard, elephant, or tapir, should we not be sceptical as to the accuracy of their statements? and if we had no doubt of their veracity, might we not suspect them to be unskilful naturalists? or, if the fact were unquestioned, should we not be disposed to believe that some vessel had been wrecked on the spot?

The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such a floating body not being devoured by sharks or other predaceous fish, such as were those of which we find the teeth preserved in some of the carboniferous strata. But if the carcass should escape, and should happen to sink where sediment was in the act of accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, included for countless ages in solid rock, is it not contrary to all calculation of chances that we should hit upon the exact spot — that mere point in the bed of an ancient ocean, where the precious relic was entombed? Can we expect for a moment, when we have only succeeded, amidst several thousand fragments of corals and shells, in finding a few bones of *aquatic* or *amphibious* animals, that we should meet with a single skeleton of an inhabitant of the land?

Clarence, in his dream, saw, "in the slimy bottom of the deep,"

> ——a thousand fearful wrecks;
> A thousand men, that fishes gnaw'd upon;
> Wedges of gold, great anchors, heaps of pearl.

Had he also beheld, amid "the dead bones that lay scattered by," the carcasses of lions, deer, and the other wild tenants of the forest and the plain, the fiction would have been deemed unworthy of the genius of Shakspeare. So daring a disregard of probability and violation of analogy would have been condemned as unpardonable, even where the poet was painting those incongruous images which present themselves to a disturbed imagination during the visions of the night.

But, as fossil mammiferous remains have been met with in strata of the more modern periods, it will be desirable to take a rapid view of the contents of successive geological formations, and inquire how far they confirm or invalidate the opinions commonly entertained respecting the doctrine of successive development.

In the first place it should be stated, that faint traces of animal remains make their appearance in strata of as early a date as any in which the impressions of plants have been detected. We are as yet but imperfectly acquainted with the fossils of the deposits called by Werner "transition," or those below the carboniferous series; yet in some of these, as in the limestone of Ludlow, for example, scales and bones of fish have been found.* In these ancient rocks we cannot expect to bring many vertebral remains to light until we have obtained more information respecting the zoophytes and testacea of the same period. The rarer species cannot be discovered until the more abundant have been found again and again; and it may be doubted whether we shall ever succeed in acquiring so extensive a knowledge of the fossil bodies of strata anterior to the coal as to entitle us to attach much importance to the absence of birds and mammalia. In

* Murchison, Proceedings of Geol. Soc. No. 34. p. 13.

rocks of high antiquity many organic forms have been obliterated by various causes, such as subterranean heat and the percolation of acidulous waters, which have operated during a long succession of ages. The number of organic forms which have disappeared from the oldest strata may be conjectured from the fact, that their former existence is in many cases merely revealed to us by the unequal weathering of an exposed face of rock, on which the petrifactions stand out in relief.

If we next consider the old red sandstone, we find that entire skeletons of fish have been discovered in it both in Scotland and in the West of England, and Wales, but no well-authenticated instance is recorded of a fossil reptile from this formation.* Neither have any reptilian remains been met with in the incumbent carboniferous group, either in the mountain limestone, or in the shales and sandstones of the coal. The supposed saurian teeth found by Dr. Hibbert in carboniferous strata near Edinburgh, have been lately shewn by Dr. Agassiz to belong to sauroidal fish, or fish of the highest rank in structure, and approaching more nearly in their osteological characters than any others to true saurians.

It would be premature to conclude that no bones of reptiles are to be found in the carboniferous formation, because it is only within a few years that several dis-

* Scales of a tortoise, nearly allied to Trionyx, are stated in the Geol. Trans. second series, vol. iii. part 1. p. 144., to have been found abundantly in the bituminous schists of Caithness, in Scotland, and in the same formation in the Orkneys. These schists have been shewn by Professor Sedgwick and Mr. Murchison to be of the age of the old red sandstone. But M. Agassiz has lately decided that the scales in question are those of a fish (see figure of them, plate 16., Geol. Trans., same part).

tinct species and genera of fish have been ascertained to abound in the same. It should also be recollected, that if we infer from the fossil flora of the coal, and other circumstances before enumerated, that our latitudes were occupied at the remote period in question by an ocean interspersed with small islands, such islands may, like those of the modern Pacific, have been almost entirely destitute of mammalia and reptiles.*

In regard to birds, they are usually wanting in deposits of all ages, even where fossil animals of the highest order occur in abundance.†

There was evidently a long period, of which the formations from the magnesian limestone to the chalk inclusive may be said to contain the history, when reptiles of various kinds were largely developed on the earth: their remains are particularly numerous in the lias and oolitic strata. As there are now mammalia entirely confined to the land, others which, like the bat and vampyre, fly in the air; others, again, of amphibious habits, which inhabit rivers, like the hippopotamus, otter, and beaver; others exclusively aquatic and marine, like the seal, whale, and narwal, so in the early ages under consideration, there were terrestrial, winged, and aquatic reptiles. There were iguanodons walking on the land, pterodactyles winging their way through the air, monitors and crocodiles in the rivers, and the ichthyosaur and plesiosaur in the ocean. It appears also that some of these ancient saurians approximated more nearly in their organization to the type of living mammalia than do any of our existing reptiles.

I shall not dwell here on a question, which will

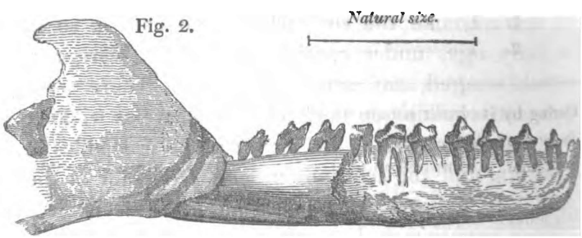
* See p. 199.

† See Book iii. ch. 15.

afterwards be discussed more fully, how far the almost entire suppression of one class of vertebrata and the development of another, as, for example, the predominance of reptiles over mammalia, or of these over reptiles, may be reconcileable with the notion of constant and uniform laws governing the distribution of animal life at particular periods.* I shall now merely call the reader's attention to a striking exception to the general rule of the non-occurrence of any signs of warm-blooded quadrupeds in secondary rocks.

In the oolite of Stonesfield, a rock which has been well ascertained to hold a somewhat inferior position in the great oolitic series, the jaws of at least two species of small mammiferous quadrupeds have been found. A specimen of one of these, now in the Oxford Museum (see fig. 2.), was examined by M. Cuvier, and pronounced by him to be allied to the didelphis. According to this naturalist, it was probably a small carnivorous animal not larger than a mole, yet differing from all known carnivora in having ten teeth in a row.

Fig. 2.



Lower jaw of a mammiferous quadruped, from the slate of Stonesfield, near Oxford.†

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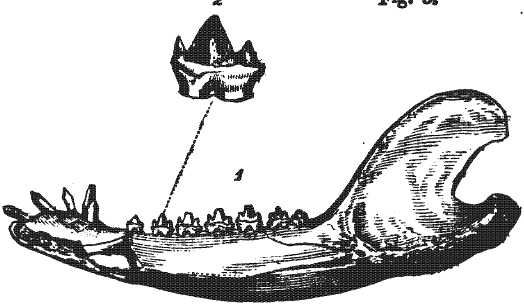
* Book iv. chap. xxiii.

† This figure (No. 2.) is from a drawing by Professor C. Prevost, published Ann. des Sci. Nat., Avril, 1825. The fossil is a lower jaw,

Another specimen now in London, in the collection of Mr. Broderip, consists also of a lower jaw, and belonged certainly to a quadruped of a distinct species, or even genus (see fig. 3.) for the number of teeth is different, and agrees precisely with that of the living didelphis.

Fig. 3.



Natural size.

*Lower jaw of Didelphis Bucklandi, from Stonefield.**

1. The jaw magnified twice in length.
2. The second molar tooth magnified six times.

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adhering by its inner side to the slab of oolite, in which it is sunk. The form of the condyle, or posterior process of the jaw, is distinctly seen, an impression of it being left on the stone, although the bone is wanting. The anterior part of the jaw has been partially broken away, so that the fangs of six molar teeth are seen fixed in their sockets, the form of the fangs being characteristic of the mammalia. The enamel of some of the teeth is well preserved.

* This figure (No. 3.) is taken from the original, in Mr. Broderip's collection. It consists of the right half of a lower jaw, of which the inner side is seen. The jaw contains seven molar teeth, one canine, and three incisors, but the end of the jaw is frac-

The occurrence of these individuals, the most ancient memorials yet known of the mammiferous type, so low down in the oolitic series, while no other representatives of the same class have yet been found in the superior secondary strata, either in the Middle or Upper Oolite, or in the Wealden, Green Sand, or Chalk, is a striking fact, and should serve as a warning to us against hasty generalizations. So important an exception to a general rule may be perfectly consistent with the conclusion, that a small number only of mammalia inhabited European latitudes when our secondary rocks were formed; but it seems fatal to the theory of progressive development, or the notion that the order of precedence in the creation of animals, considered chronologically, coincided with the order in which they would be ranked according to perfection or complexity of structure.

Of the Tertiary strata. — The tertiary strata, as will appear from what has been already stated, were deposited when the physical geography of the northern hemisphere had been entirely altered. Large inland lakes had become numerous, as in Central France and many other countries. There were gulfs of the sea, into which considerable rivers emptied themselves, where strata were formed like those of the Paris basin. There were then also littoral formations in progress,

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tured, and traces of the alveolus of a fourth incisor are seen. With this addition, the number of teeth would agree exactly with those of a lower jaw of a didelphis. The fossil is well preserved in a slab of oolitic structure containing shells of Trigoniæ and other marine remains. Two other jaws, besides those above represented, have been procured from the quarries of Stonesfield. —See Broderip, Zool. Journ. vol. iii. p. 408.

such as are indicated by the English *Crag*, and the *Faluns* of the Loire. The state of preservation of the organic remains of this period is very different from that of fossils in the older rocks, the colours of the shells, and even the cartilaginous ligaments uniting the valves, being in some cases retained. More than 1100 species of testacea have been found in the beds of the Paris basin, and nearly an equal number in the more modern formations of the Subapennine hills; and it is a most curious fact in natural history, that the zoologist has already acquired more extensive information concerning the testacea which inhabited the ancient seas of northern latitudes at those remote epochs than of the species now living in the same parallels in Europe.

Paris basin.—The strata of the Paris basin are partly of freshwater origin, and filled with the spoils of the land. They have afforded a great number of skeletons of land quadrupeds, but these relics are confined almost entirely to one small member of the group, and their conservation may be considered as having arisen from some local and accidental combination of circumstances.* On the other hand, the scarcity of terrestrial mammalia in submarine sediment is elucidated, in a striking manner, by the extremely small number of such remains hitherto procured from the calcaire grossier, one of the formations of the Parisian series.†

London clay—Plastic clay.—The inferior member of our oldest tertiary formation in England, usually termed the plastic clay, has hitherto proved as destitute of mammiferous remains as our ancient coal strata; and this point of resemblance between these deposits

* Book iv. ch. xviii. † Ibid.

is the more worthy of observation, because the ligni in the one case, and the coal in the other, are exc sively composed of terrestrial plants. From the L don clay we have procured three or four hund species of testacea, but the only bones of vertebra animals are those of reptiles and fish. On compar therefore, the contents of these marine strata those of our oolitic series, we find the supposed o of precedence inverted. In the more ancient sys of rocks, a few mammalia have been recogni whereas in the newer, if negative evidence wer be our criterion, Nature has made a retrograde stead of an advancing movement, and no animals exalted in the scale of organization than reptile discoverable. It should, however, be stated, th a freshwater formation, resting upon the London in the Isle of Wight, and like it belonging to the Ec epoch, some mammiferous remains have recently found.

Subapennine beds.—Although the Subapennine have been examined by collectors for three hur years, and have yielded more than a thousand spec testacea, the authenticated examples of imbedde mains of terrestrial mammalia are extremely sc and several of those which have been cited by e writers as belonging to the elephant or rhino have since been declared, by competent anatomis be the bones of whales and other cetacea. In abou or ten instances, perhaps, bones of the mastodon noceros, and some other land animals, have observed in this formation with marine shells atta

* Buckland and Allan, Jameson's Ed. Phil. Journ., N p. 190. Pratt, Proceedings of Geol. Soc., No. 18. 1831.

These must have been washed into the bed of the ancient sea when the strata were forming, and they serve to attest the contiguity of land inhabited by large herbivora, which renders the rarity of such exceptions more worthy of attention. On the contrary, the number of skeletons of existing animals in the upper Val d'Arno, which have been usually considered to be referrible to the same age as the Subapennine beds, occur in a deposit which was formed entirely in an inland lake, surrounded by lofty mountains.*

Not a single bone of any quadrumanous animal has ever yet been discovered in a fossil state; and their absence has appeared, to some geologists, to countenance the idea that the type of organization most nearly resembling the human came last in the order of creation, and was scarcely perhaps anterior to that of man. But the evidence on this point is quite inconclusive; for, first, we know nothing of the details of the various classes of the animal kingdom which may have inhabited the land when the secondary strata were accumulated; and in regard to some of the more modern tertiary periods, the climate of Europe does not appear to have been of such a tropical character as may have been necessary for the development of the tribe of apes, monkeys, and allied genera. Besides, it must not be forgotten, that almost all the animals which occur in subaqueous deposits are such as frequent marshes, rivers, or the borders of lakes, as the rhinoceros, tapir, hippopotamus, ox, deer, pig, and others. Species which live in trees are extremely rare in a fossil state; and we have no data as yet for determining how great a number of the one kind we

* See Book iv. ch. xvi.

ought to find, before we have a right to expect a individual of the other. Even therefore, if we led to infer, from the presence of crocodile: turtles in the London clay, and from the coco and spices found in the Isle of Sheppey, that period when our older or Eocene tertiary strat: formed, the climate was hot enough for th drumanous tribe, we nevertheless could not to discover any of their skeletons until we had considerable progress in ascertaining what the contemporary Pachydermata; and a very number of these have, as was before remarke hitherto discovered in any strata of this ep England.

The result then, of our inquiry into the evide the successive development of the animal and table kingdoms, may be stated in a few wor regard to *plants*, if we neglect the obscu ambiguous impressions found in some of the fossiliferous rocks, which can lead to no saf clusions, we may consider those which chara the great carboniferous group as the first deservi ticular attention. They are by no means confine simplest forms of vegetation, as to cryptogamic but, on the contrary, belong to all the leading di of the vegetable kingdom; some of the mor developed forms, both of dicotyledons and mo ledons having already been discovered, even the first three or four hundred species brou light: it is therefore superfluous to pursue this the argument farther.

If we then examine the animal remains of the formations, we find bones and skeletons of the old red sandstones, and even in some tr limestones below it; in other words, we have already vertebrated animals in the most ancient strata respecting the fossils of which we can be said to possess any accurate information.

In regard to birds and quadrupeds, their remains are almost entirely wanting in *marine* deposits of every era, even where interposed freshwater strata contain those fossils in abundance, as in the Paris basin. The secondary strata of Europe are for the most part marine, and there is as yet only one instance of the occurrence of mammiferous fossils in them, four or five individuals having been found in the slate of Stonesfield, a rock unquestionably of the oolitic period, and which appears, from several other circumstances, to have been formed near the point where some river entered the sea.

When we examine the tertiary groups, we find in the Eocene or oldest strata of that class the remains of a great assemblage of the highest or mammiferous class, all of extinct species, and in the Miocene beds, or those of a newer tertiary epoch, other forms, for the most part of lost species, and almost entirely distinct from the Eocene tribes. Another change is again perceived, when we investigate the fossils of later or of the Pliocene periods. But in this succession of quadrupeds, we cannot detect any signs of a progressive development of organization,—any indication that the Eocene fauna was less perfect than the Miocene, or the Miocene, than what will be designated in the fourth book the Newer Pliocene.

Recent origin of man.—If then the popular theory of the successive development of the animal and vegetable world, from the simplest to the most perfect forms, rests on a very insecure foundation; it may be asked, whether the recent origin of man lends any support to the same doctrine, or how far the influence of man may be considered as such a deviation from the analogy of the order of things previously established, as to weaken our confidence in the uniformity of the course of nature.

I need not dwell on the proofs of the low antiquity of our species, for it is not controverted by any experienced geologist; indeed, the real difficulty consists in tracing back the signs of man's existence on the earth to that comparatively modern period when species, now his contemporaries, began to predominate. If there be a difference of opinion respecting the occurrence in certain deposits of the remains of man and his works, it is always in reference to strata confessedly of the most modern order; and it is never pretended that our race co-existed with assemblages of animals and plants, of which *all or even a great part of the species* are extinct. From the concurrent testimony of history and tradition, we learn that parts of Europe, now the most fertile and most completely subjected to the dominion of man, were, less than three thousand years ago, covered with forests, and the abode of wild beasts. The archives of nature are in perfect accordance with historical records; and when we lay open the most superficial covering of peat, we sometimes find therein the canoes of the savage, together with huge antlers of the wild stag, or horns of the wild bull. In caves now open to the day in various parts of Europe, the bones of large beasts of prey occur in abundance; and they indicate that, at periods comparatively modern in the history of the globe, the ascendancy of man, if he existed at all, had scarcely been felt by the brutes.*

* Respecting the probable antiquity assignable to certain human

No inhabitant of the land exposes himself to so many dangers on the waters as man, whether in a savage or a civilized state *; and there is no animal, therefore, whose skeleton is so liable to become imbedded in lacustrine or submarine deposits: nor can it be said that his remains are more perishable than those of other animals; for in ancient fields of battle, as Cuvier has observed, the bones of men have suffered as little decomposition as those of horses which were buried in the same grave.† But even if the more solid parts of our species had disappeared, the impression of their form would have remained engraven on the rocks, as have the traces of the tenderest leaves of plants, and the soft integuments of many animals. Works of art, moreover, composed of the most indestructible materials, would have outlasted almost all the organic contents of sedimentary rocks. Edifices, and even entire cities, have, within the times of history, been buried under volcanic ejections, submerged beneath the sea, or engulphed by earthquakes; and had these catastrophes been repeated throughout an indefinite lapse of ages, the high antiquity of man would have been inscribed in far more legible characters on the framework of the globe than are the forms of the ancient vegetation which once covered the islands of the northern ocean, or of those gigantic reptiles which at still later periods peopled the seas and rivers of the northern hemisphere.‡

Dr. Prichard has argued that the human race have

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bones and works of art found intermixed with remains of extinct animals in several caves in France, see Book iii. ch. xiv.

* See Book iii. ch. xvi. † Ibid.

‡ Ibid.

not always existed on the surface of the earth, because "the strata of which our continents are composed were once a part of the ocean's bed"—"mankind had a beginning, since we can look back to the period when the surface on which they lived began to exist."* This proof, however, is insufficient, for many thousands of human beings now dwell in various quarters of the globe where marine species lived within the times of history, and, on the other hand, the sea now prevails permanently over large districts once inhabited by thousands of human beings. Nor can this interchange of sea and land ever cease while the present causes are in existence. It is conceivable, therefore, that terrestrial species might be older than the continents which they inhabit, and aquatic species of higher antiquity than the lakes and seas which they people.

Doctrine of successive development not confirmed by the admission that man is of modern origin.—It is on other grounds that we are entitled to infer that man is, comparatively speaking, of modern origin; and if this be assumed, we may then ask whether his introduction can be considered as one step in a progressive system, by which, as some suppose, the organic world advanced slowly from a more simple to a more perfect state? In reply to this question, it should first be observed, that the superiority of man depends not on those faculties and attributes which he shares in common with the inferior animals, but on his reason, by which he is distinguished from them. When it is said that the human race is of far higher dignity than were any pre-existing beings on the earth, it is the intellectual and moral attributes only of our race, not the

* Phys. Hist. of Mankind, vol. ii. p. 594.

animal, which are considered; and it is by no means clear, that the organization of man is such as would confer a decided pre-eminence upon him, if, in place of his reasoning powers, he was merely provided with such instincts as are possessed by the lower animals.

If this be admitted, it would by no means follow, even if there had been sufficient geological evidence in favour of the theory of progressive development, that the creation of man was the last link in the same chain. For the sudden passage from an irrational to a rational animal is a phenomenon of a distinct kind from the passage from the more simple to the more perfect forms of animal organization and instinct. To pretend that such a step, or rather leap, can be part of a regular series of changes in the animal world, is to strain analogy beyond all reasonable bounds.

Introduction of man, to what extent a change in the system.—But setting aside the question of progressive development, another and a far more difficult one may arise out of the admission that man is comparatively of modern origin. Is not the interference of the human species, it may be asked, such a deviation from the antecedent course of physical events, that the knowledge of such a fact tends to destroy all our confidence in the uniformity of the order of nature, both in regard to time past and future? If such an innovation could take place after the earth had been exclusively inhabited for thousands of ages by inferior animals, why should not other changes as extraordinary and unprecedented happen from time to time? If one new cause was permitted to supervene, differing in kind and energy from any before in operation, why may not others have come into action at different epochs? Or what security have we that they may not arise hereafter? And if such be the case, how can the experience of one period, even though we are acquainted with all the possible effects of the then existing causes, be a standard to which we can refer all natural phenomena of other periods?

Now these objections would be unanswerable, if adduced against one who was contending for the absolute uniformity throughout all time of the succession of sublunary events—if, for example, he was disposed to indulge in the philosophical reveries of some Egyptian and Greek sects, who represented all the changes both of the moral and material world as repeated at distant intervals, so as to follow each other in their former connexion of place and time. For they compared the course of events on our globe to astronomical cycles; and not only did they consider all sublunary affairs to be under the influence of the celestial bodies, but they taught that on the earth, as well as in the heavens, the same identical phenomena recurred again and again in a perpetual vicissitude. The same individual men were doomed to be re-born, and to perform the same actions as before; the same arts were to be invented, and the same cities built and destroyed. The Argonautic expedition was destined to sail again with the same heroes, and Achilles with his Myrmidons to renew the combat before the walls of Troy.

> Alter erit tum Tiphys, et altera quæ vehat Argo
> Dilectos heroas: erunt etiam altera bella,
> Atque iterum ad Trojam magnus mittetur Achilles.*

* Virgil, Eclog. iv. For an account of these doctrines, see Dugald Stewart's Elements of the Philosophy of the Human

The geologist, however, may condemn these tenets as absurd, without running into the opposite extreme, and denying that the order of nature has, from the earliest periods, been uniform in the same sense in which we believe it to be uniform at present, and expect it to remain so in future. We have no reason to suppose, that when man first became master of a small part of the globe, a greater change took place in its physical condition than is now experienced when districts, never before inhabited, become successively occupied by new settlers. When a powerful European colony lands on the shores of Australia, and introduces at once those arts which it has required many centuries to mature; when it imports a multitude of plants and large animals from the opposite extremity of the earth, and begins rapidly to extirpate many of the indigenous species, a mightier revolution is effected in a brief period than the first entrance of a savage horde, or their continued occupation of the country for many centuries, can possibly be imagined to have produced. If there be no impropriety in assuming that the system is uniform when disturbances so unprecedented occur in certain localities, we can with much greater confidence apply the same language to those primeval ages when the aggregate number and power of the human race, or the rate of their advancement in civilization, must be supposed to have been far inferior. In reasoning on the state of the globe immediately before our species was called into existence, we must be guided by the same rules of induction as when we speculate on the state of America in the interval that

Mind, vol. ii. chap. ii. sect. 4., and Prichard's Egypt. Mythol. p. 177.

elapsed between the introduction of man into Asia, the supposed cradle of our race, and the arrival of the first adventurers on the shores of the New World. In that interval, we imagine the state of things to have gone on according to the order now observed in regions unoccupied by man. Even now, the waters of lakes, seas, and the great ocean, which teem with life, may be said to have no immediate relation to the human race — to be portions of the terrestrial system of which man has never taken, nor ever can take, possession; so that the greater part of the inhabited surface of the planet may remain still as insensible to our presence as before any isle or continent was appointed to be our residence.

If the barren soil around Sydney had at once become fertile upon the landing of our first settlers; if, like the happy isles whereof the poets have given us such glowing descriptions, those sandy tracts had begun to yield spontaneously an annual supply of grain, we might then, indeed, have fancied alterations still more remarkable in the economy of nature to have attended the first coming of our species into the planet. Or if, when a volcanic island like Ischia was, for the first time, brought under cultivation by the enterprise and industry of a Greek colony, the internal fire had become dormant, and the earthquake had remitted its destructive violence, there would then have been some ground for speculating on the debilitation of the subterranean forces, when the earth was first placed under the dominion of man. But after a long interval of rest, the volcano bursts forth again with renewed energy, annihilates one half of the inhabitants, and compels the remainder to emigrate. The course of nature remains evidently unchanged; and, in like manner, we may suppose the general condition of the globe, immediately before and after the period when our species first began to exist, to have been the same, with the exception only of man's presence.

The modifications in the system of which man is the instrument, do not, perhaps, constitute so great a deviation from previous analogy as we usually imagine; we often, for example, form an exaggerated estimate of the extent of our power in extirpating some of the inferior animals, and causing others to multiply; a power which is circumscribed within certain limits, and which, in all likelihood, is by no means exclusively exerted by our species.* The growth of human population cannot take place without diminishing the numbers, or causing the entire destruction, of many animals. The larger carnivorous species give way before us, but other quadrupeds of smaller size, and innumerable birds, insects, and plants, which are inimical to our interests, increase in spite of us, some attacking our food, others our raiment and persons, and others interfering with our agricultural and horticultural labours. We behold the rich harvest which we have raised with the sweat of our brow devoured by myriads of insects, and are often as incapable of arresting their depredations, as of staying the shock of an earthquake, or the course of a stream of lava.

A great philosopher has observed, that we can command nature only by obeying her laws; and this principle is true even in regard to the astonishing changes which are superinduced in the qualities of certain animals and plants by domestication and garden culture. I shall point out in the third book that we can

* See Book iii. ch. ix.

only effect such surprising alterations by assisting the development of certain instincts, or by availing ourselves of that mysterious law of their organization, by which individual peculiarities are transmissible from one generation to another.*

It is probable from these, and many other considerations, that as we enlarge our knowledge of the system, we shall become more and more convinced, that the alterations caused by the interference of man deviate far less from the analogy of those effected by other animals than is usually supposed.† We are often misled, when we institute such comparisons, by our knowledge of the wide distinction between the instincts of animals and the reasoning power of man; and we are apt hastily to infer, that the effects of a rational and an irrational species, considered merely *as physical agents*, will differ almost as much as the faculties by which their actions are directed.

It is not, however, intended that a real departure from the antecedent course of physical events cannot be traced in the introduction of man. If that latitude of action which enables the brutes to accommodate themselves in some measure to accidental circumstances, could be imagined to have been at any former period so great, that the operations of instinct were as much diversified as are those of human reason, it might, perhaps, be contended, that the agency of man did not constitute an anomalous deviation from the previously established order of things. It might then have been said, that the earth's becoming at a particular period the residence of human beings, was an era in the

* See Book iii. ch. iii.

† Id. chapters v. vi. vii. and ix.

moral, not in the physical world — that our study and contemplation of the earth, and the laws which govern its animate productions, ought no more to be considered in the light of a disturbance or deviation from the system, than the discovery of the satellites of Jupiter should be regarded as a physical event affecting those heavenly bodies. Their influence in advancing the progress of science among men, and in aiding navigation and commerce, was accompanied by no reciprocal action of the human mind upon the economy of nature in those distant planets; and so the earth might be conceived to have become, at a certain period, a place of moral discipline, and intellectual improvement to man, without the slightest derangement of a previously existing order of change in its animate and inanimate productions.

The distinctness, however, of the human from all other species, considered merely as an efficient cause in the physical world, is real; for we stand in a relation to contemporary species of animals and plants widely different from that which other irrational animals can ever be supposed to have held to each other. We modify their instincts, relative numbers, and geographical distribution, in a manner superior in degree, and in some respects very different in kind, from that in which any other species can affect the rest. Besides, the progressive movement of each successive generation of men causes the human species to differ more from itself in power at two distant periods, than any one species of the higher order of animals differs from another. The establishment, therefore, by geological evidence, of the first intervention of such a peculiar and unprecedented agency, long after other parts of the animate and inanimate world existed, affords ground for concluding that the experience during thousands of ages of all the events which may happen on this globe would not enable a philosopher to speculate with confidence concerning future contingencies.

If then an intelligent being, after observing the order of events for an indefinite series of ages, had witnessed at last so wonderful an innovation as this, to what extent would his belief in the regularity of the system be weakened? — would he cease to assume that there was permanency in the laws of nature? — would he no longer be guided in his speculations by the strictest rules of induction? To these questions it may be answered, that, had he previously presumed to dogmatize respecting the absolute uniformity of the order of nature, he would undoubtedly be checked by witnessing this new and unexpected event, and would form a more just estimate of the limited range of his own knowledge, and the unbounded extent of the scheme of the universe. But he would soon perceive that no one of the fixed and constant laws of the animate or inanimate world was subverted by human agency, and that the modifications produced were on the occurrence of new and extraordinary circumstances, and those not of a *physical* but a *moral* nature. The deviation permitted would also appear to be as slight as was consistent with the accomplishment of the new *moral* ends proposed, and to be in a great degree temporary in its nature, so that, whenever the power of the new agent was withheld, even for a brief period, a relapse would take place to the ancient state of things; the domesticated animal, for example, recovering in a few generations its wild instinct, and the garden-flower and fruit-tree reverting to the likeness of the parent stock.

Now, if it would be reasonable to draw such inferences with respect to the future, we cannot but apply the same rules of induction to the past. We have no right to anticipate any modifications in the results of existing causes in time to come, which are not conformable to analogy, unless they be produced by the progressive development of human power, or perhaps by some other new relations which may hereafter spring up between the moral and material worlds. In the same manner, when we speculate on the vicissitudes of the animate and inanimate creation in former ages, we ought not to look for any anomalous results, unless where man has interfered, or unless clear indications appear of some other *moral* source of temporary derangement.

For the discussion of other popular objections advanced against the doctrine of the identity of the ancient and modern causes of change, especially those founded on the supposed suddenness of general catastrophes, and the transition from one set of organic remains to another, I must refer to the 4th Book. In the mean time, when difficulties arise in interpreting the monuments of the past, I deem it more consistent with philosophical caution to refer them to our present ignorance of all the existing agents, or all their possible effects in an indefinite lapse of time, than to causes formerly in operation, but which have ceased to act; and if in any part of the globe the energy of a cause appears to have decreased, I consider it more probable that the diminution of intensity in its action is merely local, than that its force is impaired throughout the whole globe. But should there appear reason to believe that certain agents have, at particular periods of past time, been more potent instruments of change over the entire surface of the earth than they now are, it is still more consistent with analogy to presume, that after an interval of quiescence they will recover their pristine vigour, than to imagine that they are worn out.

The geologist who assents to the truth of these principles will deem it incumbent on him to examine with minute attention all the changes now in progress on the earth, and will regard every fact collected respecting the causes in diurnal action, as affording him a key to the interpretation of some mystery in the archives of remote ages. His estimate of the value of geological evidence, and his interest in the investigation of the earth's history, will depend entirely on the degree of confidence which he feels in regard to the permanency of the great causes of change. Their constancy alone will enable him to reason from analogy, and to arrive, by a comparison of the state of things at distinct epochs, at the knowledge of the general laws which govern the economy of our system.

The uniformity of the plan being once assumed, events which have occurred at the most distant periods in the animate and inanimate world will be acknowledged to throw light on each other, and the deficiency of our information respecting some of the most obscure parts of the present creation will be removed. For as, by studying the external configuration of the existing land and its inhabitants, we may restore in imagination the appearance of the ancient continents which have passed away, so may we obtain from the deposits of ancient seas and lakes an insight into the nature of the subaqueous processes now in operation, and of many forms of organic life, which, though now existing, are veiled from sight. Rocks, also, produced by subterranean fire in former ages at great depths in the bowels of the earth, present us, when upraised by gradual movements, and exposed to the light of heaven, with an image of those changes which the deep-seated volcano may now occasion in the nether regions. Thus, although we are mere sojourners on the surface of the planet, chained to a mere point in space, enduring but for a moment of time, the human mind is not only enabled to number worlds beyond the unassisted ken of mortal eye, but to trace the events of indefinite ages before the creation of our race, and is not even withheld from penetrating into the dark secrets of the ocean, or the interior of the solid globe; free, like the spirit which the poet described as animating the universe,

——— ire per omnes
Terrasque, tractusque maris, cœlumque profundum.

BOOK II.

CHANGES OF THE INORGANIC WORLD.

Aqueous Causes.

CHAPTER I.

Division of the subject into changes of the organic and inorganic world — Inorganic causes of change divided into aqueous and igneous — Aqueous causes first considered — Destroying and transporting power of running water — Sinuosities of rivers — Two streams when united do not occupy a bed of double surface (p. 261.) — Heavy matter removed by torrents and floods — Recent inundations in Scotland — Effects of glaciers and icebergs in removing stones — Erosion of chasms through hard rocks (p. 268.) — Excavations in the lavas of Etna by Sicilian rivers — Gorge of the Simeto — Gradual recession of the cataracts of Niagara.

Division of the subject. — Geology was defined to be the science which investigates the former changes that have taken place in the organic, as well as in the inorganic kingdoms of nature; and we may next proceed to inquire what changes are now in progress in both these departments. Vicissitudes in the inorganic world are most apparent; and as on them all fluctuations in the animate creation must in a great measure depend, they may claim our first consideration. The great agents of change in the inorganic world may be divided into two principal classes, the aqueous and the igneous. To the aqueous belong Rivers, Torrents, Springs, Currents, and Tides; to the igneous, Volcanos and Earthquakes. Both these classes are instruments of decay as well as of reproduction; but they may also be regarded as antagonist forces. For the aqueous agents are incessantly labouring to reduce the inequalities of the earth's surface to a level; while the igneous are equally active in restoring the unevenness of the external crust, partly by heaping up new matter in certain localities, and partly by depressing one portion, and forcing out another, of the earth's envelope.

It is difficult, in a scientific arrangement, to give an accurate view of the combined effects of so many forces in simultaneous operation; because, when we consider them separately, we cannot easily estimate either the extent of their efficacy, or the kind of results which they produce. We are in danger, therefore, when we attempt to examine the influence exerted singly by each, of overlooking the modifications which they produce on one another; and these are so complicated, that sometimes the igneous and aqueous forces co-operate to produce a joint effect, to which neither of them unaided by the other could give rise, — as when repeated earthquakes unite with running water to widen a valley; or when a thermal spring rises up from a great depth, and conveys the mineral ingredients with which it is impregnated from the interior of the earth to the surface. Sometimes the organic combine with the inorganic causes; as when a reef, composed of shells and corals, protects one line of coast from the destroying power of tides or currents, and turns them against some other point; or when drift timber, floated into a lake, fills a hollow to which the stream would not have had sufficient velocity to convey earthy sediment.

It is necessary, however, to divide our observations on these various causes, and to classify them systematically, endeavouring as much as possible to keep in view that the effects in nature are mixed, and not simple, as they may appear in an artificial arrangement.

In treating, in the first place, of the aqueous causes, we may consider them under two divisions: first, those which are connected with the circulation of water from the land to the sea, under which are included all the phenomena of rivers and springs; secondly, those which arise from the movements of water in lakes, seas, and the ocean, wherein are comprised the phenomena of tides and currents. In turning our attention to the former division, we find that the effects of rivers may be subdivided into those of a destroying and those of a renovating nature; in the destroying are included the erosion of rocks, and the transportation of matter to lower levels; in the renovating class, the formation of deltas by the influx of sediment, and the shallowing of seas.

Action of running water. — I shall begin, then, by describing the destroying and transporting power of running water, as exhibited by torrents and rivers. It is well known that the lands elevated above the sea attract, in proportion to their volume and density, a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and the ocean. By these means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. In consequence of this provision, almost all the water is first carried to the highest regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil, than it would do if the rain had been distributed over the plains and mountains equally in proportion to their relative areas. Almost all the water is also made by these means to pass over the greatest distances which each region affords, before it can regain the sea. The rocks also, in the higher regions, are particularly exposed to atmospheric influences, to frost, rain, and vapour, and to great annual alternations of cold and heat, of moisture and desiccation.

Its destroying and transporting power.—Among the most powerful agents of decay may be mentioned that property of water which causes it to expand during congelation; so that, when it has penetrated into the crevices of the most solid rocks, it rends them open on freezing with mechanical force. For this reason, although in cold climates the comparative quantity of rain which falls is very inferior, and although it descends more gradually than in tropical regions, yet the severity of frost, and the greater inequalities of temperature, compensate in some degree for this diminished source of degradation. The solvent power of water also is very great, and acts particularly on the calcareous and alkaline elements of stone, especially when it holds carbonic acid in solution, which is abundantly supplied to almost every large river by springs, and is collected by rain from the atmosphere. The oxygen of the atmosphere is also gradually absorbed by all animal and vegetable productions, and by almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, and tends to reduce into powder, and to render fit for soils, even the hardest aggregates belonging to our globe.*

When earthy matter has once been intermixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a stream. Running water charged with foreign ingredients being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream. The obstruction causes a temporary increase of the water, which then sweeps down the barrier.

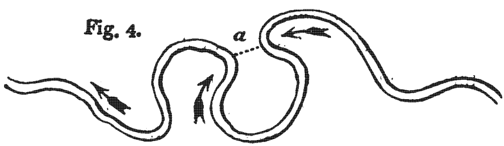
Sinuosities of Rivers.—By a repetition of these landslips, the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded, tends partly to give new direction to the lateral force of excavation. When by these, or by accidental shiftings of the alluvial matter in the channel, and numerous other causes, the current is made to cross its general line of descent, it eats out a curve in the opposite bank, or in the side of the hill bounding the valley, from which curve it is turned back again at an equal angle, so that it recrosses the line of descent, and gradually hollows out another curve lower down in the opposite bank, till the whole side of the valley, or river-bed, present a succession of salient and retiring angles. Among the causes of deviation from a straight course by which torrents and rivers tend in mountainous regions to widen the valleys through which they flow, may be mentioned the confluence of lateral torrents, swollen irregularly at d

* Sir H. Davy, Consolations in Travel, p. 271.

ferent seasons by partial storms, and discharging at different times unequal quantities of debris into the main channel.

When the tortuous flexures of a river are extremely great, the aberration from the direct line of descent is often restored by the river cutting through the isthmus which separates two neighbouring curves. Thus, in the annexed diagram, the extreme sinuosity of the

Fig. 4.



iver has caused it to return for a brief space in a con- rary direction to its main course, so that a peninsula s formed, and the isthmus (at *a*) is consumed on both ides by currents flowing in opposite directions. In his case an island is soon formed,—on either side of which a portion of the stream usually remains.* These vindings occur not only in the channels of rivers, flow- ng like the Mississippi through flat alluvial plains, but arge valleys also are excavated to a great depth hrough solid rocks in this serpentine form. In the alley of the Moselle, between Berncastle and Roarn, hich is sunk to a depth of from six to eight hundred eet through an elevated platform of transition rocks, e curves are so considerable that the river returns, fter a course of seventeen miles in one instance, and early as much in two others, to within a distance of few hundred yards of the spot it passed before.†

* See a Paper on the Excavation of Valleys, &c. by G. Poulett rope, Esq. Proceedings of Geol. Soc. No. 14., 1830.

† Ibid.

The valley of the Meuse, near Givet, and many others in different countries, offer similar windings. Mr. Scrope has remarked, that these tortuous flexures are decisively opposed to the hypothesis, that any violent and transient rush of water suddenly swept out such valleys; for great floods would produce straight channels in the direction of the current, not sinuous excavations, wherein rivers flow back again in an opposite direction to their general line of descent.

I cannot however accede to the doctrine, that the valleys of the Meuse and Moselle above alluded to were formed simply by river action; believing them, like many other deep valleys of a similar form, to have been principally due to the tides and currents of the sea, which acted throughout a great lapse of ages during the gradual elevation of the country.*

Transporting power of water.— In regard to the transporting power of water, we may often be surprised at the facility with which streams of a small size, and descending a slight declivity, bear along coarse sand and gravel; for we usually estimate the weight of rocks in air, and do not reflect on their comparative buoyancy when submerged in a denser fluid. The specific gravity of many rocks is not more than twice that of water, and very rarely more than thrice, so that almost all the fragments propelled by a stream have lost a third, and many of them half, of what we usually term their weight.

It has been proved by experiment, in contradiction to the theories of the earlier writers on hydrostatics, to be a universal law, regulating the motion of running

* For remarks on the valley of the Meuse, near St. Mihiel, alluded to in this place in a former edition, see Book iv. Ch. x.

water, that the velocity at the bottom of the stream is every where less than in any part above it, and is greatest at the surface. Also, that the superficial particles in the middle of the stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction; and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second at the bottom is ascertained to be sufficient to tear up fine clay,—six inches per second, fine sand,—twelve inches per second, fine gravel,—and three feet per second, stones of the size of an egg.*

When this mechanical power of running water is considered, we are prepared for the transportation of large quantities of gravel, sand, and mud, by the torrents and rivers which descend with great velocity from mountainous regions. But a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea. If they had not this removing power, their channels would be annually choked up, and the valleys of the lower country, and plains at the base of mountain-chains would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of running water—that two equal streams do not, when united, occupy a bed of double surface. In other words, when several rivers unite into one, the super-

* Encyc. Brit.—art. Rivers.

ficial area of the fluid mass is far less than t previously occupied by the separate streams. ' collective waters, instead of spreading themselves over a larger horizontal space, contract themselves a column of which the height is greater relativel its breadth. Hence a smaller proportion of the wl is retarded by friction against the bottom and side the channel; and in this manner the main curren often accelerated in the lower country, even where slope of the river's bed is lessened.

It not unfrequently happens, as will be afterw demonstrated by examples, that two large rivers, a their junction, have only the *surface* which one of tl had previously; and even in some cases their un waters are confined in a narrower bed than eac them filled before. By this beautiful adjustment, water which drains the interior country is made c tinually to occupy less room as it approaches the and thus the most valuable part of our contine the rich deltas, and great alluvial plains, are preven from being constantly under water.*

Floods in Scotland, 1829.—Many remarkable ill trations of the power of running water in movi stones and heavy materials were afforded by the sto and flood which occurred on the 3d and 4th of Augus 1829, in Aberdeenshire and other counties in Scotlan The elements during this storm assumed all the ch racters which mark the tropical hurricanes; the wi blowing in sudden gusts and whirlwinds, the lightni and thunder being such as is rarely witnessed in o climate, and heavy rain falling without intermissio The floods extended almost simultaneously, and wi

* See article Rivers, Encyc. Brit.

equal violence, over that part of the north-east of Scotland which would be cut off by two lines drawn from the head of Lochrannoch, one towards Inverness and the other to Stonehaven. The united line of the different rivers which were flooded could not be less than from five to six hundred miles in length; and the whole of their courses were marked by the destruction of bridges, roads, crops, and buildings. Sir T. D. Lauder has recorded the destruction of thirty-eight bridges, and the entire obliteration of a great number of farms and hamlets. On the Nairn, a fragment of sandstone, fourteen feet long by three feet wide and one foot thick, was carried above two hundred yards down the river. Some new ravines were formed on the sides of mountains where no streams had previously flowed, and ancient river-channels, which had never been filled from time immemorial, gave passage to a copious flood.*

The bridge over the Dee at Ballatu consisted of five arches, having upon the whole a water-way of 260 feet. The bed of the river, on which the piers rested, was composed of rolled pieces of granite and gneiss. The bridge was built of granite, and had stood uninjured for twenty years; but the different parts were swept away in succession by the flood, and the whole mass of masonry disappeared in the bed of the river.† "The river Don," observes Mr. Farquharson, in his account of the inundations, "has upon my own pre-

* Sir T. D. Lauder's Account of the Great Floods in Morayshire, Aug. 1829.

† From the account given by the Rev. James Farquharson, in the Quarterly Journ. of Science, &c. No. xii. New Series, p. 328.

mises forced a mass of four or five hundred ton stones, many of them two or three hundred po weight, up an inclined plane, rising six feet in e or ten yards, and left them in a rectangular l about three feet deep, on a flat ground;—the l ends abruptly at its lower extremity."*

The power even of a small rivulet, when swol rain, in removing heavy bodies, was lately exempl in the College, a small stream which flows at a m rate declivity from the eastern water-shed of Cheviot-Hills. Several thousand tons' weight of gr and sand were transported to the plain of the Till, a bridge then in progress of building was carried a some of the arch-stones of which, weighing from to three quarters of a ton each, were propelled miles down the rivulet. On the same occasion, current tore away from the abutment of a mill-da large block of greenstone-porphyry, weighing ne two tons, and transported it to the distance quarter of a mile. Instances are related as occur repeatedly, in which from one to three thousand of gravel are, in like manner, removed by this strea to still greater distances in one day.†

In the cases above adverted to, the waters of river and torrent were dammed back by the bridg which acted as partial barriers, and illustrate the i sistible force of a current when obstructed. Brid are also liable to be destroyed by the tendency of riv to shift their course, whereby the pier, or the ro on which the foundation stands, is undermined.

* Quarterly Journ. of Sci. &c. No. xii. New Series, p. 334.

† See a paper by Mr. Culley, F.G.S., Proceedings of Geo Soc. No. 12. 1829.

When we consider how insignificant are the volume and velocity of the rivers and streams in our island, when compared to those of the Alps and other lofty chains, and how, during the successive changes which the levels of various districts have undergone, the contingencies which give rise to floods must have been multiplied, we may easily conceive that the quantity of loose superficial matter distributed over Europe must be considerable. That the position also of a great portion of these travelled materials should now appear most irregular, and should often bear no relation to the existing water-drainage of the country, is a necessary consequence, as we shall afterwards see, of the combined operations of running water and subterranean movements.

Effects of ice in removing stones.—In mountainous regions and high northern latitudes, the moving of heavy stones by water is greatly assisted by the ice which adheres to them, and which, forming together with the rock a mass of less specific gravity, is readily borne along.* The snow which falls on the summits of the Alps throughout nine months of the year is drifted into the higher valleys, and being pressed downward by its own weight, forms those masses of ice and snow called *glaciers*. Large portions of these often descend into the lower valleys, where they are seen in the midst of forests and green pastures. The mean depth of the glaciers descending from Mont Blanc is from 80 to 100 feet, and in some chasms is seen to amount to 600 feet.† The surface of the moving mass is usually loaded with sand and large stones,

* Silliman's Journal, No. xxx. p. 303.

† Saussure, Voy. dans les Alpes, tom. i. p. 440.

derived from the disintegration of the surrounding rocks acted upon by frost. These transported materials are generally arranged in long ridges or mounds, sometimes thirty or forty feet high. They are often two, three, or even more in number, like so many lines of intrenchment, and consist of the debris which have been brought in by lateral glaciers. The whole accumulation is called in Switzerland "the moraine," which is slowly conveyed to inferior valleys, and left where the snow and ice melt, upon the plain, the larger blocks remaining, and the smaller being swept away by the stream to which the melting of the ice gives rise. This stream flows along the bottom of each glacier, issuing from an arch at its lower extremity.

In northern latitudes, where glaciers descend into valleys terminating in the sea, great masses of ice, on arriving at the shore, are occasionally detached and floated off together with their "moraine." The currents of the ocean are then often instrumental in transporting them to great distances. Scoresby counted 500 icebergs drifting along in latitude 69° and 70° north, which rose above the surface from the height of one to two hundred feet, and measured from a few yards to a mile in circumference.* Many of these contained strata of earth and stones, or were loaded with beds of rock of great thickness, of which the weight was conjectured to be from fifty thousand to one hundred thousand tons. Such bergs must be of great magnitude; because the mass of ice below the level of the water is between seven and eight times greater than that above. Wherever they are

* Voyage in 1822, p. 233.

dissolved, it is evident that the "moraine" will fall to the bottom of the sea. In this manner may submarine valleys, mountains, and platforms become strewed over with scattered blocks of foreign rock, of a nature perfectly dissimilar from all in the vicinity, and which may have been transported across unfathomable abysses. We have before stated, that some ice islands have been known to drift from Baffin's Bay to the Azores, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope.*

M. Lariviere relates that, being at Memel, on the Baltic, in 1821, when the ice of the river Niemen broke up, he saw a glacier thirty feet long, which had descended the stream, and had been thrown ashore. In the middle of it was a triangular piece of granite about a yard in diameter, resembling in composition the red granite of Finland.† Many rocky fragments are in this manner introduced by rivers into the Baltic; and some of much larger dimensions are carried annually by the ice from one place to another in the Gulf of Bothnia, where the sea freezes every winter to the depth of five or six feet. Blocks of stone resting on shoals are first frozen in, and then on the melting of the snow as summer approaches, when the waters of the gulf rise about three feet, they are lifted up and conveyed to great distances by the ice, which in that season has broken up into floating islands.

Excavation of rocks by running water.—The rapidity with which even the smallest streams hollow out deep channels in soft and destructible soils is re-

* For farther remarks on the transporting power of glaciers, see Book iv. ch. 11.

† Consid. sur les Blocs Errat., 1829.

markably exemplified in volcanic countries, where the sand and half-consolidated tuffs oppose but a slight resistance to the torrents which descend the mountain side. After the heavy rains which followed the eruption of Vesuvius in 1822, the water flowing from the Atrio del Cavallo cut, in three days, a new chasm through strata of tuff and ejected volcanic matter, to the depth of twenty-five feet. I found the old mule-road, in 1828, intersected by this new ravine.

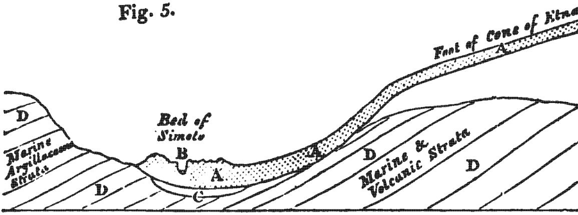
The gradual erosion of deep chasms through some of the hardest rocks, by the constant passage of running water charged with foreign matter, is another phenomenon of which striking examples may be adduced. Illustrations of this excavating power are presented by many valleys in central France, where the channels of rivers have been barred up by solid currents of lava, through which the streams have re-excavated a passage to the depth of from twenty to seventy feet and upwards, and often of great width. In these cases there are decisive proofs that neither the sea, nor any denuding wave or extraordinary body of water, has passed over the spot since the melted lava was consolidated. Every hypothesis of the intervention of sudden and violent agency is entirely excluded, because the cones of *loose* scoriæ, out of which the lavas flowed, are oftentimes at no great elevation above the rivers, and have remained undisturbed during the whole period which has been sufficient for the hollowing out of such enormous ravines.*

Recent excavation by the Simeto.—But I shall at present confine myself to examples derived from events which have happened since the time of history.

* See Book iv. ch. 19.

At the western base of Etna, a great current of lava (A A, fig. 5.), descending from near the summit of the great volcano, has flowed to the distance of five

Fig. 5.



Recent excavation of lava at the foot of Etna by the river Simeto.

or six miles, and then reached the alluvial plain of the Simeto, the largest of the Sicilian rivers, which skirts the base of Etna, and falls into the sea a few miles south of Catania. The lava entered the river about three miles above the town of Aderno, and not only occupied its channel for some distance, but, crossing to the opposite side of the valley, accumulated there in a rocky mass. Gemmellaro gives the year 1603 as the date of the eruption.* The appearance of the current clearly proves that it is one of the most modern of those of Etna: for it has not been covered or crossed by subsequent streams or ejections, and the olives on its surface are all of small size, yet older than the natural wood on the same lava. In the course, therefore, of about two centuries, the Simeto has eroded a passage from fifty to several hundred feet wide, and in some parts from forty to fifty feet deep.

The portion of lava cut through is in no part porous

* Quadro Istorico dell' Etna, 1824. Some doubts are entertained as to the exact date of this current by others, but all agree that it is not one of the older streams even of the historical era.

or scoriaceous, but consists of a compact homogene mass of hard blue rock, somewhat inferior in weigh ordinary basalt, and containing crystals of olivine glassy felspar. The general declivity of this pa the bed of the Simeto is not considerable; but consequence of the unequal waste of the lava, waterfalls occur at Passo Manzanelli, each about feet in height. Here the chasm (B, fig. 5.) is a forty feet deep, and only fifty broad.

The sand and pebbles in the river-bed consist ch of a brown quartzose sandstone, derived from the u country; but the materials of the volcanic rock i must have greatly assisted the attrition. This r like the Caltabiano on the eastern side of Etna, ha yet cut down to the ancient bed of which it was possessed, and of which the probable position is cated in the annexed diagram (C, fig. 5.).

On entering the narrow ravine where the foams down the two cataracts, we are entirely sh from all view of the surrounding country; and a g gist who is accustomed to associate the character features of the landscape with the relative age of tain rocks, can scarcely dissuade himself from the lief that he is contemplating a scene in some r gorge of a primary district. The external form the hard blue lava are as massive as any of the ancient trap-rocks of Scotland. The solid surface some parts smoothed and almost polished by attri and covered in others with a white lichen, which parts to it an air of extreme antiquity, so as great heighten the delusion. But the moment we re-asc the cliff the spell is broken: for we scarcely rece few paces, before the ravine and river disappear, we stand on the black and rugged surface of a current of lava, which seems unbroken, and which we can trace up nearly to the distant summit of that majestic cone which Pindar called "the pillar of heaven," and which still continues to send forth a fleecy wreath of vapour, reminding us that its fires are not extinct, and that it may again give out a rocky stream, wherein other scenes like that now described may present themselves to future observers.

Falls of Niagara. — The falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. That river flows from Lake Erie to Lake Ontario, the former lake being 330 feet above the latter, and the distance between them being thirty-two miles. On flowing out of the upper lake, the river is almost on a level with its banks; so that, if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the West, and of the State of New York on the East.* The river, where it issues, is about three quarters of a mile in width. Before reaching the falls, it is propelled with great rapidity, being a mile broad, about twenty-five feet deep, and having a descent of fifty feet in half a mile. An island at the very verge of the cataract divides it into two sheets of water; one of these, called the Horse-shoe Fall, is six hundred yards wide, and 158 feet perpendicular; the other, called the American Falls, is about two hundred yards in width, and 164 feet in height. The breadth of the island is about five hundred yards. This great sheet of water is precipitated over a ledge of hard limestone, in horizontal

* Captain Hall's Travels in North America, vol. i. p. 179.

strata, below which is a somewhat greater thickn of soft shale, which decays and crumbles away m rapidly, so that the calcareous rock forms an o hanging mass, projecting forty feet or more above hollow space below.

The blasts of wind, charged with spray, which out of the pool into which this enormous cascad projected, strike against the shale beds, so that disintegration is constant; and the superincum limestone, being left without a foundation, falls time to time in rocky masses. When these enorm fragments descend, a shock is felt at some dist accompanied by a noise like a distant clap of thu After the river has passed over the falls, its chara observes Captain Hall, is immediately and compl changed. It then runs furiously along the botto a deep wall-sided valley, or huge trench, which been cut into the horizontal strata by the conti action of the stream during the lapse of ages. cliffs on both sides are in most places perpendic and the ravine is only perceived on approaching edge of the precipice.*

The waters, which expand at the falls, where are divided by the island, are contracted again, their union, into a stream not more than *160 f* broad. In the narrow channel, immediately below immense rush of water, a boat can pass *across* stream with ease. The pool, it is said, into which cataract is precipitated, being 170 feet *deep, the* scending water sinks down and forms an under-curr

* Captain Hall's Travels in North America, vol. i. pp. 196. 216.

while a superficial eddy carries the upper stratum back *towards* the main fall.* This is not improbable; and we must also suppose, that the confluence of the two streams, which meet at a considerable angle, tends mutually to neutralize their forces. The bed of the river below the falls is strewed over with huge fragments which have been hurled down into the abyss. By the continued destruction of the rocks, the falls have, within the last forty years, receded nearly fifty yards, or, in other words, the ravine has been prolonged to that extent. Through this deep chasm, the Niagara flows for about seven miles; and then the table-land, which is almost on a level with Lake Erie, suddenly sinks down at a town called Queenstown, and the river emerges from the ravine into a plain, which continues to the shores of Lake Ontario.†

Recession of the Falls. — There seems good foundation for the general opinion, that the falls were once at Queenstown, and that they have gradually retrograded from that place to their present position, about seven miles distant. The table-land, extending from thence to Lake Erie, consists uniformly of the same geological formations as are now exposed to view at the falls. The upper stratum is an ancient alluvial sand, varying in thickness from 10 to 140 feet; below which is a bed of hard limestone, about ninety feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river *above*

* See Mr. Bakewell, jun. on the falls of Niagara.— Loudon's Mag. of Nat. Hist. No. xii. March, 1830.

† The memoir of Mr. Bakewell, jun., above referred to, contains two very illustrative sketches of the physical geography of the country between Lakes Erie and Ontario, including the Falls.

the falls, as do the inferior shales *below*. The lower shale is nearly of the same thickness as the limestone; but this last is said to thicken at the point now reached by the falls, a circumstance which may enable it in future to offer greater resistance to the force of the cataract.*

If the ratio of recession had never exceeded fifty yards in forty years, it must have required nearly ten thousand years for the excavation of the whole ravine; but scarcely any estimate can be formed of the quantity of time consumed in such an operation, because the retrograde movement was probably much more rapid when the whole current was confined within a space not exceeding a fourth or fifth of that which the falls now occupy. Should the erosive action not be accelerated in future, it will require upwards of thirty thousand years for the falls to reach Lake Erie (twenty-five miles distant), to which they seem destined to arrive in the course of time, unless some earthquake changes the relative levels of the district.

If that great lake should remain in its present state until the period when the ravine recedes to its shores, the sudden escape of so vast a body of water might cause a tremendous deluge; for the ravine would be much more than sufficient to drain the whole lake, of which the average depth was found, during the late survey, to be only 10 or 12 fathoms. But, in consequence of its shallowness, Lake Erie is fast filling up with sediment; and it may be questioned, whether its entire area may not be converted into dry land, before the falls recede so far.

* Monthly American Journ. July, 1831, p. 21.

CHAPTER II.

ACTION OF RUNNING WATER — *continued.*

Course of the Po — Desertion of its old channel — Artificial embankments of the Po, Adige, and other Italian rivers — Basin of the Mississippi — Its meanders — Islands — Shifting of its course — Raft of the Atchafalaya (p. 282.) — Drift wood — New-formed lakes in Louisiana — Earthquakes in valley of Mississippi — Floods caused by land-slips in the White Mountains (p. 289.) — Bursting of a lake in Switzerland — Devastations caused by the Anio at Tivoli.

Course of the Po. — The Po affords an instructive example of the manner in which a great river bears down to the sea the matter poured into it by a multitude of tributaries descending from lofty chains of mountains. The changes gradually effected in the great plain of Northern Italy, since the time of the Roman republic, are considerable. Extensive lakes and marshes have been gradually filled up, as those near Placentia, Parma, and Cremona, and many have been drained naturally by the deepening of the beds of rivers. Deserted river-courses are not unfrequent, as that of the Serio Morto, which formerly fell into the Adda, in Lombardy; and the Po itself has often deviated from its course. Subsequently to the year 1390, it deserted part of the territory of Cremona, and invaded that of Parma; its old channel being still recognizable, and bearing the name of Po Morto. Bressello is one of the towns of which the site was formerly on the left of the Po, but which is now on the right bank. There is also an old channel of the Po in the territory of Parma, called Po Vecchio, which was abandoned in the twelfth century, when a great number of towns were destroyed. There are records of parish-churches, as those of Vicobellignano, Agojolo, and Martignana, having been pulled down and afterwards rebuilt at a greater distance from the devouring stream. In the fifteenth century the main branch again resumed its deserted channel, and carried away a great island opposite Casalmaggiore. At the end of the same century it abandoned, a second time, the bed called "Po Vecchio," carrying away three streets of Casalmaggiore. The friars in the monastery de' Serviti took the alarm in 1471, demolished their buildings, and reconstructed them at Fontana, whither they had transported the materials. In like manner, the church of S. Rocco was demolished in 1511. In the seventeenth century also the Po shifted its course for a mile in the same district, causing great devastations.*

Artificial embankments of Italian rivers. — To check these and similar aberrations, a general system of embankment has been adopted; and the Po, Adige, and almost all their tributaries, are now confined between high artificial banks. The increased velocity acquired by streams thus closed in, enables them to convey a much larger portion of foreign matter to the sea; and, consequently, the deltas of the Po and Adige have gained far more rapidly on the Adriatic since the practice of embankment became almost universal. But, although more sediment is borne to the sea, part of the sand and mud, which in the

* Dell' Antico Corso de' Fiumi Po, Oglio, ed Adda, dell' Giovanni Romani. Milan, 1828.

natural state of things would be spread out by annual inundations over the plain, now subsides in the bottom of the river-channels, and their capacity being thereby diminished, it is necessary, in order to prevent inundations in the following spring, to extract matter from the bed, and to add it to the banks, of the river. Hence it happens that these streams now traverse the plain on the top of high mounds, like the waters of aqueducts, and at Ferrara the surface of the Po has become more elevated than the roofs of the houses.* The magnitude of these barriers is a subject of increasing expense and anxiety, it having been sometimes found necessary to give an additional height of nearly one foot to the banks of the Adige and Po in a single season.

The practice of embankment was adopted on some of the Italian rivers as early as the thirteenth century; and Dante, writing in the beginning of the fourteenth, describes, in the seventh circle of hell, a rivulet of tears separated from a burning sandy desert by embankments "like those which, between Ghent and Bruges, were raised against the ocean, or those which the Paduans had erected along the Brenta to defend their villas on the melting of the Alpine snows."

> Quale i Fiammingbi tra Guzzante e Bruggia,
> Temendo il fiotto che in ver lor s'avventa,
> Fanno lo schermo, perchè il mar si fuggia,
> E quale i Padovan lungo la Brenta,
> Per difender lor ville e lor castelli,
> Anzi che Chiarentana il caldo senta —
>
> *Inferno*, Canto xv.

Basin of the Mississippi.—The hydrographical basin of the Mississippi displays, on the grandest scale, the

* Prony, see Cuvier, Disc. Prélim. p. 146.

action of running water on the surface of a vast con tinent. This magnificent river rises nearly in the fort ninth parallel of north latitude, and flows to the Gu of Mexico in the twenty-ninth — a course, including meanders, of nearly five thousand miles. It pas from a cold arctic climate, traverses the temper regions, and discharges its waters into the sea in t region of the olive, the fig, and the sugar-cane.* river affords a more striking illustration of the l before mentioned, that an augmentation of volume d not occasion a proportional increase of surface, nay, even sometimes attended with a narrowing of t channel. The Mississippi is half a mile wide at junction with the Missouri †, the latter being also equal width; yet the united waters have only, fr their confluence to the mouth of the Ohio, a med width of about three quarters of a mile. The junct of the Ohio seems also to produce no increase, rather a decrease, of surface.‡ The St. Francis, Whi Arkansas, and Red rivers, are also absorbed by main stream with scarcely any apparent increase of width; and, on arriving near the sea at New Orlea it is somewhat less than half a mile wide. Its dep there is very variable, the greatest at high water bei 168 feet. The mean rate at which the whole body water flows is variously estimated. According to som it does not exceed one mile an hour.§

* Flint's Geography, vol. i. p. 21.

† Flint says (vol. i. p. 140.) that, where the Mississippi recei the Missouri, it is a mile and a half wide, but, according to C tain B. Hall, this is a great mistake. — Travels in the Uni States, vol. iii. p. 328.

‡ Flint's Geography, vol. i. p. 142.

§ Hall's Travels in North America, vol. iii. p. 330., who ci Darby.

The alluvial plain of this great river is bounded on the east and west by great ranges of mountains stretching along their respective oceans. Below the junction of the Ohio, the plain is from thirty to fifty miles broad, and after that point it goes on increasing in width, till the expanse is perhaps three times as great! On the borders of this vast alluvial tract are perpendicular cliffs, or "bluffs," as they are called, sometimes three hundred feet or more in height, composed of limestone and other rocks, and often of alluvium. For a great distance the Mississippi washes the eastern "bluffs;" and below the mouth of the Ohio, never once comes in contact with the western. The waters are thrown to the eastern side, because all the large tributary rivers entering from the west, have filled that side of the great valley with a sloping mass of clay and sand. For this reason, the eastern bluffs are continually undermined, and the Mississippi is slowly but incessantly progressing eastward.*

Curves of the Mississippi. — The river traverses the plain in a meandering course, describing immense and uniform curves. After sweeping round the half of a circle, it is carried in a rapid current diagonally across its own channel, to another curve of the same uniformity upon the opposite shore.† These curves are so regular, that the boatmen and Indians calculate distances by them. Opposite to each of them there is always a sand-bar, answering, in the convexity of its form, to the concavity of "the bend," as it is called.‡ The river, by continually wearing these

* Geograph. Descrip. of the State of Louisiana, by W. Darby, Philadelphia, 1816, p. 102.

† Flint's Geog. vol. i. p. 152.

‡ Ibid.

curves deeper, returns, like many other streams bef described, on its own tract, so that a vessel in so places, after sailing for twenty-five or thirty miles brought round again to within a mile of the p whence it started. When the waters approach near to each other, it often happens at high fl that they burst through the small tongue of land, insulate a portion, rushing through what is called "cut off" with great velocity. At one spot, ca the "grand cut off," vessels now pass from one p to another in half a mile to a distance which it form required a voyage of twenty miles to reach.*

Waste of its banks. — After the flood season, w the river subsides within its channel, it acts destructive force upon the alluvial banks, softe and diluted by the recent overflow. Several acres time, thickly covered with wood, are precipitated the stream; and large portions of the islands fo by the process before described are swept away.

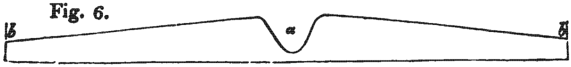
"Some years ago," observes Captain Hall, "w the Mississippi was regularly surveyed, all its isl were numbered, from the confluence of the Miss to the sea; but every season makes such revoluti not only in the number but in the magnitude situation of these islands, that this enumeration now almost obsolete. Sometimes large islands entirely melted away — at other places they h attached themselves to the main shore, or, which the more correct statement, the interval has b filled up by myriads of logs cemented together mud and rubbish."† When the Mississippi and ma

* Flint's Geog. vol. i. p. 154.

† Travels in North America, vol. iii. p. 361.

of its great tributaries overflow their banks, the waters, being no longer borne down by the main current, and becoming impeded amongst the trees and bushes, deposit the sediment of mud and sand with which they are abundantly charged. Islands arrest the progress of floating trees, and they often become in this manner reunited to the land; the rafts of trees, together with mud, constituting at length a solid mass. The coarser and more sandy portion is thrown down first nearest the banks; and finer particles are deposited at the farthest distances from the river, where an impalpable mixture subsides, forming a stiff unctuous black soil. Hence, in the alluvial plains of these rivers the land slopes back, like a natural glacis, towards the cliffs bounding the great valley (see fig. 6.), and during

Fig. 6.



a, Channel of the river. *b*, Base of the "bluffs."

inundations the highest part of the banks form narrow strips of dry ground, rising above the river on one side, and above the low flooded country on the other. The Mississippi therefore has been described as a river running on the top of a long hill or ridge, which has an elevation of twenty-four feet in its highest part, and a base three miles in average diameter. Flint, however, remarks, that this picture is not very correct, for, notwithstanding the comparative elevation of the banks, the deepest part of the bed of the river (*a*, fig. 6.) is uniformly lower than the lowest point of the alluvium at the base of the bluffs.*

It appears then that the Mississippi, by the continual

* Flint's Geography, vol. i. p. 151.

shifting of its course, sweeps away, during a great portion of the year, considerable tracts of alluvium which were gradually accumulated by the overflow of former years, and the matter now left during the spring-floods will be at some future time removed.

Raft of the Atchafalaya.—One of the most interesting features in this basin is "the raft." The dimensions of this mass of timber were given by Darby, in 1816, as ten miles in length, about 220 yards wide, and eight feet deep, the whole of which had accumulated, in consequence of some obstruction, during about thirty-eight years, in an arm of the Mississippi, called the Atchafalaya, which is supposed to have been at some past time a channel of the Red River before it intermingled its waters with the main stream. This arm is in a direct line with the general course of the Mississippi, and it catches a large portion of the drift wood annually brought down.

The mass of timber in the raft is continually increasing, and the whole rises and falls with the water. Although floating, it is covered with green bushes, like a tract of solid land, and its surface is enlivened in the autumn by a variety of beautiful flowers.

The rafts on Red River are equally remarkable; in some parts of its course, cedar trees are heaped up by themselves, and in other places pines. There is also a raft on the Washita, the principal tributary of the Red River, which seriously interrupts the navigation, concealing the whole river for seventeen leagues. This natural bridge is described in 1804 as supporting all the plants then growing in the neighbouring forest, not excepting large trees; and so perfectly was the stream concealed by the superincumbent mass, that it might be crossed in some places without any knowledge of its existence.*

Drift Wood. — Notwithstanding the astonishing number of cubic feet of timber arrested by the rafts, great deposits are unceasingly in progress at the extremity of the delta in the Bay of Mexico. "Unfortunately for the navigation of the Mississippi," observes Captain Hall, "some of the largest trunks, after being cast down from the position on which they grew, get their roots entangled with the bottom of the river, where they remain anchored, as it were, in the mud. The force of the current naturally gives their tops a tendency downwards, and, by its flowing past, soon strips them of their leaves and branches. These fixtures, called snags or planters, are extremely dangerous to the steam-vessels proceeding up the stream, in which they lie like a lance in rest, concealed beneath the water, with their sharp ends pointed directly against the bow of the vessels coming up. For the most part, these formidable snags remain so still, that they can be detected only by a slight ripple above them, not perceptible to inexperienced eyes. Sometimes, however, they vibrate up and down, alternately showing their heads above the surface and bathing them beneath it."† So imminent is the danger caused by these obstructions, that almost all the boats on the Mississippi are constructed on a particular plan, to guard against fatal accidents.‡

* Navigator, p. 263. Pittsburgh, 1821.

† Travels in North America, vol. iii. p. 362.

‡ "The boats are fitted," says Captain Hall, "with what is called a snag-chamber;—a partition formed of stout planks, which is caulked, and made so effectually water-tight, that the foremost end of the vessel is cut off as entirely from the rest of the hold as

The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest, not merely as illustrating the manner in which abundance of vegetable matter becomes, in the ordinary course of Nature, imbedded in submarine and estuary deposits, but as attesting the constant destruction of soil and transportation of matter to lower levels by the tendency of rivers to shift their courses. Each of these trees must have required many years, some of them many centuries, to attain their full size; the soil, therefore, whereon they grew, after remaining undisturbed for long periods, is ultimately torn up and swept away. Yet, notwithstanding this incessant destruction of land and up-rooting of trees, the region which yields this never-failing supply of drift wood is densely clothed with noble forests, and is almost unrivalled in its power of supporting animal and vegetable life.

Innumerable herds of wild deer and bisons feed on the luxurious pastures of the plains. The jaguar, the wolf, and the fox, are amongst the beasts of prey. The waters teem with alligators and tortoises, and their surface is covered with millions of migratory water-fowl, which perform their annual voyage between the Canadian lakes and the shores of the Mexican Gulf. The power of man begins to be sensibly felt, and the wilderness to be replaced by towns, orchards, and gardens. The gilded steam-boat, like a moving city, now stems the current with a steady pace — now

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if it belonged to another boat. If the steam-vessel happen to run against a snag, and that a hole is made in her bow, under the surface, this chamber merely fills with water." Travels in North America, vol. iii. p. 363.

shoots rapidly down the descending stream through the solitudes of the forests and prairies. Already does the flourishing population of the great valley exceed that of the thirteen United States when first they declared their independence, and, after a sanguinary struggle, were severed from the parent country.* Such is the state of a continent where rocks and trees are hurried annually, by a thousand torrents, from the mountains to the plains, and where sand and finer matter are swept down by a vast current to the sea, together with the wreck of countless forests and the bones of animals which perish in the inundations. When these materials reach the Gulf, they do not render the waters unfit for aquatic animals; but, on the contrary, the ocean here swarms with life, as it generally does where the influx of a great river furnishes a copious supply of organic and mineral matter. Yet many geologists, when they behold the spoils of the land heaped in successive strata, and blended confusedly with the remains of fishes, or interspersed with broken shells and corals, imagine that they are viewing the signs of a turbulent instead of a tranquil and settled state of the planet. They read in such phenomena the proof of chaotic disorder, and reiterated catastrophes, instead of indications of a surface as habitable as the most delicious and fertile districts now tenanted by man. They are not content with disregarding the analogy of the present course of Nature, when they speculate on the revolutions of past times, but they often draw conclusions, concerning the former state of things, directly the reverse of those to which a fair induction from facts would infallibly lead them.

* Flint's Geography, vol. i.

Formation of lakes in Louisiana. — Another striking feature in the basin of the Mississippi, illustrative of the changes now in progress, is the formation by natural causes of great lakes, and the drainage of others. These are especially frequent in the basin of the Red River in Louisiana, where the largest of them, called Bistineau, is more than *thirty miles* long and has a medium depth of from *fifteen* to *twenty* feet. In the deepest parts are seen numerous cypress-trees of all sizes, now dead, and most of them with their tops broken by the wind, yet standing erect under water. This tree resists the action of air and water longer than any other, and, if not submerged throughout the whole year, will retain life for an extraordinary period.* Lake Bistineau, as well as Black Lake, Cado Lake, Spanish Lake, Natchitoches Lake, and many others, have been formed, according to Darby, by the gradual elevation of the bed of Red River, in which the alluvial accumulations have been so great as to raise its channel, and cause its waters, during the flood season, to flow up the mouths of many tributaries, and to convert parts of their courses into lakes. In the autumn, when the level of Red River is again depressed, the waters rush back again, and some lakes become grassy meadows, with streams meandering through them.† Thus, there is a periodical flux and reflux between Red River and some of these basins, which are merely reservoirs, alternately emptied and

* Captains Clark and Lewis found a forest of pines standing erect under water in the body of the Columbia River in North America, which, they supposed, from the appearance of the trees to have been submerged only about twenty years. — Vol. ii. p. 241.

† Darby's Louisiana, p. 33.

ed like our tide estuaries — with this difference, ıt in the one case the land is submerged for several ›nths continuously, and, in the other, twice in every enty-four hours. It has happened, in several cases, ıt a bar has been thrown by Red River across some the openings of these channels, and then the lakes ;ome, like Bistineau, constant repositories of water. t even in these cases, their level is liable to annual vation and depression, because the flood of the main er, when at its height, passes over the bar; just as, ere sand-hills close the entrance of an estuary on : Norfolk or Suffolk coast, the sea, during some high e or storm, has often breached the barrier and inun- ed again the interior.

Earthquakes in basin of Mississippi. — The frequent :tuations in river courses, in various parts of the in of the Mississippi, are partly, perhaps, to be ribed to the co-operation of subterranean move- ıts, which alter from time to time the relative :ls of various parts of the surface. So late as the r 1812, the whole valley from the mouth of the io to that of the St. Francis, including a tract three ıdred miles in length, and exceeding in area the ›le basin of the Thames, was convulsed to such a ree, as to create new islands in the river, and lakes he alluvial plain, some of which were *twenty miles xtent.* I shall allude to this event, by which New Irid was in great part destroyed, when I treat of hquakes; but may state here, that it happened :tly at the same time as the fatal convulsions in the :ict of Caraccas; and the country shaken was ·ly five degrees of latitude farther removed from great centre of volcanic disturbance, than the a of the Red River before alluded to. Darby

mentions beds of marine shells on the banks of R
River, which seem to indicate that Lower Louisia
is of recent formation: its elevation, perhaps, abo
the sea, may have been due to the same series
earthquakes which continues to agitate equato
America.

When countries are liable to be so extensively
permanently affected by earthquakes, speculations c
cerning changes in their hydrographical features m
not be made without regard to the igneous as wel
the aqueous causes of change. It is scarcely ne
sary to observe, that the inequalities produced even
one shock might render the study of the alluvial p
of the Mississippi, at some future period, most
plexing to a geologist who should reason on the
tribution of transported materials, without being a
that the configuration of the country had varied m
rially during the time when the excavating or remo
power of the river was greatest.

FLOODS, BURSTING OF LAKES, ETC.

The power which running water may exert, in
lapse of ages, in widening and deepening a valley,
not so much depend on the volume and velocity of
stream usually flowing in it, as on the number
magnitude of the obstructions which have, at diffe
periods, opposed its free passage. If a torrent, h
ever small, be effectually dammed up, the size of
valley above the barrier, and its declivity below,
not the dimensions of the torrent, will determine
violence of the débâcle. The most universal sourc
local deluges are land-slips, slides, or avalanches,
they are sometimes called, when great masses of r

and soil, or sometimes ice and snow, are precipitated into the bed of a river, the boundary cliffs of which have been thrown down by the shock of an earthquake, or undermined by springs or other causes. Volumes might be filled with the enumeration of instances on record of these terrific catastrophes: I shall therefore select a few examples of very recent occurrence, the facts of which are well authenticated.

Floods caused by land-slips, 1826.—Two dry seasons in the White Mountains, in New Hampshire, were followed by heavy rains on the 28th August, 1826, when from the steep and lofty declivities which rise abruptly on both sides of the river Saco innumerable rocks and stones, many of sufficient size to fill a common apartment, were detached, and in their descent swept down before them, in one promiscuous and frightful ruin, forests, shrubs, and the earth which sustained them. No tradition existed of any similar slides at former times, and the growth of the forest on the flanks of the hills clearly showed that for a long interval nothing similar had occurred. One of these moving masses was afterwards found to have slid three miles, with an average breadth of a quarter of a mile. The natural excavations commenced generally in a trench a few yards in depth and a few rods in width, and descended the mountains, widening and deepening till they became vast chasms. At the base of these hollow ravines was seen a wide and deep mass of ruins, consisting of transported earth, gravel, rocks, and trees. Forests of spruce-fir and hemlock were prostrated with as much ease as if they had been fields of grain; for, where they disputed the ground, the torrent of mud and rock accumulated behind till it gathered sufficient force to burst the temporary barrier.

The valleys of the Amonoosuck and Saco presented, for many miles, an uninterrupted scene of desolation; all the bridges being carried away, as well as those over their tributary streams. In some places, the road was excavated to the depth of from fifteen to twenty feet; in others, it was covered with earth, rocks, and trees, to as great a height. The water flowed for many weeks after the flood, as densely charged with earth as it could be without being changed into mud, and marks were seen in various localities of its having risen on either side of the valley to more than twenty-five feet above its ordinary level. Many sheep and cattle were swept away, and the Willey family, nine in number, who in alarm had deserted their house, were destroyed on the banks of the Saco; seven of their mangled bodies were afterwards found near the river, buried beneath drift wood and mountain ruins.* The geologist should remark that the lower alluvial plains are most exposed to such violent floods, and at the same time are best fitted for the sustenance of herbivorous animals. If, therefore, any organic remains are found amidst the superficial heaps of transported matter, resulting from those catastrophes, at whatever periods they may have happened, and whatever may have been the former configuration and relative levels of the country, we may expect the imbedded fossil relics to be principally referrible to this class of mammalia.

But these catastrophes are insignificant, when compared to those which are occasioned by earthquakes, when the boundary hills, for miles in length, are

* Silliman's Journal of Science, vol. xv. No. 2. p. 216. Jan. 1829.

thrown down into the hollow of a valley. I shall have opportunities of alluding to inundations of this kind when treating expressly of earthquakes, and shall content myself at present with selecting an example, of modern date, of a flood caused by the bursting of a temporary lake; the facts having been described, with with more than usual accuracy, by scientific observers.

Flood in the Valley of Bagnes, 1818.—The valley of Bagnes is one of the largest of the lateral embranchments of the main valley of the Rhone, above the Lake of Geneva. Its upper portion was, in 1818, converted into a lake by the damming up of a narrow pass, by avalanches of snow and ice, precipitated from an elevated glacier into the bed of the river Dranse. In the winter season, during continued frost, scarcely any water flows in the bed of this river to preserve an open channel, so that the ice-barrier remained entire until the melting of the snows in spring, when a lake was formed above, about half a league in length, which finally attained in some parts a depth of about two hundred feet, and a width of about seven hundred feet. To prevent or lessen the mischief apprehended from the sudden bursting of the barrier, an artificial gallery, seven hundred feet in length, was cut through the ice, before the waters had risen to a great height. When at length they accumulated and flowed through this tunnel, they dissolved the ice, and thus deepened their channel, until nearly half of the whole contents of the lake were slowly drained off. But, at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of its descent, the waters encountered several narrow gorges, and at each of these they r to a great height, and then burst with new viole into the next basin, sweeping along rocks, fore houses, bridges, and cultivated land. For the gre part of its course the flood resembled a moving r of rock and mud, rather than of water. Some f ments of granitic rocks, of enormous magnitude, which, from their dimensions, might be comp without exaggeration to houses, were torn out more ancient alluvion, and borne down for a qu of a mile. One of the fragments moved was paces in circumference.* The velocity of the w in the first part of its course, was thirty-three fee second, which diminished to six feet before it rea the Lake of Geneva, where it arrived in six hour a half, the distance being forty-five miles.†

This flood left behind it, on the plains of Mar thousands of trees torn up by the roots, togethe the ruins of buildings. Some of the houses in town were filled with mud up to the second After expanding in the plain of Martigny, it en the Rhone and did no further damage; but bodies of men, who had been drowned above Marti were afterwards found, at the distance of about miles, floating on the farther side of the Lak Geneva, near Vevey.

The waters, on escaping from the temporary intermixed with mud and rock, swept along, for the four miles, at the rate of above twenty miles an h

* This block was measured by Capt. B. Hall, R. N.

† See an account of the inundation of the Val de Bagn 1818, in Ed. Phil. Journ., vol. i. p. 187., drawn up from Memoir of M. Escher, with a section, &c.

and M. Escher, the engineer, calculated that the flood furnished 300,000 cubic feet of water every second — an efflux which is five times greater than that of the Rhine below Basle. Now, if part of the lake had not been gradually drained off, the flood would have been nearly double, approaching in volume to some of the largest rivers in Europe. It is evident, therefore, that, when we are speculating on the excavating force which a river may have exerted in any particular valley, the most important question is, not the volume of the existing stream, nor the present levels of its channel, nor even the nature of the rocks, but the probability of a succession of floods, at some period since the time when the valley may have been first elevated above the sea.

For several months after the débâcle of 1818, the Dranse, having no settled channel, shifted its position continually from one side to the other of the valley, carrying away newly erected bridges, undermining houses, and continuing to be charged with as large a quantity of earthy matter as the fluid could hold in suspension. I visited this valley four months after the flood, and was witness to the sweeping away of a bridge, and the undermining of part of a house. The greater part of the ice-barrier was then standing, presenting vertical cliffs 150 feet high, like ravines in the lava-currents of Etna or Auvergne, where they are intersected by rivers.

Inundations, precisely similar, are recorded to have occurred at former periods in this district, and from the same cause. In 1595, for example, a lake burst, and the waters, descending with irresistible fury, destroyed the town of Martigny, where from sixty to

eighty persons perished. In a similar flood, f
years before, 140 persons were drowned.

Flood at Tivoli, 1826. — I shall conclude with
more example, derived from a land of classic reco
tions, the ancient Tibur, and which, like all the c
inundations above alluded to, occurred within the
sent century. The younger Pliny, it will be rem
bered, describes a flood on the Anio, which destr
woods, rocks, and houses, with the most sumpt
villas and works of art.* For four or five cent
consecutively, this "headlong stream," as H
truly called it, has often remained within its bo
and then, after so long an interval of rest, has a
ferent periods inundated its banks again, and wid
its channel. The last of these catastrophes happ
15th Nov. 1826, after heavy rains, such as pro
the floods before alluded to in Scotland. The w
appear also to have been impeded by an artificial
by which they were separated into two parts, a
distance above Tivoli. They broke through this
and, leaving the left trench dry, precipitated t
selves, with their whole weight, on the right
Here they undermined, in the course of a few h
a high cliff, and widened the river's channel a
fifteen paces. On this height stood the church of
Lucia, and about thirty-six houses of the town
Tivoli, which were all carried away, presenting
they sank into the roaring flood, a terrific scen
destruction to the spectators on the opposite b
As the foundations were gradually removed,
building, some of them edifices of considerable hei

* Lib. viii. Epist. 17.

was first traversed with numerous rents, which soon widened into large fissures, until at length the roofs fell in with a crash, and then the walls sank into the river, and were hurled down the cataract below.*

The destroying agency of the flood came within two hundred yards of the precipice on which the beautiful temple of Vesta stands; but fortunately this precious relic of antiquity was spared, while the wreck of modern structures was hurled down the abyss. Vesta, it will be remembered, in the heathen mythology, personified the stability of the earth; and when the Samian astronomer, Aristarchus, first taught that the earth revolved on its axis, and round the sun, he was publicly accused of impiety, "for moving the everlasting Vesta from her place." Playfair observed, that when Hutton ascribed instability to the earth's surface, and represented the continents which we inhabit as the theatre of incessant change and movement, his antagonists, who regarded them as unalterable, assailed him, in a similar manner, with accusations founded on religious prejudices.† We might appeal to the excavating power of the Anio as corroborative of one of the most controverted parts of the Huttonian theory; and, if the days of omens had not gone by, the geologists who now worship Vesta might regard the late catastrophe as portentous. We may, at least, recommend the modern votaries of the goddess to lose no time in making a pilgrimage to her shrine, for the next flood may not respect the temple.

* When at Tivoli, in 1829, I received this account from eye-witnesses of the event.

† Illustr. of Hutt. Theory, § 3. p. 147.

CHAPTER III.

PHENOMENA OF SPRINGS.

Origin of Springs — Bored wells — Distinct causes by which mineral and thermal waters may be raised to the surface — Their connection with volcanic agency (p. 304.) — Calcareous Springs — Travertin of the Elsa — Baths of San Vignone and of San Filippo, near Radicofani — Spheroidal structure in travertin, as in English magnesian limestone (p. 313.) — Bulicami of Viterbo — Lake of the Solfatara, near Rome — Travertin at Cascade of Tivoli (p. 318.) — Gypseous, Siliceous, and Ferruginous Springs — Brine Springs (p. 326.) — Carbonated Springs — Disintegration of granite in Auvergne — Petroleum Springs — Pitch Lake of Trinidad.

Origin of springs. — The action of running water on the land having been considered, we may next turn our attention to what may be termed "the subterranean drainage," or the phenomena of springs. Every one is familiar with the fact, that certain porous soils, such as loose sand and gravel, absorb water with rapidity; and that the ground composed of them soon dries up after heavy showers. If a well be sunk in such soils, we often penetrate to considerable depths before we meet with water; but this is usually found on our approaching the lower parts of the formation, where it rests on some impervious bed; for here the water, unable to make its way downwards in a direct line, accumulates as in a reservoir, and is ready to ooze out into any opening which may be made, in the same manner as we see the salt water flow into, and fill, any hollow which we dig in the sands of the shore at low tide.

The facility with which water can percolate loose and gravelly soils is clearly illustrated by the effect of the tides in the Thames between Richmond and London. The river, in this part of its course, flows through a bed of gravel overlying clay, and the porous superstratum is alternately saturated by the water of the Thames as the tide rises, and then drained again to the distance of several hundred feet from the banks when the tide falls, so that the wells in this tract regularly ebb and flow.

If the transmission of water through a porous medium be so rapid, we cannot be surprised that springs should be thrown out on the side of a hill, where the upper set of strata consist of chalk, sand, or other permeable substances, while the subjacent are composed of clay or other retentive soils. The only difficulty, indeed, is, to explain, why the water does not ooze out every where along the line of junction of the two formations, so as to form one continuous landsoak, instead of a few springs only, and these far distant from each other. The principal cause of this concentration of the waters at a few points is, first, the frequency of rents and fissures, which act as natural drains; secondly, the existence of inequalities in the upper surface of the impermeable stratum, which lead the water, as valleys do on the external surface of a country, into certain low levels and channels.

That the generality of springs owe their supply to the atmosphere is evident from this, that they become languid, or entirely cease to flow, after long droughts, and are again replenished after a continuance of rain. Many of them are probably indebted for the constancy and uniformity of their volume to the great extent of the subterranean reservoirs with which they communicate, and the time required for these to empty themselves by percolation. Such a gradual and regulated discharge is exhibited, though in a less perfect degree, in every great lake, which is not sensibly affected in its level by sudden showers, but only slightly raised; so that its channel of efflux, instead of being swoln suddenly like the bed of a torrent, is enabled to carry off the surplus water gradually.

Much light has been thrown, of late years, on the theory of springs, by the boring of what are called by the French "Artesian wells," because the method has long been known and practised in Artois; and it is now demonstrated that there are sheets, and, in some places, currents of fresh water, at various depths in the earth. The instrument employed in excavating these wells is a large auger, and the cavity bored is usually from three to four inches in diameter. If a hard rock is met with, it is first triturated by an iron rod, and the materials, being thus reduced to small fragments or powder, are readily extracted. To hinder the sides of the well from falling in, as also to prevent the spreading of the ascending water in the surrounding soil, a jointed pipe is introduced, formed of wood in Artois, but in other countries more commonly of metal. It frequently happens that, after passing through hundreds of feet of retentive soils, a water-bearing stratum is at length pierced, when the fluid immediately ascends to the surface and flows over. The first rush of the water up the tube is often violent, so that for a time the water plays like a fountain, and then, sinking, continues to flow over tranquilly, or sometimes remains stationary at a certain depth below the orifice of the well.

This spouting of the water in the first instance is probably owing to the disengagement of air and carbonic acid gas, for both of these have been seen to bubble up with the water.*

At Sheerness, at the mouth of the Thames, a well was bored on a low tongue of land near the sea, through 300 feet of the blue clay of London, below which a bed of sand and pebbles was entered, belonging, doubtless to the plastic clay formation: when this stratum was pierced, the water burst up with impetuosity, and filled the well. By another perforation at the same place, the water was found at the depth of 328 feet, below the surface clay; it first rose rapidly to the height of 189 feet, and then, in the course of a few hours, ascended to an elevation of eight feet above the level of the ground. In 1824, a well was dug at Fulham, near the Thames, at the Bishop of London's, to the depth of 317 feet, which, after traversing the tertiary strata, was continued through 67 feet of chalk. The water immediately rose to the surface, and the discharge was above 50 gallons per minute. In the garden of the Horticultural Society at Chiswick, the borings passed through 19 feet of gravel, 242 feet of clay and loam, and 67 feet of chalk, and the water then rose to the surface from a depth of 329 feet. † At the Duke of Northumberland's, above Chiswick, the borings were carried to the extraordinary depth of 620 feet, so as to enter the chalk, when a considerable volume of water was obtained, which rose four feet above the surface of the ground. In a well of Mr. Brooks, at Hammersmith, the rush of water from a depth of 360

* Consult Héricart de Thury's work on "Puits Forés."

† Sabine, Journ. of Sci., No. 33. p. 72. 1824.

feet was so great, as to inundate several buildings ar do considerable damage; and at Tooting, a sufficie stream was obtained to turn a wheel, and raise ti water to the upper stories of the houses.* In the ca of three wells bored through the chalk, at Tours, the depth of several hundred feet, the water rose thir two feet above the level of the soil, and the discha amounted to three hundred cubic yards of water ev twenty-four hours. †

Excavations have been made in the same way to depth of eight hundred, and even twelve hundred fee France (the latter at Toulouse), and without succes A similar failure was experienced in 1830, in borin Calcutta, to the depth of more than 150 feet, thro the alluvial clay and sands of Bengal. Mr. Bri the British consul in Egypt, obtained water betw Cairo and Suez, in a calcareous sand, at the dept thirty feet; but it did not rise in the well.§ geological structure of the Sahara is supposed, by Rozet, to favour the prospect of a supply of water artesian wells, as the parched sands on the outskirt the desert rest on a substratum of argillaceous ma

The rise and overflow of the water in these we generally referred, and apparently with reason, to same principle as the play of an artificial foun Let the porous stratum, or set of strata *a a*, res the impermeable rock *d*, and be covered by ano mass of an impermeable nature. The whole mas may easily, in such a position, become saturated

* Héricart de Thury, p. 49.

† Bull. de la Soc. Géol. de France, tom. iii. p. 194.

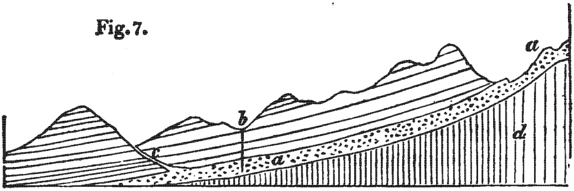
‡ Id. tom. ii. p. 272.

§ Boué, Résumé des Prog. de la Géol. en 1832, p. 184.

|| Bull. de la Soc. Géol. de France, tom. ii. p. 364.

water, which may descend from its higher and exposed parts—a hilly region to which clouds are attracted,

Fig. 7.



and where rain falls in abundance. Suppose that at some point, as at *b*, an opening be made which gives a free passage upwards to the waters confined in *a a* at so low a level that they are subjected to the pressure of a considerable column of water collected in the more elevated portion of the same stratum. The water will then rush out, just as the liquid from a large barrel which is tapped, and it will rise to a height corresponding to the level of its point of departure, or, rather, to a height, which balances the pressure previously exerted by the confined waters against the roof and sides of the stratum or reservoir *a a*. In like manner, if there happen to be a natural fissure *c*, a spring will be produced at the surface on precisely the same principle.

Among the causes of the failure of artesian wells, we may mention those numerous rents and faults which abound in some rocks, and the deep ravines and valleys by which many countries are traversed; for, when these natural lines of drainage exist, there remains a small quantity only of water to escape by artificial issues. We are also liable to be baffled by the great thickness either of porous or impervious strata, or by the dip of the beds, which may carry off the waters from adjoining high lands, to some trough in an opposite direction; as when the borings are made at the foot of an escarpment where the strata incline inwards, or in a direction opposite to the face of the cliffs.

The mere distance of hills or mountains need not discourage us from making trials; for the waters which fall on these higher lands readily penetrate to great depths through highly inclined or vertical strata, or through the fissures of shattered rocks, and after flowing for a great distance, must often re-ascend and be brought up again by other fissures, so as to approach the surface in the lower country. Here they may be concealed beneath a covering of undisturbed horizontal beds, which it may be necessary to pierce in order to reach them. It should be remembered, that the course of waters flowing under ground bears but a remote resemblance to that of rivers on the surface, there being, in the one case, a constant descent from a higher to a lower level from the source of the stream to the sea; whereas, in the other, the water may at one time sink far below the level of the ocean, and afterwards rise again high above it.

Among other curious facts ascertained by aid of the borer, it is proved that in strata of different ages and compositions there are often open passages by which the subterranean waters circulate. Thus, at St. Ouen, in France, five distinct sheets of water were intersected in a well, and from each of these a supply was obtained. In the third water-bearing stratum, at the depth of 150 feet, a cavity was found in which the borer fell suddenly about a foot, and thence the water ascended in great volume.* The same falling

* H. de Thury, p. 295.

the instrument, as in a hollow space, has been remarked in England and other countries. At Tours, in 1830, a well was perforated quite through the chalk, when the water suddenly brought up, from a depth of 364 feet, a great quantity of fine sand, with much vegetable natter and shells. Branches of a thorn several inches ong, much blackened by their stay in the water, were ecognized, as also the stems of marsh plants, and some of their roots, which were still white, together with the seeds of the same, in a state of preservation which showed that they had not remained more than three or four months in the water. Among the seeds were those of the marsh-plant *Galium uliginosum;* and among the shells, a freshwater species (*Planorbis narginatus*), and some land species, as *Helix rotundata* and *H. striata.* M. Dujardin, who, with others, observed his phenomenon, supposes that the waters had flowed from some valleys of Auvergne or the Vivarais since he preceding autumn.*

An analogous phenomenon is recorded at Riemke, near Bochum in Westphalia, where the water of an artesian well brought up, from a depth of 156 feet, several small fish, three or four inches long, the nearest streams in the country being at the distance of some eagues.†

In both cases it is evident that water had penetrated to great depths, not simply by filtering through porous mass, for then it would have left behind the hells, fish, and fragments of plants, but by flowing hrough some open channels in the earth. Such examples may suggest the idea that the leaky beds of ivers are often the feeders of springs.

* Bull. de la Soc. Géol. de France, tom. i. p. 95.

† Id. p. 248.

MINERAL AND THERMAL SPRINGS.

Almost all springs, even those which we consider the purest, are impregnated with some foreign ingredients, which, being in a state of chemical solution, are so intimately blended with the water, as not to affect its clearness, while they render it, in general, more agreeable to our taste, and more nutritious than simple rain-water. But the springs called mineral contain an unusual abundance of earthy matter in solution, and the substances with which they are impregnated correspond remarkably with those evolved in a gaseous form by volcanos. Many of these springs are thermal, and they rise up through all kinds of rock; as, for example, through granite, gneiss, limestone, or lava, but are most frequent in volcanic regions, or where violent earthquakes have occurred at eras comparatively modern.

The water given out by hot springs is generally more voluminous and less variable in quantity at different seasons than that proceeding from any others. In many volcanic regions, jets of steam, called by the Italians "stufas," issue from fissures, at a temperature high above the boiling point, as in the neighbourhood of Naples, and in the Lipari Isles, and are disengaged unceasingly for ages. Now, if such columns of steam, which are often mixed with other gases, should be condensed before reaching the surface, by coming in contact with strata filled with cold water, they may give rise to thermal and mineral springs of every degree of temperature. It is, indeed, by this means only, and not by hydrostatic pressure, that we can account for the rise of such bodies of water from great depths; nor can we hesitate to admit the adequacy of the cause, if we suppose the expansion of the same elastic fluids to be sufficient to raise columns of lava to the lofty summits of volcanic mountains. Several gases, the carbonic acid in particular, are disengaged in a free state from the soil in many districts, especially in the regions of active or extinct volcanos; and the same are found more or less intimately combined with the waters of all mineral springs, both cold and thermal. Dr. Daubeny and other writers have remarked, not only that these springs are most abundant in volcanic regions, but that when remote from them, their site usually coincides with the position of some great derangement in the strata; a fault, for example, or great fissure, indicating that a channel of communication has been opened with the interior of the earth at some former period of local convulsion.

The small area of volcanic regions may appear, at first view, an objection to this theory, but not so when we include earthquakes among the effects of igneous agency. A large proportion of the land hitherto explored by geologists can be shown to have been rent or shaken by subterranean movements since the oldest tertiary strata were formed. It will also be seen, in the sequel, that new springs have burst out, and others have had the volume of their waters augmented, and their temperature suddenly raised after earthquakes; so that the description of these springs might almost with equal propriety have been given under the head of "igneous causes," as they are agents of a mixed nature, being at once igneous and aqueous.

But how, it will be asked, can the regions of volcanic heat send forth such inexhaustible supplies of water? The difficulty of solving this problem would, in truth,

be insurmountable, if we believed that all the at
spheric waters found their way into the basin of
ocean; but in boring near the shore, we often
with streams of fresh water at the depth of se
hundred feet below the sea level; and these pro
descend, in many cases, far beneath the bottom
sea, when not artificially intercepted in their c
Yet, how much greater may be the quantity
water which sinks beneath the floor of the
through the porous strata of which it is often
posed, or through fissures rent in it by earthq
After penetrating to a considerable depth, this
may encounter a heat of sufficient intensity to c
it into vapour, even under the high pressure to
it would then be subjected. This heat woul
bably be nearest the surface in volcanic countri
farthest from it in those districts which hav
longest free from eruptions or earthquakes:
pursue this inquiry farther would lead us to
pate many topics belonging to another division
subject.

It would follow from the views above exp
that there must be a two-fold circulation of ter
waters; one caused by solar heat, and the ot
heat generated in the interior of our planet
know that the land would be unfit for vegeta
deprived of the waters raised into the atmosph
the sun; but it is also true that mineral sprin
powerful instruments in rendering the surface s
vient to the support of animal and vegetabl
Their heat is said to promote the development
aquatic tribes in many parts of the ocean, an
substances which they carry up from the bowels

earth to the habitable surface, are of a nature and in a form which adapts them peculiarly for the nutrition of animals and plants.

As these springs derive their chief importance to the geologist from the quantity and quality of the earthy materials which, like volcanos, they convey from below upwards, they may properly be considered in reference to the ingredients with which they are impregnated. These consist of almost all known substances; but the most predominant are, carbonate of lime, carbonic and sulphuric acids, iron, silica, magnesia, alumine, and salt, besides petroleum, or liquid bitumen, and its various modifications, such as mineral pitch, naptha, and asphaltum.

Calcareous springs.—Our first attention is naturally directed to springs which are highly charged with calcareous matter; for these produce a variety of phenomena of much interest in geology. It is known that rain-water has the property of dissolving the calcareous rocks over which it flows, and thus in the smallest ponds and rivulets, matter is often supplied for the earthy secretions of testacea, and for the growth of certain plants on which they feed. But many springs hold so much carbonic acid in solution, that they are enabled to dissolve a much larger quantity of calcareous matter than rain-water; and when the acid is dissipated in the atmosphere, the mineral ingredients are thrown down, in the form of tufa or travertin.*

Auvergne.—Calcareous springs, although most abundant in limestone districts, are by no means confined

* The more loose and porous rock, usually containing incrusted plants and other substances, is called tufa, the more compact, travertin. See Glossary, articles Tufa and Travertin.

to them, but flow out indiscriminately from all ro formations. In Central France, a district where t primary rocks are unusually destitute of limesto springs copiously charged with carbonate of lime i up through the granite and gneiss. Some of these thermal, and probably derive their origin from deep source of volcanic heat, once so active in region. One of these springs, at the northern ba the hill upon which Clermont is built, issues from canic peperino, which rests on granite. It has for by its incrustations, an elevated mound of traverti white concretionary limestone, 240 feet in length, at its termination, sixteen feet high and twelve Another incrusting spring in the same depart situated at Chaluzet, near Pont Gibaud, rises gneiss country, at the foot of a regular volcanic at least twenty miles from any calcareous rock. masses of tufaceous deposit, produced by this s have an oolitic texture.

Valley of the Elsa.—If we pass from the vo district of France to that which skirts the Ape in the Italian peninsula, we meet with innum springs, which have precipitated so much calc matter, that the whole ground in some pa Tuscany is coated over with travertin, and s hollow beneath the foot.

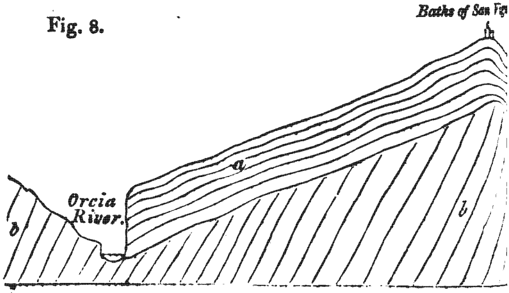
In other places in the same country, compact are seen descending the slanting sides of hills much in the manner of lava currents, except tha are of a white colour, and terminate abruptly they reach the course of a river. These con the calcareous precipitate of springs, some of still flowing, while others have disappeared or ch their position. Such masses are frequent on the of the hills which bound the valley of the Elsa, one of the tributaries of the Arno, which flows near Colle, through a valley several hundred feet deep, shaped out of a lacustrine formation, containing fossil shells of existing species. The travertin is unconformable to the lacustrine beds, and its inclination accords with the slope of the sides of the valley.

One of the finest examples which I saw, was at the Molino delle Caldane, near Colle.

The Sena, and several other small rivulets which feed the Elsa, have the property of lapidifying wood and herbs; and, in the bed of the Elsa itself, aquatic plants, such as Charæ, which absorb large quantities of carbonate of lime, are very abundant. Carbonic acid is also seen in the same valley, bubbling up from many springs, where no precipitate of tufa is observable. Targioni, who in his travels has mentioned a great number of mineral waters in Tuscany, found no difference between the deposits of cold and thermal springs. They issue sometimes from the older Apennine limestone, shale, and sandstone, while, in other places, they flow from more modern deposits; but even in the latter case, their source may probably be in or below the older series of strata.

Baths of San Vignone. — Those persons who have merely seen the action of petrifying waters in our own country, will not easily form an adequate conception of the scale on which the same process is exhibited in those regions which lie nearer to the active centres of volcanic disturbance. One of the most striking examples of the rapid precipitation of carbonate of lime from thermal waters occurs in the hill of San Vignone in Tuscany, at a short distance from Radicofani, and only a few hundred yards from the high road between Sienna and Rome. The spring issues from near the summit of a rocky hill, about 100 feet in height. The top of the hill is flat, and stretches in a gently inclined platform to the foot of Mount Amiata, a lofty eminence, which consists in great part of volcanic products. The fundamental rock, from which the spring issues, is a black slate, with serpentine (*b b*, Fig. 8.), belonging to the older Apennine formation. The water is hot, has a strong taste, a

Fig. 8.



Section of Travertin, San Vignone.

when not in very small quantity, is of a bright g colour. So rapid is the deposition near the sou that in the bottom of a conduit-pipe for carrying off water to the baths, and which is inclined at an a of 30°, half a foot of solid travertin is formed e year. A more compact rock is produced where water flows slowly, and the precipitation in wi when there is least evaporation, is said to be solid, but less in quantity by one fourth, tha summer. The rock is generally white; some par it are compact, and ring to the hammer; others cellular, and with such cavities as are seen in carious part of bone or the siliceous millstone of Paris basin. A portion of it also below the villag

San Vignone consists of incrustations of long vegetable tubes, and may be called tufa. Sometimes the travertin assumes precisely the botryoidal and mammillary forms, common to similar deposits in Auvergne, of a much older date, hereafter to be mentioned; and, like them, it often scales off in thin, slightly undulating layers.

A large mass of travertin (*c*, Fig. 8.) descends the hill from the point where the spring issues, and reaches to the distance of about half a mile east of San Vignone. The beds take the slope of the hill at about an angle of 6°, and the planes of stratification are perfectly parallel. One stratum, composed of many layers, is of a compact nature, and fifteen feet thick; it serves as an excellent building stone, and a mass of fifteen feet in length was, in 1828, cut out for the new bridge over the Orcia. Another branch of it (*a*, Fig. 8.) descends to the west, for 250 feet in length, of varying thickness, but sometimes 200 feet deep: it is then cut off by the small river Orcia, precisely as some glaciers in Switzerland descend into a valley till their progress is suddenly arrested by a transverse stream of water.

The abrupt termination of the mass of rock at the river, when its thickness is undiminished, clearly shows that it would proceed much farther if not arrested by the stream, over which it impends slightly. But it cannot encroach upon the channel of the Orcia being constantly undermined, so that its solid fragments are seen strewed amongst the alluvial gravel. However enormous, therefore, the mass of solid rock may appear which has been given out by this single spring, we may feel assured that it is insignificant in volume when compared to that which has been carried to the sea since the time when it began to flow. What may have been the length of that period of time, we have no data for conjecturing. In quarrying the traver Roman tiles have been sometimes found at the de of five or six feet.

Baths of San Filippo. — On another hill, not m miles from that last mentioned, and also conne with Mount Amiata, the summit of which is a three miles distant, are the celebrated baths of Filippo. The subjacent rocks consist of alterna of black slate, limestone, and serpentine, of h inclined strata, belonging to the Apennine form and, as at San Vignone, near the boundary of a te basin of marine origin, consisting chiefly of blue laceous marl. There are three warm springs containing carbonate and sulphate of lime, an phate of magnesia. The water which suppli bath falls into a pond, where it has been kno deposit a solid mass *thirty feet thick*, in about *years.** A manufactory of medallions in basso-r is carried on at these baths. The water is con by canals into several pits, in which it deposi vertin and crystals of sulphate of lime. After thus freed from its grosser parts, it is conveye tube to the summit of a small chamber, and ma fall through a space of ten or twelve feet. Th rent is broken in its descent by numerous cr sticks, by which the spray is dispersed around certain moulds, which are rubbed lightly over w solution of soap, and a deposition of solid matte marble is the result, yielding a beautiful cast o figures formed in the mould.† The geologist

* Dr. Grosse on the Baths of San Filippo. Ed. Phil. vol. ii. p. 292.

† Id. p. 297.

derive from these experiments considerable light, in regard to the high inclination at which some semi-crystalline precipitations can be formed; for some of the moulds are disposed almost perpendicularly, yet the deposition is nearly equal in all parts.

A hard stratum of stone, about a foot in thickness, is obtained from the waters of San Filippo in four months; and, as the springs are powerful, and almost uniform in the quantity given out, we are at no loss to comprehend the magnitude of the mass which descends the hill, which is a mile and a quarter in length and the third of a mile in breadth, in some places attaining a thickness of 250 feet at least. To what length it might have reached it is impossible to conjecture, as it is cut off, like the travertin of San Vignone, by a small stream, where it terminates abruptly. The remainder of the matter held in solution is carried on probably to the sea.

Spheroidal structure in travertin.—But what renders this recent limestone of peculiar interest to the geologist, is the spheroidal form which it assumes, analogous to that of the cascade of Tivoli, afterwards to be described. The lamination of some of the concentric masses is so minute that sixty may be counted in the thickness of an inch, yet, notwithstanding these marks of gradual and successive deposition, sections are sometimes exhibited of what might seem to be perfect spheres. This tendency to a mammillary and globular structure arises from the facility with which the calcareous matter is precipitated in nearly equal quantities on all sides of any fragment of shell or wood, or any inequality of the surface over which the mineral water flows, the form of the nucleus being readily transmitted through any number of successive envelopes. But these masses can never be perfect sphe although they often appear such when a transve section is made in any line not in the direction of point of attachment. There are, indeed, occasion seen small oolitic and pisolitic grains, of which form is globular; for the nucleus, having been for a in motion in the water, has received fresh accessio matter on all sides.

In the same manner I have seen, on the ve walls of large steam boilers, the heads of na rivets covered by a series of enveloping crus calcareous matter, usually sulphate of lime; so t concretionary nodule is formed, preserving a r globular shape, when increased to a mass s inches in diameter. In these, as in many trav there is often a combination of the concentri radiated structure, and the last-mentioned cha is one of those in which the English magnesian stone agrees with the Italian travertins.

Another point of resemblance between these in other respects so dissimilar, is the interferen one sphere with another, and the occasional occu of cavities and vacuities, constituting what has called a honeycombed structure, and also the fre interposition of loose incoherent matter, betwee ferent solid spheroidal concretions. Yet, not standing such points of analogy, Professor Sedg observes, that there are proofs of the concreti arrangement in the magnesian limestone having t place subsequently to original deposition, for in case the spheroidal forms are often quite indepen of the direction of the laminæ.*

* Geol. Trans. 2nd series, vol. iii. p. 37. I have lately some specimens of spheroidal magnesian limestone, collect

Bulicami of Viterbo.—I must not attempt to describe all the places in Italy where the constant formation of limestone may be seen, as on the Silaro, near Pæstum, on the Velino at Terni, and near the Bulicami, or hot baths in the vicinity of Viterbo. About a mile and a half north of the latter town, in the midst of a sterile plain of volcanic sand and ashes, a monticule is seen, about twenty feet high and five hundred yards in circumference, entirely composed of concretionary travertin. The laminæ are very thin, and their minute undulations so arranged, that the whole mass has at once a concentric and radiated structure. This rock has been largely quarried for lime, and much of it appears to have been removed. It has evidently been formed gradually, like the conical mounds of the geysers in Iceland, by a small jet or fountain of calcareous water, which overflowed from the summit of the monticule. A spring of hot water still issues in the neighbourhood, which is conveyed to an open tank used as a bath, the bottom and sides of which, as well as the open conduit which conveys the water, are encrusted with travertin.

Professor Sedgwick, where the calcareous laminæ are intersected at a high angle by the boundary line of the globule of which they form a part. In a former edition I stated, that on visiting Sunderland immediately after examining the travertins of Auvergne and Sicily (the former of lacustrine, the latter of submarine origin), I recognized a striking degree of identity in the prevailing concretionary forms assumed by our magnesian limestone and those of the travertins with the appearance of which my eye was then familiar. I am still convinced that much light would be thrown on the mode of formation of both these rocks by a comparison of the points in which they mutually agree with or differ from each other.

Campagna di Roma.—The country around Ro like many parts of the Tuscan States already refer to, has been at some former period the site of numer volcanic eruptions; and the springs are still copio impregnated with lime, carbonic acid, and sulphure hydrogen. A hot spring has lately been discov near Civita Vecchia, by Signor Riccioli, which dep alternate beds of a yellowish travertin, and a w granular rock, not distinguishable, in hand specin either in grain, colour, or composition, from stat marble. There is a passage between this and ordi travertin. The mass accumulated near the spring some places about six feet thick.

Lake of the Solfatara.—In the Campagna, bet Rome and Tivoli, is the lake of the Solfatara, c also Lago di Zolfo (lacus albula), into which flows tinually a stream of tepid water, from a smalle situated a few yards above it. The water is a satu solution of carbonic acid gas, which escapes from such quantities in some parts of its surface, that the appearance of being actually in ebullition. "I found by experiment," says Sir Humphry Davy, " the water taken from the most tranquil part o lake, even after being agitated and exposed to th contained in solution more than its own volume o bonic acid gas, with a very small quantity of su retted hydrogen. Its high temperature, which is p constant at 80° of Fahr., and the quantity of car acid that it contains, render it peculiarly fitted to a nourishment to vegetable life. The banks of trav are every where covered with reeds, lichen, conf and various kinds of aquatic vegetables; and a same time that the process of vegetable life is g on, the crystallizations of the calcareous matter, w is every where deposited, in consequence of the escape of carbonic acid, likewise proceed.—There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life."*

The same observer informs us, that he fixed a stick in a mass of travertin covered by the water in the month of May, and in April following he had some difficulty in breaking, with a sharp-pointed hammer, the mass which adhered to the stick, and which was several inches in thickness. The upper part was a mixture of light tufa and the leaves of confervæ: below this was a darker and more solid travertin, containing black and decomposed masses of confervæ; in the inferior part the travertin was more solid, and of a grey colour, but with cavities probably produced by the decomposition of vegetable matter.†

The stream which flows out of this lake fills a canal about nine feet broad and four deep, and is conspicuous in the landscape by a line of vapour which rises from it. It deposits calcareous tufa in this channel, and the Tiber probably receives from it, as well as from numerous other streams, much carbonate of lime in solution, which may contribute to the rapid growth of its delta. A large proportion of the most splendid edifices of ancient and modern Rome are built of travertin, derived from the quarries of Ponte Leucano, where there has evidently been a lake at a remote period, on the same plain as that already described. But the consideration of these would carry us beyond the

* Consolations in Travel, pp. 123—125.

† Id. p. 127.

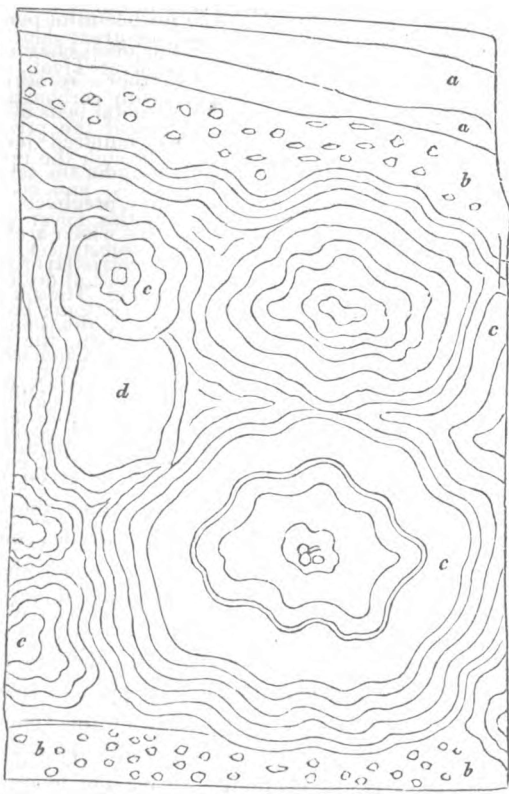
times of history, and I shall conclude with one n
example of the calcareous deposits of this neighb
hood,—those on the Anio.

Travertin of Tivoli.—The waters of the
incrust the reeds which grow on its banks, and
foam of the cataract of Tivoli forms beautiful pe
stalactites; but, on the sides of the deep chasm
which the cascade throws itself, there is see
extraordinary accumulation of horizontal beds of
and travertin, from four to five hundred fe
thickness. The section immediately under the te
of Vesta and the Sibyl, displays, in a precipice
four hundred feet high, some spheroids which are
six to eight feet in diameter, each concentric layer
about the eighth of an inch in thickness. The an
diagram exhibits about fourteen feet of this im
mass, as seen in the path cut out of the rock in de
ing from the temple of Vesta to the Grotto di N
I have not attempted to express in this drawi
innumerable thin layers of which these magi
spheroids are composed, but the lines given
some of the natural divisions into which the
separated by minute variations in the size or co
the laminæ. The undulations also are much s
in proportion to the whole circumference, than
drawing. The beds *a a* are of hard travertin a
tufa; below them is a pisolite (*b*), the globules
of different sizes: underneath this appears a m
concretionary travertin (*c c*), some of the sph
being of the above-mentioned extraordinary siz
some places (as at *d*) there is a mass of amor
limestone, or tufa, surrounded by concentric l
At the bottom is another bed of pisolite (*b*), in
the small nodules are about the size and sha

beans, and some of them of filberts, intermixed with some smaller oolitic grains. In the tufaceous strata, wood is seen converted into a light tufa.

The following seems the most probable explanation

Fig. 9.



Section of Spheroidal Concretionary Travertin under the Cascade of Tivoli.

of the origin of the rock in this singular position. The Anio flows through a deep irregular fissure or gorge in the Apennine limestone, which may have been caused by earthquakes. In this deep narrow channel there existed many small lakes, three of which have been destroyed since the time of history, by the erosive action of the torrent, the last of them having remained down to the sixth century of our era.

We may suppose a similar lake of great depth to have existed at some remote period at Tivoli, and that, into this, the waters, charged with carbonate of lime, fell from a height inferior to that of the present cascade. Having, in their passage through the upper lakes, parted with their sand, pebbles, and coarse sediment, they only introduced into this lower pool drift-wood, leaves, and other buoyant substances. In seasons when the water was low, a deposit of ordinary tufa, or of travertin, formed along the bottom; but at other times, when the torrent was swollen, the pool must have been greatly agitated, and every small particle of carbonate of lime which was precipitated must have been whirled round again and again in various eddies, until it acquired many concentric coats, so as to resemble oolitic grains. If the violence of the motion be sufficient to cause the globule to be suspended for a sufficient length of time, it would grow to the size of a pea, or much larger. Small fragments of vegetable stems being incrusted on the sides of the stream, and then washed in, would form the nucleus of oval globules, and others of irregular shapes would be produced by the resting of fragments for a time on the bottom of the basin, where, after acquiring an unequal thickness of travertin on one side, they would again be set in motion. Sometimes globules, projecting above the general level of a stratum, would attract, by chemical affinity, other matter in the act of precipitation, and thus growing on all sides, with the exception of the point of contact, might at length form spheroids nearly perfect and many feet in diameter. Masses might increase above and below, so that a vertical section might afterwards present the phenomenon so common at Tivoli, where the nucleus of some of the concentric circles has the appearance of having been suspended, without support, in the water, until it became a spheroidal mass of great dimensions.

It is probable that the date of the greater portion of this calcareous formation may be anterior to the era of history, for we know that there was a great cascade at Tivoli in very ancient times; but, in the upper part of the travertin, is shown the hollow left by a wheel, in which the outer circle and the spokes have been decomposed, and the spaces which they filled have been left void. It seems impossible to explain the position of this mould, without supposing that the wheel was imbedded before the lake was drained.

Calcareous springs in the Caucasus. — Pallas, in his journey along the Caucasus, a country now subject, from time to time, to be rent and fissured by violent earthquakes, enumerates a great many hot springs, which have deposited monticules of travertin precisely analogous in composition and structure to those of the baths of San Filippo and other localities in Italy. When speaking of the tophus-stone, as he terms these limestones, he often observes that it is *snow-white*, a description which is very applicable to the newer part of the deposit at San Filippo, where it has not become darkened by weathering. In many localities in the regions between the Caspian and Black Seas, where subterranean convulsions are frequent, travellers mention calc-sinter as an abundant product of hot springs. Near the shores of the Lake Urmia (or Maragha), for example, a marble which is much used in ornamental architecture is rapidly deposited by a thermal spring.*

It is probable that the zoophytic and shelly limestones, which constitute the coral reefs of the Indian and Pacific Oceans, are supplied with carbonate of lime and other mineral ingredients from submarine springs, and that their heat, as well as their earthy and gaseous contents, may promote the development of corals, sponges, and testacea, just as vegetation is quickened by similar causes in the lake of the Solfatara before described. But of these reefs and their probable origin I shall again have occasion to speak in the third book.

Sulphureous and gypseous springs.—The quantity of other mineral ingredients wherewith springs in general are impregnated, is insignificant in comparison to lime, and this earth is most frequently combined with carbonic acid. But, as sulphuric acid and sulphuretted hydrogen are very frequently supplied by springs, gypsum may, perhaps, be deposited largely in certain seas and lakes. The gypseous precipitates, however, hitherto known on the land, appear to be confined to a very few springs. Those at Baden, near Vienna, which feed the public bath, may be cited as examples. Some of these supply, singly, from 600 to 1000 cubic feet of water per hour, and deposit a fine powder, composed

* Hoff, Geschichte, &c. vol. ii. p. 114.

of a mixture of sulphate of lime, with sulphur and muriate of lime.*

Siliceous springs. — *Azores.* — In order that water should hold a very large quantity of silica in solution, it seems necessary that it should be raised to a high temperature †; and as it may retain a greater heat under the pressure of the sea than in the atmosphere, submarine springs may, perhaps, be more charged with silex than any to which we have access. The hot springs of the Valle das Furnas, in the Island of St. Michael, rising through volcanic rocks, precipitate vast quantities of siliceous sinter, as it is usually termed. Around the circular basin of the largest spring, called "the Caldeira," which is between twenty and thirty feet in diameter, alternate layers are seen of a coarser variety of sinter mixed with clay, including grass, ferns, and reeds, in different states of petrifaction. Wherever the water has flowed, sinter is found rising in some places eight or ten inches above the ordinary level of the stream. The herbage and leaves, more or less incrusted with silex, are said to exhibit all the successive steps of petrifaction, from the soft state to a complete conversion into stone; but in some instances, alumina, which is likewise deposited from the hot waters, is the mineralizing material. Branches of the same ferns which now flourish in the island are found completely petrified, preserving the same appearance as when vegetating, except that they acquire an ash-gray colour. Fragments of wood, and one entire bed from three to five feet in depth, com-

* C. Prevost, Essai sur la Constitution Physique du Bassin de Vienne, p. 10.

† Daubeny on Volcanos, p. 222.

posed of reeds now common in the island, have become completely mineralized.

The most abundant variety of siliceous sinter occurs in layers from a quarter to half an inch in thickness accumulated on each other often to the height of a foot and upwards, and constituting parallel, and for the most part horizontal, strata many yards in extent. This sinter has often a beautiful semi-opalescent lustre. One of the varieties differs from that of Iceland and Ischia in the larger proportion of water it contains, and in the absence of alumina and lime. A recent breccia is also in the act of forming, composed of obsidian, pumice, and scoriæ, cemented by siliceous sinter.*

Geysers of Iceland. — But the hot springs in various parts of Iceland, particularly the celebrated geysers, afford the most remarkable example of the deposition of silex.† The circular reservoirs into which the geysers fall, are filled in the middle with a variety of opal, and round the edges with sinter. The plants incrusted with the latter substance have much the same appearance as those incrusted with calcareous tufa in our own country.

In some of the thermal waters of Iceland a vesicular rock is formed, containing portions of vegetables more or less completely silicified; and amongst other products of springs in this island, is that admixture of clay and silica, called tripoli.

By analysis of the water, Mr. Faraday has ascertained that the solution of the silex is promoted by the presence of the alkali, soda. He suggests that the deposition of silica in an insoluble state takes

* Dr. Webster on the Hot Springs of Furnas, Ed. Phil. Journ., vol. vi. p. 306.

† See a cut of the Icelandic geyser, Book II. chap. 19.

place partly because the water when cooled by exposure to the air is unable to retain as much silica as when it issues from the earth at a temperature of 180° or 190° Fahr.; and partly because the evaporation of the water decomposes the compound of silica and soda which previously existed. This last change is probably hastened by the carbonic acid of the atmosphere uniting with the soda. The alkali, when disunited from the silica, would readily be dissolved in and removed by running water.*

Ischia. — It has been found, by recent analysis, that several of the thermal waters of Ischia are impregnated with a certain proportion of silica. Some of the hot vapours of that island are above the temperature of boiling water: and many fissures, near Monte Vico, through which the hot steam passes, are coated with a siliceous incrustation, first noticed by Dr. Thompson under the name of fiorite.

Ava, &c.—It has been often stated that the Danube has converted the external part of the piles of Trajan's bridge into silex; the Irawadi, in Ava, has been supposed, ever since the time of the Jesuit Padre Duchatz, to have the same petrifying power, as also Lough Neagh, in Ireland. Modern researches, however, in the Burman empire, have thrown doubt upon the lapidifying property of the Ava river†; there is certainly no foundation for the story in regard to Lough Neagh, and probably none in regard to the Danube.

Mineral waters, even when charged with a small proportion of silica, as those of Ischia, may supply certain species of corals and sponges with matter for

* Barrow's Iceland, p. 209.

† Dr. Buckland, Geol. Trans., second series, vol. ii. part iii. p. 384.

their siliceous secretions; but when in a volca archipelago, or a region of submarine volcanos, th are springs so saturated with silica as those of Icel or the Azores, we may expect layers and nodule silex and chert to be spread out far and wide the bed of the sea, and interstratified with shelly calcareous deposits, which may be forming there with matter derived from wasting cliffs or volc ejections.

Ferruginous springs.—The waters of almost springs contain some iron in solution; and it is a familiar to all, that many of them are so copio impregnated with this metal, as to stain the rock herbage through which they pass, and to bind toge sand and gravel into solid masses. We may natur then, conclude that this iron, which is constantly veyed from the interior of the earth into lakes and and which does not escape again from them into atmosphere by evaporation, must act as a colou and cementing principle in the subaqueous dep now in progress. It will be afterwards seen that m sandstones and other rocks in the sedimentary strat ancient lakes and seas are bound together or colou by iron, and this fact presents us with a striking p of analogy between the state of things at very differ epochs. In those older formations we meet with g abundance of carbonate and sulphate of iron; and chalybeate waters at present, this metal is most quently in the state of a carbonate, as in those of T bridge, for example. Sulphuric acid, however, is of the solvent, which is in many cases derived from t decomposition of pyrites.

Brine springs.—*Cheshire.*—So great is the qua tity of muriate of soda in some springs, that they yi one fourth of their weight in salt. They are rarely, however, so saturated, and generally contain, intermixed with salt, carbonate and sulphate of lime, magnesia, and other mineral ingredients. The brine springs of Cheshire are the richest in our country; those of Barton and Northwich being almost fully saturated. These brine springs rise up through strata of sandstone and red marl, which contain large beds of rock salt. The origin of the brine, therefore, may be derived in this and many other instances from beds of fossil salt; but as muriate of soda is one of the products of volcanic emanations and of springs in volcanic regions, the original source of salt may be as deep seated as that of lava.

Dead Sea. — The waters of the Dead Sea contain scarcely any thing except muriatic salts, which lends countenance, observes Dr. Daubeny, to the volcanic origin of the surrounding country, these salts being frequent products of volcanic eruptions. Many springs in Sicily contain muriate of soda, and the "fiume salso," in particular, is impregnated with so large a quantity, that cattle refuse to drink of it.

Auvergne.—A hot spring, rising through granite, at Saint Nectaire, in Auvergne, may be mentioned as one of many, containing a large proportion of muriate of soda, together with magnesia and other ingredients.*

Carbonated springs. — *Auvergne.* — Carbonic acid gas is very plentifully disengaged from springs in almost all countries, but particularly near active or extinct volcanos. This elastic fluid has the property of decomposing many of the hardest rocks with which it comes in contact, particularly that numerous class

* Annales de l'Auvergne, tome i. p. 234.

in whose composition felspar is an ingredient. It renders the oxide of iron soluble in water, and contributes, as was before stated, to the solution of calcareous matter. In volcanic districts these gaseous emanations are not confined to springs, but rise up in the state of pure gas from the soil in various places. The Grotto del Cane, near Naples, affords an example, and prodigious quantities are now annually disengaged from every part of the Limagne d'Auvergne, where it appears to have been developed in equal quantity from time immemorial. As the acid is invisible, it is not observed, except an excavation be made, wherein it immediately accumulates, so that it will extinguish a candle. There are some springs in this district, where the water is seen bubbling and boiling up with much noise, in consequence of the abundant disengagement of this gas. The whole vegetation is affected, and many trees, such as the walnut, flourish more luxuriantly than they would otherwise do in the same soil and climate — the leaves probably absorbing carbonic acid. This gas is found in springs rising through the granite near Clermont, as well as in the tertiary limestones of the Limagne.* In the environs of Pont-Gibaud, not far from Clermont, a rock belonging to the gneiss formation, in which lead-mines are worked, has been found to be quite saturated with carbonic acid gas, which is constantly disengaged. The carbonates of iron, lime, and manganese are so dissolved, that the rock is rendered soft, and the quartz alone remains unattacked.† Not far off is the small volcanic cone of Chaluzet, which once broke up through the gneiss, and sent forth a lava-stream.

* Le Coq, Annales de l'Auvergne, tome i. p. 217. May, 1828.

† Ann. Scient. de l'Auvergne, tome ii. June, 1829.

Disintegration of granite.—The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighbourhood of Clermont. This decay was called by Dolomieu, "la maladie du granite;" and the rock may with propriety be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures.

In the plains of the Po, between Verona and Parma, especially at Villa Franca, south of Mantua, I observed great beds of alluvium, consisting chiefly of primary pebbles, percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are for the most part incrusted with calc-sinter: and the rounded blocks of gneiss, which have all the outward appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces.

The subtraction of many of the elements of rocks by the solvent power of carbonic acid, ascending both in a gaseous state and mixed with spring-water in the crevices of rocks, must be one of the most powerful sources of those internal changes and re-arrangements of particles so often observed in strata of every age. The calcareous matter, for example, of shells is often entirely removed and replaced by carbonate of iron, pyrites, silex, or some other ingredient, such as mineral waters usually contain in solution. It rarely happens, except in limestone rocks, that the carbonic acid can dissolve all the constituent parts of the mass; and for this reason, probably, calcareous rocks are almost the only ones in which great caverns and long winding passages are found.

Petroleum springs.—Springs impregnated with petroleum, and the various minerals allied to it, as bitumen, naphtha, asphaltum, and pitch, are very numerous, and are, in many cases, undoubtedly connected with subterranean fires, which raise or sublime the more subtle parts of the bituminous matters contained in rocks. Many springs in the territory of Modena and Parma, in Italy, produce petroleum in abundance; but the most powerful, perhaps, yet known, are those on the Irawadi, in the Burman empire. In one locality there are said to be 520 wells, which yield annually 400,000 hogsheads of petroleum.*

Fluid bitumen is seen to ooze from the bottom of the sea, on both sides of the island of Trinidad, and to rise up to the surface of the water. Near Cape Braye there is a vortex which, in stormy weather, according to Captain Mallet, gushes out, raising the water five or six feet, and covers the surface for a considerable space with petroleum, or tar; and the same author quotes Gumilla, as stating in his "Description of the Orinoco," that, about seventy years ago, a spot of land on the western coast of Trinidad, near half way between the capital and an Indian village, sank suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants.†

Pitch lake of Trinidad.—It is probable that the great pitch lake of Trinidad owes its origin to a similar cause; and Dr. Nugent has justly remarked that in that district all the circumstances are now combined from which deposits of pitch may have originated. The Orinoco has for ages been rolling down great quantities of woody and vegetable bodies

* Symes, Embassy to Ava, vol. ii. — Geol. Trans., second series, vol. ii. part iii. p. 388.

† Dr. Nugent, Geol. Trans. vol. i. p. 69.

into the surrounding sea, where, by the influence of currents and eddies, they may be arrested and accumulated in particular places. The frequent occurrence of earthquakes and other indications of volcanic action in those parts lends countenance to the opinion, that these vegetable substances may have undergone, by the agency of subterranean fire, those transformations and chemical changes which produce petroleum, and this may, by the same causes, be forced up to the surface, where, by exposure to the air, it becomes inspissated, and forms the different varieties of pure and earthy pitch, or asphaltum, so abundant in the island.*

The bituminous shales, so common in geological formations of different ages, as also many stratified deposits of bitumen and pitch, seem clearly to attest that, at former periods, springs, in various parts of the world, were as commonly impregnated as now with bituminous matter, carried down, probably, by rivers into lakes and seas. It will, indeed, be easy to show, that a large portion of the finer particles and the more crystalline substances found in sedimentary rocks of different ages are composed of the same elements as are now held in solution by springs, while the coarser materials bear an equally strong resemblance to the alluvial matter in the beds of existing torrents and rivers.

* Dr. Nugent, Geol. Trans. vol. i. p. 67.

CHAPTER IV.

REPRODUCTIVE EFFECTS OF RUNNING WATER.

Reproductive effects of running water — Division of Deltas lacustrine, mediterranean, and oceanic — Lake deltas — Gr of the delta of the Upper Rhone in the Lake of Gene Chronological computations of the age of deltas — R deposits in Lake Superior (p. 338.) — Deltas of inland se Rapid shallowing of the Baltic — Marine delta of the R (p. 341.) — Various proofs of its increase — Stony nature deposits — Delta of the Po, Adige, Isonzo, and other entering the Adriatic — Rapid conversion of that gulf int — Mineral characters of the new deposits — Delta of th (p. 349.) — Its increase since the time of Homer — Its g why checked at present.

HAVING considered the destroying and transpo agency of running water, we have now to examine reproductive effects of the same cause. The ag gate amount of deposits accumulated in a given at the mouths of rivers, where they enter a lak sea, affords clearer data for estimating the energ the excavating power of running water on the l than the separate study of the operations of the s cause in the countless ramifications into which e great system of valleys is divided. I shall there proceed to select some of the leading facts at pre ascertained respecting the growth of deltas, and s then offer some general observations on the quan of sediment transported by rivers, and the manne its distribution beneath the waters of lakes and sea

Division of deltas into lacustrine, mediterranean, and oceanic.—Deltas may be divided into, first, those which are formed in lakes; secondly, those in inland seas; and thirdly, those on the borders of the ocean. The most characteristic distinction between the lacustrine and marine deltas consists in the nature of the organic remains which become imbedded in their deposits; for, in the case of a lake, it is obvious that these must consist exclusively of such genera of animals as inhabit the land or the waters of a river or lake; whereas, in the other case, there will be an admixture and most frequently a predominance of animals which inhabit salt water. In regard, however, to the distribution of inorganic matter, the deposits of lakes and inland seas are formed under very analogous circumstances, and may be distinguished from those on the shores of the great ocean, where the tides cooperating with currents give rise to another class of phenomena. In lakes and inland seas, even of the largest dimensions, the tides are almost insensible, but the currents, as will afterwards appear, sometimes run with considerable velocity.

DELTAS IN LAKES.

Lake of Geneva.—It is natural to begin our examination with an inquiry into the new deposits in lakes, as they exemplify the first reproductive operations in which rivers are engaged when they convey the detritus of rocks and the ingredients of mineral springs from mountainous regions. The accession of new land at the mouth of the Rhone, at the upper end of the Lake of Geneva, or the Leman Lake, presents us with an example of a considerable thickness of strata which have accumulated since the historical era. This of water is about thirty-seven miles long, and its br is from two to eight miles. The shape of the b is very irregular, the depth having been found, b measurements, to vary from 20 to 160 fathoms.* Rhone, where it enters at the upper end, is turb discoloured; but its waters, where it issues at th of Geneva, are beautifully clear and transparen ancient town, called Port Vallais, (Portus Val the Romans,) once situated at the water's edge, upper end, is now more than a mile and a half —this intervening alluvial tract having been a in about eight centuries. The remainder of th consists of a flat alluvial plain, about five or si in length, composed of sand and mud, a little above the level of the river, and full of marshe

Mr. De la Beche found, after numerous so in all parts of the lake, that there was a pretty depth of from 120 to 160 fathoms throughout t tral region, and, on approaching the delta, th lowing of the bottom began to be very sensil distance of about a mile and three quarters fr mouth of the Rhone; for a line drawn from S goulph to Vevey, gives a mean depth of somew than six hundred feet, and from that part to the the fluviatile mud is always found along the bo We may state, therefore, that the strata annual duced are about two miles in length: so that, n standing the great depth of the lake, the new d are not inclined at a high angle; the dip of th indeed, is so slight, that they would be termed, i nary geological language, horizontal.

* De la Beche, Ed. Phil. Journ. vol. ii. p. 107. Jan.

† De la Beche, MS.

The strata probably consist of alternations of finer and coarser particles; for, during the hotter months from April to August, when the snows melt, the volume and velocity of the river are greatest, and large quantities of sand, mud, vegetable matter, and drift-wood are introduced; but, during the rest of the year, the influx is comparatively feeble, so much so, that the whole lake, according to Saussure, stands six feet lower. If, then, we could obtain a section of the accumulation formed in the last eight centuries, we should see a great series of strata, probably from 600 to 900 feet thick, and nearly two miles in length, inclined at a very slight angle. In the mean time, a great number of smaller deltas are growing around the borders of the lake, at the mouths of rapid torrents, which pour in large masses of sand and pebbles. The body of water in these torrents is too small to enable them to spread out the transported matter over so extensive an area as the Rhone does. Thus, for example, there is a depth of eighty fathoms within half a mile of the shore, immediately opposite the great torrent which enters east of Ripaille, so that the dip of the strata in that minor delta must be about four times as great as those deposited by the main river at the upper extremity of the lake.*

Chronological computations of the age of deltas.— The capacity of this basin being now ascertained, it would be an interesting subject of inquiry, to determine in what number of years the Leman Lake will be converted into dry land. It would not be very difficult to obtain the elements for such a calculation, so as to approximate at least to the quantity of time required

* De la Beche, MS.

for the accomplishment of the result. The number cubic feet of water annually discharged by the riv into the lake being estimated, experiments might made in the winter and summer months, to determi the proportion of matter held in suspension or in c mical solution by the Rhone. It would be also nec sary to allow for the heavier matter drifted along at bottom, which might be estimated on hydrostat principles, when the average size of the gravel and volume and velocity of the stream at different sea were known. Supposing all these observations to l been made, it would be more easy to calculate the ture than the former progress of the delta, becau would be a laborious task to ascertain, with any gree of precision, the original depth and extent of part of the lake which is already filled up. Even i information were actually obtained by borings, it only enable us to approximate within a certain n of centuries to the time when the Rhone began to its present delta; but this would not give us the of the origin of the Leman Lake in its present because the river may have flowed into it for thous of years, without importing any sediment what Such would have been the case, if the waters had passed through a chain of upper lakes; and that was actually the fact, is indicated by the course o Rhone between Martigny and the Lake of Geneva still more decidedly, by the channels of many principal feeders.

If we ascend, for example, the valley through w the Dranse flows, we find that it consists of a succe of basins, one above the other, in each of which is a wide expanse of flat alluvial lands, separated the next basin by a rocky gorge, once evidently barrier of a lake. The river has filled these lakes, one after the other, and has partially cut through the barriers, which it is still gradually eroding to a greater depth. The examination of almost all valleys in mountainous districts affords similar proofs of the obliteration of a series of lakes, by the filling up of hollows and the cutting through of rocky barriers — a process by which running water ever labours to produce a more uniform declivity. Before, therefore, we can pretend even to hazard a conjecture as to the era at which any particular delta commenced, we must be thoroughly acquainted with the geographical features and geological history of the whole system of higher valleys which communicate with the main stream, and all the changes which they have undergone since the last series of convulsions which agitated and altered the face of the country.

The probability, therefore, of error in our chronological computations where we omit to pay due attention to these circumstances, increases in proportion to the time that may have elapsed since the last disturbance of the country by subterranean movements, and in proportion to the extent of the hydrographical basin on which we may happen to speculate. The Alpine rivers of Vallais are prevented at present from contributing their sedimentary contingent to the lower delta of the Rhone in the Mediterranean, because they are intercepted by the Leman Lake; but when this is filled, they will transport as much, or nearly as much, matter to the sea, as they now pour into that lake. They will then flow through a long, flat, alluvial plain, between Villeneuve and Geneva, from two to eight miles in breadth, which will present no superficial marks of the existence of a thickness of more than one thousand

feet of recent sediment below. Many hundred all
tracts of equal, and some of much greater area,
be seen if we follow up the Rhone from its termin
in the Mediterranean, or explore the valleys of
of its principal tributaries.

What, then, shall we think of the presumption
Luc, Kirwan, and their followers, who confiden
duced from the phenomena of modern deltas the
origin of the present form of our continents, w
pretending to have collected any one of the nu
data by which so complicated a problem can be
Had they, after making all the necessary investi
succeeded in proving, as they desired, that th
delta of the Rhone, and the new deposits
mouths of several other rivers, whether in lakes
had required about four thousand years to att
present dimensions, the conclusion would ha
fatal to the chronological theories which th
anxious to confirm.

Lake Superior.—Lake Superior is the larg
of fresh water in the world, being about 150(
phical miles in circumference when we fo
sinuosities of its coasts, and its length, on
line drawn through its centre, being about
its extreme breadth 140 geographical miles.
rage depth varies from 80 to 150 fathoms;
cording to Captain Bayfield, there is reason
that its greatest depth would not be overrat
hundred fathoms *, so that its bottom is, in so
nearly six hundred feet below the level of the
its surface about as much above it. There ar
ances in different parts of this, as of the other

* Trans. of Lit. and Hist. Soc. of Quebec, vol. ii. p

lakes, leading us to infer that its waters formerly occupied a much higher level than they reach at present; for at a considerable distance from the present shores, parallel lines of rolled stones and shells are seen rising one above the other, like the seats of an amphitheatre. These ancient lines of shingle are exactly similar to the present beaches in most bays, and they often attain an elevation of forty or fifty feet above the present level.

As the heaviest gales of wind do not raise the waters more than three or four feet*, the elevated beaches must either be referred to the subsidence of the lake at former periods, in consequence of the wearing down of its barrier, or to the upraising of the shores by earthquakes, like those which have produced similar phenomena on the coast of Chili. The streams which discharge their waters into Lake Superior are several hundred in number, without reckoning those of smaller size; and the quantity of water supplied by them is many times greater than that discharged at the Falls of St. Mary, the only outlet. The evaporation, therefore, is very great, and such as might be expected from so vast an extent of surface.

On the northern side, which is encircled by primary mountains, the rivers sweep in many large boulders with smaller gravel and sand, chiefly composed of granitic and trap rocks. There are also currents in the lake, in various directions, caused by the continued

* Captain Bayfield remarks, that Dr. Bigsby, to whom we are indebted for several communications respecting the geology of the Canadian lakes, was misinformed by the fur traders in regard to the extraordinary height (twenty or thirty feet) to which he asserts that the autumnal gales will raise the water of Lake Superior. — Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 7. 1829.

prevalence of strong winds, and to their influence we may attribute the diffusion of finer mud far and wi over great areas; for, by numerous soundings ma during the late survey, it was ascertained that t bottom consists generally of a very adhesive clay, co taining shells of the species at present existing in t lake. When exposed to the air, this clay imme ately becomes indurated in so great a degree, as to quire a smart blow to break it. It effervesces sligh with diluted nitric acid, and is of different colours different parts of the lake; in one district blue, in other red, and in a third white, hardening into a s stance resembling pipe-clay.* From these stateme the geologist will not fail to remark how closely t recent lacustrine formations in America resemble tertiary argillaceous and calcareous marls of lacus origin in Central France. In both cases, many o genera of shells most abundant, as Lymnea and orbis, are the same; and in regard to other class organic remains, there must be the closest analog I shall endeavour more fully to explain when spea of the imbedding of plants and animals in recent posits.

DELTAS OF INLAND SEAS.

Baltic. — Having thus briefly considered som the lacustrine deltas now in progress, we may turn our attention to those of inland seas.

The shallowing and conversion into land of n parts of the Baltic, especially the Gulfs of Bothnia Finland, have been demonstrated by a series of a

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5.

rate observations, for which we are in a great measure indebted to the animated controversy which has been kept up, since the middle of the last century, concerning the gradual lowering of the level of the Baltic. I shall revert to this subject when treating of the slow and insensible upheaving of the land in certain parts of Sweden, a movement which produces an apparent fall in the level of the waters, both of the Baltic and the ocean.* It is only necessary to state in this place, that the rapid gain of low tracts of land near Torneo, Pitea and Lulea, near the head of the Gulf of Bothnia, are due to the joint operation of two causes — the influx of sediment from numerous rivers, and a slow and general upward movement of the land itself, and bed of the sea, at the rate of several feet in a century.

Delta of the Rhone. — We may now turn our attention to some of the principal deltas of the Mediterranean, for no other inland sea affords so many examples of accessions of new lands at the mouths of rivers within the records of authentic history. The lacustrine delta of the Rhone in Switzerland has already been considered, and its contemporaneous marine delta may now be described. Scarcely has the river passed out of the Lake of Geneva, before its pure waters are again filled with sand and sediment by the impetuous Arve, descending from the highest Alps, and bearing along in its current the granitic detritus annually brought down by the glaciers of Mont Blanc. The Rhone afterwards receives vast contributions of transported

* Since writing the former edition, I have visited Sweden, and removed the doubts which I before entertained and expressed respecting the alleged gradual elevation of the land in Scandinavia. — See Book ii. chap. xvii.

matter from the Alps of Dauphiny, and the prin and volcanic mountains of Central France; and w at length it enters the Mediterranean, it disco the blue waters of that sea with a whitish sedin for the distance of between six and seven m throughout which space the current of fresh w is perceptible.

Proofs of its increase since historical periods.—Str description of the delta is so inapplicable to its pr configuration, as to attest a complete alteration i physical features of the country since the Aug age. It appears, however, that the head of the or the point at which it begins to ramify, has rem unaltered since the time of Pliny, for he state the Rhone divided itself at Arles into two arms. is the case at present; one of the branches bein called Le Petit Rhône, which is again subdivide fore entering the Mediterranean. The advance base of the delta, in the last eighteen centur demonstrated by many curious antiquarian ments. The most striking of these is the great d made by the old Roman road from Ugernu Beziers (part of the high road between Aix, *Sextiæ*, and Nismes, *Nemausus*). It is clear when this was first constructed, it was impo to pass in a direct line as now, across the delta that either the sea or marshes intervened in a now consisting of terra firma.* Astruc also rem that all the places on low lands, lying to the nor the old Roman road between Nismes and Be have names of Celtic origin, evidently given to t by the first inhabitants of the country; whereas

* Mém. d'Astruc, cited by Von Hoff, vol. i. p. 228.

places lying south of that road, towards the sea, have names of Latin derivation, and were clearly founded after the Roman language had been introduced.

Another proof, also, of the great extent of land which has come into existence since the Romans conquered and colonized Gaul, is derived from the fact, that the Roman writers never mention the thermal waters of Balaruc in the delta, although they were well acquainted with those of Aix, and others still more distant, and attached great importance to them, as they invariably did to all hot springs. The waters of Balaruc, therefore, must have formerly issued under the sea — a common phenomenon on the borders of the Mediterranean; and on the advance of the delta they continued to flow out through the new deposits.

Among the more direct proofs of the increase of land, we find that Mese, described under the appellation of Mesua Collis by Pomponius Mela*, and stated by him to be nearly an island, is now far inland. Notre Dame des Ports, also, was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, and is now two leagues from the sea. Several old lines of towers and sea-marks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners; which may well be conceived, when we state that the tower of Tignaux, erected on the shore so late as the year 1737, is already a French mile remote from it.†

By the confluence of the Rhone and the currents of

* Lib. II. c. v.

† Bouche, Chorographie et Hist. de Provence, vol. i. p. 23., cited by Hoff, vol. i. p. 290.

the Mediterranean, driven by winds from the south, sand-bars are often formed across the mouths of the river: by these means considerable spaces become divided off from the sea, and subsequently from the river also, when it shifts its channels of efflux. As some of these lagoons are subject to the occasional ingress of the river when flooded, and of the sea during storms, they are alternately salt and fresh. Others, after being filled with salt water, are often lowered by evaporation till they become more salt than the sea; and it has happened, occasionally, that a considerable precipitate of muriate of soda has taken place in these natural salterns. During the latter part of Napoleon's career, when the excise laws were enforced with extreme rigour, the police was employed to prevent such salt from being used. The fluviatile and marine shells enclosed in these small lakes often live together in brackish water; but the uncongenial nature of the fluid usually produces a dwarfish size, and sometimes gives rise to strange varieties in form and colour.

Captain Smyth, in the late survey of the coast of the Mediterranean, found the sea, opposite the mouths of the Rhone, to deepen gradually from four to forty fathoms, within a distance of six or seven miles, over which the discoloured fresh water extends; so that the inclination of the new deposits must be too slight to be appreciable in such an extent of section as a geologist usually obtains in examining ancient formations. When the wind blew from the south-west, the ships employed in the survey were obliged to quit their moorings; and when they returned, the new sand-banks in the delta were found covered over with a great abundance of marine shells. By this means, we learn how occasional beds of drifted marine shells may become interstratified with fresh-water strata at a river's mouth.

Stony nature of its deposits.—That a great proportion, at least, of the new deposit in the delta of the Rhone, consists of *rock*, and not of loose incoherent matter, is perfectly ascertained. In the Museum at Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter, including multitudes of broken shells of recent species. The observations lately made on this subject corroborate the former statement of Marsilli, that the earthy deposits of the coast of Languedoc form a stony substance, for which reason he ascribed a certain bituminous, saline, and glutinous nature to the substances brought down with sand by the Rhone.* If the number of mineral springs charged with carbonate of lime which fall into the Rhone and its feeders in different parts of France be considered, we shall feel no surprise at the lapidification of the newly deposited sediment in this delta. It should be remembered, that the fresh water introduced by rivers, being lighter than the water of the sea, floats over the latter, and remains upon the surface for a considerable distance. Consequently, it is exposed to as much evaporation as the waters of a lake; and the area over which the river-water is spread, at the junction of great rivers and the sea, may well be compared, in point of extent, to that of considerable lakes.

Now, it is well known, that so great is the quantity

* Hist. Phys. de la Mer.

of water carried off by evaporation in some lakes, that it is nearly equal to the water flowing in; and in some inland seas, as the Caspian, it is quite equal. We may, therefore, well suppose, that, in cases where a strong current does not interfere, the greater portion not only of the matter held mechanically in suspension, but of that also which is in chemical solution, may be precipitated at no great distance from the shore. When these finer ingredients are extremely small in quantity they may only suffice to supply crustaceous animals, corals, and marine plants, with the earthy particles necessary for their secretions; but whenever it is in excess (as generally happens if the basin of a river is partly in a district of active or extinct volcanos), then will solid deposits be formed, and the shells will at once be included in a rocky mass.

Delta of the Po.—The Adriatic presents a gr combination of circumstances favourable to the r formation of deltas—a gulf receding far into the l —a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adi besides numerous minor streams, draining on the side a great crescent of the Alps, and on the ot some of the loftiest ridges of the Apennines. Fr the northernmost point of the Gulf of Trieste, wh the Isonzo enters, down to the south of Raven there is an uninterrupted series of recent accessi of land, more than one hundred miles in len which, within the last two thousand years, have creased from *two to twenty miles in breadth.* Isonzo, Tagliamento, Piave, Brenta, Adige, and besides many other inferior rivers, contribute to advance of the coast-line, and to the shallowing of gulf. The Po and the Adige may now be conside as entering by one common delta, for two branches of the Adige are connected with arms of the Po.

In consequence of the great concentration of the flooded waters of these streams since the system of embankment became general, the rate of encroachment of the new land upon the Adriatic, especially at that point where the Po and Adige enter, is said to have been greatly accelerated. Adria was a seaport in the time of Augustus, and had, in ancient times, given its name to the gulf; it is now about twenty Italian miles inland. Ravenna was also a seaport, and is now about four Italian miles from the main sea. Yet even before the practice of embankment was introduced, the alluvium of the Po advanced with rapidity on the Adriatic; for Spina, a very ancient city, originally built in the district of Ravenna, at the mouth of a great arm of the Po, was, so early as the commencement of our era, eleven Italian miles distant from the sea.*

The greatest depth of the Adriatic, between Dalmatia and the mouths of the Po, is twenty-two fathoms; but a large part of the Gulf of Trieste and the Adriatic, opposite Venice, is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist partly of mud and partly of rock, the rock being formed of calcareous matter, encrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. i. p. 118.

calcareous precipitates.* Olivi, also, found some de-posits of sand, and others of mud, extending half way across the gulf; and he states that their distributio along the bottom was evidently determined by th prevailing current.† It is probable, therefore, tha the finer sediment of all the rivers at the head of th Adriatic may be intermingled by the influence of th current; and all the central parts of the gulf may b considered as slowly filling up with horizontal deposit similar to those of the Subapennine hills, and contai ing many of the same species of shells. The I merely introduces at present fine sand and mud; for carries no pebbles farther than the spot where it jo the Trebia, west of Piacenza. Near the north borders of the basin, the Isonzo, Tagliamento, a many other streams, are forming immense beds sand and some conglomerate; for here some h mountains of Alpine limestone approach within a f miles of the sea.

In the time of the Romans, the hot-baths of Mo falcone were on one of several islands of Alpine lim stone, between which and the mainland, on the nor was a channel of the sea, about a mile broad. T channel is now converted into a grassy plain, whi surrounds the islands on all sides. Among the num rous changes on this coast, we find that the pres channel of the Isonzo is several miles to the west its ancient bed, in part of which, at Ronchi, the Roman bridge which crossed the Via Appia was lat found buried in fluviatile silt.

Notwithstanding the present shallowness of t

* See Brocchi on the various writers on this subject. Con Fos. Subap., vol. i. p. 39.

† Ibid., vol. ii. p. 94.

Adriatic, it is highly probable that its original depth was very great; for if all the low alluvial tracts were taken away from its borders and replaced by sea, the high land would terminate in that abrupt manner which generally indicates, in the Mediterranean, a great depth of water near the shore, except in those spots where sediment imported by rivers and currents has diminished the depth. Many parts of the Mediterranean are now ascertained to be above two thousand feet deep, close to the shore, as between Nice and Genoa; and even sometimes six thousand feet, as near Gibraltar. When, therefore, we find, near Parma, and in other districts in the interior of the Italian peninsula, beds of horizontal tertiary marl attaining a thickness of about two thousand feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above a thousand feet in thickness, and extending seven or eight miles in length, we behold nothing which the analogy of the deltas in the Adriatic might not lead us to anticipate.

Delta of the Nile.—That Egypt was "the gift of the Nile," was the opinion of her priests before the time of Herodotus; but we have no authentic memorials for determining, with accuracy, the dates of successive additions made to the habitable surface of that country. The configuration and composition of the low lands leave no room for doubt, says Rennell, that "the sea once washed the base of the rocks on which the pyramids of Memphis stand, the *present* base of which is washed by the inundation of the Nile, at an elevation of 70 or 80 feet above the Mediterranean. But when we attempt to carry back our ideas to the remote period when the foundation of the delta was first laid, we are lost in the contemplation of so vast an interval of time."* We know that the base of the delta ha been considerably modified since the days of Home The ancient geographers mention seven princip mouths of the Nile, of which the most eastern, t Pelusian, has been entirely silted up, and the Me desian, or Tanitic, has disappeared. The Phatni mouth, and the Sebenitic, have been so altered, t the country immediately about them has little rese blance to that described by the ancients. The Bol tine mouth has increased in its dimensions, so a cause the city of Rosetta to be at some distance fr the sea.

The alterations produced around the Canopic mo are also important. The city Foah, which, so lat the beginning of the fifteenth century, was on embouchure, is now more than a mile inland. C pus, which, in the time of Scylax, was a des insular rock, has been connected with the firm l and Pharos, an island in times of old, now belon the continent. Homer says, its distance from E was one day's voyage by sea.† That this sh have been the case in Homer's time, Larcher others have, with reason, affirmed to be in the hig degree improbable; but Strabo has judiciously an pated their objections, observing, that Homer probably acquainted with the gradual advance of land on this coast, and availed himself of this ph menon to give an air of higher antiquity to the re period in which he laid the scene of his poem.‡ Lake Mareotis, also, together with the canal wl

* Geog. Syst. of Herod. vol. ii. p. 107.

† Odys., book iv. v. 355.

‡ Lib. I. Part i. pp. 80. 98. Consult Von Hoff, vol. i. p.

connected it with the Canopic arm of the Nile, has been filled with mud, and is become dry. Herodotus observes, "that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams, had formed deltas. Egypt, therefore, he says, like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile, he adds, should by any means have an issue into the Arabian Gulf, it might choke it up with earth in twenty thousand, or even, perhaps, in ten thousand years; and why may not the Nile have filled with mud a still greater gulf in the space of time which has passed before our age?" *

Mud of the Nile.—The analysis of the mud of the Nile gives nearly one half of argillaceous earth, and about one fourth of carbonate of lime, the remainder consisting of water, oxide of iron, and carbonate of magnesia. †

The depth of the Mediterranean is about twelve fathoms at a small distance from the shore of the delta; it afterwards increases gradually to 50, and then suddenly descends to 380 fathoms, which is, perhaps, the original depth of the sea where it has not been rendered shallower by fluviatile matter. The progress of the delta in the last two thousand years affords, perhaps, no measure for estimating its rate of growth when it was an inland bay, and had not yet protruded itself beyond the coast-line of the Mediterranean. A powerful current now sweeps along the shores of Africa, from the Straits of Gibraltar to the prominent

* Euterpe, XI.

† Girard, Mém. sur l'Egypte, tome i. pp. 348. 382.

convexity of Egypt, the western side of which is continually the prey of the waves; so that not only are fresh accessions of land checked, but ancient parts of the delta are carried away. By this cause Canopus and some other towns have been overwhelmed: but to this subject I shall again refer when speaking of tides and currents.

CHAPTER V.

OCEANIC DELTAS.

ceanic deltas — Deltas of the Ganges and Burrampooter — Its size — Rate of advance, and nature of its deposits — Formation and destruction of islands — Abundance of crocodiles — Inundations — Delta of the Mississippi (p. 360.) — Deposits of drift wood — Gradual filling up of the Yellow Sea — Estimate of the quantity of mud carried down by the Ganges — Formation of valleys illustrated by the growth of deltas — Grouping of new strata in general (p. 367.) — Convergence of deltas — Conglomerates — Various causes of stratification — Direction of laminæ — Remarks on the interchange of land and sea.

'HE remaining class of deltas are those in which vers, on entering the sea, are exposed to the influnce of the tides. In this case it frequently happens that n estuary is produced, or negative delta, as Rennell ermed it, where, instead of any encroachment of the und upon the sea, the ocean enters the river's mouth, nd penetrates into the land beyond the general coastne. Where this happens, the tides and currents are he predominating agents in the distribution of transorted sediment. The phenomena, therefore, of such stuaries, will be treated of when the movements of he ocean come under consideration. But whenever he volume of fresh water is so great as to counteract nd almost neutralize the force of tides and currents, nd in all cases where these agents have not sufficient ower to remove to a distance the whole of the sediment periodically brought down by rivers, ocea deltas are produced. Of these, I shall now sele a few illustrative examples.

Delta of the Ganges. — The Ganges and the Bu rampooter descend, from the highest mountains in t world, into a gulf which runs 225 miles into the co tinent. The Burrampooter is somewhat the lar river of the two; but it first takes the name of t Megna when joined by a smaller stream so called, a afterwards loses this second name on its union wi the Ganges, at the distance of about forty miles fr the sea. The area of the delta of the Ganges (wi out including that of the Burrampooter, which now become conterminous) is considerably more t double that of the Nile; and its head commences distance of 220 miles, in a direct line from the sea base is two hundred miles in length, including the sp occupied by the two great arms of the Ganges wh bound it on either side. That part of the delta wh borders on the sea is composed of a labyrinth of riv and creeks, all filled with salt water, except those i mediately communicating with the principal arm the Ganges. This tract alone, known by the name the Woods, or Sunderbunds, a wilderness infested tigers and alligators, is, according to Rennell, equal extent to the whole principality of Wales.*

On the sea-coast there are eight great openings, ea of which has evidently, at some ancient period, serv in its turn as the principal channel of discharge. though the flux and reflux of the tide extend even the head of the delta when the river is low; yet, whe

* Account of the Ganges and Burrampooter Rivers, by Ma Rennell, Phil. Trans. 1781.

it is periodically swollen by tropical rains, the velocity of the stream counteracts the tidal current, so that except very near the sea, the ebb and flow become insensible. During the flood season, therefore, the Ganges almost assumes the character of a river entering a lake or inland sea; the movements of the ocean being then subordinate to the force of the river, and only slightly disturbing its operations. The great gain of the delta in height and area takes place during the inundations; and, during other seasons of the year, the ocean makes reprisals, scouring out the channels, and sometimes devouring rich alluvial plains.

So great is the quantity of mud and sand poured by the Ganges into the gulf in the flood season, that the sea only recovers its transparency at the distance of sixty miles from the coast. The general slope, therefore, of the new strata must be extremely gradual. By the charts recently published, it appears that there is a gradual deepening from four to about sixty fathoms, as we proceed from the base of the delta to the distance of about one hundred miles into the Bay of Bengal. At some few points seventy, or even one hundred, fathoms are obtained at that distance.

One remarkable exception, however, occurs to the regularity of the shape of the bottom; for, opposite the middle of the delta, at the distance of thirty or forty miles from the coast, is a nearly circular space called the "swatch of no ground," about fifteen miles in diameter, where soundings of 100, and even 130, fathoms fail to reach the bottom. This phenomenon is the more extraordinary, since the depression occurs within five miles of the line of shoals; and not only do the waters charged with Gangetic sediment pass over it continually; but, during the monsoons, the sea, loaded with mud and sand, is beaten back in that direc towards the delta. As the mud is known to ext for eighty miles farther into the gulf, we may be sured that, in the course of ages, the accumulatio strata, in "the swatch" has been of enormous th ness; and we seem entitled to deduce, from the sent depth at the spot, that the original inequalitie the bottom of the Bay of Bengal were on a gr scale, and comparable to those of the main ocean.

Opposite the mouth of the Hoogly river, and im diately south of Sager Island, four miles from nearest land of the delta, a new islet was formed a thirty years ago, called Edmonston Island, w there is a lighthouse. The islet has been for r years covered with vegetation and shrubs, but whole surface was submerged for some hours di the late inundation of May, 1833, the light-kee having only escaped by ascending into the lan By this flood the dimensions of the islet were siderably diminished. Although there is evid of gain at some points, the general progress of coast is very slow; for the tides, which rise f thirteen to sixteen feet, are actively employed removing the alluvial matter, and diffusing it ov wide area.* The new strata consist entirely of s and fine mud; such, at least, are the only mate which are exposed to view in regular beds on

* It is stated in the chart published in the year 1825, by C tain Horsburgh, that the sands opposite the whole delta stre between four and five miles farther south than they had d forty years previously; and this was taken as the measure of progress of the delta itself, during the same period. But a m careful comparison of the ancient charts, during a recent surv has proved that they were extremely incorrect in their latitudes that the advance of the sands and delta was greatly exaggerated

banks of the numerous creeks. No substance so coarse as gravel occurs in any part of the delta, nor nearer the sea than 400 miles. It should be observed, however, that the superficial alluvial beds, which are thrown down rapidly from turbid waters during the floods, may be very distinct from those deposited at a greater distance from the shore, where crystalline precipitates, perhaps, are forming, on the evaporation of so great a surface, exposed to the rays of a tropical sun. The separation of sand and other matter, held in mechanical suspension, may take place where the waters are in motion; but mineral ingredients, held in chemical solution, would naturally be carried to a greater distance, where they may aid in the formation of corals and shells, and, in part, perhaps, become the cementing principle of rocky masses.

A well was sunk at Fort William, Calcutta, in the hope of obtaining water, through beds of adhesive clay, to the depth of 146 feet. A bed of yellow sand was then entered, and at the depth of 152 feet another stratum of clay.*

Islands formed and destroyed.—Major R. H. Colebrooke, in his account of the course of the Ganges relates examples of the rapid filling up of some of its branches, and the excavation of new channels, where the number of square miles of soil removed in a short time (the column of earth being 114 feet high) was truly astonishing. Forty square miles, or 25,600 acres are mentioned as having been carried away, in one place in the course of a few years.† The immense transportation of earthy matter by the Ganges and

* See India Gazette, June 9., 1831.

† Trans. of the Asiatic Society, vol. vii. p. 14.

Megna is proved by the great magnitude of the isla formed in their channels during a period far short that of a man's life. Some of these, many miles extent, have originated in large sand-banks thrown round the points at the angular turning of the ri and afterwards insulated by breaches of the stre Others, formed in the main channel, are caused some obstruction at the bottom. A large tree, sunken boat, is sometimes sufficient to check the cur and cause a deposit of sand, which accumulates t usurps a considerable portion of the channel. river then borrows on each side to supply the defici in its bed, and the island is afterwards raised by deposits during every flood. In the great gulf l Luckipour, formed by the united waters of the Ga and Burrampooter (or Megna), some of the isl says Rennell, rival in size and fertility the Is Wight. While the river is forming new islands i part, it is sweeping away old ones in others. T newly formed are soon overrun with reeds, long g the Tamarix Indica, and other shrubs, forming i netrable thickets, where tigers, buffaloes, deer, other wild animals, take shelter. It is easy, there to perceive, that both animal and vegetable rem must continually be precipitated into the flood, sometimes become imbedded in the sediment w subsides in the delta.

Two species of crocodiles, of distinct genera, abo in the Ganges and its tributary and contiguous wat and Mr. H. T. Colebrooke informs me, that he seen both kinds in places far inland, many hund miles from the sea. The Gangetic crocodile, Gavial (in correct orthography, Garial), is confined the fresh water, but the common crocodile freque both fresh and salt; being much larger and fiercer in salt and brackish water. These animals swarm in the brackish water along the line of sand-banks where the advance of the delta is most rapid. Hundreds of them are seen together in the creeks of the delta, or basking in the sun on the shoals without. They will attack men and cattle, destroying the natives when bathing, and tame and wild animals which come to drink. "I have not unfrequently," says Mr. Colebrooke, "been witness to the horrid spectacle of a floating corpse seized by a crocodile with such avidity, that he half emerged above the water with his prey in his mouth." The geologist will not fail to observe how peculiarly the habits and distribution of these saurians expose them to become imbedded in the horizontal strata of fine mud, which are annually deposited over many hundred square miles in the Bay of Bengal. The inhabitants of the land, which happen to be drowned or thrown into the water, are usually devoured by these voracious reptiles; but we may suppose the remains of the saurians themselves to be continually entombed in the new formations.

Inundations.—It sometimes happens, at the season when the periodical flood is at its height, that a strong gale of wind, conspiring with a high spring-tide, checks the descending current of the river, and gives rise to most destructive inundations. From this cause, in the year 1763, the waters at Luckipour rose six feet above their ordinary level, and the inhabitants of a considerable district, with their houses and cattle, were totally swept away.

The population of all oceanic deltas are particularly exposed to suffer by such catastrophes, recurring at considerable intervals of time; and we may safely

assume, that such tragical events have happened
and again since the Gangetic delta was inhabit
man. If human experience and forethought
always guard against these calamities, still less
inferior animals avoid them; and the monum
such disastrous inundations must be looked for
abundance in strata of all ages, if the surface
planet has always been governed by the san
When we reflect on the general order and tra
that reigns in the rich and populous delta of
notwithstanding the havoc occasionally comr
the depredations of the ocean, we perceive
necessary it is to attribute the imbedding of s
races of animals in older strata to extraordina
in the causes of decay and reproduction in th
of our planet, or to those general catastro
sudden revolutions resorted to by some theor

Delta of the Mississippi. — As the delt
Ganges may be considered a type of those
the borders of the ocean, it will be unne
accumulate examples of others on a no less m
scale, as, for example, at the mouths of th
and Amazon. To these, however, I shall
and by, when treating of the agency of curr
tides in the Mexican Gulf are so feeble, tha
of the Mississippi has somewhat of an in
character between an oceanic and mediterra
A long narrow tongue of land is protruded,
simply of the banks of the river, wearing pr
same appearance as in the inland plains c
periodical inundations, when nothing appe
water but the higher part of the sloping gl
described.* This tongue of land has advar

* Chapter II.

leagues since New Orleans was built. Great submarine deposits are also in progress, stretching far and wide over the bottom of the sea, which has become extremely shallow, not exceeding ten fathoms in depth. Opposite the mouth of the Mississippi large rafts of drift trees, brought down every spring, are matted together into a net-work many yards in thickness, and stretching over hundreds of square leagues.* They afterwards become covered over with a fine mud, on which other layers of trees are deposited the year following, until numerous alternations of earthy and vegetable matter are accumulated.

Alternation of deposits. — An observation of Darby, in regard to the strata composing part of this delta, deserves attention. In the steep banks of the Atchafalaya, an arm of the Mississippi before alluded to in our description of "the raft," the following section is observable at low water: — first, an upper stratum, consisting invariably of blueish clay, common to the banks of the Mississippi; below this a stratum of red ochreous earth, peculiar to Red River, under which the blue clay of the Mississippi again appears; and this arrangement is constant, proving, as that geographer remarks, that the waters of the Mississippi and the Red River occupied alternately, at some former periods, considerable tracts below their present point of union.† Such alternations are probably common in submarine spaces situated between two converging deltas; for, before the two rivers unite, there must almost always be a certain period when an intermediate tract will by turns be occupied and abandoned by the

* Captain Hall's Travels in North America, vol. iii. p. 338.— See also above, p. 271.

† Darby's Louisiana, p. 103.

waters of each stream; since it can rarely happen th the season of highest flood will precisely correspond i each. In the case of the Red River and Mississipp which carry off the waters from countries placed und widely distant latitudes, an exact coincidence in th time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of sediment in river water.—Very i satisfactory experiments have as yet been made enable us to determine, with any degree of accura the mean quantity of earthy matter discharged annu into the sea by some one of the principal rivers of earth. Hartsoeker computed the Rhine to contai suspension, when most flooded, one part in a hundre mud in volume *; but it appears from two sets of exp ments recently made by Mr. Leonard Horner, at Bo that $\frac{1}{10000}$th would have been a nearer approxi tion to the truth. † Sir George Staunton inferred fr several observations, that the water of the Yellow Ri in China contained earthy matter in the proportio one part to two hundred, and he calculated tha brought down in a single hour two million cubic f of earth, or forty-eight million daily; so that, if Yellow Sea be taken to be 120 feet deep, it wo require seventy days for the river to convert an Eng square mile into firm land, and 24,000 years to t the whole sea into terra firma, assuming it to

* Comment. Bonon., vol. ii. part. i. p. 237.
† Edin. New Phil. Journ., Jan. 1835.

125,000 square miles in area.* Manfredi, the celebrated Italian hydrographer, conceived the average proportion of sediment in all the running water on the globe, which reached the sea, to be $\frac{1}{175}$, and he imagined that it would require a thousand years for the sediment carried down to raise the general level of the sea about one foot. Some writers, on the contrary, as De Maillet, have declared the most turbid waters to contain far less sediment than any of the above estimates would import. One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the delta of the Ganges. "A glass of water," he says, "taken out of this river when at its height, yields about one part in four of mud. No wonder, then," he adds, "that the subsiding waters should quickly form a stratum of earth, or that the delta should encroach on the sea!"†

There must certainly be some mistake, perhaps a misprint, in the statement in the Phil. Trans.; and some have conjectured that the learned hydrographer meant one part in four hundred of mud. In former editions of this work, I expressed my regret that so much inconsistency and contradiction should be found in the statements and speculations relative to this interesting subject; and I endeavoured to point out the high geological importance of reducing to arithmetical computation the aggregate amount of solid matter transported by certain large rivers to the sea. The deficiency of data has now been, in some degree, removed by the labours of the Rev. Mr. Everest, who has

* Staunton's Embassy to China, Lond. 1797, 4to. vol. ii. p. 408.

† Phil. Trans. 1781.

instituted a series of observations "On the earthy matter brought down by the Ganges" at Ghazipur, above Calcutta.*

The first step to be made in all such calculations is to ascertain the average volume of water passing annually down the channel of a river. This might easily be accomplished if the breadth, depth, and velocity of a stream were constant and uniform throughout the year; but as all these conditions are liable to vary according to the seasons, the problem becomes extremely complex. In the Ganges, as in other rivers in hot climates, there are periodical inundations, during which by far the greatest part of the annual discharge takes place; and the most important point, therefore, to determine, is the mean breadth, depth, and velocity of the stream during this period.

Mr. Everest found that, in 1831, the number of cubic feet of water discharged by the Ganges per second was, during the

Rains, (4 months)	- -	494,208
Winter, (5 months)	- -	71,200
Hot weather, (3 months)	-	36,330

so that we may state in round numbers, that 500 cubic feet flow down during the four months of flood season, from June to September, and only 100 during the remaining eight months.

Having obtained the volume of water, we have to inquire what is the proportion of solid matter

* Journ. of Asiatic Soc., No. 6. p. 238. June, 1832. also Mr. Prinsep, Gleanings in Science, vol. iii. p. 185.

tained in it; and for this purpose, a definite quantity, as, for example, a quart, is taken from the river on different days, sometimes from the middle of the current, and sometimes nearer the banks. This water is then evaporated, the solid residuum weighed, and the mean quantity of sediment thus ascertained, throughout the rainy season. The same observations must then be repeated for the other portions of the year.

In computing the quantity of water, Mr. Everest made no allowance for the decreased velocity of the stream near the bottom, presuming that it is compensated by the increased weight of matter held in suspension there. Probably the amount of sediment is by no means exaggerated by this circumstance; but rather under-rated, as the heavier grains of sand, which can never rise into the higher parts of the stream, are drifted along the bottom.

Now the average quantity of solid matter suspended in the water during the rains was, by weight $\frac{1}{428}$th part; but, as the water is about one half the specific gravity of the dried mud, the solid matter discharged is $\frac{1}{856}$th part in bulk, or 577 cubic feet per second. This gives a total of 6,082,041,600 cubic feet for the discharge in the 122 days of the rain. The proportion of sediment in the waters at other seasons was comparatively insignificant, the total amount during the five winter months being only 247,881,600 cubic feet, and during the three months of hot weather, 38,154,240 cubic feet. The total annual discharge, then, would be 6,368,077,440 cubic feet.

In order to give some idea of the magnitude of this result, we will assume that the specific gravity of the dried mud is only one half that of granite (it would, however, be more); in that case, the earthy matt discharged in a year would equal 3,184,038,720 cul feet of granite. Now about 12½ cubic feet of gran weigh one ton; and it is computed that the gr Pyramid of Egypt, if it were a solid mass of gran would weigh about 6,000,000 tons. The mass matter, therefore, carried down annually, would, cording to this estimate, more than equal in wei and bulk forty-two of the great Pyramids of Eg and that borne down in the four months of the r would equal forty pyramids. But if, without any c jecture as to what may have been the specific gra of the mud, we attend merely to the weight of s matter actually proved by Mr. Everest to have b contained in the water, we find that the numbe tons weight which passed down in the 122 days of rainy season was 339,413,760, which would give weight of fifty-six pyramids and a half; and in whole year 355,361,464 tons, or nearly the weigh sixty pyramids.

The base of the great Pyramid of Egypt co eleven acres, and its perpendicular height is about hundred feet. It is scarcely possible to present picture to the mind which will convey an adequ conception of the mighty scale of this operation tranquilly and almost insensibly carried on by Ganges, as it glides through its alluvial plain. It m however, be stated, that if a fleet of more than eig Indiamen, each freighted with about 1400 tons wei of mud, were to sail down the river every hour every day and night for four months continuously, th would only transport from the higher country to t sea a mass of solid matter equal to that borne do by the Ganges in the flood season. Or the exertio of a fleet of about 2000 such ships going down daily with the same burden, and discharging it into the gulf, would be no more than equivalent to the operations of the great river. Yet, in addition to this, it is probable that the Burrampooter conveys annually as much solid matter to the sea as the Ganges.

The most voluminous current of lava which has flowed from Etna within historical times was that of 1669. Ferrara, after correcting Borrelli's estimate, calculated the quantity of cubic yards of lava in this current at 140,000,000. Now, this would not equal in bulk one fifth of the sedimentary matter which is carried down in a single year by the Ganges, according to the estimate above explained; so that it would require five grand eruptions of Etna to transfer a mass of lava from the subterranean regions to the surface, equal in volume to the mud carried down to the sea in one year by a single river in Bengal.

Grouping of Strata in Deltas.—The changes which have taken place in deltas, even since the times of history, may suggest many important considerations in regard to the manner in which subaqueous sediment is distributed. Notwithstanding frequent exceptions, arising from the interference of a variety of causes, there are some general laws of arrangement which must evidently hold good in almost all the lakes and seas now filling up. If a lake, for example, be encircled on two sides by lofty mountains, receiving from them many rivers and torrents of different sizes, and if it be bounded on the other sides, where the surplus waters issue, by a comparatively low country, it is not difficult to define some of the leading geological features which must characterize the lacustrine formation, when this basin shall have been gradually converted into dry land by the influx of sediment. Th strata would be divisible into two principal group the *older* comprising those deposits which originat on the side adjoining the mountains, where numero deltas first began to form; and the *newer* group co sisting of beds deposited in the more central pa of the basin, and towards the side farthest from t mountains. The following characters would form t principal marks of distinction between the strata each series. The more ancient system would be co posed, for the most part, of coarser materials, co taining many beds of pebbles and sand, often of gr thickness, and sometimes dipping at a considera angle. These, with associated beds of finer ing dients, would, if traced round the borders of the ba be seen to vary greatly in colour and mineral co position, and would also be very irregular in thickn The beds, on the contrary, in the newer group, wo consist of finer particles, and would be horizontal very slightly inclined. Their colour and mineral co position would be very homogeneous throughout la areas, and would differ from almost all the sepa beds in the older series.

The following causes would produce the diver here alluded to between the two great members such lacustrine formations:—When the rivers torrents first reach the edge of the lake, the detr washed down by them from the adjoining hei sinks at once into deep water, all the heavier pebl and sand subsiding near the shore. The finer mu carried somewhat farther out, but not to the dista of many miles, for the greater part may be seen, as, example, where the Rhone enters the Lake of Gene to fall down in clouds to the bottom not far from river's mouth. Thus alluvial tracts are soon formed at the mouths of every torrent and river, and many of these in the course of ages become of considerable extent. Pebbles and sand are then transported farther from the mountains; but in their passage they decrease in size by attrition, and are in part converted into mud and sand. At length some of the numerous deltas which are all directed towards a common centre approach near to each other — those of adjoining torrents become united, and each is merged, in its turn, in the delta of the largest river, which advances most rapidly into the lake, and renders all the minor streams, one after the other, its tributaries. The various mineral ingredients of all are thus blended together into one homogeneous mixture, and the sediment is poured out from a common channel into the lake.

As the average size of the transported particles decreases, while the force and volume of the current augments, the newer deposits are diffused continually over a wider area, and are consequently more horizontal than the older. When at first there were many independent deltas near the borders of the basin, their separate deposits differed entirely from each other; one may have been charged, like the Arve where it joins the Rhone, with white sand, and sediment derived from granite — another may have been black, like many streams in the Tyrol, flowing from the waste of decomposing rocks of dark slate — a third may have been coloured by ochreous sediment, like the Red River in Louisiana — a fourth, like the Elsa in Tuscany, may have held much carbonate of lime in solution. At first they would each form distinct deposits of sand, gravel, limestone, marl, or other materials; but after their junction new chemical combinations and a distinct colour would be the result, and the p ticles, having been conveyed ten, twenty, or a gre number of miles over alluvial plains, would bec finer.

In deltas where the causes are more complica and where tides and currents partially interfere, above description would only be applicable, with tain modifications; but if a series of earthqu accompany the growth of a delta, and change levels of the lánd from time to time, as in the re where the Indus now enters the sea, and others h after to be mentioned, the phenomena will then de still more widely from the ordinary type.

Convergence of Deltas. — If we possessed an a rate series of maps of the Adriatic for many thou years, our retrospect would, without doubt, carr gradually back to the time when the number of ri descending from the mountains into that gulf independent deltas was far greater in number. deltas of the Po and the Adige, for instance, w separate themselves within the *recent* era, as, in probability, would those of the Isonzo and the To If, on the other hand, we speculate on future chan we may anticipate the period when the numbe deltas will greatly diminish; for the Po cannot conti to encroach at the rate of a mile in a hundred ye and other rivers to gain as much in six or seven c turies upon the shallow gulf, without new juncti occurring from time to time, so that Eridanus, " king of rivers," will continually boast a greater nu ber of tributaries. The Ganges and the Burrampoo have probably become confluent within the histori era; and the date of the junction of the *Red Ri* and the Mississippi would, in all likelihood, have be known if America had not been so recently discovered. The union of the Tigris and the Euphrates must undoubtedly have been one of the modern geographical changes on our earth, and similar remarks might be extended to many other regions.

When the deltas of rivers, having many mouths, converge, a partial union at first takes place by the confluence of some one or more of their arms; but it is not until the main trunks are connected above the head of the common delta, that a complete intermixture of their joint waters and sediment takes place. The union, therefore, of the Po and Adige, and of the Ganges and Burrampooter, is still incomplete. If we reflect on the geographical extent of surface drained by rivers such as now enter the Bay of Bengal, and then consider how complete the blending together of the greater part of their transported matter has already become, and throughout how vast a delta it is spread by numerous arms, we no longer feel so much surprise at the area occupied by some ancient formations of homogeneous mineral composition. But our surprise will be still further lessened when we afterwards inquire into the action of tides and currents, in disseminating sediment.*

Formation of Conglomerates. — Along the base of the Maritime Alps, between Toulon and Genoa, the rivers, with few exceptions, are now forming strata of conglomerate and sand. Their channels are often several miles in breadth, some of them being dry, and the rest easily forded for nearly eight months in the year, whereas during the melting of the snow they are swollen, and a great transportation of mud and

* See Chap. viii.

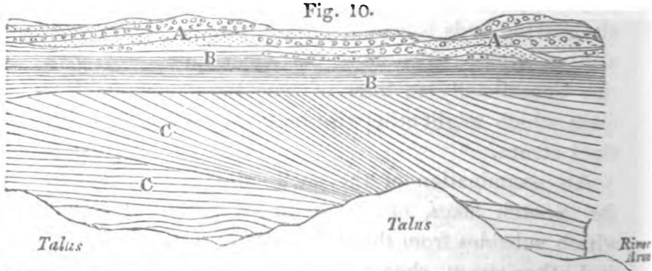
pebbles takes place. In order to keep open the main road from France to Italy, now carried along the sea-coast, it is necessary to remove annually great masses of shingle brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made by the deltas of minor rivers on this coast need not surprise us, when we recollect that there is sometimes a depth of two thousand feet at a few hundred yards from the beach, as near Nice. Similar observations might be made respecting a large proportion of the rivers in Sicily, and, among others, respecting that which, immediately north of the port of Messina, hurries annually vast masses of granitic pebbles into the sea.

Causes of Stratification in Deltas.—That the matter carried by rivers into seas and lakes is not thrown in confused and promiscuous heaps, but is spread out far and wide along the bottom, is well ascertained; and that it must for the most part be divided into distinct strata, may in part be inferred where it cannot be proved by observation. The horizontal arrangement of the strata, when laid open to the depth of twenty or thirty feet in the deltas of the Ganges, Indus, and Mississippi, is alluded to by many writers; and the same disposition is well known to obtain in all modern deposits of lakes and estuaries.

Natural divisions are often occasioned by the interval of time which separates annually the deposition of matter during the periodical rains, or melting of the snow upon the mountains. The deposit of each year may acquire some degree of consistency before that of the succeeding year is superimposed. A variety of circumstances also give rise annually, or sometimes from day to day, to slight variations in colour, fineness of the particles, and other characters, by which alternations of strata distinct in texture, and mineral ingredients, must be produced. Thus, for example, at one period of the year, drift wood may be carried down, and at another mud, as was before stated to be the case in the delta of the Mississippi; or at one time, when the volume and velocity of the stream are greatest, pebbles and sand may be spread over a certain area, over which, when the waters are low, fine matter or chemical precipitates are formed. During inundations, the current of fresh water often repels the sea for many miles; but when the river is low, salt water again occupies the same space. When two deltas are converging, the intermediate space is often, for reasons before explained, alternately the receptacle of different sediments derived from the converging streams. The one is, perhaps, charged with calcareous, the other with argillaceous matter; or one sweeps down sand and pebbles, the other impalpable mud. These differences may be repeated, with considerable regularity, until a thickness of hundreds of feet of alternating beds is accumulated. The multiplication, also, of shells and corals in particular spots, must give rise occasionally to lines of separation, and divide a mass which might otherwise be homogeneous into distinct strata.

An examination of the shell marl now forming in the Scotch lakes, or the sediment termed "warp," which subsides from the muddy water of the Humber, and other rivers, shews that recent deposits are often composed of a great number of extremely thin layers, either even or slightly undulating, and preserving a general parallelism to the planes of stratification. Sometimes, however, the laminæ in modern strata are disposed diagonally at a considerable angle, which appears to take place where there are conflicting movements in the waters. In January, 1829, I visited, in company with Professor L. A. Necker, of Geneva, the confluence of the Rhone and Arve, when those rivers were very low, and were cutting channels through the vast heaps of debris thrown down from the waters of the Arve, in the preceding spring. One of the sandbanks which had formed, in the spring of 1828, where the opposing currents of the two rivers neutralized each other, and caused a retardation in the motion, had been undermined; and the following is an exact representation of the arrangement of laminæ exposed in a vertical section. The length of the portion here seen is about twelve feet, and the height five. The strata A A consist of irregular alternations of pebbles and sand in undulating beds: below these are seams of very fine sand B B, some as thin as paper, others about a quarter of an inch thick. The strata C C are

Fig. 10.



Section on the banks of the Arve at its confluence with the Rhone, showing the stratification of deposits where currents meet.

composed of layers of fine greenish-gray sand, as thin as paper. Some of the inclined beds will be seen to be thicker at their upper, others at their lower extremity, the inclination of some being very considerable. These layers must have accumulated one on the other by lateral apposition, probably when one of the rivers was very gradually increasing or diminishing in velocity, so that the point of greatest retardation caused by their conflicting currents shifted slowly, allowing the sediment to be thrown down in successive layers on a sloping bank. The same phenomenon is exhibited in older strata of all ages; and when they are treated of, I shall endeavour more fully to illustrate the origin of such a structure.

Constant interchange of land and sea.—I may here conclude my remarks on deltas, observing that, imperfect as is our information of the changes which they have undergone within the last three thousand years, they are sufficient to shew how constant an interchange of sea and land is taking place on the face of our globe. In the Mediterranean alone, many flourishing inland towns, and a still greater number of ports, now stand where the sea rolled its waves since the era of the early civilization of Europe. If we could compare with equal accuracy the ancient and actual state of all the islands and continents, we should probably discover that millions of our race are now supported by lands situated where deep seas prevailed in earlier ages. In many districts not yet occupied by man, land animals and forests now abound where ships once sailed, and on the other hand, we shall find, on inquiry, that inroads of the ocean have been no less considerable. When to these revolutions, produced by aqueous causes, we add analogous changes wrought by igneous agency, we shall, perhaps, acknowledge the justice of the conclusion of Aristotle, who declared that the whole land and sea on our globe periodically changed places.*

* See above, Book i. p. 21.

GLOSSARY

OF GEOLOGICAL AND OTHER SCIENTIFIC TERMS USED IN THIS WORK.

Acephalous. The Acephala are that division of molluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of animals with bivalve shells, and a few which are devoid of shells. *Etym.*, *α*, *a*, without, and *κεφαλη*, *cephale*, the head.

Adipocire. A substance apparently intermediate between fat and wax, into which dead animal matter is converted when buried in the earth, and in a certain stage of decomposition. *Etym.*, *adeps*, fat, and *cera*, wax.

Alembic. An apparatus for distilling.

Algæ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *alga*, sea-weed.

Alluvial. The adjective of alluvium, which see.

Alluvion. Synonymous with alluvium, which see.

Alluvium. Earth, sand, gravel, stones, and other transported matter which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *alluo*, to wash upon. For a further explanation of the term, as used in this work, see Vol. III. p. 218., and Vol. IV. p. 57.

Alum-stone, Alumen, Aluminous. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the alluminous earth of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

AMMONITE. An extinct and very numerous genus of the order of molluscous animals called Cephalopoda, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not been seen in the tertiary beds. They are named from their resemblance to the horns on the statues of Jupiter Ammon.

AMORPHOUS. Bodies devoid of regular form. *Etym.*, *α*, *a*, without, and *μορφη*, *morphe*, form.

AMYGDALOID. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, *αμυγδαλα*, *amygdala*, an almond.

ANALCIME. A simple mineral of the Zeolite family, also called Cubizite, of frequent occurrence in the trap-rocks.

ANALOGUE. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil-shell is the analogue of the latter.

ANOPLOTHERE, ANOPLOTHERIUM. A fossil extinct quadruped belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defence, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, *ανοπλος*, *anoplos*, unarmed, and *θηριον*, *therion*, a wild beast.

ANTAGONIST POWERS. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

ANTENNÆ. The articulated horns with which the heads of insects are invariably furnished.

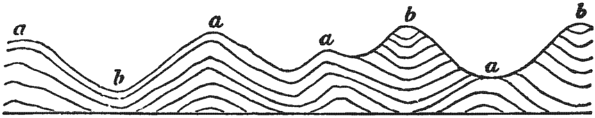
ANTHRACITE. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, *ανθραξ*, *anthrax*, coal.

ANTHRACOTHERIUM. A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were found in lignite and coal of the tertiary strata. *Etym.*, *ανθραξ*, *anthrax*, coal, and *θηριον*, *therion*, wild beast.

Anthropomorphous. Having a form resembling the human. *Etym.*, ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form.

Anticlinal Axis. If a range of hills, or a valley, be composed of strata, which on the two sides dip in opposite directions, the imaginary line that lies between them, towards which the strata on each side rise, is called the anticlinal axis. In a row of houses with steep roofs facing the south, the slates represent inclined strata dipping north and south, and the ridge is an east and west anticlinal axis. In the accompanying diagram, *a*, *a* are the anticlinal, and *b*, *b* the synclinal lines. *Etym.*, αντι, *anti*, against, and κλινω, *clino*, to incline.

Fig. 11.



Antiseptic. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be antiseptic. *Etym.*, αντι, *against*, and σηπω, *sepo*, to putrefy.

Arenaceous. Sandy. *Etym.*, *arena*, sand.

Argillaceous. Clayey, composed of clay. *Etym.*, *argilla*, clay.

Arragonite. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

Augite. A simple mineral of a dark green, or black colour, which forms a constituent part of many varieties of volcanic rocks.

Avalanches. Masses of snow which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

Basalt. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides, called basaltic columns. Remarkable examples of this kind are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Æthiopian word signifying iron. The rock often contains much iron.

"Basin" of Paris, "Basin" of London. Deposits lying in a hollow or trough, formed of older rocks; sometimes used in geology almost synonymously with "formations," to express the deposits lying in a certain cavity or depression in older rocks.

Belemnite. An extinct genus of the order of molluscous animals called Cephalopoda, having a long, straight, and chambered conical shell. *Etym.*, *βελεμνον*, *belemnon*, a dart.

Bitumen. Mineral pitch, of which the tar-like substance which is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *bitumen*, pitch.

Bituminous Shale. An argillaceous shale, much impregnated with bitumen, which is very common in the coal measures.

Blende. A metallic ore, a compound of the metal zinc with sulphur. It is often found in brown shining crystals; hence its name among the German miners, from the word *blenden*, to dazzle.

Bluffs. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

Botryoidal. Resembling a bunch of grapes. *Etym.*, *βοτρυς*, *botrys*, a bunch of grapes, and *ειδος*, *eidos*, form.

Boulders. A provincial term for large rounded blocks of stone lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

Breccia. A rock composed of angular fragments connected together by lime or other mineral substance. An Italian term.

Calc Sinter. A German name for the deposits from springs holding carbonate of lime in solution—petrifying springs. *Etym.*, *kalk*, lime, *sintern*, to drop.

CALCAIRE GROSSIER. An extensive stratum, or rather series of strata, found in the Paris Basin, belonging to the Eocene tertiary period. See Table I. E, Vol. IV. p. 309. *Etym.*, *calcaire*, limestone, and *grossier*, coarse.

CALCAREOUS ROCK. Limestone. *Etym.*, *calx*, lime.

CALCAREOUS SPAR. Crystallized carbonate of lime.

CALCEDONY. A siliceous simple mineral, uncrystallized. Agates are partly composed of calcedony.

CARBON. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *carbo*, coal.

CARBONATE of LIME. Lime combines with great avidity with carbonic acid, a gaseous acid only obtained fluid when united with water, — and all combinations of it with other substances are called *Carbonates*. All limestones are carbonates of lime, and quick lime is obtained by driving off the carbonic acid by heat.

CARBONATED SPRINGS. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries; and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

CARBONIC ACID GAS. A natural gas which often issues from the ground, especially in volcanic countries. *Etym.*, *carbo*, coal, because the gas is obtained by the slow burning of charcoal.

CARBONIFEROUS. A term usually applied, in a technical sense, to an ancient group of secondary strata, (see Table I. M, Vol. IV. p. 312.); but any bed containing coal may be said to be carboniferous. *Etym.*, *carbo*, coal, and *fero*, to bear.

CATACLYSM. A deluge. *Etym.*, κατακλυζω, *catacluzo*, to deluge.

CEPHALOPODA. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, κεφαλη, *cephale*, head, and ποδα, *poda*, feet.

CETACEA. An order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and narwal are examples. *Etym.*, *cete*, whale.

CHALK. A white earthy limestone, the uppermost of the secondary series of strata. See Table I. F, Vol. IV., p. 309.

CHERT. A siliceous mineral, nearly allied to calcedony and flint, but less homogeneous and simple in texture. A gradual passage from chert to limestone is not uncommon.

CHLORITIC SAND. Sand coloured green by an admixture of the simple mineral chlorite. *Etym.*, χλωρος, *chloros*, green.

CLEAVAGE. Certain rocks, usually called slate-rocks, may be cleaved into an indefinite number of thin laminæ which are parallel to each other, but which are generally not parallel to the planes of the true strata or layers of deposition. The planes of cleavage, therefore, are distinguishable from those of stratification; and they also differ from joints, which are fissures or lines of parting, at definite distances, and often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms are joints. The masses of rock included between joints cannot be cleaved into an indefinite number of laminæ or slates, having their planes of cleavage parallel to the joints. See first part of Chap. xxvii. Book iv.

CLINKSTONE, called also phonolite, a felspathic rock of the Trap family, usually fissile. It is sonorous when struck with a hammer, whence its name.

COAL FORMATION. This term is generally understood to mean the same as the Coal Measures. See Table I., M, Vol. IV. p. 312. There are, however, "coal formations" in all the geological periods, wherever any of the varieties of coal forms a principal constituent part of a group of strata.

COLEOPTERA. An order of insects (Beetles) which have four wings, the upper pair being crustaceous and forming a shield. *Etym.*, κολεος, *coleos*, a sheath, and πτερον, *pteron*, a wing.

CONFORMABLE. When the planes of one set of strata are generally parallel to those of another set which are in contact, they are said to be conformable. Thus the set *a*, *b*, Fig. 115., Vol. IV. p. 133., rest conformably on the inferior set *c*, *d*; but *c*, *d* rest unconformably on E.

CONGENERS. Species which belong to the same genus.

CONGLOMERATE OR PUDDINGSTONE. Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a siliceous, calcareous, or argillaceous nature. *Etym.*, *con*, together, *glomero*, to heap.

CONIFERÆ. An order of plants which, like the fir and pine, bear cones or tops in which the seeds are contained. *Etym.*, *conus*, cone, and *fero*, to bear.

Coomb. A provincial name in different parts of England for a valley on the declivity of a hill, and which is generally without water.

Cornbrash. A rubbly limestone, forming a soil extensively cultivated in Wiltshire for the growth of corn. It is a provincial term adopted by Smith. Brash is derived from brecan, Saxon, to break. See Table I. H, Vol. IV. p. 310.

Cornstone. A provincial name for a red limestone, forming a subordinate bed in the Old Red Sandstone group.

Cosmogony, Cosmology. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

Crag. A provincial name in Norfolk and Suffolk for a deposit, usually of gravel, belonging to the Older Pliocene period. See Table I., C, Vol. IV. p. 309.

Crater. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *crater*, a great cup or bowl.

Cretaceous. Belonging to chalk. *Etym.*, *creta*, chalk.

Crop Out. A miner's or mineral surveyor's term, to express the rising up or exposure at the surface of a stratum or series of strata.

Crust of the Earth. See Earth's crust.

Crustacea. Animals having a shelly coating or crust which they cast periodically. Crabs, shrimps, and lobsters, are examples.

Cryptogamic. A name applied to a class of plants, such as ferns, mosses, sea-weeds, and fungi, in which the fructification or organs of reproduction are concealed. *Etym.*, κρυπτος, *kryptos*, concealed, and γαμος, *gamos*, marriage.

Crystals. Simple minerals are frequently found in regular forms, with facets like the drops of cut glass of chandeliers. Quartz being often met with in rocks in such forms, and beautifully transparent like ice, was called *rock-crystal*, κρυσταλλος, *crystallos*, being Greek for ice. Hence the regular *forms* of other minerals are called crystals, whether they be clear or opake.

CRYSTALLIZED. A mineral which is found in regular forms or crystals is said to be crystallized.

CRYSTALLINE. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystalline* texture. Sugar-candy and calcareous spar are crystallized.

CYCADEÆ. An order of plants which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds by botanists, which spreads in a circle. The term is derived from *κυκας*, *cycas*, a name applied by the ancient Greek naturalist Theophrastus to a palm.

CYPERACEÆ. A tribe of plants answering to the English sedges; they are distinguished from grasses by their stems being solid, and generally triangular, instead of being hollow and round. Together with *gramineæ* they constitute what writers on botanical geography often call *glumaceæ*.

DEBACLE. A great rush of waters, which, breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *débacler*, French, to unbar, to break up as a river does at the cessation of a long-continued frost.

DELTA. When a great river, before it enters the sea, divides into separate streams, they often diverge and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, was first called, in the case of the Nile, a delta, from its resemblance to the letter of the Greek alphabet which goes by that name Δ. Geologists apply the term to alluvial land formed by a river at its mouth, without reference to its precise shape.

DENUDATION. The carrying away by the action of running water of a portion of the solid materials of the land, by which inferior rocks are laid bare. *Etym.*, *denudo*, to lay bare.

DESICCATION. The act of drying up. *Etym.*, *desicco*, to dry up.

DEOXIDIZED, DEOXIDATED. Deprived of oxygen. Disunited from oxygen.

DIAGONAL STRATIFICATION. For an explanation of this term, see Vol. IV. p. 91.

Dicotyledonous. A grand division of the vegetable kingdom, founded on the plant having two *cotyledons* or seed-lobes. *Etym.*, δις, *dis*, double, and κοτυληδων, cotyledon.

Dike. When a mass of the unstratified or igneous rocks, such as granite, trap, and lava, appears as if injected into a great rent in the stratified rocks, cutting across the strata, it forms a dike; and as they are sometimes seen running along the ground, and projecting, like a wall, from the softer strata on both sides of them having wasted away, they are called in the north of England and in Scotland *dikes*, the provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads.

Diluvium. Those accumulations of gravel and loose materials which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

Dip. When a stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass, and the angle it makes with the horizon is called the angle of dip or inclination.

Diptera. An order of insects, comprising those which have only two wings. *Etym.*, δις, *dis*, double, and πτερον, *pteron*, wing.

Dolerite. One of the varieties of the trap-rocks, composed of augite and felspar.

Dolomite. A crystalline limestone, containing magnesia as a constituent part. Named after the French geologist Dolomieu.

Dunes. Low hills of blown sand that skirt the shores of Holland, England, Spain, and other countries.

Earth's Crust. Such superficial parts of our planet as are accessible to human observation.

Elytra. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles. They cover the body and protect the true membranous wing. *Etym.*, ελυτρον, *elytron*, a sheath.

Eocene. See explanation of this word, Vol. III. p. [illegible]3.

Escarpment, the abrupt face of a ridge of high land. *Etym.*, *escarper*, French, to cut steep.

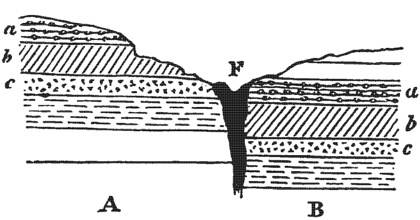
Estuaries. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym.*, *æstus*, the tide.

Experimentum Crucis. A decisive experiment, so called because, like a cross or direction post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture whereby the nature of the thing is extorted, as it were, by violence.

Exuviæ. Properly speaking, the transient parts of certain animals which they put off or lay down to assume new ones, as serpents and caterpillars shift their skins; but in geology it refers not only to the cast-off coverings of animals, but to fossil shells and other remains which animals have left in the strata of the earth. *Etym.*, *exuere*, to put off or divest.

Faluns. A French provincial name for some tertiary strata abounding in shells in Touraine, which resemble in lithological characters the "crag" of Norfolk and Suffolk.

Fault, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c.



The strata *a*, *b*, *c*, &c., must at one time have been continuous; but a fracture having taken place at the fault F, either by the upheaving of the portion A, or the sinking of the portion B, the strata were so displaced, that the bed *a* in B is many feet lower than the same bed *a* in the portion A.

Fauna. The various kinds of animals peculiar to a country constitute its **Fauna**, as the various kinds of plants constitute its FLORA. The term is derived from the FAUNI, or rural, deities in Roman Mythology.

FELSPAR. A simple mineral, which, next to quartz, constitutes the chief material of rocks. The white angular portions in granite are felspar. This mineral always contains some alkali in its composition. In *common felspar* the alkali is potash; in another variety, called Albite or Cleavlandite, it is soda. Glassy felspar is a term applied when the crystals have a considerable degree of transparency. *Compact* felspar is a name of more vague signification. The substance so called appears to contain both potash and soda.

FELSPATHIC. Of or belonging to felspar.

FERRUGINOUS. Any thing containing iron. *Etym.*, *ferrum*, iron.

FLOETZ ROCKS. A German term applied to the secondary strata by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds. *Etym.*, *flötz*, a layer or stratum.

FLORA. The various kinds of trees and plants found in any country constitute the flora of that country in the language of botanists.

FLUVIATILE. Belonging to a river. *Etym.*, *fluvius*, a river.

FORMATION. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

FOSSIL. All minerals were once called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth. *Etym.*, *fossilis*, any thing that may be dug out of the earth.

FOSSILIFEROUS. Containing organic remains.

GALENA. A metallic ore, a compound of lead and sulphur. It has often the appearance of highly polished lead. *Etym.*, γαλεω, *galeo*, to shine.

GARNET. A simple mineral, generally of a deep red colour, crystallized; most commonly met with in mica slate, but also in granite and other igneous rocks.

GASTEROPODS. A division of the Testacea in which, as in the limpet, the foot is attached to the body. *Etym.*, γαστηρ, belly and ποδα, *poda*, feet.

GAULT. A provincial name in the east of England for a series of beds of clay and marl, the geological position of which is between the upper and lower green-sand. See Table I. F, Vol. IV. p. 309.

GEM, or GEMMULE, from the Latin *gemma*, a bud. The term, applied to zoophytes, means a young animal not confined within an envelope or egg.

GEOLOGY, GEOGNOSY. Both mean the same thing; but, with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth *geognosy* (*Etym.*, γεα, *gea*, earth, and γινωσκω, *ginosco*, to know), and our theoretical speculations as to its formation *geology* (*Etym.*, γεα, and λογος, *logos*, a discourse).

GLACIER. Vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym.*, *glace*, French for ice.

GLACIS. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

GNEISS. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica and a laminated texture. The word is a German miner's term.

GRAMINEÆ. The order of plants to which grasses belong. *Etym.*, *gramen*, grass.

GRANITE. An unstratified or igneous rock, generally found inferior to or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is usually composed of three simple minerals, felspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets, afford good examples of the most common varieties of granite.

GREENSAND. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. See Table I. F, Vol. IV. p. 309. The name is given to these beds because they often, but not always, contain an abundance of green earth or chlorite scattered through the substance of the sandstone, limestone, &c. See Vol. IV. p. 284.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREYWACKÉ. *Grauwacke*, a German name, generally adopted by geologists for the lowest members of the secondary strata. O, Table I. Vol. IV. p. 313.; see also Vol. IV. p. 304. The rock is very often of a grey colour, hence the name, *grau*, being German for grey, and *wacke* being a provincial miner's term.

GRIT. A provincial name for a coarse-grained sandstone.

GYPSUM. A mineral composed of lime and sulphuric acid, hence called also *sulphate of lime*. Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abundantly near Paris, that plaster of Paris is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation is unknown.

GYPSEOUS, of or belonging to gypsum.

GYROGONITES. Bodies found, in fresh-water deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of fresh-water plants of the genus *chara*. See Vol. III. p. 283. *Etym.*, γυρος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

HEMIPTERA. An order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membranous at the apex, ἡμισυ, *hemisu*, half, and πτερον, *pteron*, wing.

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

HORNSTONE. A siliceous mineral substance, sometimes approaching nearly to flint, or common quartz. It has a conchoidal fracture, and is infusible, which distinguishes it from compact felspar.

HUMERUS. The bone of the upper arm.

HYDROPHYTES. Plants which grow in water. *Etym.*, ὑδωρ, *hydor*, water, and φυτον, *phyton*, plant.

HYPOGENE ROCKS. For an explanation of this term, see Vol. IV. p. 385.

Incandescent. White hot — having a more intense degree of heat than red heat.

Iceberg. Great masses of ice, often the size of hills, which float in the polar and adjacent seas. *Etym.*, ice, and *berg*, German for hill.

Ichthyosaurus. A gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.* ἰχθυς, *ichthus*, a fish, and σαυρα, *saura*, a lizard.

Induction. A consequence, inference, or general principle drawn from a number of particular facts, or phenomena. The inductive philosophy, says Mr. Whewell, has been rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications.

Infusory Animalcules. Minute living creatures found in many *infusions*; and the term *infusori* has been given to all such animalcules, whether found in infusions or in stagnant water, vinegar, &c.

Inspissated. Thickened. *Etym.*, *spissus*, thick.

Invertebrated Animals. Animals which are not furnished with a back-bone. For a further explanation, see "Vertebrated Animals."

Isothermal. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from ισος, *isos*, equal, and θερμη, *therme*, heat.

Joints, Jointed Structure. See "Cleavage."

Jura Limestone. The limestones belonging to the Oolitic Group (see Table I. H, Vol. IV. p. 310.) constitute the chief part of the mountains of the Jura, between France and Switzerland, and hence the geologists of the Continent have given the name to the group.

Kimmeridge Clay. A thick bed of clay, constituting a member of the Oolite Group. See Table I. H, Vol. IV. p. 310. So called because it is found well developed at Kimmeridge in the isle of Purbeck, Dorsetshire.

LACUSTRINE. Belonging to a lake. *Etym.*, *lacus*, a lake.

LAMANTINE. A living species of the herbivorous cetacea or whale tribe, which inhabits the mouths of rivers on the coasts of Africa and South America: the sea-cow.

LAMELLIFEROUS. Having a structure consisting of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

LAMINÆ. Latin for plates; used in geology, for the smaller layers of which a stratum is frequently composed.

LANDSLIP. A portion of land that has slid down in consequence of disturbance by an earthquake, or from being undermined by water washing away the lower beds which supported it.

LAPIDIFICATION — Lapidifying process. Conversion into stone. *Etym.*, *lapis*, stone, and *fio*, to make.

LAPILLI. Small volcanic cinders. *Lapillus*, a little stone.

LAVA. The stone which flows in a melted state from a volcano.

LEUCITE. A simple mineral found in volcanic rocks, crystallized, and of a white colour. *Etym.*, λευκος, *leucos*, white.

LIAS. A provincial name, adopted in scientific language, for a particular kind of limestone, which, being characterized together with its associated beds, by peculiar fossils, forms a particular group of the secondary strata. See Table I. Vol. IV. p. 311.

LIGNIPERDOUS. A term applied to insects which destroy wood. *Etym.*, *lignum*, wood, and *perdo*, to destroy.

LIGNITE. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

LITHODOMI. Molluscous animals which form holes in solid rocks, in which they lodge themselves. The holes are not perforated mechanically, but the rock appears to be dissolved. *Etym.*, λιθος, *lithos*, stone, and δεμω, *demo*, to build.

LITHOGENOUS POLYPS. Animals which form coral.

LITHOGRAPHIC STONE. A slaty compact limestone, of a yellowish colour and fine grain, used in lithography, which is the art of drawing upon and printing from stone. *Etym.*, λιθος, *lithos*, stone, and γραφω, *grapho*, to write.

LITHOIDAL. Having a stony structure.

LITHOLOGICAL. A term expressing the stony structure or character of a mineral mass. We speak of the lithological character of a stratum as distinguished from its zoological character. *Etym.*, λιθος, *lithos*, stone, and λογος, *logos*, discourse.

Lithophagi. Molluscous animals which form holes in solid stones. See "Lithodomi." *Etym.*, λιθος, *lithos*, stone, and φαγειν, *phagein*, to eat.

Lithophytes. The animals which form stone-coral.

Littoral. Belonging to the shore. *Etym.*, *littus*, the shore.

Loam. A mixture of sand and clay.

Lophiodon. A genus of extinct quadrupeds, allied to the Tapir, named from eminences on the teeth.

Lycopodiaceæ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses, generally found in mountainous heaths in the north of England.

Lydian Stone. A kind of quartz or flint, allied to hornstone, but of a greyish black colour.

Macigno. In Italy this term has been applied to a siliceous sandstone sometimes containing calcareous grains, mica, &c.

Madrepore. A genus of corals, but generally applied to all the corals distinguished by superficial star-shaped cavities. There are several fossil species.

Magnesian Limestone. An extensive series of beds, the geological position of which is immediately above the coal-measures; so called because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part. See Table I. L, Vol. IV. p. 312.

Mammiferous. Mammifers. Animals which give suck to their young. To this class all the warm-blooded quadrupeds, and the cetacea, or whales, belong. *Etym.*, *mamma*, a breast, *fero*, to bear.

Mammillary. A surface which is studded over with rounded projections. *Etym.*, *mammilla*, a little breast or pap.

Mammoth. An extinct species of the elephant (*E. primigenius*), of which the fossil bones are frequently met with in various countries. The name is of Tartar origin, and is used in Siberia for animals that burrow under ground.

MANATI. One of the cetacea, the sea-cow or lamantine (*Trichechus manatus*, Lin.)

MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.

MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young. The kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.

MASTODON. A genus of fossil extinct quadrupeds allied to the elephants; so called from the form of the hind teeth or grinders, which have their surface covered with conical mammillary crests. *Etm.*, *μαστος*, *mastos*, pap, and *οδων*, *odon*, tooth.

MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix. *Matrix*, womb.

MECHANICAL ORIGIN, ROCKS OF. Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystalline texture, which are of chemical origin.

MEDUSÆ. A genus of marine radiated animals, without shells; so called because their organs of motion spread out like the snaky hair of the fabulous Medusa.

MEGALOSAURUS. A fossil gigantic amphibious animal of the saurian or lizard and crocodile tribe. *Etym.*, *μεγαλη*, *megale*, great, and *σαυρα*, *saura*, lizard.

MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, *μεγα*, *mega*, great, and *θηριον*, *therion*, wild beast.

MELASTOMA. A genus of MELASTOMACEA, an order of exotic plants of the evergreen tree, and shrubby kinds. *Etym.*, *μελας*, *melas*, black, and *στομα*, *stoma*, mouth; because the fruit of one of the species stains the lips.

MESOTYPE. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the trap rocks.

METAMORPHIC ROCKS. For an explanation of this term, see Vol. IV. p. 386.

MICA. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life, but mineralogists apply the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.

Mica-slate, Mica-schist, Micaceous Schistus. One of the lowest of the stratified rocks, belonging to the hypogene or primary class, which is characterized by being composed of a large proportion of mica united with quartz.

Miocene. See an explanation of this term, Vol. III. p. 392.

Molasse. A provincial name for a soft green sandstone, associated with marl and conglomerates, belonging to the Miocene tertiary period, extensively developed in the lower country of Switzerland. See Vol. IV. p. 140. *Etym.*, French, *molle*, soft.

Mollusca, Molluscous Animals. Animals, such as shell-fish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

Monad. The smallest of visible animalcules, spoken of by Buffon and his followers as constituting the elementary molecules of organic beings.

Monitor. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

Monocotyledonous. A grand division of the vegetable kingdom (including palms, grasses, lilaceæ, &c.), founded on the plant having only one *cotyledon*, or seed lobe. *Etym.*, *μονος*, *monos*, single.

Moschus. A quadruped resembling the chamois or mountain goat, from which the perfume musk is obtained.

Mountain Limestone. A series of limestone strata, of which the geological position is immediately below the coal measures, and with which they also sometimes alternate. See Table I., M, Vol. IV. p. 312.

Moya. A term applied in South America to mud poured out from volcanos during eruptions.

Multilocular. Many-chambered, a term applied to those shells which, like the nautilus, ammonite, and others, are divided into many compartments. *Etym.*, *multus*, many, and *loculus*, a partition.

Muriate of Soda. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

Musaceæ. A family of tropical monocotyledonous plants, including the banana and plantains.

Muschelkalk. A limestone which, in geological position, belongs to the red sandstone group. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone. *Etym.*, *muschel*, shell, and *kalkstein*, limestone. See Table I., K, Vol. IV. p. 312.

Naptha. A very thin, volatile, inflammable, and fluid mineral substance, of which there are springs in many countries, particularly in volcanic districts.

Nenuphar. A yellow water-lily.

New Red Sandstone. A series of sandy, argillaceous, and often calcareous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish grey. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. The European formation so called lies in a geological position immediately above the coal measures. See Table I., K, Vol. IV. p. 313.

Nodule. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

Normal Groups. Groups of certain rocks taken as a rule or standard. *Etym.*, *norma*, rule or pattern.

Nucleus. A solid central piece, around which other matter is collected. The word is Latin for kernel.

Nummulites. An extinct genus of the order of molluscous animals called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and λιθος, *lithos*, stone, from its resemblance to a coin.

Obsidian. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced, most probably, by water that was contained in or had access to the melted stone, and converted into steam. There are very often portions in masses of solid obsidian, which are partially converted into pumice.

Ogygian Deluge. A great inundation mentioned in fabulous history, supposed to have taken place in the reign of *Ogyges* in Attica, whose death is fixed in Blair's Chronological Tables in the year 1764 before Christ.

Old Red Sandstone. A stratified rock belonging to the Carboniferous Group. See Table I., N. Vol. IV. p. 313.

Olivine. An olive-coloured, semi-transparent, simple mineral, very often occurring in the form of grains and of crystals in basalt and lava.

Oolite, Oolitic. A limestone, so named because it is composed of rounded particles, like the roe or eggs of a fish. The name is also applied to a large group of strata, H, Table I. Vol. IV. p. 310, characterized by peculiar fossils, because limestone of this kind occurs in this group in England, France, &c. *Etym.*, ὠον, *oon*, egg, and λιθος, *lithos*, stone.

Opalized Wood. Wood petrified by siliceous earth, and acquiring a structure similar to the simple mineral called opal.

Ophidious Reptiles. Vertebrated animals, such as snakes and serpents. *Etym.*, οφις, *ophis*, a serpent.

Organic Remains. The remains of animals and plants (*organized* bodies) found in a fossil state.

Orthocerata, or Orthoceræ. An extinct genus of the order of molluscous animals, called Cephalopoda, that inhabited a long-chambered conical shell, like a straight horn. *Etym.*, *ορθος*, *orthos*, straight, and *κερας*, *ceras*, horn.

Osseous Breccia. The cemented mass of fragments of bones of extinct animals found in caverns and fissures. *Osseus* is a Latin adjective, signifying bony.

Osteology. That division of anatomy which treats of the bones, from *οστεον*, *osteon*, bone, and λογος, *logos*, a discourse.

Outliers. When a portion of a stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier* and the term is adopted in geological language.

Ovate. The shape of an egg. *Etym.*, *ovum*, egg.

Ovipositing. The laying of eggs.

Oxide. The combination of a metal with oxygen; rust is oxide of iron.

Oxygen. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.*, παχυς, *pachus*, thick, and δερμα, *derma*, skin, or hide.

PACHYDERMATOUS. Belonging to pachydermata.

PALÆOTHERIUM, PALEOTHERE. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig, or tapir, but of great size. *Etym.*, παλαιος *palaios*, ancient, and θηριον, *therion*, wild beast.

PALEONTOLOGY. The science which treats of fossil remains, both animal and vegetable. *Etym.*, παλαιος, *pelaios*, ancient, οντα, *onta*, beings, and λογος, *logos*, a discourse.

PELAGIAN, PELAGIC. Belonging to the *deep* sea. *Etym.*, *pelagus*, sea.

PEPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriæ, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym.*, *petra*, rock, and *oleum*, oil.

PHÆNOGAMOUS or PHANEROGAMIC PLANTS. A name given by Linnæus to those plants in which the reproductive organs are apparent. *Etym.*, φανερος, *phaneros*, evident, or φαινω, *phaino*, to show, and γαμος, *gamos*, marriage.

PHLEGRÆAN FIELDS. Campi Phlegræi, or "the Burnt Fields." The country around Naples, so named by the Greeks, from the traces of igneous action every where visible.

PHONOLITE. See Clinkstone.

PHRYGANEA. A genus of four-winged insects, the larvæ of which, called caddis worms, are used by anglers as a bait.

PHYSICS. The department of science which treats of the properties of natural bodies, laws of motion, &c.; sometimes called natural philosophy and mechanical philosophy. *Etym.*, φυσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants — synonymous with botany and botanical. *Etym.*, φυτον, *phyton*, plant, and λογος, *logos*, discourse.

PHYTOPHAGOUS. Plant-eating. *Etym.*, φυτον, *phyton*, plant, and φαγειν, *phagein*, to eat.

PISOLITE. A stone possessing a structure like an agglutination of pease. *Etym.*, πισον, *pison*, pea, and λιθος, *lithos*, stone.

PISTIA. Vol. III. p. 63. The plant mentioned by Malte-Brun is probably the *Pistia Stratiotes*, a floating plant, related to English duck-weed, but very much larger.

PIT COAL. Ordinary coal; called so because it is obtained by sinking pits in the ground.

PITCH STONE. A rock of a uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance like indurated pitch.

PLASTIC CLAY. One of the beds of the Eocene tertiary period (see Table I. E, Vol. IV. p. 309.), so called because it is used for making pottery. The formation to which this name is applied is a series of beds chiefly sands, with which the clay is associated. *Etym.*, πλασσω, *plasso*, to form or fashion.

PLESIOSAURUS. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.*, πλησιον, *plesion*, near to, and σαυρα, *saura*, a lizard.

PLIOCENE. See explanation of this term, Vol. III. p. 390.

PLUTONIC ROCKS. Granite, porphyry, and other igneous rocks, supposed to have consolidated from a melted state at a great depth from the surface. For an explanation of this term, see Vol. IV. p. 344.

POLYPARIA. CORALS. A numerous class of invertebrated animals, belonging to the great division called Radiata.

PORPHYRY. An unstratified or igneous rock. The term is as old as the time of Pliny, and was applied to a red rock with small, angular, white bodies diffused through it, which are crystallized felspar, brought from Egypt. The term is hence applied to every species of unstratified rock in which detached crystals of felspar or some other mineral are diffused through a base of other mineral composition. *Etym.*, πορφυρα, *porphyra*, purple.

PORTLAND LIMESTONE, PORTLAND BEDS. A series of limestone strata, belonging to the upper part of the Oolite Group (see Table I. H, Vol. IV. p. 310.), found chiefly in England, in the Island of Portland on the coast of Dorsetshire. The great supply of the building stone used in London is from these quarries.

Pozzuolana. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called in this country Roman cement. It gets its name from Pozzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

Precipitate. Substances which having been dissolved in a fluid, are separated from it by combining chemically and forming a solid, which falls to the bottom of the fluid. This process is the opposite to that of chemical solution.

Producta. An extinct genus of fossil bivalve shells, occurring only in the older secondary rocks. It is closely allied to the living genus Terebratula.

Pubescence. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

Puddingstone. See "Conglomerate."

Pumice. A light spongy lava, of a white colour, produced by gases, or watery vapour getting access to the particular kind of glassy lava called obsidian, when in a state of fusion—it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

Purbeck Limestone, Purbeck Beds. Limestone strata belonging to the Wealden Group. See Table I. G, Vol. IV. p. 310.

Pyrites (Iron). A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock stratified and unstratified. The shining metallic bodies, so often seen in common roofing slate, are a familiar example of the mineral. The word is Greek, and comes from πυρ, *pyr*, fire; because, under particular circumstances, the stone produces spontaneous heat, and even inflammation.

Pyrometer. An instrument for measuring intense degrees of heat.

Quadrumana. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivative of the Latin word for the number four, and *manus*, hand; the four feet of those animals being in some degree usable as hands.

Qua-qua-versal Dip. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.*, *quâ-quâ versum*, on every side.

QUARTZ. A German provincial term, universally adopted in scientific language, for a simple mineral composed of pure silex, or earth of flints: rock-crystal is an example.

RED MARL. A term often applied to the New Red Sandstone, which is the principal member of the Red Sandstone Group. See Table I. K, Vol. IV. p. 311.

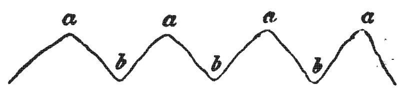
RETICULATE. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

ROCK SALT. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire, and it is then called *rock*-salt.

RUMINANTIA. Animals which ruminate or chew the cud, such as the ox, deer, &c. *Etym.*, the Latin verb *rumino*, meaning the same thing.

SACCHAROID, SACCHARINE. When a stone has a texture resembling that of loaf-sugar. *Etym.*, *σακχαρ*, *sacchar*, sugar, and *ειδος*, *eidos*, form.

SALIENT ANGLE. In a zigzag line, *a a* are the salient angles, *b b* the re-entering angles. *Etym.*, *salire*, to leap or bound forward.



SALT SPRINGS. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.

SANDSTONE. Any stone which is composed of an agglutination of grains of sand, whether calcareous, siliceous, or of any other mineral nature.

SAURIAN. Any animal belonging to the lizard tribe. *Etym.*, *σαυρα*, *saura*, a lizard.

SCHIST is often used as synonymous with slate; but it may be very useful to distinguish between a schistose and a slaty structure. The granitic or primary *schists*, as they are termed, such as gneiss, mica-schist, and others, cannot be split into an indefinite number of parallel laminæ, like rocks which have a true slaty cleavage. The uneven schistose layers of mica-schist and gneiss are probably layers of deposition which have assumed a crystalline texture. See "Cleavage." *Etym.*, *schistus*, adj. Latin; that which may be split.

SCHISTOSE ROCKS. See "Schist."

SCORIÆ. Volcanic cinders. The word is Latin for cinders.

SEAMS. Thin layers which separate two strata of greater magnitude.

SECONDARY STRATA. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them, called *primary*, and from a third series above them called *tertiary*. See Vol. IV. p. 281., and Table I. Vol. IV. p. 308.

SECULAR REFRIGERATION. The periodical cooling and consolidation of the globe from a supposed original state of fluidity from heat. *Sæculum*, age or period.

SEDIMENTARY ROCKS, are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

SELENITE. Crystallized gypsum, or sulphate of lime — a simple mineral.

SEPTARIA. Flattened balls of stone, generally a kind of ironstone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.

SERPENTINE. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of colour, like the skin of some serpents.

SHALE. A provincial term, adopted by geologists, to express an indurated slaty clay. *Etym.*, German *schalen*, to peel, to split.

SHELL MARL. A deposit of clay, peat, and other substances mixed with shells, which collects at the bottom of lakes.

SHINGLE. The loose and completely water-worn gravel on the sea-shore.

SILEX. The name of one of the pure earths, being the Latin word for *flint*, which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.

SILICA. One of the pure earths. *Etym.*, *silex*, flint, because found in that mineral.

SILICATE. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.

SILICEOUS. Of or belonging to the earth of flint. *Etym.*, *silex*, which see. A siliceous rock is one mainly composed of silex.

SILICIFIED. Any substance that is petrified or mineralized by *siliceous* earth.

SILT. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus the mouth of a river is silted up when its entrance into the sea is impeded by such accumulation of loose materials.

SIMPLE MINERAL. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature; for, when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral in the sense we use the term, but it is a chemical compound of sulphur and iron.

SLATE. See "Cleavage" and "Schist."

SOLFATARA. A volcanic vent from which sulphur, sulphureous, watery, and acid vapours and gases are emitted.

SPORULES. The reproductory corpuscula (minute bodies) of cryptogamic plants. *Etym.*, σπορα, *spora*, a seed.

STALACTITE. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, σταλαζω, *stalazo*, to drop.

STALAGMITE. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone: such a crust is called *stalagmite*, from σταλαγμα, *stalagma*, a drop, in opposition to *stalactite*, which see.

STATICAL FIGURE. The figure which results from the equilibrium of forces. From στατος, *statos*, stable, or standing still.

STERNUM. The breast bone, or the flat bone occupying the front of the chest.

STILBITE. A crystallized simple mineral, usually white, one of the Zeolite family, frequently included in the mass of the trap rocks.

STRATIFIED. Rocks arranged in the form of *strata*, which see.

STRATIFICATION. An arrangement of rocks in *strata*, which see.

STRATA, STRATUM. The term stratum, derived from the Latin verb *struo*, to strew or lay out, means a bed or mass of matter spread out over a certain surface by the action of water, or in some cases by wind. The deposition of successive layers of sand and gravel in the bed of a river, or in a canal, affords a perfect illustration both of the form and origin of stratification. A large portion of the masses constituting the earth's crust are thus stratified, the successive strata of a given rock, preserving a general parallelism to each other; but the planes of stratification not being perfectly parallel throughout a great extent like the planes of *cleavage*, which see.

STRIKE. The direction or line of bearing of strata, which is always at right angles to their prevailing dip. For a fuller explanation, see Vol. IV. p. 338.

SUBAPENNINES. Low hills which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene period.

SYENITE. A kind of granite, so called because it was brought from Syene in Egypt. For geological acceptation of the term, see Vol. IV. p. 351.

SYNCLINAL AXIS. See "Anticlinal." *Etym.*, συν, *syn*, together, and κλινω, *clino*, to incline.

TALUS. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

TARSI. The feet in insects, which are articulated, and formed of five or a less number of joints.

TERTIARY STRATA. A series of sedimentary rocks, with characters which distinguish them from two other great series of strata — the secondary and primary, which lie beneath them.

TESTACEA. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

THERMAL. Hot. *Etym.*, θερμος, *thermos*, hot.

THERMO-ELECTRICITY. Electricity developed by heat.

THIN OUT. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out, or disappear.

TRACHYTE. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of porphyry. It sometimes contains hornblende and augite; and when these last predominate, the trachyte passes into the varieties of trap called greenstone, basalt, dolorite, &c. The term is derived from τραχυς, *trachus*, rough, because the rock has a peculiar rough feel.

TRAP and TRAPPEAN ROCKS. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as basalt, amygdaloid, dolorite, greenstone, and others. The term is derived from *trappa*, a Swedish word for stair, because the rocks of this class sometimes occur in large tabular masses, rising one above another, like steps. For further explanation, see Vol. IV. p. 352.

TRAVERTIN. A concretionary limestone, usually hard and semi-crystalline, deposited from the water of springs holding lime in solution. *Etym.* This stone was called by the ancients Lapis Tiburtinus, the stone being formed in great quantity by the river Anio, at Tibur, near Rome. Some suppose travertin to be an abbreviation of trasteverino from trans-tiburtinus.

TROPHI, of Insects. Organs which form the mouth, consisting of an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

TUFA, CALCAREOUS. A porous rock deposited by calcareous waters on their exposure to the air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime. The more solid form of the same deposit is called "travertin," into which it passes.

TUFA, VOLCANIC. See "Tuff."

TUFACEOUS. A rock with the texture of tuff or tufa, which see.

TUFF or TUFA, VOLCANIC. An Italian name for a variety of volcanic rock of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose matter ejected from a volcano.

TURBINATED. Shells which have a spiral or screw-form structure. *Etym.*, *turbinatus*, made like a top.

UNCONFORMABLE. See "Conformable."

UNOXIDIZED, UNOXIDATED. Not combined with oxygen.

VEINS, MINERAL. Cracks in rocks filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal, hence their name.

VERTEBRATED ANIMALS. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

VESICLE. A small, circular, inclosed space, like a little bladder. *Etym.*, diminutive of *vesica*, Latin for a bladder.

VITRIFICATION. The conversion of a body into glass by heat.

VOLCANIC BOMBS. Volcanos throw out sometimes detached masses of melted lava, which, as they fall, assume rounded forms (like bomb-shells), and are often elongated into a pear shape.

VOLCANIC FOCI. The subterranean centres of action in volcanos, where the heat is supposed to be in the highest degree of energy.

WACKE. A rock nearly allied to basalt, of which it may be regarded as a soft and earthy variety.

ZEOLITE. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ζεω, *zeo*, to boil, and λιθος, *lithos*, stone.

ZOOPHYTES. Corals, sponges, and other aquatic animals allied to them; so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym.*, ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

END OF THE FIRST VOLUME.

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