PRESENT STATE OF THE TEMPLE OF SERAPIS, AT PUZZUOLI.

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.

"Verè scire est per causas scire."—BACON.

IN TWO VOLUMES.

VOL. I.

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PREFACE.

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 edition in octavo	1832.
2d Vol. 2d edition do.	Jan. 1833.
3d Vol. 1st edition do.	May 1833.
New edition (called the 3d) of the whole work in 4 vols. 12mo.	May 1834.
4th edition, 4 vols. 12mo.	June 1835.

I have acknowledged on former occasions the valuable assistance afforded me by several of my friends in the execution of this work, and have especially returned my thanks to Mr. Murchison, Mr. Broderip, Dr. Fitton, Mr. Lonsdale, and Capt. Basil Hall, for their zealous co-operation, and for the corrections and improvements which were adopted at their suggestion.

In the Prefaces to the third and fourth editions, I gave lists 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 and Additions in the Fifth Edition, as compared to the Fourth.

VOLUME I.

VOLUME II.

New Wood Cuts in the Fifth Edition.

VOLUME I.

VOLUME II.

A general view or summary of the contents of this work cannot fail to be useful in pointing out more clearly the course of reasoning adopted, and the order in which the different subjects are treated. I therefore hope that the student, by referring from time to time to the subjoined summary, will more easily understand the plan of the whole, and the bearing on geology of several digressions which I have introduced on collateral topics, especially on certain departments of natural history.

GENERAL VIEW OR 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 are referred 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, it was supposed that the causes by which the crust of the earth, and its habitable surface, were 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 next considered (Chap. V. to p. 89, Vol. I.), and it is contended that neither the imaged universality of certain sedimentary formations (Chap. V.), nor the different climates which appear to have formerly pervaded the northern hemisphere (Chaps. VI. VII. VIII.), nor the alleged progressive development of organic life as inferred from the study of fossil remains (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 curiosity; and the author is aware that in endeavouring to attain this object, he has occasionally carried the beginner beyond his depth. It is presumed, however, that the reader will understand enough to be convinced that the forces formerly employed to remodel the crust of the earth were the same in kind and energy as those now acting: or, at least, he will perceive that the opposite hypothesis is very questionable; and if so, 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 their direct bearing on Geology.

The first of these treatises, or that relating to the changes known to have taken place in the *inorganic* creation 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 igneous causes, such as the volcano and earthquake, and all subterranean movements, are considered (Book II. Chaps. IX. to XIX.).

The other treatise, or that on the changes of the *organic* world, is also divided into two parts; the first of which comprehends all questions relating to the real existence and variability of species, and the limits assigned to their duration (Chaps. I. to XI. Book III.). The second explains the processes by which the remains of animals and cussed in the first part of the Third Book; after reading which, the student comes in a great degree prepared to follow the views and speculations of the author on the laws by which the extinction and successive disappearance of species may be governed.

From these remarks it will be seen that a study of systematic treatises on the recent changes of the organic and inorganic world afford a good preliminary exercise for those who desire to interpret geological monuments. They are thus enabled to proceed from the known to the unknown, or from the observed effects of causes now in action to the analogous effects of the same or similar causes which have acted at remote periods. It was necessary to dwell thus fully on the connexion of the Second and Third Books with the Fourth, because the relation of these parts of the work to each other is the least obvious. In order to comprehend the plan of other parts, it will be sufficient to peruse the abridged Table of Contents.

London, October 1836.

ABRIDGED TABLE

OF THE

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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 referable, 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 yield 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 recognised, 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, or at the close of the eighteenth century, 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 earth 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 demarkation 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. 24.)—Adopted by the Greeks—System of Pythagoras—of Aristotle (p. 29.)—Dogmas concerning the extinction and reproduction of genera and species—Strabo's theory of elevation by earthquakes (p. 31.)—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 immovable 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 coincidence 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 recognised, 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

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

† Menù, Inst. c. i. 66 and 67.

lived, grew, and 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 intellectual 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.†

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

* 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 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.

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.

The great flood of the Chinese, which their traditions carry back to the period of Yaou, something more than 2000 years before our era, has been identified by some persons with the universal deluge described in the Old Testament; but according to Mr. Davis, who accompanied two of our embassies to China, and who has carefully examined their written accounts, the Chinese cataclysm is therein described as interrupting the business of agriculture, rather than as involving a general destruction of the human race. The great Yu was celebrated for having "opened nine channels to draw off the waters," which "covered the low hills and bathed the foot of the highest mountains." Mr. Davis suggests that a great derangement of the waters of the Yellow River, one of the largest in the world, might even now cause the flood of Yaou to be repeated, and lay the most fertile and populous plains of China under water. In modern times the bursting of the banks of an artificial canal, into which a portion of the Yellow River has been turned, has repeatedly given rise to the most dreadful accidents, and is a source of perpetual anxiety to the government. It is easy, therefore, to imagine how much greater may have been the inundation, if this valley was ever convulsed by a violent earthquake.*

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

* See Davis on "The Chinese," published by the Society for the Diffusion of Useful Knowledge, vol. i. p. 128.

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

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 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 wickedness 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

* Prichard's Egypt. Mythol. p. 177.

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

‡ Prichard's Egypt. Mythol. p. 182.

§ Ibid. p. 193.

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 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.

* Plato's Timæus.

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 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

* Aristophanes, Birds, 694.

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 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 reborn 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 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.

* Ovid's Metamor. lib. 15.

† 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.

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.‡

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

* 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.

§ 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.

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 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 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 (λανθάνει); 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

* Meteor. lib. i cap. 12.

† De Die Nat.

‡ Lib. ii. cap. 14, 15, and 16.

§ Ibid.

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 forever. 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 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 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 36,425 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

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

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 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 Zanthus 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

* 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 the two first 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.

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, neither 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 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.‖

* "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 Latin translation, and in the original Greek, *αναφυσηματα*, gaseous eruptions? or *inflations* of land?—Ibid., p. 93.

‡ Strabo, lib. vi. p. 396. § Book iv. ‖ L. vi. ch. xiii.

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 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, shows 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.—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.*

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

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

† 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.

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 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 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.§

* 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.

‡ Sale's Koran, chap. xi. see note.

§ Ibid.

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 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, five hundred 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, five hundred 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.'"

* 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.

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 sprang 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 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

* 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.

termino"——"appropinquante magno judicii die," left lasting monuments of the popular delusion.*

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 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 skilful 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

* In Sicily, in particular, the title-deeds of many valuable grants of land to the monasteries are headed by such preambles, composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

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 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 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 inter-

* De Fossilib. pp. 109 and 176.

† Brocchi, Con. Foss. Subap. Disc. sui Progressi. vol. i. p. 57.

‡ De Metallicis.

§ Dies Caniculares.

nal 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 to 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 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; exemplying 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 with living species, pointed out their resemblance, and traced the various

* Storia Naturale.

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

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. 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 had 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 ascendancy 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.†

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

† 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."

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 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 extravagant 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 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 meantime, 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 *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.‡

* 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 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.

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

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 recognise, therefore," says Leibnitz, a double origin of primitive masses, the one by refrigeration from igneous fusion, the other by concretion from 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.‡ Hook 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 are more certain tokens of antiquity

* Unde jam duplex origo intelligitur primorum corporum, una, cum ab ignis fusione refrigescerent, alterâ, 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.

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, Hook 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 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, analagous 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, Lecture, Feb. 29. 1688.

† 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

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 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 brought 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, 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 men-

(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 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. † Ibid. p. 312.

tions 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 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.

* Posth. 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.

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 to the order of their

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

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.

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

* 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.

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 shown 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

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

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 and sinking of the waters in the Baltic, to which I shall have occasion to advert more particularly hereafter (ch. 17. book 2.).

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 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

* 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.

of contending, in his preliminary chapter, against St. Jerome, and four other principal interpreters of Scripture, besides several professors of divinity, "that springs 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 earthquakes, as expounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri.‖ 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 Santorin 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

* 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 although 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.

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 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 an 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 Strabo, 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."†

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 mira-*

* 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.

*cles.** 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 showing 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? 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

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

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 scattered 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

* Sui Testacei della Sicilia.

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 shown 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 currents. The Tuscan naturalist laboured to show that both the larger and smaller valleys of the Appennines 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

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

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

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 connected 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 Appennines, 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 firmness and discrimination.

Arduino, 1759.—In the year following, Arduino,‡ in his memoirs on the mountains of Padua, Vicenza, and Verona, deduced, from original observations, the distinction of rocks into primary, secondary, and tertiary, and showed 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

* John Gesner published at Leyden, in Latin.

† Part ii. chap. 9.

‡ Giornale del Griselini, 1759.

§ 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 professor-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 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 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

ship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

* Sui Corpi Marini del Feltrino, 1761.

† 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."

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 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 recognised by geologists in various parts of Germany. He supposed the European continents to have remained

* 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.

covered by the sea until the formation 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 tha

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

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

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.*

Cortesi—Spallanzani—Wallerius—Whitehurst.—While these Italian naturalists, together with Cortesi and Spallanzani, were busily engaged in pointing out the analogy between the deposites 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 of Siberia, Pallas announced the result, that the granite 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

* This argument of Testa has been strengthened of late years by 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.

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

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.

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. 67.)—Controversy between the Vulcanists and Neptunists—Intemperance of the rival Sects—Hutton's Theory of the Earth—His Discovery of Granite Veins (p. 70.)—Originality of his Views—Why opposed—Playfair's Illustrations—Influence of Voltaire's Writings on Geology (p. 73.)—Imputations cast on the Huttonians by Williams, Kirwan, and De Luc—Smith's Map of England (p. 77.)—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.†

* Nov. comm. Petr. XVII. Cuvier, Eloge de Pallas.

† 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."

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 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, with the exception of a valuable treatise on metaliferous veins, 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

* Cuvier, Eloge de Werner.

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 to 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 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 greywacké 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 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

* 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.

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 referable 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, recognised 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

* Cuvier, Eloge de Desmarest.

Europe, the igneous origin of which was denied by the school of Freyberg.*

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 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

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

† Journ. de Phys. tom. xxv. p. 191.

‡ Ib. tom. xxxvii. part ii. p. 200.

§ Cuvier, Eloge de Desmarest.

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, 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 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 analagous 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."

* Ed. Phil. Trans. 1788.

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 chrystalline 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 analagous 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 of faith in the school of Freyberg; and if any one ventured to doubt the possibility of our

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

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 forever 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.

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 successively 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 recal 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 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

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

† 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."

§ 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.

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 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 opinions, 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 Kingdom," in 1789; a work of great

* As an instance of his desire to throw doubt indiscriminately on all geological data, we may recal 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."

† The Task, book iii. "The Garden."

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 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.‖

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

‖ 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

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.

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.*

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 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 degrees of the church, to use the term *hypothesis*, instead of theory. They now speak of the Copernican *theory*.

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

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; 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.

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 pro-

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

fessed 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

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

the European divisions of the secondary strata are in great part English, and are, indeed, 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 shown, 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 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

* Book iv. chap. ii.

† Discours sur les Révol., &c.

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 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. 88.)—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. 89.)

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 referable. 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 recognised 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 statutes, 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 9000 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 eye-witnesses 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 100 instead of 2000 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 5000 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 three feet. A repetition of two thousand shocks, of equal violence, might produce a mountain-chain one hundred miles long, and six thousand feet high. Now, should one or two 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 acted 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.

It may afford, perhaps, a more lively illustration of the principle here insisted upon, if I recal to the reader's recollection the legend of the Seven Sleepers. The scene of that popular fable was placed in the two centuries which elapsed between the reign of the emperor Decius and the death of Theodosius the younger. In that interval of time (between the years 249 and 450 of our era) the union of the Roman empire had been dissolved, and some of its fairest provinces overrun by the barbarians of the north. The seat of government had passed from Rome to Constantinople, and the throne from a Pagan persecutor to a succession of Christian and orthodox princes. The genius of the empire had been humbled in the dust, and the altars of Diana and Hercules were on the point of being transferred to Catholic saints and martyrs. The legend relates "that when Decius was still persecuting the Christians, seven noble youths of Ephesus concealed themselves in a spacious cavern in the side of an adjacent mountain, where they were doomed to perish by the tyrant, who gave orders that the entrance should be firmly secured with a pile of huge stones. They immediately fell into a deep slumber, which was miraculously prolonged, without injuring the powers of life, during a period of 187 years. At the end of that time the slaves of Adolius, to whom the inheritance of the mountain had descended, removed the stones to supply materials for some rustic edifice: the light of the sun darted into the cavern, and the seven sleepers were permitted to awake. After a slumber, as they thought, of a few hours, they were pressed by the calls of hunger, and resolved that Jamblichus, one of their number, should secretly return to the city to purchase bread for the use of his companions. The youth could no longer recognise the once familiar aspect of his native country, and his surprise was increased by the appearance of a large cross triumphantly erected over the principal gate of Ephesus. His singular dress and obsolete language confounded the baker, to whom he offered an ancient medal of Decius as the current coin of the empire; and Jamblichus, on the suspicion of a secret treasure, was dragged before the judge. Their mutual inquiries produced the amazing discovery, that two centuries were almost elapsed since Jamblichus and his friends had escaped from the rage of a Pagan tyrant."*

This legend was received as authentic throughout the Christian world before the end of the sixth century, and was afterwards introduced by Mahomet as a divine revelation into the Koran, and from hence was adopted and adorned by all the nations from Bengal to Africa who professed the Mahometan faith. Some vestiges even of a similar tradition have been discovered in Scandinavia. "This easy and universal belief," observes the philosophical historian of the Decline and Fall, "so expressive of the sense of mankind, may be ascribed to the genuine merit of the fable itself. We imperceptibly advance from youth to age, without observing the gradual, but incessant, change of human affairs; and even in our larger experience of history, the imagination is accustomed, by a perpetual series of causes and effects, to unite the most distant revolutions. But if the interval between two memorable eras could be instantly annihilated; if it were possible, after a momentary slumber of two hundred years, to display the new world to the eyes of a spectator who still retained a lively and recent impression of the old, his surprise and his reflections would furnish the pleasing subject of a philosophical romance."†

Prejudices arising from our peculiar position as inhabitants of the land.—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.

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 the 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

* Gibbon, Decline and Fall, chap. xxiii. † Ibid.

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 recognise 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 3000 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 annihilated 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 the 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, the 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 combatted on the ground of 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 pro-

* See Book iv. chap. iii.

ducts, 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, he 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 600 feet above the level of the ocean, and is in parts 1200 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. No hypothetical agency is required to cause the sudden escape of the confined 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 not witnessed within the last 3000 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 new 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 recognising the slightest analogy between 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. 100.)—Evidence in regard to temperature, from the fossils of tertiary and secondary rocks (p. 108.)—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. 110.)

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 recognise 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 circumstances 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

* 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.

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 referable 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, the associated unknown species belong, for the most part, to *genera* which are now most

* Professors Guidotti of Parma, and Bonelli of Turin, pointed out to me, in 1828, many examples in confirmation of this point: thus the common Orthoceras of the Mediterranean, (*O. raphanista,*) was said to attain 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 in the Red Sea. Murex cornutus, fossil at Asti, is now only known recent in warmer latitudes; Senegal being 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 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.

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 six or seven degrees to the north 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 phenomenon 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 mamalia 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.

Fig. 1.

Pleurotoma rotata. *Subapennine hills, Italy.*(a)

* Of the genus Pleurotoma a very few living representatives have yet been found in the Mediterranean; yet no less than twenty-five species were to be seen in the museum at Turin, in 1828, all procured by Professor Bonelli from the Subapennine strata of northern Italy. The genus Cypræ is represented by many large fossil species in the Subapennine hills.

† Book iii. chaps. 14, 15, &c.

(a) For another figure of this species, and of *P. vulpecula*, see Vol. II. plate X.

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 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 fresh water shells, thirteen in number, can be identified with species and varieties now existing in that country. 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 Reverend 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 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, respect-

* Geol. Proceedings, No. 36. June, 1834.
† Phil. Mag., Sept. 1829 and Jan 1830.

ing 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 the 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.

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 Hamburg.† 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 the 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 Petersburg 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° 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

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

† 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.

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?

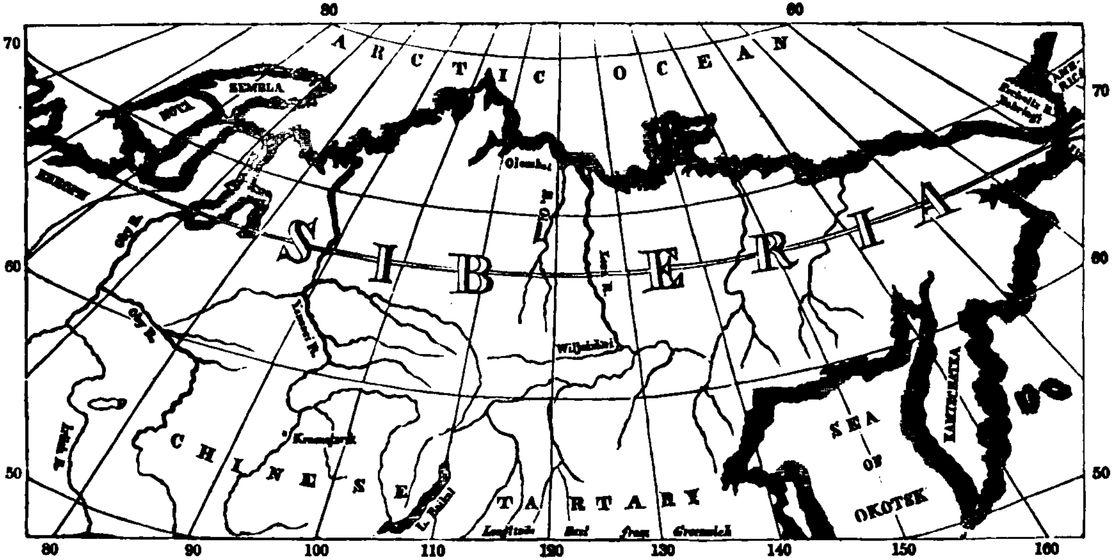
Pallas and other writers describe the bones of the mammoth as abounding throughout all the Lowland of Siberia, stretching in a direction west and east, from the borders of Europe to the extreme point nearest America, and south and north, from the base of the mountains of central Asia to the shores of the Arctic sea. (See Map, fig. 2, p. 104.) 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 elephantine 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 course 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

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

† Nov. Com. Petrop. vol. 17, p. 584.

Fig. 2.



Map showing the course of the Siberian rivers from south to north, from temperate to arctic regions, in the country where the fossil bones of the Mammoth abound.

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 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 thirty years, the entire carcass of a mammoth (or extinct species of elephant) 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.†

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

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

† Journal du Nord, St. Petersburg, 1807.

‡ 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 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.

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 the 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 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

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° Farenheit, 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.)

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

† See Book iii. chaps. xv. and xvi.

near their mouths. (See Map, p. 104.) 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 and often frozen into 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.

Humboldt remarks that near the mouths of the Lena a considerable thickness of frozen soil may be found at all seasons at the depth of a few feet; so that if a carcass be once imbedded in mud in such a region and in such a climate, its putrefaction may be arrested for indefinite ages.*

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 co-existed 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 rein-deer."

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 expe-

* Humboldt, Fragmens Asiatiques, tom. ii. p. 393.

rienced in part of Sweden; and as the shores of the Gulph 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 similiar 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 inclosed 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 extermination 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 referable 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

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

land. Yet, after 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 referable 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?‡

It may seem premature to discuss this question, 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 the strata 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, in reply to this objection, we must bear in mind, in the first place, that, 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

* 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, Esqs. No. IV.

§ Fossil Flora, No. IV.

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 here speaking of *living* species formed to inhabit within or near the tropics. But 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

* Fossil Flora, No. X.

† This has been proved by Mr. Lindley's experiments.

same land, the destruction of which provided materials for the sandstones and conglomerates of the group of 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. 116.)—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. 125.)—Conditions necessary for the production of the extreme of heat, and its probable effects on organic life (p. 130.)

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 temperature may be the same in two places which enjoy very different climates, for the seasons may be neary 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 3000 to 5000 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. 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 north-

* We are indebted to Baron Alex. Humboldt for collecting together, in a beautiful essay, the scattered data on which he 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, Memoires d'Arcueil, tom. iii. translated in the Edin. Phil. Journ. vol. iii. July, 1820.

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

ward 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 lands on the north between the 60th and 70th parallel, while to the south it is separated from the equator by the Indian Ocean.

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 characterised 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 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 and drift ice on temperature.—Among other influential causes, both of remarkable diversity in the mean annual heat,

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

† On Isothermal Lines, &c.

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° 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 Rennel, 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 three or four 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 seventy-eight 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 the sea. As it has been known to 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

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

† Ibid. p. 153.

‡ Ibid. p. 25.

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 1500 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 Scotland, ice is found every where in digging wells, in summer, at the depth of four feet! Other bergs have been occasionally met with, at midsummer, in a state of rapid thaw, as far south as lat. 40°, and longitude about 60° West, 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.‡ It is a well-known fact that every four or five years a large number of icebergs, floating from

* 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.

‡ Rennell on Currents, p. 95.

Greenland, double Cape Langaness, and are stranded on the west coast of Iceland. The inhabitants are then aware that their crops will fail, in consequence of fogs which are generated almost incessantly; and the dearth of food is not confined to the land, for the temperature of the water is so changed that the fish entirely desert the coast.

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 on 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 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 the equator by 10° than

* Humboldt on Isothermal Lines.

the ice around the north pole. But the recent voyages of Weddell and Biscoe have shown 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 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 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 aërial 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.

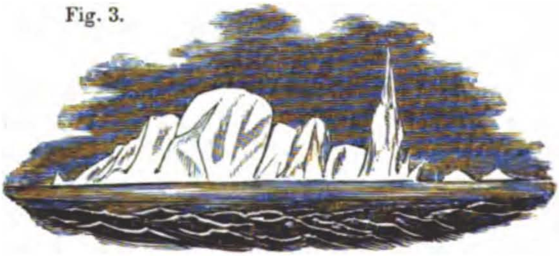
The cold of the antarctic regions was conjectured by Cook to be due to the existence of a large tract of land between the seventieth degree of south

* 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.

latitude and the pole; and it is worthy of observation, that even now, after the most recent voyages, the area still unexplored within the antarctic circle is much 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 herbivorous animals are met with in the northern hemisphere, nay, where man himself exists, and where there are ports and villages, are described as most wintry 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, and they are occasionally seen in lat. 42° N. near the termination of the great bank of Newfoundland, and at the Azores, lat. 42° N., to which 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 (see fig. 3.) was two miles in circumference, and

Fig. 3.



Iceberg seen off the Cape of Good Hope, April 1829.
Lat. 39° 13′ S. *Long.* 48° 46′ E.

150 feet high, appearing like chalk when the sun was obscured, and having the lustre of refined sugar when the sun was shining on it. 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 cubic 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

* 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.

† On Icebergs in low Latitudes, by Capt. Horsburgh, by whom the sketch was made. Phil. Trans. 1830.

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

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 was referred by many astronomers to the precession of the equinoxes, or the acceleration of the earth's motion in its perihelium; in consequence of which the spring and summer of the southern hemisphere are now 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 there must be a greater loss of heat by radiation in the southern hemisphere 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 counterbalance 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 particular 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

* 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.

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 that 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 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

* Malte-Brun's System of Geography, book 1. p. 6.

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. facing p. 130.) 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. 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 we might look not only

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

† 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 îsles au-dessus de son niveau, hauteur qui ne surpasse pas mille mètres (3280 ft.)"—

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 latitudes, 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

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.)

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; 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 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 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

* 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 (Vol. I. p. 117) on the increasing density of sea-water in proportion to the degree of cold.

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 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 wintry. They who should then inhabit such small isles and coral reefs as are now seen in the Indian Ocean

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

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 encrusted wtih 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 a wilderness of snow.

If the reader hesitate to suppose so extensive an alteration of temperature as the probable consequence of geographical changes, confined to one hemisphere, he should remember how great are the local anomalies in climate now resulting from the peculiar distribution of land and sea in certain regions. Thus, in the island of South Georgia, before mentioned (p. 119), Captain Cook found the everlasting snows descending to the level of the sea, between lat. 54° and 55° S.; no trees or shrubs were to be seen, and in summer a few rocks only, after a partial melting of the ice and snow, were scantily covered with moss and tufts of grass. If such a climate can now exist at the level of the sea in a latitude corresponding to that of Yorkshire, in spite of all those equalizing causes before enumerated, by which the mixture of the temperatures of distant regions is facilitated throughout the globe, what rigours might we not anticipate in a winter generated by the transfer of the mountains of India to our arctic circle!

But we have still to contemplate the additional refrigeration which might be effected by changes in the relative position of land and sea in the southern hemisphere. If the remaining continents were transferred from the equatorial and contiguous latitudes to the south polar regions, the intensity of cold produced might, perhaps, render the globe uninhabitable. We are too ignorant of the laws governing the direction of subterranean forces, to determine whether such a crisis be within the limits of possibility. At the same time, it may be observed, that no distribution of land can well be imagined more irregular, or, as it were, capricious, 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.

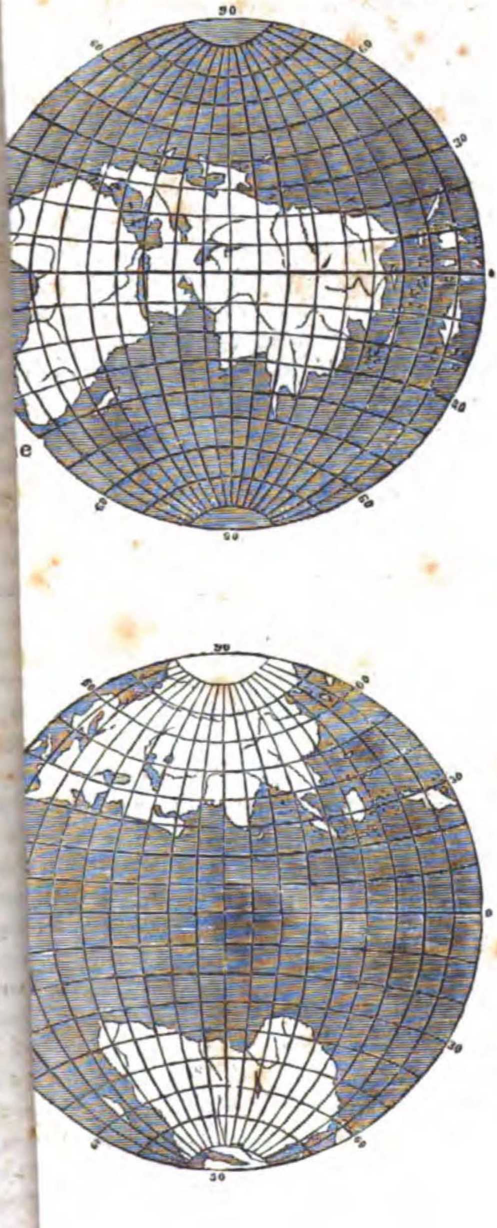
Position of land and sea which might give rise to the extreme of heat.—Let us now turn from the contemplation of the winter of the "great year," and consider the opposite train of circumstances which would bring on the spring and summer. To imagine all the lands to be collected together in equatorial 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 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 a considerable depth, 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, they arrived at extreme northern and southern regions, and

* Humboldt on Isothermal Lines.

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

PLATE I.



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 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 droves of turtles might wander again through regions now tenanted 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

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

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 shown, 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. 135.)—Changes in physical geography, between the carboniferous period and the chalk—Abrupt transition from the secondary to the tertiary fossils (p. 137.)—Accession of land, and elevation of mountain chains, after the consolidation of the secondary rocks—Explanation of Map, showing the area covered by sea, since the commencement of the tertiary period (p. 141.)—Remarks on the theory of the diminution of central heat (p. 145.)—Astronomical causes of fluctuations in climate (p. 147.)

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, recal 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 shown 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

* 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 his opinion, and believes that the coal and plants alluded to occur in the carboniferous series.

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, 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 referable 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 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

* 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.

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

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 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

* 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.

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

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 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 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 oppossum.

When describing the Wealden, one of the upper members of the great secondary series, and evidently of freshwater origin, I shall point out the

* 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.

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

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 antarctic, and a large part of the continents intratropical, 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 embedded 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, 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. 141, the reader will see how great have been the physical revolutions which have occurred since the commencement of the tertiary period.

* See Book iv. chap. xxiii. † Ibid.

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

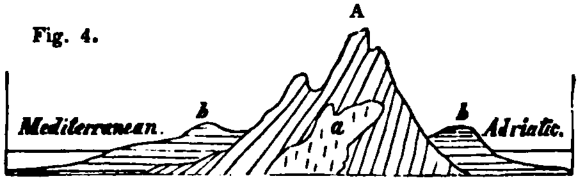
In the present state of Europe, the chalk and associated strata are of considerable extent, and sometimes rise to the summits of lofty mountains. As all the members of this group contain almost exclusively marine remains, it follows that every tract which they now occupy has, since their origin, been 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. 141), 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 1000 to 2000 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 transverse section across the Italian

Fig. 4.



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 2000 to 4000 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 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 11,000 feet, since the deposition of some of the newer or cretaceous 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 show them to be the equivalents of our chalk and green-sand series.† The ter-

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

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

tiary 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 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 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 Auther 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

* M. Elie de Beaumont, Ann. des Sci. Nat., Dec. 1829, p. 346.

† See Book iv. chap. 23.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Inverness
Edinburgh
Berwick
Newcastle
Belfast
Dublin
Chester
Bristol
London
Portsmouth
Groningen
Luneburg
Magdeburg
Brussels
Liege
Treves
Quimper
Laval
Alençon
Paris
Angers
Nantes
Orleans
Blois
Stuttgard
Dijon
Limoges
Clermont
Lyons
Geneva
Bordeaux
Cahors
Cantal
Rodez
Bayonne
Pampeluna
Montpellier
Aix
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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.

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

This Map will enable the reader to perceive at a glance the great extent of change in the physical geography of Europe, which can be proved to have taken place since some of the older tertiary strata began to be deposited. The proofs of submergence, during some part or other of this period, in all the districts distinguished by ruled lines, are of a most unequivocal character; for the area thus described is now covered by deposits containing the fossil remains of animals which could only have lived under water. The most ancient part of the period referred to cannot be deemed very remote, considered geologically; because the deposits of the Paris and London basins, of Auvergne, and many other districts belonging to the older tertiary epoch, are newer than the greater part of the sedimentary rocks, (those commonly called secondary and transition,) of which the crust of the globe is composed. The species, moreover, of marine and freshwater testacea, of which the remains are found in these older tertiary formations, are not entirely distinct from such as now live; a proportion of more than three in a hundred of the fossils having been identified with species now living.† Yet, notwithstanding the 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 parts 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

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

† See Book iv. ch. 5.

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.

A strait of the sea separating England and Wales has also been introduced, on the evidence afforded by shells of existing species found in a deposit of gravel, sand, loam, and clay, called the northern drift by Mr. Murchison, who has traced it from Lancashire to the Bristol channel, over the space indicated in the map.† Mr. Trimmer has discovered similar recent marine shells on the northern coast of North Wales, and on Moel Tryfane, near the Menai Straits, at the height of 1392 feet above the level of the sea!

Some raised sea-beaches, one of them at the mouth of Carlingford Bay, Ireland, in which recent marine shells occur, lately observed by Professor Sedgwick and Mr. Murchison, have required an extension of the sea over part of the eastern shore of Ireland.

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, at several places and at various heights above the level of the sea, attests 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

* Ch. xxi. and xxii.

† See Proceedings of Geol. Soc. vol. ii. p. 334.

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 show 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

* See Book iv. chap. iii.

in physical geography which have taken place within 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 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

* 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.

† Allgemeine Literatur Zeitung, No. cxxxix. July, 1833.

than from its opposite extreme of cold. A glance at the map (Pl. I. fig. 1. p. 130) will show 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 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 one to three, which is as near as possible the average general ratio throughout the globe, it is as nine to twenty-three.* 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 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

* 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 one part in four. 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 one-sixteenth of that zone.

diminished during that period by $\frac{1}{100}$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 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 nine feet ten 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 arise up from unknown depths, flow out upon the surface, and, before they 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

* 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.

† 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.

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, 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 eccentricity 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 eccentricity 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,

* Treatise on Astronomy, § 337.

† The theorem is thus stated:—"The eccentricity 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.

Mars, Jupiter, and 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 Herschell, we suppose an extreme case, as if the earth's orbit should ever become as eccentric 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.

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. 151.)—Differences between the organic remains of successive formations—Remarks on the comparatively modern origin of the human race (p. 158.)—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. 161.)

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 referable to one uninterrupted succession of physical events, governed by the laws of Nature now in operation.

* Ann. du Bur. des Long. 1834.

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 indentity 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."*

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,

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

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 be 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 in, 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 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,

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

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 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 shown 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 distinct 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

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

† 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 shown 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.)

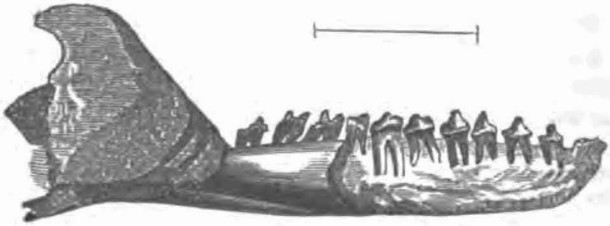
‡ See p. 135. § See Book iii. ch. 15.

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 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. 5.), 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. 5. *Natural size.*



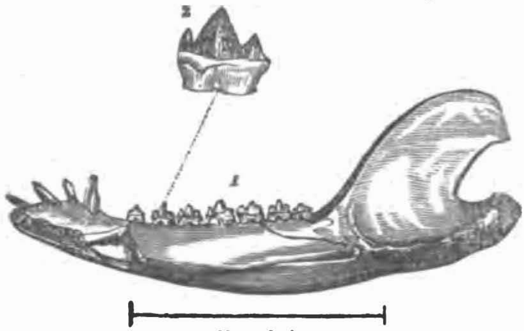
Lower jaw of a mammiferous quadruped, from the slate of Stonesfield near Oxford.†

* Book iv. chap. xxiii.

† This figure (No. 5.) is from a drawing by Professor C. Prevost, published Ann. des. Sci. Nat., Avril, 1825. The fossil is a lower jaw, adhering by its inner side to

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. 6), for the number of teeth is different, and agrees precisely with that of the living didelphis.

Fig. 6.



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

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

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

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. 6) 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 fractured, 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.

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, 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 is the more worthy of observation, because the lignite, in the one case, and the coal in the other, are exclusively composed of terrestrial plants. From the London clay we have procured three or four hundred species of testacea, but the only bones of vertebrated animals are those of reptiles and fish. On comparing, therefore, the contents of these marine strata with those of our oolitic series, we find the supposed order of precedence inverted. In

* Book iv. ch. xviii. † Ibid.

the more ancient system of rocks, a few mammalia have been recognised; whereas in the newer, if negative evidence were to be our criterion, Nature has made a retrograde, instead of an advancing movement, and no animals more exalted in the scale of organization than reptiles are discoverable. It should, however, be stated, that in a freshwater formation, resting upon the London clay, in the Isle of Wight, and like it belonging to the Eocene epoch, some mammiferous remains have recently been found.*

Subapennine beds.—Although the Subapennine strata have been examined by collectors for 300 years, and have yielded more than a thousand species of testacea, the authenticated examples of imbedded remains of terrestrial mammalia are extremely scanty; and several of those which have been cited by earlier writers as belonging to the elephant or rhinoceros, have since been declared, by competent anatomists, to be the bones of whales and other cetacea. In about five or ten instances, perhaps, bones of the mastodon, rhinoceros, and some other land animals, have been observed in this formation with marine shells attached. 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 referable 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 inclusive; 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

* Buckland and Allan, Jameson's Ed. Phil. Journ., No. 27, p. 190. Pratt, Geol. Trans. 2d series, vol. iii. p. 451.—Read, 1830.

† See Book iv. ch. xvi.

we ought to find, before we have a right to expect a single individual of the other. Even, therefore, if we were led to infer, from the presence of crocodiles and turtles in the London clay, and from the cocoa-nuts and spices found in the Isle of Sheppey, that at the period when our older or Eocene tertiary strata were formed, the climate was hot enough for the quadrumanous tribe, we nevertheless could not hope to discover any of their skeletons until we had made considerable progress in ascertaining what were the contemporary Pachydermata; and a very small number of these have, as was before remarked, been hitherto discovered in any strata of this epoch in England.

The result then, of our inquiry into the evidence of the successive development of the animal and vegetable kingdoms, may be stated in a few words. In regard to *plants*, if we neglect the obscure and ambiguous impressions found in some of the oldest fossiliferous rocks, which can lead to no safe conclusions, we may consider those which characterize the great carboniferous groups as the first deserving particular attention. They are by no means confined to the simplest forms of vegetation, as to cryptogamic plants; but, on the contrary, belong to all the leading divisions of the vegetable kingdom; some of the more fully developed forms, both of dicotyledons and monocotyledons having already been discovered, even among the first three or four hundred species brought to light: it is therefore superfluous to pursue this part of the argument farther.

If we then examine the animal remains of the oldest formations, we find bones and skeletons of fish in the old red sandstones, and even in some transition 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 when 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 3000 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.*

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 inde-

* Respecting the probable antiquity assignable to certain human 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.

structible 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 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 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 phe-

* See Book iii. ch. xvi.

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

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

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 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 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 physi-*

* See Book iii. ch. ix.

† See Book iii. ch. iii.

‡ Id. chapters v. vi. vii. and ix.

sal 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 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 a 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 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. 171.)—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. 174.)—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.

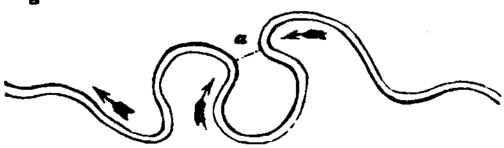
Sinuosities of Rivers.—By a repetition of these landslips, the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded, tends partly to give new directions 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 hills 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 sides of the valley, or river-bed, present a succession of salient and retiring angles. Among the causes of deviation from a straight

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

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, swoln irregularly at different 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 river has caused it to

Fig. 7.



return for a brief space in a contrary direction to its main course, so that a peninsula is formed, and the isthmus (at *a*) is consumed on both sides by currents flowing in opposite directions. In this case an island is soon formed,—on either side of which a portion of the stream usually remains.

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-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

* Encyc. Brit.—art. Rivers.

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 superficial area of the fluid mass is far less than that previously occupied by the separate streams. The collective waters, instead of spreading themselves out over a larger horizontal space, contract themselves into a column of which the height is greater relatively to its breadth. Hence a smaller proportion of the whole is retarded by friction against the bottom and sides of the channel; and in this manner the main current is often accelerated in the lower country, even where the slope of the river's bed is lessened.

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

Floods in Scotland, 1829.—Many remarkable illustrations of the power of running water in moving stones and heavy materials were afforded by the storm and flood which occurred on the 3d and 4th of August, 1829, in Aberdeenshire and other counties in Scotland. The elements during this storm assumed all the characters which mark the tropical hurricanes; the wind blowing in sudden gusts and whirlwinds, the lightning and thunder being such as is rarely witnessed in our climate, and heavy rain falling without intermission. The floods extended almost simultaneously, and with 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,

* See article Rivers, Encyc. Brit.

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 premises forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds weight, up an inclined plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep, on a flat ground;—the heap ends abruptly at its lower extremity."†

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

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

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

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

† Quarterly Journ. of Sci. &c. No. xii New Series, p. 331.

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

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, 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 100 to 200 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 50,000 to 100,000 tons. Such bergs must be of great magnitude; because the mass of ice below the level of the water is between seven

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

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

‡ Voyage in 1822, p. 233.

the Caltabiano on the eastern side of Etna, has not yet cut down to the ancient bed of which it was dispossessed, and of which the probable position is indicated in the annexed diagram, (c, Fig. 8.)

On entering the narrow ravine where the water foams down the two cataracts, we are entirely shut out from all view of the surrounding country; and a geologist who is accustomed to associate the characteristic features of the landscape with the relative age of certain rocks, can scarcely dissuade himself from the belief that he is contemplating a scene in some rocky gorge of a primary district. The external forms of the hard blue lava are as massive as any of the most ancient trap-rocks of Scotland. The solid surface is in some parts smoothed and almost polished by attrition, and covered in others with a white lichen, which imparts to it an air of extreme antiquity, so as greatly to heighten the delusion. But the moment we re-ascend the cliff the spell is broken: for we scarcely recede a few paces, before the ravine and river disappear, and we stand on the black and rugged surface of a vast 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 600 yards wide, and 158 feet perpendicular; the other, called the American Falls, is about 200 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 strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the calcareous rock forms an overhanging mass, projecting forty feet or more above the hollow space below.

The blasts of wind, charged with spray, which rise out of the pool

* Captain Hall's Travels in North America, vol. i. p. 179.

into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant; and the superincumbent limestone, being left without a foundation, falls from time to time in rocky masses. When these enormous fragments descend, a shock is felt at some distance, accompanied by a noise like a distant clap of thunder. After the river has passed over the falls, its character, observes Captain Hall, is immediately and completely changed. It then runs furiously along the bottom of a deep wall-sided valley, or huge trench, which has been cut into the horizontal strata by the continued action of the stream during the lapse of ages. The cliffs on both sides are in most places perpendicular, and the ravine is only perceived on approaching the edge of the precipice.*

The waters, which expand at the falls, where they are divided by the island, are contracted again, after their union, into a stream not more than 160 yards broad. In the narrow channel, immediately below this immense rush of water, a boat can pass across the stream with ease. The pool, it is said, into which the cataract is precipitated, being 170 feet deep, the descending water sinks down and forms an under-current, 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* the falls, as do the inferior shales *below*. The lower shale is

* Hall's Travels in North America, vol. i. pp. 195, 196. 216.

† See Mr. Bakewell, jun. on the Falls of Niagara, with two descriptive drawings of the country between Lakes Erie and Ontario, including the Falls.—Loudon's Mag. of Nat. Hist. No. xii. March, 1830.

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 10,000 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 30,000 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.

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. 182.)—Drift wood—New-formed lakes in Louisiana—Earthquakes in valley of Mississippi—Floods caused by land-slips in the White Mountains (p. 186.)—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

* Monthly American Journ. July, 1831, p. 21.

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 recognisable, 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 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.

* Dell' Antico Corso de' Fiumi Po, Oglio, ed Adda, dell' Giovanni Romani. Milan, 1828.

† Prony, see Cuvier, Disc. Prélim. p. 146.

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 Flamminghi 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 hydrograpical basin of the Mississippi displays, on the grandest scale, the action of running water on the surface of a vast continent. This magnificent river rises nearly in the forty-ninth parallel of north latitude, and flows to the Gulf of Mexico in the twenty-ninth—a course, including its meanders, of nearly 5000 miles. It passes from a cold arctic climate, traverses the temperate regions, and discharges its waters into the sea in the region of the olive, the fig, and the sugar-cane.* No river affords a more striking illustration of the law before mentioned, that an augmentation of volume does not occasion a proportional increase of surface, nay, is even sometimes attended with a narrowing of the channel. The Mississippi is half a mile wide at its junction with the Missouri,† the latter being also of equal width; yet the united waters have only, from their confluence to the mouth of the Ohio, a medial width of about three quarters of a mile. The junction of the Ohio seems also to produce no increase, but rather a decrease, of surface.‡ The St. Francis, White, Arkansas, and Red rivers, are also absorbed by the main stream with scarcely any apparent increase of its width; and, on arriving near the sea at New Orleans, it is somewhat less than half a mile wide. Its depth there is very variable, the greatest at high water being 168 feet. The mean rate at which the whole body of water flows is variously estimated. According to some, it does not exceed one mile an hour.§

The alluvial plain of this great river is bounded on the east and west by great ranges of mountains stretching along their respective oceans.

* Flint's Geography, vol. i. p. 21.

† Flint says (vol. i. p. 140) that, where the Mississippi receives the Missouri, it is a mile and a half wide, but, according to Captain B. Hall, this is a great mistake.—Travels in North America, vol. iii. p. 328.

‡ Flint's Geography, vol. i. p. 142.

§ Hall's Travels in North America, vol. iii. p. 330, who cites Darby.

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 curves deeper, returns, like many other streams before described, on its own tract, so that a vessel in some places, after sailing for twenty-five or thirty miles, is brought round again to within a mile of the place whence it started. When the waters approach so near to each other, it often happens at high floods that they burst through the small tongue of land, and insulate a portion, rushing through what is called the "cut off" with great velocity. At one spot, called the "grand cut off," vessels now pass from one point to another in half a mile to a distance which it formerly required a voyage of twenty miles to reach.§

Waste of its banks.—After the flood season, when the river subsides within its channel, it acts with destructive force upon the alluvial banks, softened and diluted by the recent overflow. Several acres at a time, thickly covered with wood, are precipitated into the stream; and large portions of the islands formed by the process before described are swept away.

"Some years ago," observes Captain Hall, "when the Mississippi was regularly surveyed, all its islands were numbered, from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are entirely melted away—at other places they have attached themselves

* Geograph. Descrip. of the State of Louisiana, by W. Darby, Philadelphia, 1816, p. 102.

† Flint's Geog. vol. i. p. 152. ‡ Ibid. § Ibid. p. 154.

to the main shore, or, which is the more correct statement, the interval has been filled up by myriads of logs cemented together by mud and rubbish."* When the Mississippi and many 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. 9.), and during the inundations of 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.

Fig. 9.

a, Channel of the river. *b*, Base of the "bluffs."

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. 9.) is uniformly lower than the lowest point of the alluvium at the base of the bluffs.†

It has been said of a mountain torrent that "it lays down what it will remove, and removes what it has laid down;" and in like manner the Mississippi, by the continual 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

* Travels in North America, vol. iii. p. 361.

† Flint's Geography, vol. i. p. 151.

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.‡

The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest, not merely as

* 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 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.

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 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 cyprus 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, Nachitoches 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 filled like our tide estuaries—with this difference, that in the one case the land is submerged for several months continuously, and, in the other, twice in every twenty-four hours. It has happened, in several cases, that a bar has been thrown by Red River across some of the openings of these channels, and then the lakes become, like Bastineau, constant repositories of water. But even in these cases, their level is liable to annual elevation and depression, because the flood of the main river, when at its height, passes over the bar; just as, where sand-hills close the entrance of an estuary on the Norfolk or Suffolk coast, the sea, during some high tide or storm, has often breached the barrier and inundated again the interior.

Earthquakes in basin of Mississippi.—The frequent fluctuations in river-courses, in various parts of the basin of the Mississippi, are partly, perhaps, to be ascribed to the co-operation of subterranean movements, which alter from time to time the relative levels of various parts of the surface. So late as the year 1812, the whole valley from the mouth of the Ohio to that of the St. Francis, including a tract 300 miles in length, and exceeding in area the whole basin of the Thames, was convulsed to such a degree, as to create new islands in the river, and lakes in the allu-

* 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.

vial plain, some of which were *twenty miles in extent*. I shall allude to this event, by which New Madrid was in great part destroyed, when I treat of earthquakes; but may state here, that it happened exactly at the same time as the fatal convulsions in the district of Caraccas; and the country shaken was nearly five degrees of latitude farther removed from the great centre of volcanic disturbance, than the basin of the Red River before alluded to. Darby mentions beds of marine sholls on the banks of Red River, which seem to indicate that Lower Louisiana is of recent formation; its elevation, perhaps, above the sea, may have been due to the same series of earthquakes which continues to agitate equatorial America.

When countries are liable to be so extensively and permanently affected by earthquakes, speculations concerning changes in their hydrographical features must not be made without regard to the igneous as well as the aqueous causes of change. It is scarcely necessary to observe, that the inequalities produced even by one shock might render the study of the alluvial plain of the Mississippi, at some future period, most perplexing to a geologist who should reason on the distribution of transported materials, without being aware that the configuration of the country had varied materially during the time when the excavating or removing power of the river was greatest.

FLOODS, BURSTING OF LAKES, ETC.

The power which running water may exert, in the lapse of ages, in widening and deepening a valley, does not so much depend on the volume and velocity of the stream usually flowing in it, as on the number and magnitude of the obstructions which have, at different periods, opposed its free passage. If a torrent, however small, be effectually dammed up, the size of the valley above the barrier, and its declivity below, and not the dimensions of the torrent, will determine the violence of the débâcle. The most universal source of local deluges are landslips, slides, or avalanches, as they are sometimes called, when great masses of rock 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 recent occurrence, the facts of which are well authenticated.

Floods caused by landslips, 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 fonnd 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 referable 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 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 more than usual accuracy, by scientific observers.

Flood in the Valley of Bagnes, 1818.—The valley of Bagnes is one of

* Silliman's Journal, vol. xv. No. 2, p. 216. Jan. 1829.

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 200 feet, and a width of about 700 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 rose to a great height, and then burst with new violence into the next basin, sweeping along rocks, forests, houses, bridges, and cultivated land. For the greater part of its course the flood resembled a moving mass of rock and mud, rather than of water. Some fragments of granitic rocks, of enormous magnitude, and which, from their dimensions, might be compared without exaggeration to houses, were torn out of a more ancient alluvion, and borne down for a quarter of a mile. One of the fragments moved was sixty paces in circumference.* The velocity of the water, in the first part of its course, was thirty-three feet per second, which diminished to six feet before it reached the Lake of Geneva, where it arrived in six hours and a half, the distance being forty-five miles.†

This flood left behind it, on the plains of Martigny, thousands of trees torn up by the roots, together with the ruins of buildings. Some of the houses in that town were filled with mud up to the second story. After expanding in the plain of Martigny, it entered the Rhone and did no further damage; but some bodies of men, who had been drowned above Martigny, were afterwards found, at the distance of about thirty miles, floating on the farther side of the Lake of Geneva, near Vevey.

The waters on escaping from the temporary lake, intermixed with mud and rock, swept along, for the first four miles, at the rate of above twenty miles an hour; and M. Escher, the engineer, calculated that the flood

* This block was measured by Capt. B. Hall, R. N.

† See an account of the inundation of the Val de Bagnes, in 1818, in Ed. Phil. Journ., vol. i. p. 187, drawn up from the Memoir of M. Escher, with a section, &c.

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, fifty years before, 140 persons were drowned.

Flood at Tivoli, 1826.—I shall conclude with one more example, derived from a land of classic recollections, the ancient Tibur, and which, like all the other inundations above alluded to, occurred within the present century. The younger Pliny, it will be remembered, describes a flood on the Anio, which destroyed woods, rocks, and houses, with the most sumptuous villas and works of art.* For four or five centuries consecutively, this "headlong stream," as Horace truly called it, has often remained within its bounds, and then, after so long an interval of rest, has at different periods inundated its banks again, and widened its channel. The last of these catastrophes happened 15th Nov. 1826, after heavy rains, such as produced the floods before alluded to in Scotland. The waters appear also to have been impeded by an artifical dike, by which they were separated into two parts, a short distance above Tivoli. They broke through this dike; and, leaving the left trench dry, precipitated themselves, with their whole weight, on the right side. Here they undermined, in the course of a few hours, a high cliff, and widened the river's channel about fifteen paces. On this height stood the church of St. Lucia, and about thirty-six houses of the town of Tivoli, which were

* Lib. viii. Epist. 17.

all carried away, presenting, as they sank into the roaring flood, a terrific scene of destruction to the spectators on the opposite bank. As the foundations were gradually removed, each building, some of them edifices of considerable height, 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 run, 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 connexion with volcanic agency (p. 195.)—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. 201.)—Bulicami of Viterbo—Lake of the Solfatara, near Rome—Travertin at Cascade of Tivoli (p. 204.)—Gypseous, Siliceous, and Ferruginous Springs—Brine Springs (p. 209.)—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 land-soak, 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 swollen 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

* Consult Hériocart de Thury's work on "Puits Forés."

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 fifty gallons per minute. In the garden of the Horticultural Society at Chiswick, the borings passed through nineteen feet of gravel, 242 feet of clay and loam, and sixty-seven 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 feet was so great, as to inundate several buildings and do considerable damage; and at Tooting, a sufficient stream was obtained to turn a wheel, and raise the water to the upper stories of the houses.† In the last of three wells bored through the chalk, at Tours, to the depth of several hundred feet, the water rose thirty-two feet above the level of the soil, and the discharge amounted to 300 cubic yards of water every twenty-four hours.‡

Excavations have been made in the same way to the depth of 800, and even 1200 feet in France (the latter at Toulouse), and without success.§ A similar failure was experienced in 1830, in boring at Calcutta, to the depth of more than 150 feet, through the alluvial clay and sands of Bengal. Mr. Briggs, the British consul in Egypt, obtained water between Cairo and Suez, in a calcareous sand, at the depth of thirty feet; but it did not rise in the well.‖ The geological structure of the Sahara is supposed, by M. Rozet, to favour the prospect of a supply of water from Artesian wells, as the parched sands on the outskirts of the desert rest on a substratum of argillaceous marl.¶

The rise and overflow of the water in these wells is generally referred, and apparently with reason, to the same principle as the play of an artificial fountain. Let the porous stratum, or set of strata *a a*, rest on the impermeable rock *d*, and be covered by another mass of an impermeable nature. The whole mass *a a* may easily, in such a position, become saturated with water, which may descend from its higher and exposed parts—a hilly region to which clouds are attracted, and where rain

* Sabine, Journ. of Sci., No. 33, p. 72, 1824.

† Héricart de Thury, p. 49.

‡ Bull. de la Soc. Géol. de France, tom. iii. p. 194.

§ Ibid. 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.

Fig. 10.

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 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 of 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 374 feet, a great quantity of fine sand, with much vegetable matter and shells. Branches of a thorn several inches long, much blackened by their stay in the water, were recognised, 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 marjinatus*), and some land species, as *Helix rotundata* and *H. striata*. M. Dujardin, who, with others, observed this phenomenon, supposes that the waters had flowed from some valleys of Auvergne or the Vivarais since the 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 leagues.‡

In both cases it is evident that water had penetrated to great depths, not simply by filtering through a porous mass, for then it would have left behind the shells, fish, and fragments of plants, but by flowing through some open channels in the earth. Such examples may suggest the idea that the leaky beds of rivers are often the feeders of springs.

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.

* H. de Thury, p. 295.

† Bull. de la Soc. Géol. de France, tom. i. p. 95.

‡ Ibid. p. 248.

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 believe that all the atmospheric waters found their way into the basin of the ocean; but in boring near the shore, we often meet with streams of fresh water at the depth of several hundred feet below the sea level; and these probably descend, in many cases, far beneath the bottom of the sea, when not artificially intercepted in their course. Yet, how much greater may be the quantity of salt water which sinks beneath the floor of the ocean, through the porous strata of which it is often composed, or through fissures rent in it by earthquakes! After penetrating to a considerable depth, this water may encounter a heat of sufficient intensity to convert it into vapour, even under the high pressure to which it would then be subjected. This heat would probably be nearest the surface in volcanic countries, and farthest from it in those districts which have been longest free from eruptions or earthquakes; but to pursue this inquiry farther would lead us to anticipate many topics belonging to another division of our subject.

It would follow from the views above explained, that there must be a two-fold circulation of terrestrial waters; one caused by solar heat, and the other by heat generated in the interior of our planet. We know that the land would be unfit for vegetation, if deprived of the waters raised into the atmosphere by the sun; but it is also true that mineral springs are powerful instruments in rendering the surface subservient to the support of animal and vegetable life. Their heat is said to promote the development of the aquatic tribes in many parts of the ocean, and the substances which they carry up from the bowels of the 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 which they hold in solution. These consist of a great variety of 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 to them, but flow out indiscriminately

* The more loose and porous rock, usually containing incrusted plants and other substances, is called tufa; the more compact, travertin. See Glossary, 'Tufa,' 'Travertin,' end of Vol. I.

from all rock formations. In Central France, a district where the primary rocks are unusually destitute of limestone, springs copiously charged with carbonate of lime rise up through the granite and gneiss. Some of these are thermal, and probably derive their origin from the deep source of volcanic heat, once so active in that region. One of these springs, at the northern base of the hill upon which Clermont is built, issues from volcanic peperino, which rests on granite. It has formed, by its incrustations, an elevated mound of travertin, or white concretionary limestone, 240 feet in length, and, at its termination, sixteen feet high and twelve wide. Another incrusting spring in the same department, situated at Chaluzet, near Pont Gibaud, rises in a gneiss country, at the foot of a regular volcanic cone, at least twenty miles from any calcareous rock. Some masses of tufaceous deposit, produced by this spring, have an oolitic texture.

Valley of the Elsa.—If we pass from the volcanic district of France to that which skirts the Apennines in the Italian peninsula, we meet with innumerable springs which have precipitated so much calcareous matter, that the whole ground in some parts of Tuscany is coated over with travertin, and sounds hollow beneath the foot.

In other places in the same country, compact rocks are seen descending the slanting sides of hills, very much in the manner of lava currents, except that they are of a white colour, and terminate abruptly when they reach the course of a river. These consist of the calcareous precipitate of springs, some of them still flowing, while others have disappeared or changed their position. Such masses are frequent on the slope 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 lucustrine formation, containing fossil shells of existing species. The travertin is unconformable to the lucustrine beds, and its inclination accords with the slope of the sides of the valley.

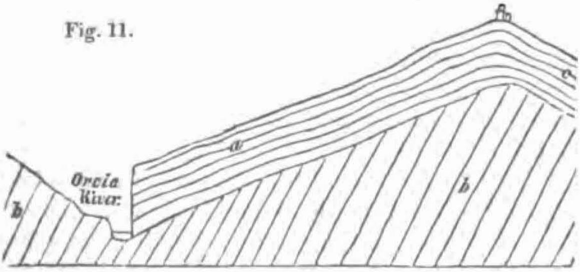
One of the finest examples which I saw, was at the Molino delle Caldane, near Colle.

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. 11.), belonging to the older Apennine formation. The water is hot, has a strong taste, and, when not in

Baths of San Vignone.

Fig. 11.



Section of Travertin, San Vignone.

very small quantity, is of a bright green colour. So rapid is the deposition near the source, that in the bottom of a conduit-pipe for carrying off the water to the baths, and which is inclined at an angle of 30°, half a foot of solid travertin is formed every year. A more compact rock is produced where the water flows slowly, and the precipitation in winter, when there is least evaporation, is said to be more solid, but less in quantity by one-fourth, than in summer. The rock is generally white; some parts of it are compact, and ring to the hammer; others are cellular, and with such cavities as are seen in the carious part of bone or the siliceous millstone of the Paris basin. A portion of it also below the village of 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. 11.) 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. 11.) 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 travertin, Roman tiles have been sometimes found at the depth of five or six feet.

Baths of San Filippo.—On another hill, not many miles from that last mentioned, and also connected with Mount Amiata, the summit of which is about three miles distant, are the celebrated baths of San Filippo. The subjacent rocks consist of alternations of black slate, limestone, and serpentine, of highly inclined strata, belonging to the Apennine formation, and, as at San Vignone, near the boundary of a tertiary basin of marine origin, consisting chiefly of blue argillaceous marl. There are three warm springs here, containing carbonate and sulphate of lime, and sulphate of magnesia. The water which supplies the baths falls into a pond, where it has been known to deposit a solid mass *thirty feet thick*, in about *twenty years.** A manufactory of medallions in basso-relievo is carried on at these baths. The water is conducted by canals into several pits, in which it deposits travertin and crystals of sulphate of lime. After being thus freed from its grosser parts, it is conveyed by a tube to the summit of a small chamber, and made to fall through a space of ten or twelve feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds, which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould.† The geologist may derive from these experiments considerable

* Dr. Grosse on the Baths of San Filippo. Ed. Phil. Journ. vol. ii. p. 292.

† Ibid. p. 297.

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 spheres although they often appear such when a transverse section is made in any line not in the direction of the point of attachment. There are, indeed, occasionally seen small oolitic and pisolitic grains, of which the form is globular; for the nucleus, having been for a time in motion in the water, has received fresh accessions of matter on all sides.

In the same manner I have seen, on the vertical walls of large steam boilers, the heads of nails or rivets covered by a series of enveloping crusts of calcareous matter, usually sulphate of lime; so that a concretionary nodule is formed, preserving a nearly globular shape, when increased to a mass several inches in diameter. In these, as in many travertins, there is often a combination of the concentric and radiated structure, and the last-mentioned character is one of those in which the English magnesian limestone agrees with the Italian travertins.

Another point of resemblance between these rocks, in other respects so dissimilar, is the interference of one sphere with another, and the occasional occurrence of cavities and vacuities, constituting what has been called a honeycombed structure, and also the frequent interposition of loose incoherent matter, between different solid spheroidal concretions.

Yet, notwithstanding such points of analogy, Professor Sedgwick observes, that there are proofs of the concretionary arrangement in the magnesian limestone having taken place subsequently to original deposition, for in this case the spheroidal forms are often quite independent of the direction of the laminæ.*

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 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, and near the hot baths called the Bulicami, a monticule is seen, about twenty feet high and five hundred yards in circumference, entirely composed of concretionary travertin. This rock has been largely quarried for lime, and much of it appears to have been removed. The laminæ are very thin, and their minute undulations so arranged, that the whole mass has at once a concentric and radiated structure. The beds dip at an angle of 40° or more from the centre of the monticule outwards. The whole mass 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.

Campagna di Roma.—The country around Rome, like many parts of the Tuscan States already referred to, has been at some former period the site of numerous volcanic eruptions; and the springs are still copiously impregnated with lime, carbonic acid, and sulphuretted hydrogen. A hot spring has lately been discovered near Civita Vecchia, by Signor Riccioli, which deposits alternate beds of a yellowish travertin, and a white granular rock, not distinguishable, in hand specimens, either in grain, colour, or composition, from statuary marble. There is a passage between this and ordinary travertin. The mass accumulated near the spring is in some places about six feet thick.

Lake of the Solfatara.—In the Campagna, between Rome and Tivoli,

* Geol. Trans. 2d series, vol. iii. p. 37. I have lately seen some specimens of spheroidal magnesian limestone, collected by 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 recognised 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.

is the lake of the Solfatara, called also Lago di Zolfo (lacus albula,) into which flows continually a stream of tepid water, from a smaller lake situated a few yards above it. The water is a saturated solution of carbonic acid gas, which escapes from it in such quantities in some parts of its surface, that it has the appearance of being actually in ebullition. "I have found by experiment," says Sir Humphry Davy, "that the water taken from the most tranquil part of the lake, even after being agitated and exposed to the air, contained in solution more than its own volume of carbonic acid gas, with a very small quantity of sulphuretted hydrogen. Its high temperature, which is pretty constant at 80° of Fahr., and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford nourishment to vegetable life. The banks of travertin are every where covered with reeds, lichen, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life is going on, the crystallizations of the calcareous matter, which 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."*

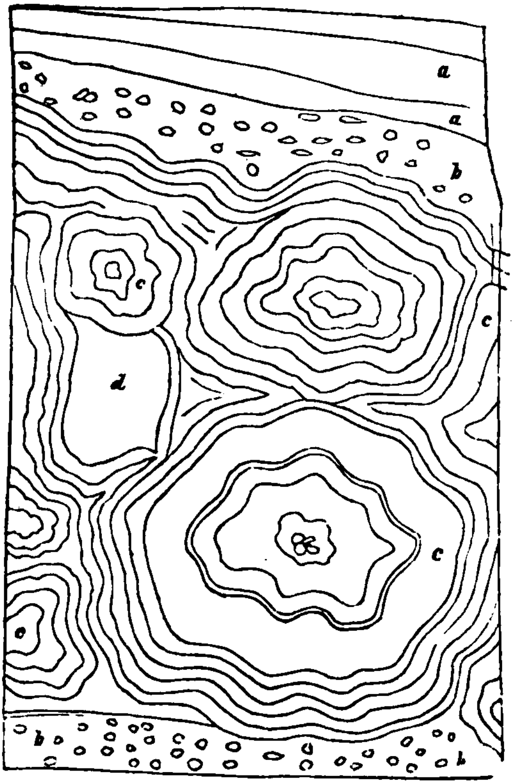
The same observer informs us, that he fixed a stick in a mass of travertin covered by the water in the month of May, and in April following he had some difficulty in breaking, with a sharp-pointed hammer, the mass which adhered to the stick, and which was several inches in thickness. The upper part was 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 gray 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 times of history, and I shall conclude with one more example of the calcareous deposits of this neighbourhood,—those on the Anio.

* Consolations in Travel, pp. 123—125. † Ibid. p 127.

Travertin of Tivoli.—The waters of the Anio incrust the reeds which grow on its banks, and the foam of the cataract of Tivoli forms beautiful pendant stalactites; but, on the sides of the deep chasm into which the cascade throws itself, there is seen an extraordinary accumulation of horizontal beds of tufa and travertin, from four to five hundred feet in thickness. The section immediately under the temples of Vesta and the Sibyl, displays, in a precipice about four hundred feet high, some spheroids which are from *six to eight feet in diameter*, each concentric layer being about the eighth of an inch in thickness. The annexed diagram exhibits about fourteen feet of this immense mass, as seen in the path cut out of the rock in descending from the temple of Vesta to the Grotto di Nettuno. I have not attempted to express in this drawing the innumerable thin layers of which these magnificent spheroids are composed, but the lines given mark some of the natural divisions into which they are separated by minute variations in the size or colour of the laminæ. The undulations also are much smaller, in proportion to the whole circumfer-

Fig. 12.



Section of Spheroidal Concretionary Travertin under the Cascade of Tivoli.

ence, than in the drawing. The beds *a a* are of hard travertin and soft tufa; below them is a pisolite (*b*), the globules being of different sizes: underneath this appears a mass of concretionary travertin (*c c*), some of the spheroids being of the above-mentioned extraordinary size. In some places (as at *d*) there is a mass of amorphous limestone, or tufa, surrounded by concentric layers. At the bottom is another bed of pisolite (*b*), in which the small nodules are about the size and shape of 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 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 deposite 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 of a mixture of sulphate of lime, with sulphur and muriate of lime.†

* Von Hoff, Geschichte, &c., vol. ii. p. 114.

† C. Prevost, Essai sur la Constitution Physique du Bassin de Vienne, p. 10.

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, 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, composed 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

* Daubeny on Volcanos, p. 222.

† 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.

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 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 their siliceous secretions; but when in a volcanic archipelago, or a region of submarine volcanos, there are springs so saturated with silica as those of Iceland or the Azores, we may expect layers and nodules of silex and chert to be spread out far and wide over the bed of the sea, and interstratified with shelly and calcareous deposits, which may be forming there, or with matter derived from wasting cliffs or volcanic ejections.

Ferruginous springs.—The waters of almost all springs contain some iron in solution; and it is a fact familiar to all, that many of them are so copiously impregnated with this metal, as to stain the rocks or herbage through which they pass, and to bind together sand and gravel into solid masses. We may naturally, then, conclude that this iron, which is constantly conveyed from the interior of the earth into lakes and seas, and which does not escape again from them into the atmosphere by evaporation, must act as a colouring and cementing principle in the subaqueous

* Barrow's Iceland, p. 209.

† Dr. Buckland, Geol. Trans. 2d series, vol. ii. part iii. p. 384.

deposits now in progress. It will be afterwards seen that many sandstones and other rocks in the sedimentary strata of ancient lakes and seas are bound together or coloured by iron, and this fact presents us with a striking point of analogy between the state of things at very different epochs. In those older formations we meet with great abundance of carbonate and sulphuret of iron; and in chalybeate waters, at present, this metal is most frequently in the state of a carbonate, as in those of Tunbridge, for example. Sulphuric acid, however, is often the solvent, which is in many cases derived from the decomposition of pyrites.

Brine springs.—Cheshire.—So great is the quantity of muriate of soda in some springs, that they yield 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 and those of Droitwich fully saturated.* They are known to have flowed for more than 1000 years, and the quantity of salt which they have carried into the Severn and Mersey must be enormous. 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 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

* L. Horner, Geol. Trans. vol. ii. p. 94.

† Annales de l'Auvergne, tome i. p. 234.

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.

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,

* Le Coq, Annales de l'Auvergne, tome i. p. 217. May, 1828.

† Ann. Scient. de l'Auvergne, tome ii. June, 1829.

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 La 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 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 lend 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 varities of pure and earthy pitch, or asphaltum, so abundant in the island.‡

The bituminous shades, 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

* Symes, Embassy to Ava, vol. ii.—Geol. Trans., second series, vol. ii. part iii. p. 388.

† Dr. Nugent, Geol. Trans. vol. i. p. 69. ‡ Ibid. p. 67.

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.

CHAPTER IV.

REPRODUCTIVE EFFECTS OF RUNNING WATER.

Reproductive effects of running water—Division of Deltas into lacustrine, mediterranean, and oceanic—Lake deltas—Growth of the delta of the Upper Rhone in the Lake of Geneva—Chronological computations of the age of deltas—Recent deposits in Lake Superior (p. 216.)—Deltas of inland seas—Rapid shallowing of the Baltic—Marine delta of the Rhone (p. 217.)—Various proofs of its increase—Stony nature of its deposits—Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic—Rapid conversion of that gulf into land—Mineral characters of the new deposits—Delta of the Nile (p. 222.)—Its increase since the time of Homer—Its growth why checked at present.

Having considered the destroying and transporting agency of running water, we have now to examine the reproductive effects of the same cause. The aggregate amount of deposits accumulated in a given time at the mouths of rivers, where they enter a lake or sea, affords clearer data for estimating the energy of the excavating power of running water on the land, than the separate study of the operations of the same cause in the countless ramifications into which every great system of valleys is divided. I shall therefore proceed to select some of the leading facts at present ascertained respecting the growth of deltas, and shall then offer some general observations on the quantity of sediment transported by rivers, and the manner of its distribution beneath the waters of lakes and seas.

Divisions 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 co-operating 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 sheet of water is about thirty-seven miles long, and its breadth is from two to eight miles. The shape of the bottom is very irregular, the depth having been found, by late measurements, to vary from 20 to 160 fathoms.* The Rhone, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vellais, (Portus Valesiæ of the Romans,) once situated at the water's edge, at the upper end, is now more than a mile and a half inland—this intervening alluvial tract having been acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river, and full of marshes.

Mr. De la Beche found, after numerous soundings in all parts of the lake, that there was a pretty uniform depth of from 120 to 160 fathoms throughout the central region, and, on approaching the delta, the shallowing of the bottom began to be very sensible at a distance of about a mile and three-quarters from the mouth of the Rhone; for a line drawn from St. Gingoulph to Vevey, gives a mean depth of somewhat less than 600 feet, and from that part to the Rhone, the fluviatile mud is always found along the bottom.† We may state, therefore, that the new strata annually produced are thrown down upon a slope about two miles in length: so that, nothwithstanding the great depth of the lake, the new deposits are not inclined at a high angle; the dip of the beds, indeed, is

* De la Beche, Ed. Phil. Journ. vol. ii. p. 107. Jan. 1820.

† De la Beche, MS.

so slight, that they would be termed, in ordinary geological language, horizontal.

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, (the supposed original depth of the head of the lake,) 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 for the accomplishment of the result. The number of cubic feet of water annually discharged by the river into the lake being estimated, experiments might be made in the winter and summer months, to determine the proportion of matter held in suspension or in chemical solution by the Rhone. It would be also necessary to allow for the heavier matter drifted along at the bottom, which might be estimated on hydrostatical principles, when the average size of the gravel and the volume and velocity of the stream at different seasons were known. Supposing all these observations to have been made, it would be more easy to calculate the future than the former progress of the delta, because it would be a laborious task to ascertain, with any degree of precision, the original depth and extent of that part of the lake which is already filled up. Even if this information were actually obtained by borings, it would only enable us to approximate within a certain number of centuries to the time when the Rhone began to form its present delta; but this would not give us the date of the origin of the Leman Lake in its present form, because the

* De la Beche, MS.

river may have flowed into it for thousands of years, without importing any sediment whatever. Such would have been the case, if the waters had first passed through a chain of upper lakes; and that this was actually the fact, is indicated by the course of the Rhone between Martigny and the Lake of Geneva, and, still more decidedly, by the channels of many of its principal feeders.

If we ascend, for example, the valley through which the Dranse flows, we find that it consists of a succession of basins, one above the other, in each of which there is a wide expanse of flat alluvial lands, separated from the next basin by a rocky gorge, once evidently the 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 the 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 1000 feet of recent sediment below. Many hundred alluvial tracts of equal, and some of much greater area, may be seen if we follow up the Rhone from its termination in the Mediterranean, or explore the valleys of many of its principal tributaries.

What, then, shall we think of the presumption of De Luc, Kirwan, and their followers, who confidently deduced from the phenomena of modern deltas the recent origin of the present form of our continents, without pretending to have collected any one of the numerous data by which so complicated a problem can be solved? Had they, after making all the necessary investigations, succeeded in proving, as they desired, that the lower delta of the Rhone, and the new deposits at the mouths of several other rivers, whether in lakes or seas, had required about 4000 years to attain their present dimensions, the conclusion would have been fatal to the chronological theories which they were anxious to confirm.

Lake Superior.—Lake Superior is the largest body of fresh water in the world, being about 1500 geographical miles in circumference when we follow the sinuosities of its coasts, and its length, on a curved line drawn through its centre, being about 360, and its extreme breadth 140 geographical miles. Its average depth varies from 80 to 150 fathoms; but, according to Captain Bayfield, there is reason to think that its greatest depth would not be overrated at 200 fathoms,* so that its bottom is, in some parts, nearly 600 feet below the level of the Atlantic, its surface about as much above it. There are appearances in different parts of this, as of the other Canadian 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 prevalence of strong winds,

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

† 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.

and to their influence we may attribute the diffusion of finer mud far and wide over great areas; for, by numerous soundings made during the late survey, it was ascertained that the bottom consists generally of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree, as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third white, hardening into a substance resembling pipe-clay.* From these statements, the geologist will not fail to remark how closely these recent lacustrine formations in America resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France. In both cases, many of the genera of shells most abundant, as Lymnea and Planorbis, are the same; and in regard to other classes of organic remains, there must be the closest analogy, as I shall endeavour more fully to explain when speaking of the imbedding of plants and animals in recent deposits.

DELTAS OF INLAND SEAS.

Baltic—Having thus briefly considered some of the lacustrine deltas now in progress, we may next turn our attention to those of inland seas.

The shallowing and conversion into land of many parts of the Baltic, especially the Gulfs of Bothnia and Finland, have been demonstrated by a series of accurate 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, Piteo and Luleo, 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

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

† Since writing the third 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.

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 matter from the Alps of Dauphiny, and the primary and volcanic mountains of Central France; and when at length it enters the Mediterranean, it discolours the blue waters of that sea with a whitish sediment, for the distance of between six and seven miles, throughout which space the current of fresh water is perceptible.

Proofs of its increase since historical periods.—Strabo's description of the delta is so inapplicable to its present configuration, as to attest a complete alteration in the physical features of the country since the Augustan age. It appears, however, that the head of the delta, or the point at which it begins to ramify, has remained unaltered since the time of Pliny, for he states that the Rhone divided itself at Arles into two arms. This is the case at present; one of the branches being now called Le Petit Rhône, which is again subdivided before entering the Mediterranean. The advance of the base of the delta, in the last eighteen centuries, is demonstrated by many curious antiquarian monuments. The most striking of these is the great detour made by the old Roman road from Ugernum to Beziers (part of the high road between Aix, *Aquæ Sextiæ*, and Nismes, *Nemausus*.) It is clear that, when this was first constructed, it was impossible to pass in a direct line as now, across the delta, and that either the sea or marshes intervened in a tract now consisting of terra firma.* Astruc also remarks, that all the places on low lands, lying to the north of the old Roman road between Nismes and Beziers, have names of Celtic origin, evidently given to them by the first inhabitants of the country; whereas, the 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.

* Mém. d'Astruc, cited by Von Hoff, vol. i. p. 288.

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 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 mouth 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

* Lib. II. c. v.

† Bouche, Chorographie et Hist. de Provence, vol. i. p. 23, cited by Von Hoff, vol. i. p. 290.

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 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 lie 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 great combination of circumstances favourable to the rapid formation of deltas—a gulf receding far into the land—a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adige, besides numerous minor streams, draining on the one side a great crescent of the Alps, and on the other some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste, where the Isonzo enters, down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than one hundred miles in length, which, within the last 2000 years, have increased from *two to twenty miles in breadth.* The Isonzo, Tagliamento, Piave, Brenta, Adige, and Po, besides many other inferior

* Hist. Phys. de la Mer.

rivers, contribute to the advance of the coast-line, and to the shallowing of the gulf. The Po and the Adige may now be considered 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 it 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, incrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or calcareous precipitates.† Olivi, also, found some deposits of sand, and others of mud, extending half way across the gulf; and he states that their distribution along the bottom was evidently determined by the prevailing current.‡ It is probable therefore, that the finer sediment of all the rivers at the head of the Adriatic may be intermingled by the influence of the current; and all the central parts of the gulf may be considered as slowly filling up with horizontal deposits, similar to those of the Subapennine hills, and containing many of the same species of shells. The Po merely introduces at present fine sand and mud; for it carries no pebble farther than the spot where it joins the Trebia, west of Piacenza. Near the northern borders of the basin, the Isonzo, Tagliamento, and many other streams, are forming immense beds of sand and some conglomerate; for here some high mountains of Alpine limestone approach within a few miles of the sea.

In the time of the Romans, the hot-baths of Monfalcone were on one

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. i. p. 118.

† See Brocchi, vol. i. p. 39.

‡ Ibid. vol. ii. p. 94.

of several islands of Alpine limestone, between which and the mainland, on the north, was a channel of the sea, about a mile broad. This channel is now converted into a grassy plain, which surrounds the islands on all sides. Among the numerous changes on this coast, we find that the present channel of the Isonzo is several miles to the west of its ancient bed, in part of which, at Ronchi, the old Roman bridge which crossed the Via Appia was lately found buried in fluviatile silt.

Notwithstanding the present shallowness of the 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 2000 feet deep, close to the shore, as between Nice and Genoa; and even sometimes 6000 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 2000 feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above 1000 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 seventy or eighty 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 has been considerably modified since the days of Homer. The ancient geographers mention seven principal mouths of the Nile, of which the most eastern, the Pelusian, has been entirely silted up, and the Mendesian, or Tanitic, has disappeared. The Phatnitic mouth, and the Sebenitic, have been so altered, that the country immediately about them has little resemblance to that described by the ancients. The Bolbitine mouth has increased in its dimensions, so as to cause the city of Rosetta to be at some distance from the sea.

The alterations produced around the Canopic mouth are also important. The city Foah, which, so late as the beginning of the fifteenth century,

* Geog. Syst. of Herod. vol. ii. p. 107.

was on this embouchure, is now more than a mile inland. Canopus, which, in the time of Scylax, was a desolate insular rock, has been connected with the firm land; and Pharos, an island in times of old, now belongs to the continent. Homer says, its distance from Egypt was one days voyage by sea.* That this should have been the case in Homer's time, Larcher and others have, with reason, affirmed to be in the highest degree improbable: but Strabo has judiciously anticipated their objections, observing, that Homer was probably acquainted with the gradual advance of the land on this coast, and availed himself of this phenomenon to give an air of higher antiquity to the remote period in which he laid the scene of his poem.† The lake Mareotis, also, together with the canal which 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 20,000, or even, perhaps, in 10,000 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, nearly one-tenth of carbon, the remainder consisting of water, silex, 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 fifty, 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 2000 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 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.

* Odys., book iv. v. 355.

† Lib. I. Part i. pp. 80. 98. Consult Von Hoff, vol. i. p. 244.

‡ Euterpe, XI.

§ Girard, Mém. sur l'Egypte, tom i. pp. 348. 382.

CHAPTER V.

OCEANIC DELTAS.

Oceanic 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. 228.)—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. 232.)—Convergence of deltas—Conglomerates—Various causes of stratification—Direction of laminæ—Remarks on the interchange of land and sea.

The remaining class of deltas are those in which rivers, on entering the sea, are exposed to the influence of the tides. In this case it frequently happens that an estuary is produced, or negative delta, as Rennell termed it, where, instead of any encroachment of the land upon the sea, the ocean enters the river's mouth, and penetrates into the land beyond the general coastline. Where this happens, the tides and currents are the predominating agents in the distribution of transported sediment. The phenomena, therefore, of such estuaries, will be treated of when the movements of the ocean come under consideration. But whenever the volume of fresh water is so great as to counteract and almost neutralize the force of tides and currents, and in all cases where these agents have not sufficient power to remove to a distance the whole of the sediment periodically brought down by rivers, oceanic deltas are produced. Of these, I shall now select a few illustrative examples.

Delta of the Ganges.—The Ganges and the Burrampooter descend, from the highest mountains in the world, into a gulf which runs 225 miles into the continent. The Burrampooter is somewhat the larger river of the two; but it first takes the name of the Megna when joined by a smaller stream so called, and afterwards loses this second name on its union with the Ganges, at the distance of about forty miles from the sea. The area of the delta of the Ganges (without including that of the Burrampooter, which has now become conterminous) is considerably more than double that of the Nile; and its head commences at a distance of 220 miles, in a direct line from the sea. Its base is 200 miles in length, including the space occupied by the two great arms of the Ganges which bound it on either side. The part of the delta which borders on the sea is composed of a labyrinth of rivers and creeks, all filled with salt water, except those immediately communicating with the principal arm of the Ganges. This tract alone, known by the name of the Woods, or

Sunderbunds, a wilderness infested by tigers and alligators, is, according to Rennell, equal in extent to the whole principality of Wales.*

On the sea-coast there are eight great openings, each of which has evidently, at some ancient period, served in its turn as the principal channel of discharge. Although the flux and reflux of the tide extend even to the head of the delta when the river is low, yet, when 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 180, 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 direction towards the delta. As the mud is known to extend for eighty miles farther into the gulf, we may be assured that, in the course of ages, the accumulation of strata in "the swatch" has been of enormous thickness; and we seem entitled to deduce, from the present depth at the spot, that the original inequalities of the bottom of the Bay of Bengal were on a grand scale, and comparable to those of the main ocean.

Opposite the mouth of the Hoogly river, and immediately south of Sangor Island, four miles from the nearest land of the delta, a new islet was

* Account of the Ganges and Burrampooter Rivers, by Major Rennell, Phil. Trans. 1781.

formed about twenty years ago, called Edmonstone Island, on the centre of which a beacon was erected as a land-mark in 1817. In 1818 the island had become two miles long and half a mile broad, and was covered with vegetation and shrubs. Some houses were then built upon it, and in 1820 it was used as a pilot station. The severe gale of 1823 divided it into two parts, and so reduced its size as to leave the beacon standing out in the sea, where, after remaining seven years, it was washed away. At length the islet has been converted by successive storms into a sand-bank.

Although there is evidence of gain at some points, the general progress of the coast is very slow; for the tides, which rise from thirteen to sixteen feet, are actively employed in removing the alluvial matter, and diffusing it over a wide area. The new strata consist entirely of sand and fine mud; such, at least, are the only materials which are exposed to view in regular beds on the 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 great 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 Megna is proved by the great magnitude of the islands formed in their channels during a period far short of that of a man's life. Some of these, many miles in extent, have originated in large sand-banks thrown up round the points at the angular turning of the

* See India Gazette, June 9, 1831.

† Trans. of the Asiatic Society, vol. vii. p. 14.

river, and afterwards insulated by breaches of the stream. Others, formed in the main channel, are caused by some obstruction at the bottom. A large tree, or a sunken boat, is sometimes sufficient to check the current, and cause a deposit of sand, which accumulates till it usurps a considerable portion of the channel. The river then borrows on each side to supply the deficiency in its bed, and the island is afterwards raised by fresh deposits during every flood. In the great gulf below Luckipour, formed by the united waters of the Ganges and Burrampooter (or Megna), some of the islands, says Rennell, rival in size and fertility the Isle of Wight. While the river is forming new islands in one part, it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the Tamarix Indica, and other shrubs, forming impenetrable thickets, where tigers, buffalos, deer, and other wild animals, take shelter. It is easy, therefore, to perceive, that both animal and vegetable remains must continually be precipitated into the flood, and sometimes become imbedded in the sediment which subsides in the delta.

Two species of crocodiles, of distinct genera, abound in the Ganges and its tributary and contiguous waters; and Mr. H. T. Colebrooke informs me that he has seen both kinds in places far inland, many hundred miles from the sea. The Gangetic crocodile, or Gavial (in correct orthography, Garial), is confined to the fresh water, but the common crocodile frequents 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 again and again since the Gangetic delta was inhabited by man. If human experience and forethought cannot always guard against these calamities, still less can the inferior animals avoid them; and the monuments of such disastrous inundations must be looked for in great abundance in strata of all ages, if the surface of our planet has always been governed by the same laws. When we reflect on the general order and tranquillity that reigns in the rich and populous delta of Bengal, notwithstanding the havoc occasionally committed by the depredations of the ocean, we perceive how unnecessary it is to attribute the imbedding of successive races of animals in older strata to extraordinary energy in the causes of decay and reproduction in the infancy of our planet, or to those general catastrophes and sudden revolutions resorted to by some theorists.

Delta of the Mississippi.—As the delta of the Ganges may be considered a type of those formed on the borders of the ocean, it will be unnecessary to accumulate examples of others on a no less magnificent scale, as, for example, at the mouths of the Orinoco and Amazon. To these, however, I shall revert by-and-by, when treating of the agency of currents. The tides of the Mexican Gulf are so feeble, that the delta of the Mississippi has somewhat of an intermediate character between an oceanic and mediterranean delta. A long narrow tongue of land is protruded, consisting simply of the banks of the river, wearing precisely the same appearance as in the inland plains during the periodical inundations, when nothing appears above water but the higher part of the sloping glacis before described.* This tongue of land has advanced many 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

* Chapter II.

† Captain Hall's Travels in North America, vol. iii. p. 338.—See also *ante*. p. 182.

water:—first, an upper stratum, consisting invariably of bluish 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 waters of each stream; since it can rarely happen that the season of highest flood will precisely correspond in each. In the case of the Red River and Mississippi, which carry off the waters from countries placed under widely distant latitudes, an exact coincidence in the time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of sediment in river water.—Very few satisfactory experiments have as yet been made, to enable us to determine, with any degree of accuracy, the mean quantity of earthy matter discharged annually into the sea by some one of the principal rivers of the earth. Hartsoeker computed the Rhine to contain in suspension, when most flooded, one part in a hundred of mud in volume;† but it appears from two sets of experiments, recently made by Mr. Leonard Horner, at Bonn, that $\frac{1}{10000}$th would have been a nearer approximation to the truth.‡ Sir George Staunton inferred from several observations, that the water of the Yellow River in China, contained earthy matter in the proportion of one part to two hundred, and he calculated that it brought down in a single hour two million cubic feet of earth, or forty-eight million daily; so that, if the Yellow Sea be taken to be 120 feet deep, it would require seventy days for the river to convert an English square mile into firm land, and 24,000 years to turn the whole sea into terra firma, assuming it to be 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 1000 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. One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the delta of

* Darby's Louisiana, p. 103. † Comment. Bonon., vol. ii. part i. p. 237.

‡ Edin. New Phil. Journ., Jan. 1835.

§ Staunton's Embassy to China, Lond. 1797, 4to. vol. ii. p. 408.

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 instituted a series of observations "On the earthy matter brought down by the Ganges" at Ghazipúr, 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 500,000 cubic feet flow down during the four months of the flood season, from June to September, and only 100,000 during the remaining eight months.

Having obtained the volume of water, we have next to inquire what *is* the proportion of solid matter contained 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

* Phil. Trans. 1781.

† Journ. of Asiatic Soc., No. 6. p. 238. June, 1832. See also Mr. Prinsep, Gleanings in Science, vol. iii. p. 185.

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 underrated, 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 matter discharged in a year would equal 3,184,038,720 cubic feet of granite. Now about 12½ cubic feet of granite weigh one ton; and it is computed that the great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 tons. The mass of matter, therefore, carried down annually, would, according to this estimate, more than equal in weight and bulk forty-two of the great pyramids of Egypt, and that borne down in the four months of the rains would equal forty pyramids. But if, without any conjecture as to what may have been the specific gravity of the mud, we attend merely to the weight of solid matter actually proved by Mr. Everest to have been contained in the water, we find that the number of tons weight which passed down in the 122 days of the rainy season was 339,413,760, which would give the weight of fifty-six pyramids and a half; and in the whole year 355,361,464 tons, or nearly the weight of sixty pyramids.

The base of the great Pyramid of Egypt covers eleven acres, and its perpendicular height is about five hundred feet. It is scarcely possible to present any picture to the mind which will convey an adequate conception of the mighty scale of this operation, so tranquilly and almost insensibly carried on by the Ganges, as it glides through its alluvial plain. It may, however, be stated, that if a fleet of more than eighty Indiamen, each freighted with about 1400 tons weight of mud, were to sail down the river every hour of every day and night for four months continuously, they would only transport from the higher country to the sea a mass of solid matter equal to that borne down by the Ganges in the flood season. Or the exertions 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 Borelli'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. The strata would be divisible into two principal groups: the *older* comprising those deposits which originated on the side adjoining the mountains, where numerous deltas first began to form; and the *newer* group consisting of beds deposited in the more central parts of the basin, and towards the side farthest from the mountains. The following characters would form the principal marks of distinction between the strata in each series. The more ancient system would be composed, for the most part, of coarser materials, containing many beds of pebbles and sand, often of great thickness, and sometimes dipping at a considerable angle. These, with associated beds of finer ingredients, would, if traced round the borders of the basin, be seen to vary greatly in colour and mineral composition, and would also be very irregular in thickness. The beds, on the contrary, in the newer group, would consist of finer particles, and would be horizontal, or very slightly inclined. Their colour and mineral composition would be very homogeneous throughout large areas, and would differ from almost all the separate beds in the older series.

The following causes would produce the diversity here alluded to, between the two great members of such lacustrine formations:—When the rivers and torrents first reach the edge of the lake, the detritus washed down by them from the adjoining heights sinks at once into deep water, all the heavier pebbles and sand subsiding near the shore. The finer mud is carried somewhat farther out, but not to the distance of many miles, for the greater part may be seen, as, for example, where the Rhone enters the Lake of Geneva, to fall down in clouds to the bottom, not far from the 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 particles having been conveyed ten, twenty, or a greater number of miles over alluvial plains, would become finer.

In deltas where the causes are more complicated, and where tides and currents partially interfere, the above description would only be applicable, with certain modifications; but if a series of earthquakes accompany the growth of a delta, and change the levels of the land from time to time, as in the region where the Indus now enters the sea, and others hereafter to be mentioned, the phenomena will then depart still more widely from the ordinary type.

Convergence of Deltas.—If we possessed an accurate series of maps of the Adriatic for many thousand years, our retrospect would, without doubt, carry us gradually back to the time when the number of rivers descending from the mountains into that gulf by independent deltas was far greater in number. The deltas of the Po and the Adige, for instance, would separate themselves within the *recent* era, as, in all probability, would those of the Isonzo and the Torre. If, on the other hand, we speculate on future changes, we may anticipate the period when the number of deltas will greatly diminish; for the Po cannot continue to encroach at the rate of a mile in a hundred years, and other rivers to gain as much in six or seven centuries upon the shallow gulf, without new junctions occurring from time to time, so that Eridanus, "the king of rivers," will continually boast a greater number of tributaries. The Ganges and the Burrampooter, have probably become confluent within the historical era; and the date of the junction of the Red River and the Mississippi would, in all likelihood, have been 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 pebbles takes place. In order to keep open the main road from France to Italy, now car-

* See Chap. viii.

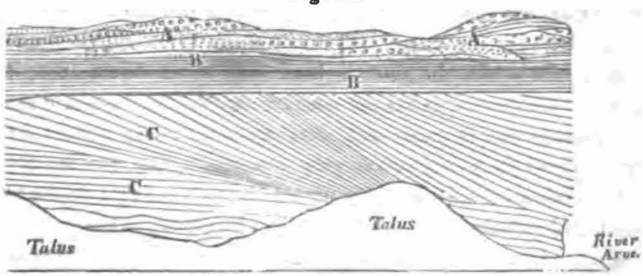
ried along the sea-coast, it is necessary to remove annually great masses of shingle brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made 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, shows 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 sand-banks 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 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.

Fig. 13.



Section on the banks of the Arve at its confluence with the Rhone, showing the stratification of deposits where currents meet.

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 3000 years, they are sufficient to show 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.*

CHAPTER VI.

DESTROYING AND TRANSPORTING EFFECTS OF TIDES AND CURRENTS.

Although the movements of great bodies of water, termed tides and currents, are in general due to very distinct causes, their effects cannot be studied separately; for they produce, by their joint action, those changes which are objects of geological interest. These forces may be viewed in the same manner as we before considered rivers, first, as employed in

* See *ante*, Book i. p. 29.

destroying portions of the solid crust of the earth, and removing them to other places; secondly, as reproductive of new strata.

Tides.—It would be superfluous at the present day to offer any remarks on the cause of the tides. They are not perceptible in lakes, or in most inland seas; in the Mediterranean even, deep and extensive as is that sea, they are scarcely sensible to ordinary observation, their effects being quite subordinate to those of the winds and currents. In some places, however, as in the Straits of Messina, there is an ebb and flow to the amount of two feet and upwards; at Naples and at the Euripus, of twelve or thirteen inches; and at Venice, according to Rennell, of five feet.* In the Syrtes, also, of the ancients, two wide shallow gulfs which penetrate very far within the northern coast of Africa, between Carthage and Cyrene, the rise is said to exceed five feet.†

In islands remote from any continent, the ebb and flow of the ocean is very slight, as at St. Helena, for example, where it is rarely above three feet.‡ In any given line of coast, the tides are greatest in narrow channels, bays, and estuaries, and least in the intervening tracts where the land is prominent. Thus, at the entrance of the estuary of the Thames and Medway, the rise of the spring tides is eighteen feet; but when we follow our eastern coast from thence northward, towards Lowestoff and Yarmouth, we find a gradual diminution, until, at the places last mentioned, the highest rise is only seven or eight feet. From this point there begins again to be an increase, so that at Cromer, where the coast again retires towards the west, the rise is sixteen feet; and towards the extremity of the gulf called "the Wash," as at Lynn and in Boston deeps, it is from twenty-two to twenty-four feet, and in some extraordinary cases twenty-six feet. From thence again there is a decrease towards the north, the elevation at the Spurn Point being from nineteen to twenty feet, and at Flamborough Head and the Yorkshire coast from fourteen to sixteen feet.§

At Milford Haven in Pembrokeshire, at the mouth of the Bristol Channel, the tides rise thirty-six feet; and at King-Road near Bristol, forty-two feet. At Chepstow on the Wye, a small river which opens into the estuary of the Severn, they reach fifty feet, and sometimes sixty-nine, and even seventy-two feet.‖ A current which sets in on the French coast, to the west of Cape La Hague, becomes pent up by Guernsey, Jersey, and other islands, till the rise of the tide is from twenty to forty-five feet,

* Geog. of Herod. vol. ii. p. 331. † Ibid. p. 328.

‡ Romme, Vents et Courans, vol. ii. p. 2. Rev. F. Fallows, Quart. Journ. of Science, March, 1829.

§ The heights of these tides are given on the authority of Captain Hewett, R. N.

‖ On the authority of Captain Beaufort, R. N.

which last height it attains at Jersey, and at St. Malo, a seaport of Brittany.

Currents.—The most extensive and best determined system of currents, is that which has its source in the Indian Ocean, under the influence of the trade winds; and which, after doubling the Cape of Good Hope, inclines to the northward, along the western coast of Africa, then crosses the Atlantic, near the equator, and is lost in the Caribbean Sea, yet seems to be again revived in the current which issues from the Gulf of Mexico, by the Straits of Bahama, and flows rapidly in a north-easterly direction by the bank of Newfoundland, towards the Azores.

We learn from the posthumous work of Rennell on this subject, that the Lagullas current, so called from the cape and bank of that name, is formed by the junction of two streams, flowing from the Indian Ocean; the one from the channel of Mozambique, down the south-east coast of Africa; the other, from the ocean at large. The collective stream is from ninety to one hundred miles in breadth, and runs at the rate of from two and a half to more than four miles per hour. It is at length turned westward by the Lagullas bank, which rises from a sea of great depth to within one hundred fathoms of the surface. It must, therefore, be inferred, says Rennell, that the current here is more than one hundred fathoms deep, otherwise the main body of it would pass across the bank, instead of being deflected eastward, so as to flow round the Cape of Good Hope. From this cape it flows northward, along the western coast of Africa, taking the name of the South Atlantic current. It then enters the Bight, or Bay of Benin, and is turned westward, partly by the form of the coast there, and partly, perhaps, by the Guinea current, which runs from the north into the same great bay. From the centre of this bay proceeds the Equatorial current, holding a westerly direction across the Atlantic, which it traverses, from the coast of Guinea to that of Brazil, flowing afterwards by the shores of Guiana to the West Indies. The breadth of this current varies from 160 to 450 geographical miles, and its velocity is from twenty-five to seventy-nine miles per day, the mean rate being about thirty miles. The length of its whole course is about 4000 miles. As it skirts the coast of Guiana, it is increased by the influx of the waters of the Amazon and Orinoco, and by their junction acquires accelerated velocity. After passing the island of Trinidad, it expands, and is almost lost in the Caribbean Sea; but there appears to be a general movement of that sea towards the Mexican gulf, which discharges the most powerful of all currents through the Straits of Florida, where the waters run in the northern part with a velocity of five miles an hour, having a breadth of from thirty-five to fifty miles.

The temperature of the Gulf of Mexico is 86°, in summer, or 6° higher than that of the ocean, in the same parallel (25° N. lat.) and a large proportion of this warmth is retained, even where the stream reaches the

43° N. lat. After issuing from the Straits of Florida, the current runs in a northerly direction to Cape Hatteras, in North Carolina, about 35° N. lat., where it is more than seventy miles broad, and still moves at the rate of seventy-five miles per day. In about the 40° N. lat., it is turned more towards the Atlantic by the extensive banks of Nantucket and St. George, which are from 200 to 300 feet beneath the surface of the sea; a clear proof that the current exceeds that depth. On arriving near the Azores, the stream widens, and overflows, as it were, forming a large expanse of warm water in the centre of the North Atlantic, over a space of 200 or 300 miles from north to south, and having a temperature of from 8° to 10° Fahr. above the surrounding ocean. The whole area, covered by the gulf water, is estimated by Rennell at 2000 miles in length, and, at a mean, 350 miles in breadth; an area more extensive than that of the Mediterranean. The warm water has been sometimes known to reach the Bay of Biscay, still retaining five degrees of temperature above that of the adjoining ocean, and a branch of the gulf current occasionally drifts fruits, plants, and wood, the produce of America, and the West Indies, to the shores of Ireland, and the Hebrides.

From the above statements we may understand the description, given by Rennell, of the principal currents, which, he says, are oceanic rivers, from 50 to 250 miles in breadth, having a rapidity exceeding that of the largest navigable rivers of the continents, and so deep as to be sometimes obstructed, and occasionally turned aside, by banks which do not rise within forty or fifty fathoms of the surface of the sea.*

Greatest Velocity of Currents.—The ordinary velocity of the principal currents of the ocean is from one to three miles per hour; but when the boundary lands converge, large bodies of water are driven gradually into a narrower space, and then wanting lateral room, are compelled to raise their level. Whenever this occurs, their velocity is much increased. The current which runs through the Race of Alderney, between the island of that name and the main land, has a velocity of above eight English miles an hour. Captain Hewett found that in the Pentland Firth the stream, in ordinary spring tides, runs ten miles and a half an hour, and about thirteen miles during violent storms. The greatest velocity of the tidal current through the "Shoots," or New Passage, in the Bristol Channel, is fourteen English miles an hour; and Captain King observed, in his recent survey of the Straits of Magellan, that the tide ran at the same rate through the "First Narrows."

Causes of Currents.—That movements of no inconsiderable magnitude should be impressed on an expansive ocean, by winds blowing for many months in one direction, may easily be conceived, when we observe the effects produced in our own seas by the temporary action of the same

* Rennell on Currents, p. 58.

cause. It is well known that a strong south-west or north-west wind invariably raises the tides to an unusual height along the east coast of England and in the Channel; and that a north-west wind of any continuance causes the Baltic to rise two feet and upwards above its ordinary level. Smeaton ascertained by experiment that, in a canal four miles in length, the water was kept up four inches higher at one end than at the other, merely by the action of the wind along the canal; and Rennell informs us that a large piece of water, ten miles broad, and generally only three feet deep, has, by a strong wind, had its waters driven to one side, and sustained so as to become six feet deep, while the windward side was laid dry.*

As water, therefore, he observes, when pent up so that it cannot escape, acquires a higher level, so, in a place *where it can escape*, the same operation produces a current; and this current will extend to a greater or less distance, according to the force by which it is produced.

Currents flowing alternately in opposite directions are also occasioned by the rise and fall of the tides. The effect of this cause is, as before observed, most striking in estuaries and channels between islands.

A third cause of oceanic currents is evaporation by solar heat, of which the great current setting through the Straits of Gibraltar into the Mediterranean is a remarkable example, and will be fully considered in the next chapter. A stream of colder water also flows from the Black Sea into the Mediterranean. It must happen in many other parts of the world that large quantities of water raised from one tract of the ocean by solar heat, are carried to some other where the vapour is condensed and falls in the shape of rain, and this in flowing back again to restore equilibrium, will cause sensible currents.

These considerations naturally lead to the inquiry, whether the level of contiguous seas, where currents prevail, varies considerably. Arago is of opinion that, so far as observations have hitherto been made, the difference in relative level is not great, or at least that it is insufficient to bear out the hypothesis that currents in general are referable to the action of prevailing winds. He admits the important and remarkable fact that the level of the Mediterranean near Alexandria is lower, by twenty-six feet six inches, than the Red Sea near Suez at low water, and about thirty feet lower than the Red Sea at the same place at high water. This result was obtained during the French expedition to Egypt, from the measurements of M. Lepère.†

It was formerly imagined that there was an equal, if not greater diversity, in the relative levels of the Atlantic and Pacific, on the opposite sides of the isthmus of Panama. But the levellings recently carried across that isthmus by Mr. Lloyd, to ascertain the relative height of the Pacific

* Rennell on the Channel current.

† An. du Bureau des Long. pour l'an 1836.

Ocean at Panama, and of the Atlantic at the mouth of the river Chagres, have shown, that the difference of mean level between those oceans is not considerable, and contrary to expectation the difference which does exist is in favour of the greater height of the Pacific. According to the result of this survey, on which great dependence may be placed, the mean height of the Pacific is three feet and a half, or 3.52 above the Atlantic, if we assume the mean level of a sea to coincide with the mean between the extremes of the elevation and depression of the tides; for between the extreme levels of the greatest tides in the Pacific, at Panama, there is a difference of 27.44 feet; and at the usual spring tides 21.22 feet: whereas at Chagres this difference is only 1.16 feet, and is the same at all seasons of the year.

The tides, in short, in the Caribbean Sea are scarcely perceptible, not equalling those in some parts of the Mediterranean, whereas the rise is very high in the Bay of Panama; so that the Pacific is at high tide lifted up several feet above the surface of the Gulf of Mexico, and then at low water let down as far below it.* But astronomers are agreed that, on mathematical principles, the rise of the tidal wave above the mean level of a particular sea must be greater than the fall below it; and although the difference has been hitherto supposed insufficient to cause an appreciable error, it is, nevertheless, worthy of observation, that the error, such as it may be, would tend to reduce the small difference, now inferred, from the observations of Mr. Lloyd, to exist between the levels of the two oceans.

There is still another way in which heat and cold must occasion great movements in the ocean, a cause to which, perhaps, currents are principally due. It is now ascertained that there is in sea water no point, as in fresh water, at which an increase of cold causes the fluid to begin again to expand. In the ocean, therefore, whenever the temperature of the surface is lowered, condensation takes place, and the superficial water, having its specific gravity increased, falls to the bottom, upon which lighter water rises immediately and occupies its place. When this circulation of ascending and descending currents has gone on for a certain time in high latitudes, the inferior parts of the sea are made to consist of colder or heavier fluid than the corresponding depths of the ocean between the tropics. If there be a free communication, if no chain of submarine mountains divide the polar from the equatorial basins, a horizontal movement will arise by the flowing of colder water from the poles to the equator, and there will then be a reflux of warmer superficial water from the equator to the poles. A well-known experiment has been adduced to elucidate this mode of action in explanation of the "trade winds."† If a

* Phil. Trans., 1830, p. 59.

† See Capt. B. Hall's clear Explanation of the Theory of the Trade Winds. Fragments of Voyages, second series, vol. i., and his letter in the Appendix to Daniell's Meteorology.

long trough, divided in the middle by a sluice or partition, have one end filled with water and the other with quicksilver, both fluids will remain quiet so long as they are divided; but when the sluice is drawn up, the heavier fluid will rush along the bottom of the trough, while the lighter, being displaced, will rise, and, flowing in an opposite direction, spread itself at the top. In like manner the expansion and contraction of sea-water by heat and cold have a tendency to set under-currents in motion from the poles to the equator, and to cause counter-currents at the surface, which are impelled in a direction contrary to that of the prevailing trade winds. The geographical and other circumstances being very complicated, we cannot expect to trace separately the movements due to each cause, but must be prepared for many anomalies, especially as the configuration of the bed of the ocean must often modify and interfere with the course of the inferior currents, as much as the position and form of continents and islands are found to alter the direction of those on the surface.

Each of the four causes above mentioned, the wind, the tides, evaporation, and the expansion and contraction of water by heat and cold, may be conceived to operate independently of the others, and although the influence of all the rest were annihilated. But there is another cause, the rotation of the earth on its axis, which can only come into play when the waters have already been set in motion by some one or all of the forces above described, and when the direction of the current so raised happens to be from south to north, or from north to south.*

The principle on which this cause operates is probably familiar to the reader, as it has long been recognised in the case of the trade winds. Without enlarging, therefore, on the theory, it will be sufficient to offer an example of the mode of action alluded to. When a current flows from the Cape of Good Hope towards the Gulf of Guinea, it consists of a mass of water, which, on doubling the Cape, in lat. 35°, has a rotatory velocity of about 800 miles an hour; but when it reaches the line, it arrives at a parallel where the surface of the earth is whirled round at the rate of 1000 miles an hour, or about 200 miles faster.† If this great mass of water was transferred suddenly from the higher to the lower latitude, the deficiency of its rotatory motion, relatively to the land and water with

* In an interesting essay in the United Service Journal (Dec. 1833), an attempt is made to introduce the earth's rotation as a primary cause of currents. But the author appears to misconceive the mode in which alone this rotation could produce any effect, and reasons as if it would in all latitudes cause currents from east to west. He also seems never to have heard of Mr. Lloyd's levellings across the Isthmus of Panama, by which the waters of the Gulf of Mexico are proved (if there be any difference) to be lower than the mean level of the Pacific. He also assumes erroneously that the quantity of rain is greatly in excess in *high* instead of *low* latitudes.

† See a table in Capt. Hall's work, before cited.

which it would come into juxtaposition, would be such as to cause an apparent motion of the most rapid kind (of no less than 200 miles an hour) from east to west.

In the case of such a sudden transfer, the eastern coast of America, being carried round in an opposite direction, might strike against a large body of water with tremendous violence, and a considerable part of the continent might be submerged. This disturbance does not occur, because the water of the stream, as it advances gradually into new zones of the sea which are moving more rapidly, acquires by friction an accellerated velocity. Yet as this motion is not imparted instantaneously, the fluid is unable to keep up with the full speed of the new surface over which it is successively brought. Hence, to borrow the language of Herschel, when he speaks of the trade winds, "it lags or hangs back, in a direction opposite to the earth's rotation, that is, from east to west,"* and thus a current which would have run simply towards the north but for the rotation, may acquire a relative direction towards the west, or become a south-easterly current.

We may next consider a case where the circumstances are the converse of the above. The Gulf stream flowing from about lat. 20°, is at first impressed with a velocity of rotation of about 940 miles an hour, and runs to the lat. 40°, where the earth revolves only at the rate of 766 miles, or 174 miles slower. In this case a relative motion of an opposite kind may result: and the current may retain an excess of rotatory velocity, tending continually to deflect it eastward.

Thus it will be seen that the currents depend, like the tides, on no temporary or accidental circumstances, but on the laws which preside over the motions of the heavenly bodies. But although the sum of their influence in altering the surface of the earth may be very constant throughout successive epochs, yet the points where these operations are displayed in fullest energy shift perpetually. The height to which the tides rise, and the violence and velocity of currents, depend in a great measure on the actual configuration of the land, the contour of a long line of continental or insular coast, the depth and breadth of channels, the peculiar form of the bottom of seas—in a word, on a combination of circumstances which are made to vary continually by many igneous and aqueous causes, and, among the rest, by the tides and currents themselves. Although these agents, therefore, of decay and reproduction are local in reference to periods of short duration, such as those which history embraces, they are nevertheless universal, if we extend our views to a sufficient lapse of ages.

Action of the Sea on the British Coasts.—If we follow the eastern and southern shores of the British islands, from our Ultima Thule in Shetland

* Treatise on Astronomy, chap. 3.

to the Land's End in Cornwall, we shall find evidence of a series of changes since the historical era, very illustrative of the kind and degree of force exerted by tides and currents, co-operating with the waves of the sea. In this survey we shall have an opportunity of tracing their joint power on islands, promontories, bays, and estuaries; on bold, lofty cliffs, as well as on low shores; and on every description of rock and soil, from granite to blown sand.

Shetland Islands.—The northernmost group of the British islands, the Shetland, are composed of a great variety of rocks, including granite, gneiss, mica-slate, serpentine, greenstone, and many others, with some secondary rocks, chiefly sandstone and conglomerate. These islands are exposed continually to the uncontrolled violence of the Atlantic, for no land intervenes between their western shores and America. The prevalence, therefore, of strong westerly gales causes the waves to be sometimes driven with irresistible force upon the coast, while there is also a current setting from the north. The spray of the sea aids the decomposition of the rocks, and prepares them to be breached by the mechanical force of the waves. Steep cliffs are hollowed out into deep caves and lofty arches; and almost every promontory ends in a cluster of rocks, imitating the forms of columns, pinnacles, and obelisks.

Drifting of large Masses of Rock.—Modern observations show that the reduction of continuous tracts to such insular masses is a process in which Nature is still actively engaged. "The Isle of Stenness," says Dr. Hibbert, "presents a scene of unequalled desolation. In stormy winters, huge blocks of stones are overturned or are removed from their native beds, and hurried up a slight acclivity to a distance almost incredible. In the winter of 1802, a tabular-shaped mass, eight feet two inches by seven feet, and five feet one inch thick, was dislodged from its bed, and removed to a distance of from eighty to ninety feet. I measured the recent bed from which a block had been carried away the preceding winter (A. D. 1818), and found it to be seventeen feet and a half by seven feet, and the depth two feet eight inches. The removed mass had been borne to a distance of thirty feet, when it was shivered into thirteen or more lesser fragments, some of which were carried still farther, from 30 to 120 feet. A block nine feet two inches by six feet and a half, and four feet thick, was hurried up the acclivity to a distance of 150 feet.*

At Northmavine, also; angular blocks of stone have been removed in a similar manner to considerable distances by the waves of the sea, some of which are represented in Fig. 14.†

* Descrip. of Shetland Islands, p. 527. Edin. 1822.

† For this and the three following representations of rocks in the Shetland Isles, I am indebted to Dr. Hibbert's work, before cited, which is rich in antiquarian and geological research.

Fig. 14.

Stony fragments drifted by the sea. Northmavine, Shetland.

Effects of Lightning.—In addition to numerous examples of masses detached and driven by the waves, tides, and currents from their place, some remarkable effects of lightning are recorded in these isles. At Funzie, in Fetlar, about the middle of the last century, a rock of mica-schist, 105 feet long, ten feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large, and several smaller, fragments. One of these, twenty-six feet long, ten feet broad, and four feet thick, was simply turned over. The second, which was twenty-eight feet long, seventeen broad, and five feet in thickness, was hurled across a high point to the distance of fifty yards. Another broken mass, about forty feet long, was thrown still farther, but in the same direction, quite into the sea. There were also many smaller fragments scattered up and down.*

When we thus see electricity co-operating with the violent movements of the ocean in heaping up piles of shattered rocks on dry land, and beneath the waters, we cannot but admit that a region which shall be the theatre, for myriads of ages, of the action of such disturbing causes, might present, at some future period, if upraised far above the bosom of the deep, a scene of havoc and ruin that may compare with any now found by the geologist on the surface of our continents.

In some of the Shetland Isles, as on the west of Meikle Roe, dikes, or veins of soft granite, have mouldered away; while the matrix in which they were inclosed, being of the same substance, but of a firmer texture, has remained unaltered. Thus, long narrow ravines, sometimes twenty-feet wide, are laid open, and often give access to the waves. After describing some huge cavernous apertures into which the sea flows for 250 feet in Roeness, Dr. Hibbert enumerates other ravages of the ocean. "A mass of rock, the average dimensions of which may perhaps be rated at twelve or thirteen feet square, and four and a half or five in thickness,

* Dr. Hibbert, from MSS. of Rev. George Low, of Fetlar.

was first moved from its bed, about fifty years ago, to a distance of thirty feet, and has since been twice turned over."

Passage forced by the sea through porphyritic rocks.—" But the most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean;—the Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery—the waves having, in their repeated assaults, forced themselves an entrance. This breach, named the Grind of the Navir (Fig. 15.), is widened every winter by the overwhelming surge that, finding a passage

Fig. 15.

Grind of the Navir—Passage forced by the sea through rocks of hard porphyry.

through it, separates large stones from its sides, and forces them to a distance of no less than 180 feet. In two or three spots, the fragments which have been detached are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry."*

It is evident, from this example, that although the greater indestructibility of some rocks may enable them to withstand, for a longer time, the action of the elements, yet they cannot permanently resist. There are localities in Shetland, in which rocks of almost every variety of mineral composition are suffering disintegration; thus the sea makes great inroads on the clay slate of Fitfel Head, on the serpentine of the Vord Hill in Fetlar, and on the mica-schist of the Bay of Triesta, on the east coast of the same island, which decomposes into angular blocks. The quartz rock on the east of Walls, and the gneis and mica-schist of Garthness, suffer the same fate.

* Hibbert, p. 528.

Destruction of Islands.—Such devastation cannot be incessantly committed for thousands of years without dividing islands, until they become at last mere clusters of rocks, the last shreds of masses once continuous.

Fig. 16.

Granitic rocks named the Drongs, between Papa Stour and Hillswick Ness.

To this state many appear to have been reduced, and innumerable fantastic forms are assumed by rocks adjoining these islands, to which the name of Drongs is applied, as it is to those of similar shape in Feroe.

The granitic rocks (Fig. 16.) between Papa Stour and Hillswick Ness afford an example. A still more singular cluster of rocks is seen to the south of Hillswick Ness (Fig. 17.) which presents a variety of forms, as viewed from different points, and has often been likened to a small fleet of vessels with spread sails.* We may imagine that in the course of time Hillswick Ness itself may present a similar wreck, from the unequal

Fig. 17.

Granite rocks to the south of Hillswick Ness, Shetland.

decomposition of the rocks whereof it is composed, consisting of gneiss and mica-schist, traversed in all directions by veins of felspar porphyry.

* Hibbert, p. 519.

Midway between the groups of Shetland and Orkney is Fair Island, said to be composed of sandstone with high perpendicular cliffs. The current runs with such velocity, that during a calm, and when there is no swell, the rocks on its shores are white with the foam of the sea driven against them. The Orkneys, if carefully examined, would probably illustrate our present topic as much as the Shetland group. The north-east promontory of Sanda, one of these islands, has been cut off in modern times by the sea, so that it became what is now called Start Island, where a lighthouse was erected in 1807, since which time the new strait has grown broader.

East coast of Scotland.—To pass over to the main land of Scotland we find that, in Inverness-shire, there have been inroads of the sea at Fort George, and others in Morayshire, which have swept away the old town of Findhorn. On the coast of Kincardineshire, an illustration was afforded, at the close of the last century, of the effect of promontories in protecting a line of low-shore. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach, protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent, that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated 150 yards inland, where it has maintained its ground ever since, the new village having been built farther inland on the new shore. In the Bay of Montrose, we find the North Esk and the South Esk rivers pouring annually into the sea large quantities of sand and pebbles, yet they have formed no deltas; for the tides scour out the channels; and the current, setting across their mouths, sweeps away all the materials. Considerable beds of shingle, brought down by the North Esk, are seen along the beach.

Proceeding southwards, we find that at Arbroath, in Forfarshire, which stands on a rock of red sandstone, gardens and houses have been carried away within the last thirty years by encroachments of the sea. It has become necessary to remove the lighthouses at the mouth of the estuary of the Tay, in the same county, at Button Ness, which were built on a tract of blown sand, the sea having encroached for three-quarters of a mile.

Force of Waves and Currents in Estuaries.—The combined power which waves and currents can exert in estuaries to considerable depths, was remarkably exhibited during the building of the Bell Rock Lighthouse, off the mouth of the Tay. The Bell Rock is a sunken reef, consisting of red sandstone, being from twelve to sixteen feet under the surface at high water, and about twelve miles from the mainland. At the distance of 100 yards, there is a depth, in all directions, of two or three fathoms at low water. In 1807, during the erection of the lighthouse, six large blocks of granite, which had been landed on the reef, were removed by the force of the sea, and thrown over a rising ledge to the distance of twelve or fifteen paces; and an anchor, weighing about 22 cwt., was thrown up upon the rock.* Mr. Stevenson informs us, moreover, that drift stones, measuring upwards of thirty cubic feet, or more than two tons weight, have, during storms, been often thrown upon the rock from the deep water.†

Submarine forests.—Among the proofs that the sea has encroached both on the estuaries of the Tay and Forth, may be mentioned the submarine forests which have been traced for several miles by Dr. Fleming, along the margins of those estuaries on the north and south shores of the county of Fife.‡ The alluvial tracts, however, on which such forests grow, generally occupy spaces which may be said to be in dispute between the river and the sea, and to be alternately lost and won. *Estuaries* (a term which we confine to inlets entered both by rivers and tides of the sea) have a tendency to become silted up in parts; but the same tracts, after remaining dry, perhaps, for thousands of years, are again liable to be overflowed, for they are always low, and, if inhabited, must generally be secured by artificial embankments. Meanwhile the sea devours, as it advances, the high as well as the low parts of the coast, breaking down, one after another, the rocky bulwarks which protect the mouths of estuaries. The changes of territory, therefore, within the general line of coast are all of a subordinate nature, in no way tending to arrest the march of the great ocean, nor to avert the destiny eventually awaiting the whole region; they are like the petty wars and conquests of the independent states and republics of Greece, while the power of Macedon was steadily pressing on, and preparing to swallow up the whole.

On the coast of Fife, at St. Andrew's, a tract of land which intervened between the castle of Cardinal Beaton and the sea, has been entirely swept away, as were the last remains of the Priory of Crail, in the same county, in 1803. On both sides of the Frith of Forth, land has been consumed; at North Berwick in particular, and at Newhaven, where an arsenal and dock, built in the reign of James IV., in the fifteenth century, has been overflowed.

East coast of England.—If we now proceed to the English coast, we find records of numerous lands having been destroyed at Northumberland, as those near Bamborough and Holy Island, and at Tynemouth Castle, which now overhangs the sea, although formerly separated from it by a strip of land. At Hartlepool, and several other parts of the coast of Durham composed of magnesian limestone, the sea has made considerable inroads.

Coast of Yorkshire.—Almost the whole coast of Yorkshire, from the

* Account of the Erection of the Bell Rock Lighthouse, p. 163.

† Ed. Phil. Journ. vol. iii. p. 54. 1820.

‡ Quart. Journ. of Sci., &c., No. XIII. *N. S.* March, 1830.

mouth of the Tees to that of the Humber, is in a state of gradual dilapidation. That part of the cliffs which consists of lias, the oolite series, and chalk, decays slowly. They present abrupt and naked precipices, often 300 feet in height; and it is only at a few points that the grassy covering of the sloping talus marks a temporary relaxation of the erosive action of the sea. The chalk cliffs are washed into caves in the projecting headland of Flamborough, where they are decomposed by the salt spray, and slowly crumble away. But the waste is most rapid between that promontory and Spurn Point, or the coast of Holderness, as it is called, a tract consisting of beds of clay, gravel, sand, and chalk rubble. The irregular intermixture of the argillaceous beds causes many springs to be thrown out, and this facilitates the undermining process, the waves beating against them, and a strong current setting chiefly from the north. The wasteful action is very conspicuous at Dimlington Height, the loftiest point in Holderness, where the beacon stands on a cliff 146 feet above high water, the whole being composed of clay, with pebbles scattered through it.*

In the old maps of Yorkshire, we find spots, now sand-banks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde. "Of Hyde," says Pennant, "only the tradition is left; and near the village of Hornsea, a street called Hornsea Beck has long since been swallowed."† Owthorne and its church have also been in great part destroyed, and the village of Kilnsea; but these places are now removed farther inland. The rate of encroachment at Owthorne, at present, is about *four yards a year*.‡ Not unreasonable fears are entertained that at some future time the Spurn Point will become an island, and that the ocean, entering into the estuary of the Humber, will cause great devastation.§ Pennant, after speaking of the silting up of some ancient ports in that estuary, observes, "But, in return, the sea has made most ample reprisals; the site, and even the very names of several places, once towns of note upon the Humber, are now only recorded in history; and Ravensper was at one time a rival to Hull (Madox, Ant. Exch. i. 422), and a port so very considerable in 1332, that Edward Baliol and the confederated English barons sailed from hence to invade Scotland; and Henry IV., in 1399, made choice of this port to land at, to effect the deposal of Richard II.; yet the whole of this has long since been devoured by the merciless ocean: extensive sands, dry at low water, are to be seen in their stead."‖

* Phillips's Geology of Yorkshire, p. 61.

† Arctic Zoology, vol. i. p. 10. Introduction.

‡ For this information I am indebted to Mr. Phillips, of York.

§ Phillips's Geology of Yorkshire, p. 60.

‖ Arct. Zool. vol. i. p. 13. Introduction.

Pennant describes Spurn Head as a promontory in the form of a sickle, and says the land, for some miles to the north, was "perpetually preyed on by the fury of the German Sea, which devours whole acres at a time, and exposes on the shores considerable quantities of beautiful amber."*

According to Bergmann, a strip of land, with several villages, was carried away near the mouth of the Humber in 1475.

Lincolnshire.—The maritime district of Lincolnshire consists chiefly of lands that lie below the level of the sea, being protected by embankments. Great parts of this fenny tract were, at some unknown period, a woody country, but were afterwards inundated, and are now again recovered from the sea. Some of the fens were embanked and drained by the Romans; but after their departure the sea returned, and large tracts were covered with beds of silt containing marine shells, now again converted into productive lands. Many dreadful catastrophes are recorded by incursions of the sea, whereby several parishes have been at different times overwhelmed.

Norfolk.—We come next to the cliffs of Norfolk and Suffolk, where the decay is in general incessant and rapid. At Hunstanton, on the north, the undermining of the lower arenaceous beds at the foot of the cliff causes masses of red and white chalk to be precipitated from above. Between Hunstanton and Weybourne, low hills, or dunes, of blown sand, are formed along the shore, from fifty to sixty feet high. They are composed of dry sand, bound in a compact mass by the long creeping roots of the plant called Marram (Arundo arenaria.) Such is the present set of the tides, that the harbours of Clay, Wells, and other places, are securely defended by these barriers; affording a clear proof that it is not the strength of the material at particular points that determines whether the sea shall be progressive or stationary, but the general contour of the coast.

The waves constantly undermine the low chalk cliffs, covered with sand and clay, between Weybourne and Sherringham, a certain portion of them being annually removed. At the latter town I ascertained, in 1829, some facts which throw light on the rate at which the sea gains upon the land. It was computed, when the present inn was built, in 1805, that it would require seventy years for the sea to reach the spot: the mean loss of land being calculated, from previous observations, to be somewhat less than one yard annually. The distance between the house and the sea was fifty yards; but no allowance was made for the slope of the ground being *from* the sea, in consequence of which, the waste was naturally accelerated every year, as the cliff grew lower, there being at each succeeding period less matter to remove when portions of equal area fell down. Between the years 1824 and 1829, no less than seventeen

* Arct. Zool. vol. i. p. 13. Introduction.

yards were swept away, and only a small garden was then left between the building and the sea. There is now a depth of twenty feet (sufficient to float a frigate) at one point in the harbour of that port, where, only forty-eight years ago, there stood a cliff fifty feet high, with houses upon it! If once in half a century an equal amount of change were produced suddenly by the momentary shock of an earthquake, history would be filled with records of such wonderful revolutions of the earth's surface; but, if the conversion of high land into deep sea be gradual, it excites only local attention. The flag-staff of the Preventive Service station, on the south side of this harbour, has, within the last fifteen years, been thrice removed inland, in consequence of the advance of the sea.

Farther to the south we find cliffs, composed, like those of Holderness before mentioned, of alternating strata of blue clay, gravel, loam, and fine sand. Although they sometimes exceed 200 feet in height, the havoc made on the coast is most formidable. The whole site of ancient Cromer now forms part of the German Ocean, the inhabitants having gradually retreated inland to their present situation, from whence the sea still threatens to dislodge them. In the winter of 1825, a fallen mass was precipitated from near the lighthouse, which covered twelve acres, extending far into the sea, the cliffs being 250 feet in height.* The undermining by springs has sometimes caused large portions of the upper part of the cliffs, with houses still standing upon them, to give way, so that it is impossible, by erecting breakwaters at the base of the cliffs, permanently to ward off the danger.

On the same coast, the ancient villages of Shipden, Wimpwell, and Eccles, have disappeared; several manors and large portions of neighbouring parishes having, piece after piece, been swallowed up; nor has there been any intermission, from time immemorial, in the ravages of the sea along a line of coast twenty miles in length, in which these places stood.† Hills of blown sand, between Eccles and Winterton, have barred up and excluded the tide for many hundred years from the mouths of several small estuaries; but there are records of nine breaches from 20 to 120 yards wide, having been made through these, by which immense damage was done to the low grounds in the interior. A few miles south of Happisburgh, also, are hills of blown sand, which extend to Yarmouth; and these are supposed to protect the coast, but in fact their formation proves that a temporary respite of the incursions of the sea on this part is permitted by the present set of the tides and currents. Were it otherwise, the land, as we have seen, would give way, though made of solid rock.

* Taylor's Geology of East Norfolk, p. 32. † Ibid.

Silting up of Estuaries.—At Yarmouth, the sea has not advanced upon the sands in the slightest degree since the reign of Elizabeth. In the time of the Saxons, a great estuary extended as far as Norwich, which city is represented, even in the thirteenth and fourteenth centuries, as "situated on the banks of an arm of the sea." The sands whereon Yarmouth is built first became firm and habitable ground about the year 1008, from which time a line of dunes has gradually increased in height and breadth, stretching across the whole entrance of the ancient estuary, and obstructing the ingress of the tides so completely, that they are only admitted by the narrow passage which the river keeps open, and which has gradually shifted several miles to the south. The ordinary tides at the river's mouth rise, at present, only to the height of three or four feet, the spring tides to about eight or nine.

By the exclusion of the sea thousands of acres in the interior have become cultivated lands; and, exclusive of smaller pools, upwards of sixty fresh-water lakes have been formed, varying in depth from fifteen to thirty feet, and in extent from 1 acre to 1200.* The Yare, and other rivers, frequently communicate with these sheets of water; and thus they are liable to be filled up gradually with lacustrine and fluviatile deposits, and to be converted into land covered with forests. When the sea at length returns (for as the whole coast gives way, this must inevitably happen sooner or later), these tracts will be again submerged, and submarine forests may then be found, as along the margins of many estuaries.†

Yarmouth does not project beyond the general line of coast which has been rounded off by the predominating current from the north-west. It must not be imagined, therefore, that the acquisition of new land fit for cultivation in Norfolk and Suffolk indicates any permanent growth of the eastern limits of our island, to compensate its reiterated losses. No *delta* can form on such a shore.

That great banks should be thrown across the estuary of the Yare, or any other estuary on our eastern coast, where there is not a large body of river-water to maintain an open channel, is perfectly intelligible, when we bear in mind that the marine current, sweeping along the coast, is charged with the materials of wasting cliffs, and ready to form a bar anywhere, the instant its course is interrupted or checked by any opposing stream. The mouth of the Yare has been, within the last five centuries, diverted about four miles to the south; so it is evident that at some remote period the river Alde entered the sea at Aldborough, until its ancient outlet was barred up and at length transferred to a point no less

* Taylor's Geology of East Norfolk, p. 10.

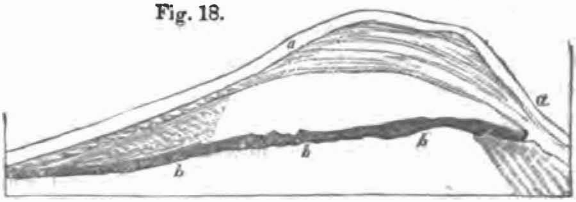
† For remarks on the origin of Submarine Forests, see Book III. chap. 16.

than ten miles distant to the south-west. In this case ridges of sand and shingle like those of Lowestoff Ness, which will be described by-and-by, have been thrown up between the river and the sea; and an ancient sea-cliff is to be seen, now inland.

It may be asked why the rivers on our east coast are always deflected southwards, although the tidal current flows alternately from the south and north? The cause is to be found in the superior force of what is commonly called "the flood tide from the north," a tidal wave derived from the Atlantic, a small part of which passes eastward up the English Channel, and through the Straits of Dover and then northwards, while the principal body of water, moving much more rapidly in a more open sea, first passes the Orkneys, and then turning, flows down between Norway and Scotland, and sweeps with great velocity along our eastern coast. It is well known that the highest tides on this coast are occasioned by a powerful north-west wind, which raises the eastern part of the Atlantic, and causes it to pour a greater volume of water into the German Ocean. This circumstance of a violent *off-shore* wind being attended with a rise of the waters, instead of a general retreat of the sea, naturally excites the wonder of the inhabitants of our coast. In many districts they look with confidence for a rich harvest of that valuable manure, the sea-weed, when the north-westerly gales prevail, and are rarely disappointed. The phenomenon is so well calculated to awaken curiosity, that I have heard the cause discussed by peasants and fishermen; and more than once they have hazarded a theory of their own to account for it. The most ingenious idea which I have heard suggested was this: a vast body of surface water, say they, is repelled by the wind from the shore, which afterwards returns, in order to restore the level of the sea; by this means a strong under-current is produced, which tears up the weed from the bed of the sea, and casts it ashore. The true explanation, however, of the phenomenon is doubtless that above mentioned.

Coast of Suffolk.—The cliffs of Suffolk, to which we next proceed, are somewhat less elevated than those of Norfolk, but composed of similar alternations of clay, sand, and gravel. From Gorleston in Suffolk, to within a few miles north of Lowestoff, the cliffs are slowly undermined. Near the last-mentioned town, there is an inland cliff about sixty feet high, the sloping talus of which is covered with turf and heath. Between the cliff and the sea is a low, flat tract of sand, called the Ness, nearly three miles long, and for the most part out of the reach of the highest tides. The point of the Ness projects from the base of the original cliff to the distance of 660 yards. This accession of land, says Mr. Taylor, has been effected at distinct and distant intervals, by the influence of currents running between the land and a shoal about a mile off Lowestoff, called the Holm Sand. The lines of growth in the Ness are indicated by a series of concentric ridges or embankments inclosing

Fig. 18.



*Map of Lowestoff Ness, Suffolk.**

a, a. The dotted lines express a series of ridges of sand and shingle, forming the extremity of the triangular space called the Ness.

b, b, b. The dark line represents the inland cliff on which the town of Lowestoff stands, between which and the sea is the Ness.

limited areas, and several of these ridges have been formed within the observation of persons now living. A rampart of heavy materials is first thrown up to an unusual altitude by some extraordinary tide, attended with a violent gale. Subsequent tides extend the base of this high bank of shingle, and the interstices are then filled with sand blown from the beach. The Arundo and other marine plants by degrees obtain a footing; and creeping along the ridge, give solidity to the mass, and form in some cases a matted covering of turf. Meanwhile another mound is forming externally, which by the like process rises and gives protection to the first. If the sea forces its way through one of the external and incomplete mounds, the breach is soon repaired. After a while the marine plants within the areas inclosed by these embankments are succeeded by a better species of herbage, affording good pasturage, and the sands become sufficiently firm to support buildings.†

Destruction of Dunwich by the Sea.—The sea undermines the high cliffs near Corton, a few miles north of Lowestoff, as also two miles south of the same town, at Pakefield, a village which has been in part swept away during the present century. From thence to Dunwich the destruction is constant. At the distance of 250 yards from the wasting cliff at Pakefield, where we must suppose land to have existed at no remote period, the sea is sixteen feet deep at low water, and in the roadstead beyond, twenty-four feet. Of the gradual destruction of Dunwich, once the most considerable seaport on this coast, we have many authentic records. Gardner in his history of that borough, published in 1754, shows, by reference to documents beginning with Doomsday Book, that the cliffs at Dunwich, Southwold, Eastern, and Pakefield, have been always subject to wear away. At Dunwich, in particular, two tracts of land which had been taxed in the eleventh century, in the time of King Edward the Con-

* From Mr. R. C. Taylor's Mem., see below.

† The formation of the Ness is well described by Mr. R. C. Taylor, Phil. Mag., p. 297. Oct. 1827.

fessor, are mentioned, in the Conqueror's survey, made but a few years afterwards, as having been devoured by the sea. The losses, at a subsequent period, of a monastery,—at another of several churches,—afterwards of the old port,—then of 400 houses at once,—of the church of St. Leonard, the high road, town-hall, gaol, and many other buildings, are mentioned, with the dates when they perished. It is stated that, in the sixteenth century, not one quarter of the town was left standing; yet the inhabitants retreating inland, the name was preserved, as has been the case with many other ports, when their ancient site has been blotted out. There is, however, a church, of considerable antiquity, still standing, the last of twelve mentioned in some records. In 1740, the laying open of the churchyard of St. Nicholas and St. Francis, in the sea-cliffs, is well described by Gardner, with the coffins and skeletons exposed to view—some lying on the beach, and rocked—

"In cradle of the rude imperious surge."

Of these cemeteries no remains can now be seen. Ray also says, "that ancient writings make mention of a wood a mile and a half to the east of Dunwich, the site of which must at present be so far within the sea."* This city, once so flourishing and populous, is now a small village, with about twenty houses, and one hundred inhabitants.

There is an old tradition, "that the tailors sat in their shops at Dunwich, and saw the ships in Yarmouth Bay;" but when we consider how far the coast at Lowestoff Ness projects between these places, we cannot give credit to the tale, which, nevertheless, proves how much the inroads of the sea in times of old had prompted men of lively imagination to indulge their taste for the marvellous.

Gardner's description of the cemeteries laid open by the waves remind us of the scene which has been so well depicted by Bewick,† and of which numerous points on the same coast might have suggested the idea. On the verge of a cliff, which the sea has undermined, are represented the unshaken tower and western end of an abbey. The eastern aisle is gone, and the pillars of the cloister are soon to follow. The waves have almost isolated the promontory, and invaded the cemetery, where they have made sport with the mortal relics, and thrown up a skull upon the beach. In the foreground is seen a broken tombstone, erected, as its legend tells, "to *perpetuate* the memory of one whose name is obliterated, as is that of the county for which he was 'Custos Rotulorum.'" A cormorant is perched on the monument, defiling it, as if to remind some moraliser, like Hamlet, of "the base uses" to which things sacred may be turned. Had this excellent artist desired to satirise certain popular

* Consequences of the Deluge, Phys. Theol. Discourses.

† History of British Birds, vol. ii. p. 220. Ed. 1821.

theories of geology, he might have inscribed the stone to the memory of some philosopher who taught "the permanency of existing continents"—"the era of repose"—"the impotence of modern causes."

South of Dunwich are two cliffs, called Great and Little Cat Cliff. That which bears the name of Great has become the smaller of the two, and is only fifteen feet high, the more elevated portion of the hill having been carried away; on the other hand, the Lesser Cat Cliff has gained in importance, for the sea has here been cutting deeper into a hill which slopes towards it. But at no distant period, the ancient names will again become appropriate, for at Great Cliff the base of another hill will soon be reached, and at Little Cat Cliff the sea will, at about the same time, arrive at a valley.

The incursions of the sea at Aldborough were formerly very destructive, and this borough is known to have been once situated a quarter of a mile east of the present shore. The inhabitants continued to build farther inland, till they arrived at the extremity of their property, and then the town decayed greatly; but two sand-banks, thrown up at a short distance, now afford a temporary safeguard to the coast. Between these banks and the present shore, where the current now flows, the sea is twenty-four feet deep on the spot where the town formerly stood.

Continuing our survey of the Suffolk coast to the southward, we find that the cliffs of Bawdsey and Felixtow are foundering slowly, and that the point on which Landguard Fort is built suffers gradual decay. It appears that, within the memory of persons now living, the Orwell river continued its course in a more direct line to the sea, and entered to the north instead of the south of the low bank on which the fort last mentioned is built.

Essex.—Harwich, in Essex, stands on an isthmus, which will probably become an island in little more than half a century; for the sea will then have made a breach near Lower Dover Court, should it continue to advance as rapidly as it has done during the last fifty years. Within ten years, there was a considerable space between the battery at Harwich, built twenty-three years ago, and the sea; part of the fortification has already been swept away, and the rest overhangs the water. Since the year 1807, a field called the Vicar's Field, which belonged to the living of Harwich, has been totally annihilated.*

At Walton Naze, in the same county, the cliffs, composed of London clay, capped by the shelly sands of the crag, reach the height of about 100 feet, and are annually undermined by the waves. The old churchyard of Walton has been washed away, and the cliffs to the south are constantly disappearing.

Kent.—Isle of Sheppey.—On the coast bounding the estuary of the

* On authority of Dr. Mitchell, F. G. S.

Thames, there are numerous examples both of the gain and loss of land. The Isle of Sheppey, which is now about six miles long by four in breadth, is composed of London clay. The cliffs on the north, which are from sixty to eighty feet high, decay rapidly, fifty acres having been lost within the last twenty years. The church at Minster, now near the coast, is said to have been in the middle of the island fifty years ago;* and it has been conjectured that, at the present rate of destruction, the whole isle will be annihilated in about half a century. On the coast of the mainland to the east of Sheppey is Herne Bay; a place still retaining the name of a bay, although it is no longer appropriate, as the waves and currents have swept away the ancient headlands. There was formerly a small promontory in the line of the shoals where the present pier is built, by which the larger bay was divided into two, called the Upper and Lower.†

Still farther east stands the church of Reculver, upon a cliff composed of clay and sand, about twenty feet high. Reculver (Regulvium), was an important military station in the time of the Romans, and appears, from Leland's account, to have been, so late as Henry VIII.'s reign, nearly one mile distant from the sea.

Fig. 19.

View of Reculver Church, taken in the year 1781.

1. Isle of Sheppey.
2. Ancient chapel now destroyed. The cottage between this chapel and the cliff was demolished by the sea, in 1782.

In the "Gentleman's Magazine," there is a view of it, taken in 1781, which still represents a considerable space as intervening between the north wall of the churchyard and the cliff.‡ Some time before the year 1780, the waves had reached the site of the ancient Roman camp, or for-

* For this information I am indebted to W. Gunnel, Esq.

† On the authority of W. Richardson, Esq., F. G. S.

‡ Vol. ii. New Series, 1809, p. 801.

tification, the walls of which had continued for several years after they were undermined to overhang the sea, being firmly cemented into one mass. They were eighty yards nearer the sea than the church, and they are spoken of in the "Topographica Britannica" in the year 1780, as having recently fallen down. In 1804, part of the churchyard with some

Fig. 20.

Reculver Church, in 1834.

adjoining houses was washed away, and the ancient church, with its two lofty spires, a well known land-mark, was dismantled and abandoned as a place of worship. It is still standing (1834,) but would probably have been annihilated ere this, had not the force of the waves been checked by an artificial causeway of stones and large wooden piles driven into the sands to break the force of the waves.*

Isle of Thanet.—The isle of Thanet was, in the time of the Romans, separated from the rest of Kent by a navigable channel through which the Roman fleets sailed on their way to and from London. Bede describes this small estuary as being, in the beginning of the eighth century, three furlongs in breadth; and it is supposed that it began to grow shallow about the period of the Norman conquest. It was so far silted up in the year 1485, that an act was then obtained to build a bridge across it; and it has since become marsh land, with small streams running through it. On the coast, Bedlam Farm, belonging to the hospital of that name, has lost eight acres in the last twenty years, the land being composed of

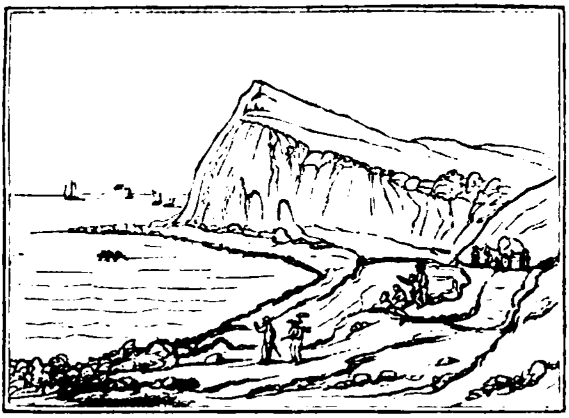
* Dr. Mitchell, Proceedings of Geol. Soc. vol. ii. No. 1.

chalk from forty to fifty feet above the level of the sea. It has been computed, that the average waste of the cliff between the North Foreland and the Reculvers, a distance of about eleven miles, is not less than two feet per annum. The chalk cliffs on the south of Thanet, between Ramsgate and Pegwell Bay, have on an average lost three feet per annum for the ten last years (preceding 1830).

Goodwin Sands.—The Goodwin Sands lie opposite this part of the Kentish coast. They are about ten miles in length, and are in some parts three, and in others seven miles distant from the shore; and, for a certain space, are laid bare at low water. That they are a remnant of land, and not "a mere accumulation of sea sand," as Rennell imagined,* may be presumed from the fact that, when the erection of a lighthouse on this shoal was in contemplation by the Trinity Board in the year 1817, it was found, by borings, that the bank consisted of fifteen feet of sand, resting on blue clay. An obscure tradition has come down to us, that the estates of Earl Goodwin, the father of Harold, who died in the year 1053, were situated here, and some have conjectured that they were overwhelmed by the flood mentioned in the Saxon chronicle, *sub anno* 1099. The last remains of an island, consisting, like Sheppey, of clay, may perhaps, have been carried away about that time.

There are other records of waste in the county or Kent, as at Deal; and at Dover, where Shakspeare's cliff, composed entirely of chalk, has suffered greatly, and continually diminishes in height, the slope of the hill being towards the land. About the year 1810 there was an immense landslip from this cliff, by which Dover was shaken as if by an earthquake, and a still greater one in 1772.†

Fig. 21.



Shakspeare's Cliff in 1836, seen from the North-east.

* Geog. of Herod. vol. ii. p. 326. † Dodsley's Ann. Regist. 1772.

Straits of Dover.—In proceeding from the northern parts of the German Ocean towards the Straits of Dover, the water becomes gradually more shallow, so that in the distance of about 200 leagues we pass from a depth of 120, to that of 58, 38, 24, and 18 fathoms. In the same manner the English Channel deepens progressively from Dover to its entrance, formed by the Land's End of England, and the Isle of Ushant on the Coast of France; so that the strait between Dover and Calais may be said to part two seas.*

Whether England was formerly united with France has often been a favourite subject of speculation; and in 1753 a society at Amiens proposed this as a subject of a prize essay, which was gained by the celebrated Desmarest, then a young man. He founded his principal arguments on the identity of composition of the cliffs on the opposite sides of the channel, on a sub-marine chain extending from Boulogne to Folkestone, only fourteen feet under low water, and on the identity of the noxious animals in England and France, which could not have swum across the Straits, and would never have been introduced by man. He also attributed the rupture of the isthmus to the preponderating violence of the current from the north.† It will hardly be disputed that the ocean might have effected a breach through the land which, in all probability, once united this country to the Continent, in the same manner as it now gradually forces a passage through rocks of the same mineral composition, and often many hundred feet high, upon the coast.

Although the time required for such an operation was probably very great, yet we cannot estimate it by reference to the present rate of waste on both sides of the channel; for when, in the thirteenth century, the sea burst through the isthmus of Staveren, which formerly united Friesland with North Holland, it opened, in about one hundred years, a strait more than half as wide as that which divides England from France, after which the dimensions of the new channel remained almost stationary. The greatest depth of the straits between Dover and Calais is twenty-nine fathoms, which exceeds only by one fathom the greatest depth of the Mississippi at New Orleans. If the moving column of water in the great American river, which, as was before mentioned, does not flow rapidly, can maintain an open passage to that depth in its alluvial accumulations, still more might a channel of the same magnitude be excavated by the resistless force of the tides and currents of "the ocean stream,"

ποταμοιο μεγα σθενος Ωκεανοιο.

In framing these speculations, however, we must not overlook the great effects which particular combinations of causes might produce without

* Stevenson on the Bed of the German Ocean.—Ed. Phil. Journ., No. v. p. 45.

† Cuvier, Eloge de Desmarest.

violence. The chalk supposed in this instance to have been removed, was of itself a marine deposit, and must at some period have emerged from the deep. It may have been upraised gradually, as the coast of Sweden, with the bed of the adjacent ocean and Baltic sea, are now rising;* or there may have been oscillations of level in the lands once connecting France and England. In that case, and especially if the movements were slow, a great amount of excavation may have been produced by a comparatively feeble power exerted by waves and currents cutting through successive portions of the chalk as it emerged. And here I may mention, that strata of chalky rubble and sand found at the base of the cliffs near Dover and Brighton, seem to indicate some changes in the relative level of sea and land since our coasts acquired a considerable part of their actual height and contour.†

At Folkestone, the sea undermines the chalk and subjacent strata. About the year 1716 there was a remarkable sinking of a tract of land near the sea, so that houses became visible at points near the shore from whence they could not be seen previously. In the description of this subsidence in the Philosophical Transactions, it is said, "that the land consisted of a solid stony mass (chalk), resting on wet clay (gault), so that it slid forwards towards the sea, just as a ship is launched on tallowed planks." It is also stated that, within the memory of persons then living, the cliff there had been washed away to the extent of ten rods.‡

Encroachments of the sea at Hythe are also on record; but between this point and Rye there has been a gain of land within the times of history; the rich level tract called Romney Marsh, or Dungeness, about ten miles in width and five in breadth, and formed of silt, having received great accession. It has been necessary, however, to protect it from the sea, from the earliest periods, by embankments, the towns of Lydd and Romney being the only parts of the marsh above the level of the highest tides.§ These additions of land are exactly opposite that part of the English Channel where the conflicting tide-waves from the north and south meet; for, as that from the north is, for reasons already explained, the most powerful, they do not neutralize each other's force till they arrive at this distance from the straits of Dover. Rye, on the south of this tract, was once destroyed by the sea, but it is now two miles distant from it. The neighbouring town of Winchelsea was destroyed in the reign of Edward I., the mouth of the Rother stopped up, and the river diverted into another channel. In its old bed an ancient vessel, apparently a Dutch merchantman, was recently found. It was built entirely of oak, and much blackened.‖ Large quantities of hazel-nuts, peat, and wood are found in digging in Romney marsh.

* See Book ii. chap. 17.
† See Book iv. chap. 22.
‡ Phil. Trans., 1716.
§ On the authority of Mr. J. Meryon, of Rye.
‖ Edin. Journ. of Sci., No. xix. p. 56.

South Coast of England.—To pass over some points near Hastings, where the cliffs have wasted at several periods, we arrive at the promontory of Beachy Head. Here a mass of chalk, three hundred feet in length, and from seventy to eighty in breadth, fell, in the year 1813, with a tremendous crash; and similar slips have since been frequent.*

Sussex.—About a mile to the west of the town of Newhaven the remains of an ancient entrenchment are seen, on the brow of Castle Hill. This earth-work, supposed to be Roman, was evidently once of considerable extent and of an oval form, but the greater part has been cut away. The cliffs, which are undermined here, are high; more than one hundred feet of chalk being covered by tertiary clay and sand, from sixty to seventy feet in thickness. In a few centuries the last vestiges of the plastic clay formation on the southern borders of the chalk of the South Downs on this coast will be annihilated, and future geologists will learn, from historical documents, the ancient geographical boundaries of this group of strata in that direction. On the opposite side of the estuary of the Ouse, on the east of Newhaven harbour, a bed of shingle, composed of chalk flints, derived from the waste of the adjoining cliffs, had accumulated at Seaford for several centuries. In the great storm of November, 1824, this bank was entirely swept away, and the town of Seaford inundated. Another great beach of shingle is now forming from fresh materials.

The whole coast of Sussex has been incessantly encroached upon by the sea from time immemorial; and, although sudden inundations only, which overwhelmed fertile or inhabited tracts, are noticed in history, the records attest an extraordinary amount of loss. During a period of no more than eighty years, there are notices of about *twenty* inroads, in which tracts of land of from twenty to *four hundred acres* in extent were overwhelmed at once; the value of the tithes being mentioned by Nicholas, in his Taxatio Ecclesiastica.† In the reign of Elizabeth, the town of Brighton was situated on that tract where the chain pier now extends into the sea. In the year 1665 twenty-two tenements had been destroyed under the cliff. At that period there still remained under the cliff 113 tenements, the whole of which were overwhelmed in 1703 and 1705. No traces of the ancient town are now preceptible, yet there is evidence that the sea has merely resumed its ancient position at the base of the cliffs, the site of the old town having been merely a beach abandoned by the ocean for ages.

Hampshire—Isle of Wight.—It would be endless to allude to all the localities on the Sussex and Hampshire coasts where the land has given way; but I may point out the relation which the geological structure of the Isle of Wight bears to its present shape, as attesting that the coast

* Webster, Geol. Trans., vol. ii. p. 192.

† Mantell, Geology of Sussex, p. 293.

owes its outline to the continued action of the sea. Through the middle of the island runs a high ridge of chalk strata, in a vertical position, and in a direction east and west. This chalk forms the projecting promontory of Culver Cliff on the east, and of the Needles on the west; while Sandown Bay on the one side, and Compton Bay on the other, have been hollowed out of the softer sands and argillaceous strata, which are inferior to the chalk.

The same phenomena are repeated in the Isle of Purbeck, where the line of vertical chalk forms the projecting promontory of Handfast Point; and Swanage Bay marks the deep excavation made by the waves in the softer strata, corresponding to those of Sandown Bay.

Hurst-Castle Bank.—The entrance of the channel called the Solent is becoming broader by the waste of the cliffs in Colwell Bay; it is crossed for more than two-thirds of its width by the shingle bank of Hurst Castle, which is about seventy yards broad and twelve feet high, presenting an inclined plane to the west. This singular bar consists of a bed of rounded chalk flints, resting on a submarine argillaceous base. The flints and a few other pebbles, intermixed, are exclusively derived from the waste of Hordwell, and other cliffs to the westward, where tertiary strata, capped with a covering of chalk flints, from five to fifty feet thick, are rapidly undermined.

Storm of Nov. 1824.—In the great storm of November, 1824, this bank of shingle was moved bodily forwards for forty yards towards the north-east; and certain piles which served to mark the boundaries of two manors, were found, after the storm, on the opposite side of the bar. At the same time many acres of pasture land were covered by shingle, on the farm of Westover, near Lymington.

The cliffs between Hurst Shingle Bar and the mouth of the Stour and Avon are undermined continually. Within the memory of persons now living, it has been necessary thrice to remove the coast-road farther inland. The tradition, therefore, is probably true, that the church of Hordwell was once in the middle of that parish, although now very near the sea. The promontory of Christ Church Head gives way slowly. It is the only point between Lymington and Poole Harbour in Dorsetshire, where any hard stony masses occur in the cliff. Five layers of large ferruginous concretions, somewhat like the septaria of the London clay, have occasioned a resistance at this point, to which we may ascribe this headland. In the meantime, the waves have cut deeply into the soft sands and loam of Poole Bay; and, after severe frosts, great landslips take place, which, by degrees, become enlarged into narrow ravines, or chines, as they are called, with vertical sides. One of these chines near Boscomb, has been deepened twenty feet within a few years. At the head of each there is a spring, the waters of which have been chiefly instrumental in producing these narrow excavations, which are sometimes from 100 to 150 feet deep.

Isle of Portland.—The peninsulas of Purbeck and Portland are continually wasting away. In the latter, the soft argillaceous substratum (Kimmeridge clay) hastens the dilapidation of the superincumbent mass of limestone.

In 1665 the cliffs adjoining the principal quarries in Portland gave way to the extent of 100 yards, and fell into the sea; and in December, 1734, a slide to the extent of 150 yards occurred on the east side of the isle, by which several skeletons, buried between slabs of stone, were discovered. But a much more memorable occurrence of this nature, in 1792, occasioned probably by the undermining of the cliffs, is thus described in Hutchins's History of Dorsetshire: "Early in the morning the road was observed to crack: this continued increasing, and before two o'clock the ground had sunk several feet, and was in one continued motion, but attended with no other noise than what was occasioned by the separation of the roots and brambles, and now and then a falling rock. At night it seemed to stop a little, but soon moved again; and before morning, the ground, from the top of the cliff to the water-side, had sunk in some places fifty feet perpendicular. The extent of ground that moved was about *a mile and a quarter* from north to south, and 600 yards from east to west.

Formation of the Chesil Bank.—Portland is connected with the main land by the Chesil Bank, a ridge of shingle about seventeen miles in length, and, in most places, nearly a quarter of a mile in breadth. The pebbles forming this immense barrier are chiefly of limestone; but there are many of quartz, jasper, chert, and other substances, all loosely thrown together. What is singular, they gradually increase in size from west to east—from the Portland end of the bank to that which attaches to the main land. The formation of this bar may probably be ascribed, like that of Hurst Castle, to a meeting of tides, or to a submarine shoal or reef between the peninsula and the land. We have seen that slight obstructions in the course of the Ganges will cause, in the course of a man's life, islands many times larger than the whole of Portland, and which, in some cases, consist of a column of earth more than 100 feet deep. In like manner those transported materials which are annually swept away from large tracts of our coast, may give rise, wherever they encounter any impediment in their course, to banks of sand and shingle many miles in length. The course of the shingles in Dorsetshire, and on the shores of Sussex and Kent, appears to be from west to east, the prevalent winds, and, consequently, the chief forces of the waves, being in that direction.* The storm of 1824 burst over the Chesil Bank with

* See Palmer on Motion of Shingle Beaches, Phil. Trans., 1834, p. 568.

great fury, and the village of Chesilton, built upon its southern extremity, was overwhelmed, with many of the inhabitants. The fundamental rocks whereon the shingle rests are found at the depth of a few yards only below the level of the sea.

This same storm carried away part of the Breakwater, at Plymouth, and huge masses of rock from two to five tons in weight, were lifted from the bottom of the weather side, and rolled fairly to the top of the pile. One block of limestone, weighing seven tons, was washed round the western extremity of the Breakwater, and carried 150 feet.* It was in the same month, and also during a spring-tide, that a great flood is mentioned on the coasts of England, in the year 1099. Florence of Worcester says, "On the third day of the nones of Nov. 1099, the sea came out upon the shore, and buried towns and men very many, and oxen and sheep innumerable." We also read in the Saxon Chronicle, already cited, for the year 1099, "This year eke on St. Martin's mass day, the 11th of Novembre, sprung up so much of the sea-flood, and so myckle harm did, as no man minded that it ever afore did, and there was the ylk day a new moon."

Dorsetshire—Devonshire—Cornwall.—At Lyme Regis, in Dorsetshire, the "Church Cliffs," as they are called, consisting of lias about 100 feet in height, have gradually fallen away, at the rate of one yard a year, since 1800.† The cliffs of Devonshire and Cornwall, which are chiefly composed of hard rocks, decay less rapidly. Near Penzance in Cornwall, there is a projecting tongue of land, called the "Green," formed of granitic sand, from which more than thirty acres of pasture land have been gradually swept away in the course of the last two or three centuries.‡ It is also said that St. Michael's Mount, now an insular rock, was formerly situated in a wood, several miles from the sea; and its old Cornish name (Caraclowse in Cowse) signifies, according to Carew, the Hoare Rock in the Wood.§ Between the Mount and Newlyn there is seen under the sand black vegetable mould, full of hazel nuts, and the branches, leaves, roots, and trunks of forest trees, all of indigenous species. This vegetable stratum has been traced seaward as far as the ebb permits, and seems to indicate some ancient estuary on that shore.

Tradition of loss of land in Cornwall.—The oldest historians mention a celebrated tradition in Cornwall, of the submersion of the Lionnesse, a country which formerly stretched from the Land's End to the Scilly

* De la Beche, Geol. Man. p. 82.

† This ground was measured by Dr. Carpenter of Lyme, in 1800, and again in 1829, as I am informed, by Miss Mary Anning of Lyme, well known by her discoveries in fossil remains.

‡ Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 129.

§ Ibid. p. 135.

Islands. The tract, if it existed, must have been thirty miles in length, and perhaps ten in breadth. The land now remaining on either side is from 200 to 300 feet high; the intervening sea about 300 feet deep. Although there is no evidence for this romantic tale, it probably originated in some catastrophe occasioned by former inroads of the Atlantic upon this exposed coast.*

West coast of England.—Having now brought together an ample body of proofs of the destructive operations of the waves, tides, and currents, on our eastern and southern shores, it will be unnecessary to enter into details of changes on the western coast, for they present merely a repetition of the same phenomena, and in general on an inferior scale. On the borders of the estuary of the Severn the flats of Somersetshire and Gloucestershire have received enormous accessions, while, on the other hand, submarine forests on the coast of Cheshire and Lancashire indicate the overflowing of alluvial tracts. Since the year 1764, the coast of Cheshire between the rivers Mersey and Dee has lost many hundred yards, and some affirm more than half a mile, by the advance of the sea upon the abrupt cliffs of red clay and marls. Within the period above mentioned several light-houses have been successively abandoned.† There are traditions in Pembrokeshire‡ and Cardiganshire§ of far greater losses of territory than that which the Lionnesse tale of Cornwall pretends to commemorate. They are all important, as demonstrating that the earliest inhabitants were familiar with the phenomenon of incursions of the sea.

Loss of land on the coast of France.—The French coast, particularly that of Brittany, where the tides rise to an extraordinary height, is the constant prey of the waves. In the ninth century many villages and woods are reported to have been carried away, the coast undergoing great change, whereby the hill of St. Michael was detached from the main land. The parish of Bourgneuf, and several others in that neighbourhood, were overflowed in the year 1500. In 1735, during a great storm, the ruins of Palnel were seen uncovered in the sea.‖ A romantic tradition, moreover, has descended from the fabulous ages of the destruction of the south-western part of Brittany, whence we may probably infer some great inroad of the sea at a remote period.¶

* Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 130.

† Stevenson, Jameson's Ed. New Phil. Journ. No. 8, p. 386.

‡ Camden, who cites Gyraldus, also Ray, "On the Deluge," Phys. Theol. p. 228.

§ Meyrick's Cardigan.

‖ Von Hoff, Geschichte, &c. vol. i. p. 49. ¶ Ibid. p. 48.

CHAPTER VII.

ACTION OF TIDES AND CURRENTS—*continued.*

Action of tides and currents, *continued*—Inroads of the sea upon the delta of the Rhine in Holland—changes in the arms of the Rhine—Estuary of the Bies Bosch, formed in 1421—Zuyder Zee, in the 13th century—Islands destroyed—Delta of the Ems converted into a bay—Estuary of the Dollart formed (p. 272.)—Encroachment of the sea on the coast of Sleswick—On shores of North America—Tidal wave, called the Bore—Influence of tides and currents on the mean level of seas—Action of currents in inland lakes and seas—Baltic—Cimbrian deluge (p. 276.)—Straits of Gibraltar—No under-current there—Whether salt is precipitated in the Mediterranean—Waste of shores of Mediterranean.

Inroads of the sea at the mouths of the Rhine.—The line of British coast considered in the preceding chapter, offered no example of the conflict of two great antagonist forces; the entrance, on the one hand, of a river draining a large continent, and on the other, the flux and reflux of the tide, aided by a strong current. But when we pass over by the Straits of Dover to the Continent, and proceed northwards, we find an admirable illustration of such a contest, where the Rhine and the ocean are opposed to each other, each disputing the ground now occupied by Holland; the one striving to shape out an estuary, the other to form a delta. There was evidently a period when the river obtained the ascendency, when the shape of the coast and set of the tides were probably very different; but for the last 2000 years, during which man has witnessed and actively participated in the struggle, the result has been in favour of the ocean; the area of the whole territory having become more and more circumscribed; natural and artificial barriers having given way, one after another; and many hundred thousand human beings having perished in the waves.

Changes in the arms of the Rhine.—The Rhine, after flowing from the Grison Alps, copiously charged with sediment, first purifies itself in the Lake of Constance, where a large delta is formed; then, swelled by the Aar and numerous other tributaries, it flows for more than 600 miles towards the north; when entering a low tract, it divides into two arms, north of Cleves, a little below the village of Pannerden—a point which must therefore be considered the head of its delta. In speaking of the delta I do not mean to assume that all that part of Holland which is comprised within the several arms of the Rhine can be called a delta in the strictest sense of the term; because some portion of the country thus circumscribed, as for example, a part of Gelderland and Utrecht, consists of strata which may have been deposited in the sea before the Rhine existed. These older tracts may either have been raised like the Ullah Bund in Cutch, during the period when the sediment of the Rhine was converting a part of the sea into land, or they may have constituted islands previously.

When the river divides north of Cleves, the left arm takes the name of the Waal; and the right, retaining that of the Rhine, is connected, a little farther to the north, by an artificial canal with the river Yssel. Still lower down, the Rhine takes the name of the Leck, a name which was given to distinguish it from another arm called the old Rhine, which was sanded up until after the year 1825, when a channel was cut for it, by which it now enters the sea at Catwyck. It is common, in all great deltas, that the principal channels of discharge should shift from time to time; but in Holland so many magnificent canals have been constructed, and have so diverted, from time to time, the course of the waters, that the geographical changes in this delta are endless, and their history, since the Roman era, forms a complicated topic of antiquarian research. The present head of the delta is about forty geographical miles from the nearest part of the gulf called the Zuyder Zee, and more than twice that distance from the general coast line. The present head of the delta of the Nile is about 80 or 90 geographical miles from the sea; that of the Ganges, as we before stated, 220; and that of the Mississippi about 180, reckoning from the point where the Atchafalaya branches off, to the extremity of the new tongue of land in the Gulf of Mexico. But the comparative distance between the heads of deltas and the sea affords scarcely any data for estimating the relative magnitude of the alluvial tracts formed by their respective rivers. For the ramifications depend on many varying and temporary circumstances, and the area over which they extend does not hold any constant proportion to the volume of water in the river.

The Rhine therefore has at present three mouths. About two-thirds of its waters flow to the sea by the Waal, and the remainder is carried partly to the Zuyder Zee by the Yssel, and partly to the ocean by the Leck. As the whole coast to the south, as far as Ostend, and on the north, to the entrance of the Baltic, has, with few exceptions, from time immemorial, yielded to the force of the waves, it is evident that the delta of the Rhine, if it had advanced, would have become extremely prominent; and even if it had remained stationary, would long ere this have projected far beyond the rounded outline of the coast, like that strip of land already described, at the mouth of the Mississippi. But we find, on the contrary, that the islands which skirt the coast have not only lessened in size, but in number also, while great bays have been formed in the interior by incursions of the sea. I shall confine myself to the enumeration of some of the leading facts, in confirmation of these views, and begin with the southernmost part of the delta, where the Waal enters, which is at present united with the Meuse, in the same manner as an arm of the

Po, before mentioned, has become confluent with the Adige. The Meuse itself had once a common embouchure with the Scheldt, by Sluys and Ostburg, but this channel was afterwards sanded up, as were many others between Walcheren, Beveland, and other islands, at the mouths of these rivers. The new accessions were almost all within the coast line, and were far more than counterbalanced by inroads of the sea, whereby large tracts of land, and dunes of blown sand, together with towns and villages, were swept away between the fourteenth and eighteenth centuries. Besides parts of Walcheren, Beveland, and several populous districts in Kadzand, the island Orisant was in the year 1658 entirely annihilated.

Inroads of the sea in Holland.—One of the most memorable irruptions occurred in 1421, where the tide pouring into the mouth of the united Meuse and Waal, burst through a dam in the district named Bergse-Veld, and overflowed seventy-two villages, forming a large sheet of water called the Bies Bosch. Thirty-five of the villages were irretrievably lost, and no vestige even of their ruins was afterwards seen. The rest were redeemed, and the site of the others, though still very generally represented on maps as an estuary, has in fact been gradually filled up by alluvial deposits, and is now, as I am informed by Professor Moll, an immense plain, yielding abundant crops of hay, though still uninhabited. To the north of the Meuse is a long line of shore covered with sand dunes, where great encroachments have taken place from time to time, in consequence chiefly of the prevalence of south-easterly winds which blow down the sands towards the sea. The church of Scheveningen, not far from the Hague, was once in the middle of the village, and now stands on the shore; half the place having been overwhelmned by the waves in 1570. Catwyck, once far from the sea, is now upon the shore; two of its streets having been overflowed, and land torn away to the extent of 200 yards in 1719. It is only by aid of embankments, that Petten, and several other places farther north, have been defended against the sea.

Formation of the Zuyder Zee and Straits of Staveren.—Still more important are the changes which have taken place on the coast opposite the right arm of the Rhine, or the Yssel, where the ocean has burst through a large isthmus, and entered the inland lake Flevo, which, in ancient times, was, according to Pomponius Mela, formed by the overflowing of the Rhine over certain low lands. It appears that, in the time of Tacitus, there were several lakes in the present site of the Zuyder Zee, between Friesland and Holland. The successive inroads by which these, and a great part of the adjoining territory, were transformed into a great gulf, began about the commencement, and were completed towards the close of the thirteenth century. Alting gives the following relation of the occurrence, drawn from manuscript documents of contemporary inhabitants of the neighbouring provinces. In the year 1205, the island now called Wieringen, to the south of the Texel, was still a part of the mainland, but during several high floods, of which the dates are given, ending in December, 1251, it was separated from the continent. By subsequent incursions, the sea consumed great parts of the rich and populous isthmus, a low tract which stretched on the north of Lake Flevo, between Staveren in Friesland, and Medemblick in Holland, till at length a breach was completed about the year 1282, and afterwards widened. Great destruction of land took place when the sea first broke in, and many towns were swept away; but there was afterwards a reaction to a certain extent, large tracts at first submerged having been gradually redeemed. The new straits south of Staveren are more than half the width of those of Dover, but are very shallow, the greatest depth not exeeeding two or three fathoms. The new bay is of a somewhat circular form, and between *thirty* and *forty* miles in diameter. How much of this space may formerly have been occupied by Lake Flevo, is unknown.

Destruction of Islands.—A series of islands stretching from the Texel to the mouths of the Weser and Elbe, are evidently the last relics of a tract once continuous. They have greatly diminished in size, and have lost about a third of their number since the time of Pliny; for that naturalist counted twenty-three islands between the Texel and Eider, whereas there are now only sixteen, including Heligoland and Neuwerk.* Heligoland, at the mouth of the Elbe, began in the year 800 to be much consumed by the waves. In the years 1300, 1500, and 1649, other parts were swept away, till at last a small portion only of the original island remained, consisting of a rock of red marl (of the keuper formation of the Germans), about 200 feet high. Since 1770, a current has cut a passage no less than ten fathoms deep through this remaining portion, and has formed two islands, Heligoland and Sandy Island.† The fact of the new channel being laid down in all the charts as sixty feet deep is important, as showing the excavating power of marine currents under favourable circumstances. On the other hand some few islands have extended their bounds in one direction, or become connected with others, by the sanding-up of channels; but even these, like Juist, have generally given way as much on the north towards the sea as they have gained on the south, or land side.

The Dollart formed.—While the delta of the Rhine has suffered so materially from the movements of the ocean, it can hardly be supposed that minor rivers on the same coast should have been permitted to extend their deltas. It appears, that in the time of the Romans there was an alluvial plain of great fertility, where the Ems entered the sea by three arms. This low country stretched between Groningen and East Friesland, and sent out a peninsula to the north-east towards Emden. A flood,

* Von Hoff, vol. i. p. 364. † Ibid. p. 57.

in 1277, first destroyed part of the peninsula. Other inundations followed at different periods throughout the fifteenth century. In 1507, a part only of Torum, a considerable town, remained standing; and in spite of the erection of dams, the remainder of that place, together with market-towns, villages, and monasteries, to the number of fifty, were finally overwhelmed. The new gulf, which was called the Dollart, although small in comparison to the Zuyder Zee, occupied no less than six square miles at first; but part of this space was, in the course of the two following centuries, again redeemed from the sea. The small bay of Leybucht, farther north, was formed in a similar manner in the thirteenth century; and the bay of Harlbucht, in the middle of the sixteenth. Both of these have since been partially reconverted into dry land. Another new estuary, called the Gulf of Jahde, near the mouth of the Weser, scarcely inferior in size to the Dollart, has been gradually hollowed out since the year 1016, between which era and 1651 a space of about four square miles has been added to the sea. The rivulet which now enters this inlet is very small; but Arens conjectures, that an arm of the Weser had once an outlet in that direction.

Coast of Sleswick.—Farther north we find so many records of waste on the western coast of Sleswick, as to lead us to anticipate, that, at no distant period in the history of the physical geography of Europe, Jutland may become an island, and the ocean may obtain a more direct entrance into the Baltic. So late as 1825 the sea made a breach and entered the Lym-Fiord, so that the northern extremity of Jutland was converted into an island; and this passage is still open (1835).

Destruction of Northstrand by the sea.—Northstrand, up to the year 1240, was, with the islands Sylt and Föhr, so nearly connected with the mainland as to appear a peninsula, and was called North Friesland, a highly cultivated and populous district. It measured from nine to eleven geographical miles from north to south, and six to eight from east to west. In the above-mentioned year it was torn asunder from the continent, and in part overwhelmed. The Isle of Northstrand, thus formed, was, towards the end of the sixteenth century, only four geographical miles in circumference, and was still celebrated for its cultivation and numerous population. After many losses, it still contained 9000 inhabitants. At last, in the year 1634, on the evening of the 11th of October, a flood passed over the whole island, whereby 1300 houses, with many churches, were lost; 50,000 head of cattle perished, and above 6000 men. Three small islets, one of them still called Northstrand, alone remained, which are now continually wasting.

Inroads of the sea on the eastern shores of North America.—After so many authentic details respecting the destruction of the coast in parts of Europe best known, it will be unnecessary to multiply examples of analogous changes in more distant regions of the world. It must not, however, be imagined that our own seas form any exception to the general rule. Thus, for example, if we pass over to the eastern coast of North America, where the tides rise to a great elevation, we find many facts attesting the incessant demolition of land. At Cape May, for example, on the north side of Delaware Bay, in the United States, the encroachment of the sea was shown by observations made consecutively for sixteen years, from 1804 to 1820, to average about nine feet a year;* and at Sullivan's Island, which lies on the north side of the entrance of the habour of Charlestown, in South Carolina, the sea carried away a quarter of a mile of land in three years, ending in 1786.†

Tidal wave called "the Bore."—Before concluding my remarks on the action of the tides, I must not omit to mention the wave called "the Bore," which is sometimes produced in a river where a large body of water is made to rise suddenly, in consequence of the contraction of the channel. This wave terminates abruptly on the inland side; because the quantity of water contained in it is so great, and its motion so rapid, that time is not allowed for the surface of the river to be immediately raised by means of transmitted pressure. A tide wave thus rendered abrupt has a close analogy, observes Mr. Whewell, to the waves which curl over and break on a shelving shore.‡

The Bore which enters the Severn, where the phenomenon is of almost daily occurrence, is sometimes nine feet high, and at spring tides rushes up the estuary with extraordinary rapidity. The same phenomenon is frequently witnessed in the principal branches of the Ganges, and in the Megna. "In the Hoogly, or Calcutta river," says Rennell, "the Bore commences at Hoogly Point, the place where the river first contracts itself, and is perceptible above Hoogly Town; and so quick is its motion, that it hardly employs four hours in travelling from one to the other, though the distance is nearly seventy miles. At Calcutta it sometimes occasions an instantaneous rise of five feet; and both here, and in every other part of its track, the boats, on its approach, immediately quit the shore, and make for safety to the middle of the river. In the channels, between the islands in the mouth of the Megna, the height of the Bore is said to exceed twelve feet, and is so terrific in its appearance, and dangerous in its consequences, that no boat will venture to pass at spring tide."§ These waves may sometimes cause inundations, undermine cliffs, and still more frequently sweep away trees and land animals from low shores, so that they may be carried down, and ultimately imbedded in fluviatile or submarine deposits.

* New Monthly Mag., vol. vi. p. 69.

† Von Hoff, vol. i. p. 96.

‡ Phil. Trans., 1833, p. 204.

§ Rennell, Phil. Trans. 1781.

ACTION OF CURRENTS IN INLAND LAKES AND SEAS.

In such large bodies of water as the North American lakes, the continuance of a strong wind in one direction often causes the elevation of the water, and its accumulation on the leeward side; and while the equilibrium is restoring itself, powerful currents are occasioned. In October 1833, a strong current in Lake Erie, caused partly by the set of the waters towards the outlet of the lake, and partly by the prevailing wind, burst a passage through the sandy isthmus called Long Point Peninsula, and soon excavated a channel more than nine feet deep and 900 feet wide. Its width and breadth have since increased, and a new and costly pier has been erected; for it is hoped that the event will permanently improve the navigation of Lake Erie for steam-boats.* In the Black Sea, also, although free from tides, we learn from Pallas that there is a sufficiently strong current to undermine the cliffs in many parts, and particularly in the Crimea.

The redundancy of river water in the Baltic, especially during the melting of ice and snow in spring, causes in general an outward current through the channel called the Cattegat. But after a continuance of north-westerly gales, especially during the height of the spring tides, the Atlantic rises; and, pouring a flood of water into the Baltic, commits dreadful devastations on the isles of the Danish Archipelago. This current even acts, though with diminished force, as far eastward as the vicinity of Dantzic.† Accounts written during the last ten centuries attest the wearing down of promontories on the Danish coast, the deepening of gulfs, the severing of peninsulas from the main land, and the waste of islands, while in several cases marsh land, defended for centuries by dikes, has at last been overflowed, and thousands of the inhabitants whelmed in the waves.

Thus the island Barsoe, on the coast of Sleswick, has lost, year after year, an acre at a time. The island Alsen suffers in like manner. The peninsula Zingst was converted into an island in 1625. There is a tradition that the isle of Rugen was originally torn by a storm from the main land of Pomerania: and it is known, in later times, to have lost ground, as in the year 1625, when a tract of land was carried away. Some of these islands consist of ancient alluvial accumulations, containing blocks of granite, which are also spread over the neighbouring main land. The Marsh Islands are mere banks, like the lands formed of the "warp" in the Humber, protected by dikes. Some of them, after having been inhabited with security for more than ten centuries, have been suddenly

* MS. of Capt. Bayfield, R. N.

† See examples in Von Hoff, vol. i. p. 73, who cites Pisansky.

overwhelmed. In this manner, in 1216, no less than 10,000 of the inhabitants of the Eyderstede and Ditmarsch perished; and on the 11th of October, 1634, the islands and the whole coast, as far as Jutland, suffered by a dreadful deluge.

Cimbrian Deluge.—I have before enumerated the ravages of the ocean on the western shores of Sleswick, and there are memorials of a series of like catastrophes on the eastern coast of that peninsula. Jutland was the Cimbrica Chersonesus of the ancients, and was then evidently the theatre of similar calamities; for Florus says, "Cimbri, Theutoni, atque Tigurini, ab extremis Galliæ profugi, cùm terras eorum inundasset Oceanus, novas sedes toto orbe quærebant."* Some have wished to connect this "Cimbrian Deluge" with the bursting of the isthmus between England and France, and with other supposed convulsions; but when we consider the fate of Heligoland and Northstrand, and the other terrific inundations in Jutland and Holstein since the Christian era, wherein thousands have perished, we need not resort to any such extraordinary catastrophes to account for the historical relation. The wave which in 1634 devastated the whole coast of Jutland, committed such havoc, that we must be cautious how we reject hastily the traditions of like events on the coast of Kent, Cornwall, Pembrokeshire, and Cardigan; for, however sceptical we may be as to the amount of territory destroyed, it is very possible that former inroads of the sea may have been greater on those shores than any witnessed in modern times.

Straits of Gibraltar.—That the level of the Mediterranean is from twenty to thirty feet lower than that of the Red Sea, at Suez, has been already stated.†

It is well known that a powerful current sets constantly from the Atlantic into the Mediterranean, and its influence extends along the whole southern borders of that sea, and even to the shores of Asia Minor. Captain Smyth found, during his survey, that the central current ran constantly at the rate of from three to six miles an hour eastward into the Mediterranean, the body of water being three miles and a half wide. But there are also two lateral currents—one on the European, and one on the African side—each of them about two miles and a half broad, and flowing at about the same rate as the central stream. These lateral currents ebb and flow with the tide, setting alternately into the Mediterranean and into the Atlantic. The excess of water constantly flowing in is very great, and there is only one cause to which this can be attributed, the loss of water in the Mediterranean by evaporation. That the level of this sea should be considerably depressed by this means is quite conceivable, since we know that the winds blowing from the shores of Africa are hot and dry; and hygrometrical experiments recently made in Malta

* Lib. iii. cap. 3.

† See Vol. I. p. 241.

and other places, show that the mean quantity of moisture in the air investing the Mediterranean, is equal only to one half of that in the atmosphere of England. The temperature also of the great inland sea is upon an average higher, as was before stated, by 3½° of Fahrenheit, than the western part of the Atlantic Ocean, which must greatly promote its evaporation. The Black Sea being situated in a higher latitude, and being the receptacle of rivers flowing from the north, is much colder, and its expenditure far less; accordingly, it does not draw any supply from the Mediterranean, but, on the contrary, contributes to it by a current flowing outwards, for the most part of the year, through the Dardanelles. The discharge, however, at the Bosphorus is so small when compared to the volume of water carried in by rivers, as to imply a great amount of evaporation even in the Black Sea.

Whether salt be precipitated in the Mediterranean.—It is, however, objected, that evaporation carries away only fresh water, and that the current from the Atlantic is continually bringing in salt water: why, then, do not the component parts of the waters of the Mediterranean vary? or how can they remain so nearly the same as those of the ocean? Some have imagined that the excess of salt might be carried away by an under-current running in a contrary direction to the superior; and this hypothesis appeared to receive confirmation from a late discovery that the water taken up about fifty miles within the Straits, from a depth of 670 fathoms, contained a quantity of salt *four times greater* than the water of the surface. Dr. Wollaston*, who analysed this water obtained by Captain Smyth, truly inferred that an under-current of such denser water, flowing outward, if of equal breadth and depth with the current near the surface, would carry out as much salt below as is brought in above, although it moved with less than one-fourth part of the velocity, and would thus prevent a perpetual increase of saltness in the Mediterranean beyond that existing in the Atlantic. It was also remarked by others, that the result would be the same if, the swiftness being equal, the inferior current had only one-fourth of the volume of the superior. At the same time there appeared reason to conclude that this great specific gravity was only acquired by water at immense depths; for two specimens of the water, taken at the distance of some hundred miles from the Straits, and at depths of 400, and even 450 fathoms, were found by Dr. Wollaston not to exceed in density that of many ordinary samples of sea-water. Such being the case, we can now prove that the vast amount of salt brought into the Mediterranean *does not* pass out again by the Straits; for it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the Capes of Trafalgar and Spartel, which are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on

* Phil. Trans., 1829, part. i. p. 29.

the side of Cape Spartel, is only 220 fathoms. It is therefore evident that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than 220 fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar.

The idea of the existence of a counter-current, at a certain depth, first originated in the following circumstance :—M. De l'Aigle, commander of a privateer called the Phœnix, of Marseilles, gave chase to a Dutch merchant-ship, near Ceuta Point, and coming up with her in the middle of the gut, between Tariffa and Tangier, gave her one broadside, which directly sunk her. A few days after, the sunk ship, with her cargo of brandy and oil, was cast ashore near Tangier, which is at least four leagues to the westward of the place where she went down, and directly against the strength of the *central* current.* This fact, however, affords no evidence of an under-current, because the ship, when it approached the coast, would necessarily be within the influence of a lateral current, which, running westward twice every twenty-four hours, might have brought back the vessel to Tangier.

What, then, becomes of the excess of salt ?—for this is an inquiry of the highest geological interest. The Rhone, the Po, and many hundred minor streams and springs, pour annually into the Mediterranean large quantities of carbonate of lime, together with iron, magnesia, silica, alumina, sulphur, and other mineral ingredients, in a state of chemical solution. To explain why the influx of this matter does not alter the composition of this sea has never been regarded as a difficulty ; for it is known that calcareous rocks are forming in the delta of the Rhone, in the Adriatic, on the coast of Asia Minor, and in other localities. Precipitation is acknowledged to be the means whereby the surplus mineral matter is disposed of, after the consumption of a certain portion in the secretions of testacea, zoophytes, and other marine animals. But before muriate of soda can, in like manner, be precipitated, the whole Mediterranean ought, it is said, to become as much saturated with salt as Lake Aral, the Dead Sea, or the brine-springs of Cheshire.

It is undoubtedly true, in regard to small bodies of water, that every particle must be fully saturated with muriate of soda, before a single crystal of salt can be formed ; such is probably the case in all natural salterns : such, for example, as those described by travellers as occurring on the western borders of the Black Sea, where extensive marshes are said to be covered by thin films of salt after a rapid evaporation of sea-water. The salt *étangs* of the Rhone, where salt has sometimes been precipitated in considerable abundance, have been already mentioned. But whether

* Phil. Trans. 1724.

it be necessary that every part of a sea of enormous depth should be fully saturated before any precipitate can take place, is a question of some difficulty. In the narrowest part of the Straits of Gibraltar, where they are about nine miles broad, between the Isle of Tariffa and Alcanzar Point, the depth varies from 160 to 500 fathoms: but between Gibraltar and Ceuta, Captain Smyth sounded to the enormous depth of 950 fathoms; where he found a gravelly bottom, with fragments of broken shells. Saussure sounded to the depth of 2000 feet, within a few yards of the shore, at Nice; and M. Bérard has lately fathomed to the depth of more than 6000 feet in several places without reaching the bottom.*

The central abysses of this sea are, in all likelihood, at least as deep as the Alps are high; and, as at the depth of 700 fathoms only, water has been found to contain a proportion of salt four times greater than at the surface, we may presume that the excess of salt may be much greater at the depth of two or three miles. After evaporation, the surface water becomes impregnated with a slight excess of salt, and its specific gravity being thus increased, it instantly falls to the bottom, while lighter water rises to the top, or flows in laterally, being always supplied by rivers and the current from the Atlantic. The heavier fluid, when it arrives at the bottom, cannot stop if it can gain access to any lower part of the bed of the sea, not previously occupied by water of the same density. In this manner the bottom of the nethermost submarine abysses must annually receive new supplies of brine, while the water at the surface, being incessantly renewed by rivers and the current from the ocean, can never become saturated.

How far this accumulation of brine can extend before the inferior strata will part with any of their salt, and what difference in such a chemical process the immense pressure of the incumbent ocean might occasion, are questions which cannot be answered in the present state of science. There is also another curious topic of speculation; what changes may be effected by volcanic heat, so active in many parts of the bottom of the Mediterranean. A sub-marine hotspring or stufa would give rise to a new set of phenomena. Perhaps it may be said that their effect would only be to cause ascending and descending currents, and thereby to promote the intermixture of the upper and lower waters of the sea. A solfatara, or rent through which inflammable gases are continually escaping, might certainly convert sea-water into steam; and in this case salt would be precipitated in the space from which the steam was expelled. Additional supplies of water might then find their way into the fissure, being injected into every pore of the rock by the vast pressure of the incumbent ocean. If, by a repetition of this process, the cavity was filled with salt, other crystals of the same mineral would more easily be formed from a

* Bull. de la Soc. Géol. de France.—Résumé, p. 72. 1832.

solution, and might then spread along the bottom of the sea. Yet even in this case it should seem that the fluid must first be fully saturated. It is certainly most difficult to explain on chemical principles how a deposit of salt may take place at the bottom of the Mediterranean, but it is nevertheless a fact that the waters of that sea, notwithstanding the constant influx of salt water from the Atlantic, contain but a slight excess of muriate of soda above the ordinary waters of the ocean.

In regard to the probable origin of those continuous masses of rock-salt which we find in Poland, Hungary, Transylvania, and Spain, geologists have entertained very different opinions; but the theory which has obtained most favour in later times attributes them not to precipitation from an aqueous menstruum, but to sublimation from volcanic exhalations rising from below, which insinuate themselves into rents and vacuities, caused by the fracture and decomposition of rocks.

The Straits of Gibraltar are said to become gradually wider by the wearing down of the cliffs on each side at many points; and the current sets along the coast of Africa, so as to cause considerable inroads in various parts, particularly near Carthage. Near the Canopic mouth of the Nile, at Aboukir, the coast was greatly devastated in the year 1784, when a small island was nearly consumed. By a series of similar operations, the old site of the cities of Nicopolis, Taposiris, Parva, and Canopus, have become a sand-bank.*

Sand-Hills.—It frequently happens, where the sea is encroaching on a coast, that perpendicular cliffs of considerable height, composed of loose sand, supply, as they crumble away, large quantities of fine sand, which being in mid-air when detached, are carried by the winds to great distances, covering the land or barring up the mouths of estuaries. This is exemplified in Poole Bay, in Hampshire, and in many points of the coast of Norfolk and Suffolk. But a violent wind will sometimes drift the sand of a sea beach, and carry it up with fragments of shells to great heights, as in the case of the sands of Barry, at the northern side of the estuary of the Tay, where hills of this origin attain the height of 140 feet.

On the coast of France and Holland long chains of these dunes have been formed in many parts, and often give rise to very important geological changes, by damming up the mouths of estuaries, and preventing the free ingress of the tides, or free efflux of river water.

* Clarke's Travels in Europe, Asia, and Africa, vol. iii. pp. 340 and 363, 4th edition.

CHAPTER VIII.

REPRODUCTIVE EFFECTS OF TIDES AND CURRENTS.

Reproductive effects of tides and currents—Silting up of estuaries does not compensate the loss of land on the borders of the ocean—Bed of the German Ocean (p. 285.)—Composition and extent of its sand-banks—Strata deposited by currents on the southern and eastern shores of the Mediterranean—Transportation by currents of the sediment of the Amazon, Orinoco, and Mississippi (p. 287.)—Stratification.

From the facts enumerated in the last chapter, it appears that, on the borders of the ocean, currents and tides co-operating with the waves of the sea are most powerful instruments in the destruction and transportation of rocks; and as numerous tributaries discharge their alluvial burden into the channel of one great river, so we find that many rivers deliver their earthy contents to one marine current, to be borne by it to a distance, and deposited in some deep receptacle of the ocean. The current not only receives this tribute of sedimentary matter from streams draining the land, but acts also itself on the coast, as does a river on the cliffs which bound a valley. The course of currents on the British shores is ascertained to be as tortuous as that of ordinary rivers. Sometimes they run between sand-banks, which consist of matter thrown down at certain points where the velocity of the stream had been retarded; but it very frequently happens, that as in a river one bank is made of low alluvial gravel, while the other is composed of some hard and lofty rock constantly undermined, so the current, in its bends, strikes here and there upon a coast, which then forms one bank, while a shoal under water forms the other. If the coast be composed of solid materials, it yields slowly; so also if it be of great height, for in that case a large quantity of matter must be removed before the sea can penetrate to any distance. But the openings where rivers enter are generally the points of least resistance, and it is here, therefore, that the ocean makes the widest and deepest breaches.

A current alone cannot shape out and keep open an estuary, because it holds in suspension, like the river, during certain seasons of the year, a large quantity of sediment; and where the waters, flowing in opposite directions, meet, this matter subsides. For this reason, in inland seas, and even on the borders of the ocean, where the rise of the tide happens to be slight, it is scarcely possible to prevent a harbour from silting up; and it is often expedient to carry out a jetty beyond the point where the marine current and the river neutralize each other's force; for beyond this point a free channel is maintained by the superior strength of the current.

Estuaries, how formed.—The formation and keeping open of large estuaries are due to the *combined influence* of the tidal currents and rivers; for when the tide rises, a large body of water suddenly enters the mouth of the river, where, becoming confined within narrow bounds, while its momentum is not destroyed, it is urged on, and, having to pass through a contracted channel, rises and runs with increased velocity, just as a stream, when it reaches the arch of a bridge scarcely large enough to give passage to its waters, rushes with a steep fall through the arch. During the ascent of the tide, a body of fresh water, flowing down in an opposite direction from the higher country, is arrested in its course for several hours; and thus a large lake of brackish water is accumulated, which, when the sea ebbs, is let loose, as on the removal of an artificial sluice or dam. By the force of this retiring water, the alluvial sediment both of the river and of the sea is swept away, and transported to such a distance from the mouth of the estuary, that a small part only can return with the next tide.

It sometimes happens, that during a violent storm a large bar of sand is suddenly made to shift its position, so as to prevent the free influx of the tides, or efflux of river water. Thus about the year 1500 the sands at Bayonne were suddenly thrown across the mouth of the Adour. That river, flowing back upon itself, soon forced a passage to the northward, along the sandy plain of Capbreton, till at last it reached the sea at Boucau, at the distance of *seven leagues* from the point where it had formerly entered. It was not till the year 1579 that the celebrated architect Louis de Foix, undertook, at the request of Henry III., to re-open the ancient channel, which he at last effected with great difficulty.*

Tides in Estuaries.—In the estuary of the Thames at London, and in the Gironde, the tide flows five hours and ebbs seven, and in all estuaries the water requires a longer time to run down than up; so that the preponderating force is always in the direction which tends to keep open a deep and broad passage. But as both the river and the tidal current are ready to part with their sediment whenever their velocity is checked, there is naturally a tendency in all estuaries to silt up partially, since eddies, and backwaters, and points where opposing streams meet, are very numerous, and constantly change their position.

Silting up of Estuaries does not compensate for loss of coasts.—Many writers have declared that the gain on our eastern coast, since the earliest periods of history, has more than counterbalanced the loss; but they have been at no pains to calculate the amount of loss, and have often forgotten that, while the new acquisitions are manifest, there are rarely any natural

* Nouvelle Chronique de la Ville de Bayonne, pp. 113. 139. 1827.

monuments to attest the former existence of the land that has been carried away. They have also taken into their account those tracts artificially recovered, which are often of great agricultural importance, and may remain secure, perhaps, for thousands of years, but which are only a few feet above the mean level of the sea, and are therefore exposed to be overflowed again by a small proportion of the force required to remove cliffs of considerable height on our shores. If it were true that the area of land annually abandoned by the sea in estuaries were equal to that invaded by it, there would still be no compensation *in kind*.

It will seem, at first sight, somewhat paradoxical, but it is nevertheless true, that the greater number of estuaries, although peculiarly exposed to the invasion of the sea, are usually contracting in size, even where the whole line of coast is giving way. But the fact is, that the inroads made by the ocean upon estuaries, although extremely great, are completed during periods of comparatively short duration; and in the intervals between these irruptions, the mouths of rivers, like other parts of the coast, usually enjoy a more or less perfect respite. All the estuaries, taken together, constitute but a small part of a great line of coast; it is, therefore, most probable, that if our observations extend to a few centuries only, we shall not see any, and very rarely all, of this small part exposed to the fury of the ocean. The coast of Holland, and Friesland, if studied for several consecutive centuries since the Roman era, would generally have led to the conclusion that the land was encroaching fast upon the sea, and that the aggrandizement within the estuaries far more than compensated the losses on the open coast. But when our retrospect embraces the whole period, an opposite inference is drawn: and we find that the Zuyder Zee, the Bies Bosch, Dollart, and Yahde, are modern gulfs and bays, and that these points have been the principal theatres of the retreat, instead of the advance, of the land. If we possessed records of the changes on our coast for several thousand years, they would probably present us with similar results; and although we have hitherto seen our estuaries, for the most part, become partially converted into dry land, and bold cliffs intervening between the mouths of rivers consumed by the sea, this has merely arisen from the accidental set of the currents and tides during a brief period.

The current which flows round from the north-west, and bears against the eastern coast of England, transports, as we have seen, materials of various kinds. Aided by the winds and waves, it undermines and sweeps away the granite, gneiss, trap rocks, and sandstone of Shetland, and removes the gravel and loam of the cliffs of Holderness, Norfolk, and Suffolk, which are between fifty and two hundred feet in height, and which waste at the rate of from one to six yards annually. It also bears away, in co-operation with the Thames and the tides, the strata of London clay on the coast of Essex and Sheppey. The sea at the same time consumes the chalk with its flints for many miles continuously on the shores of Kent and Sussex—commits annual ravages on the fresh-water beds, capped by a thick covering of chalk flints, in Hampshire, and continually saps the foundations of the Portland limestone. It receives, besides, during the rainy months, large supplies of pebbles, sand, and mud, which numerous streams from the Grampians, Cheviots, and other chains, send down to the sea. To what regions, then, is all this matter consigned? It is not retained in mechanical suspension by the waters of the ocean, nor does it mix with them in a state of chemical solution,—it is deposited *somewhere*, yet certainly not in the immediate neighbourhood of our shores; for, in that case, there would soon be a cessation of the encroachment of the sea, and large tracts of low land, like Romney Marsh, would almost every where encircle our island.

As there is now a depth of water, exceeding thirty feet, in some spots where cities flourished but a few centuries ago, it is clear that the current not only carries far away the materials of the wasted cliffs, but removes also the ruins of many of the regular strata at the bottom of the sea.

So great is the quantity of matter held in suspension by the tidal current on our shores, that the waters are in some places artificially introduced into certain lands below the level of the sea; and by repeating this operation, which is called "warping," for two or three years, considerable tracts have been raised, in the estuary of the Humber, to the height of about six feet. If a current, charged with such materials, meets with deep depressions in the bed of the ocean, it must often fill them up; just as a river, when it meets with a lake in its course, fills it gradually with sediment.

But in the one case, the sheet of water is converted into land; whereas, in the other, a shoal only is raised, overflowed at high water, or at least by spring tides. The only records which we at present possess of the gradual shallowing of seas are confined, as might be expected, to estuaries, havens, and certain channels of no great depth; and to some inland seas, as the Baltic, Adriatic, and Arabian Gulf. It is only of late years, that accurate surveys and soundings have afforded data of comparison in very deep seas, of which future geologists will avail themselves.

An extraordinary gain of land is described to have taken place at the head of the Red Sea, the Isthmus of Suez having doubled in breadth since the age of Herotodus. In his time, and down to that of Arrian, Heroopolis was on the coast; now it is as far distant from the Red Sea as from the Mediterranean.* Suez in 1541 received into its harbour the fleet of Solyman II.; but it is now changed into a sand-bank. The country called Tehama on the Arabian side of the Gulf has increased from three to six miles since the Christian era. Inland from the present ports are the

* Danville, Mém. sur l'Egypte, p. 108.—Von Hoff, vol. i. p. 390.

ruins of more ancient towns, which were once on the sea-shore, and bore the same names. It is said that the blown sand from the deserts supplies some part of the materials of this new land, and that the rest is composed of shells and corals, of which the growth is very rapid.

Filling up of the German Ocean.—The German Ocean is deepest on the Norwegian side, where the soundings give 190 fathoms; but the mean depth of the whole basin may be stated at not more than thirty-one fathoms.* The bed of this sea is traversed by several enormous banks, one of which, occupying a central position, trends for the Frith of Forth, in a north-easterly direction, to a distance of 110 miles; others run from Denmark and Jutland upwards of 105 miles to the north-west; while the greatest of all, the Dogger Bank, extends for upwards of 354 miles from north to south. The whole superficies of these enormous shoals is equal to about one-fifth of the whole area of the German Ocean, or to about one-third of the whole extent of England and Scotland.† The average height of the banks measures, according to Mr. Stevenson, about seventy-eight feet, the upper portion of them consisting of fine and coarse siliceous sand, mixed with comminuted corals and shells.‡

It has been supposed by some writers, that these vast submarine hills are made up bodily of drift sand, and other loose materials, principally supplied from the waste of the English, Dutch, and other coasts. But the late survey of the North Sea, conducted by Captain Hewett, affords ground for suspecting that this opinion is very erroneous. If such immense mounds of sand and mud had been accumulated under the influence of currents, the same causes ought nearly to have reduced to a level the entire bottom of the German Ocean; instead of which some long narrow ravines are found to intersect the banks. One of these varies from seventeen to forty-four fathoms in depth, and has very precipitous sides: in one part, called the "Inner Silver Pits," it is fifty-five fathoms deep. The shallowest parts of the Doggerbank were found to be forty-two feet under water, except in one place, where the wreck of a ship had caused a shoal; so that we may suppose the currents, which vary in their velocity from a mile to two miles and a-half per hour, to have power to prevent the accumulation of drift matter in places of less depth. It seems, then, that the great banks above alluded to, and the ravines which intersect them, cannot be due to the tides and currents now existing in this sea. They may, however, have been caused in great part by the movements of the ocean at some former period, when the bed of this sea, and the surface of the land adjoining, assumed its actual configuration.

* Stevenson on the Bed of the German Ocean, or North Sea.—Ed. Phil. Journ. No. V. p. 44. 1820.

† Ibid., p. 47. ‡ Ibid.

Strata deposited by currents.—It appears extraordinary, that in some tracts of the sea, adjoining the coast of England, where we know that currents are not only sweeping along rocky masses, thrown down, from time to time, from the high cliffs, but also occasionally scooping out channels in the regular strata, there should exist fragile shells and tender zoophites in abundance, which live uninjured by these violent movements. The ocean, however, is in this respect a counterpart of the land; and as, on the continents, rivers may undermine their banks, uproot trees, and roll along sand and gravel, while their waters are inhabited by testacea and fish, and their alluvial plains are adorned with rich vegetation and forests, so the sea may be traversed by rapid currents, and its bed may here and there suffer great local derangement, without any interruption of the general order and tranquillity.

One important character in the formations produced by currents, is, the immense extent over which they may be the means of diffusing homogeneous mixtures, for these are often co-extensive with a great line of coast, and, by comparison with their deposits, the deltas of rivers must shrink into insignificance. In the Mediterranean, the same current which is rapidly destroying many parts of the African coast, between the Straits of Gibraltar and the Nile, preys also upon the delta of the Nile, and drifts the sediment of that great river to the eastward. To this source may be attributed the rapid accretions of land on parts of the Syrian shores where rivers do not enter.

It is the opinion of M. Girard, one of the scientific men who accompanied Napoleon's expedition to Egypt, and who were employed on the survey of the ancient canal of Amron, communicating between the Nile and the Red Sea, that the isthmus of Suez itself is merely a bar formed by the deposition of this current and of the Nile, and that the two seas were formerly united.* It is certain, as before stated, that the isthmus is daily gaining in width by the accession of fresh deposits on the shores of the Mediterranean.†

The ruins of ancient Tyre are now far inland, and those of ancient Sidon are two miles distant from the coast, the modern town having been removed towards the sea.‡ But the south coast of Asia Minor affords far more striking examples of advances of the land upon the sea, where small streams co-operate with the current before mentioned. Captain Beaufort, in his Survey of that coast, has pointed out the great alterations effected on these shores since the time of Strabo, where havens are filled up, islands joined to the mainland, and where the whole continent has increased many miles in extent. Strabo himself, on comparing the out-

* Description de l'Egypte, Mémoires, tom. i. p. 33.

† Quarterly Review, No. lxxxvi. p. 445.

‡ Von Hoff, vol. i. p. 253.

line of the coast in his time with its ancient state, was convinced, like our countryman, that it had gained very considerably upon the sea. The new formed strata of Asia Minor consist *of stone*, not of loose, incoherent materials. Almost all the streamlets and rivers, like many of those in Tuscany and the south of Italy, hold abundance of carbonate of lime in solution, and precipitate travertin, or sometimes bind together the sand and gravel into solid sandstones and conglomerates: every delta and sand bar thus acquires solidity, which often prevents streams from forcing their way through them, so that their mouths are constantly changing their position.*

Distribution of the sediment of the Amazon by currents.—Among the greatest deposits now in progress, and of which the distribution is chiefly determined by currents, we may class those between the mouths of the Amazon and the southern coast of North America. It has been before stated that a great current flows along the coast of Africa, from the south, which, when it reaches the head of the Gulf of Guinea, and is opposed by the waters brought to the same spot by the Guinea current, streams off in a westerly direction, and pursues its rapid course quite across the Atlantic to the continent of South America. Here one portion proceeds along the northern coast of Brazil to the Caribbean Sea and the Gulf of Mexico. Captain Sabine found that this current was running with the astonishing rapidity of four miles an hour where it crosses the stream of the Amazon, which river preserves part of its original impulse, and has its waters not wholly mingled with those of the ocean at the distance of 300 miles from its mouth.† The sediment of the Amazon is thus constantly carried to the north-west as far as to the mouths of the Orinoco, and an immense tract of swamp is formed along the coast of Guinea, with a long range of muddy shoals bordering the marshes, and becoming converted into land.‡ The sediment of the Orinoco is partly detained, and settles near its mouth, causing the shores of Trinidad to extend rapidly, and is partly swept away into the Caribbean Sea by the Guinea current. According to Humboldt, much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico. The rivers, also, which descend from the high platform of Mexico, between the mouths of the Norte and Tampico, when they arrive, swollen by tropical rains, at the edge of that platform, bear down an enormous quantity of rock and mud to the sea; but the current, setting across their mouths, prevents the growth of deltas, and preserves an almost uniform curve in that line of coast.§ It must, therefore, exert a great transporting power, and it cannot fail to sweep

* Karamania, or a brief Description of the Coast of Asia Minor, &c. London, 1817.

† Experiments to determine the Figure of the Earth, &c., p. 445.

‡ Lochead's Observations on the Nat. Hist. of Guiana. Edin. Trans., vol. iv.

§ This coast has been recently examined by Captain Vetch.—See also Bauza's new chart of the Gulf of Mexico.

away part of the matter which is discharged from the mouths of the Norte and the Mississippi.

Area over which strata may be formed by currents.—In regard to the distribution of sediment by currents, it may be observed, that the rate of subsidence of the finer mud carried down by every great river into the ocean, must be extremely slow; for the more minute the separate particles of mud, the slower will they sink to the bottom, and the sooner will they acquire what is called their terminal velocity. It is well known that a solid body, descending through a resisting medium, falls by the force of gravity, which is constant, but its motion is resisted by the medium more and more as its velocity increases, until the resistance becomes sufficient to counteract the further increase of velocity. For example, a leaden ball, one inch diameter, falling through air of density as at the earth's surface, will never acquire greater velocity than 260 feet per second, and, in water, its greatest velocity will be eight feet six inches per second. If the diameter of the ball were $\frac{1}{100}$ of an inch, the terminal velocities in air would be twenty-six feet, and in water .86 of a foot per second.

Now, every chemist is familiar with the fact, that minute particles descend with extreme slowness through water, the extent of their surface being very great in proportion to their weight; and the resistance of the fluid depending on the amount of surface. A precipitate of sulphate of baryta, for example, will sometimes require more than five or six hours to subside one inch;* while oxalate and phosphate of lime require nearly an hour to subside about an inch and a-half and two inches respectively,† so exceedingly small are the particles of which these substances consist.

When we recollect that the depth of the ocean is supposed frequently to exceed three miles, and that currents run through different parts of that ocean at the rate of four miles an hour, and when at the same time we consider that some fine mud carried down by rivers, as well as the impalpable powder showered down by volcanos, may subside at the rate of only an inch per hour, we shall be prepared to find examples of the transportation of sediment over areas of indefinite extent.

It is not uncommon for the emery powder used in polishing glass to take more than an hour to sink one foot. Suppose mud, composed of particles twice as coarse, to fall at the rate of two feet per hour, and these to be discharged into that part of the Gulf Stream which preserves a mean velocity of three miles an hour for a distance of two thousand miles; in twenty-eight days these particles will be carried 2016 miles, and will have fallen only to a depth of 224 fathoms.

In this example, however, it is assumed that the current retains its superficial velocity at the depth of 224 fathoms, for which we have as yet

* On the authority of Mr. Faraday.

† On the authority of Mr. R. Phillips.

no data. Experiments should be made to ascertain the rate of currents at considerable distances from the surface, and the time taken by the finest river sediment to settle in sea-water of a given depth, and then the geologist may determine the area over which homogenous mixtures may be simultaneously distributed in certain seas.

Stratification.—In regard to the internal arrangement of formations deposited in the deep sea by currents far from the land, we may infer that in them, as in deltas, there is usually a division into strata; for, in both cases, the accumulations are successive, and, for the most part, interrupted. The waste of cliffs on the British coast is almost entirely confined to the winter months; so that running waters in the sea, like those on the land, are periodically charged with sediment, and again become pure.

CHAPTER IX.

IGNEOUS CAUSES.

Changes of the inorganic world, *continued*—Igneous causes—Division of the subject—Distinct volcanic regions—Region of the Andes—System of volcanos extending from the Aleutian isles to the Moluccas (p. 295.)—Polynesian archipelago—Volcanic region extending from the Caspian Sea to the Azores—Former connexion of the Caspian, Lake Aral, and Sea of Azof—Tradition of deluges on the shores of the Bosphorus, Hellespont, and Grecian isles (p. 298.)—Periodical alternation of earthquakes in Syria and Southern Italy—Western limits of the European region (p. 302.)—Earthquakes rarer and more feeble as we recede from the centres of volcanic action—Extinct volcanos not to be included in lines of active vents.

We have hitherto considered the changes wrought, since the times of history and tradition, by the continued action of aqueous causes on the earth's surface; and we have next to examine those resulting from igneous agency. As the rivers and springs on the land, and the tides and currents in the sea, have, with some slight modifications, been fixed and constant to certain localities from the earliest periods of which we have any records, so the volcano and the earthquake have, with few exceptions, continued, during the same lapse of time, to disturb the same regions. But as there are signs, on almost every part of our continent, of great power having been exerted by running water on the surface of the land, and by waves, tides, and currents on cliffs bordering the sea, where, in modern times, no rivers have excavated, and no waves or tidal currents undermined—so we find signs of volcanic vents and violent subterranean movements in places where the action of fire has long been dormant. We can explain why the intensity of the force of aqueous causes should be developed in succession in different districts. Currents, for example, tides, and the waves of the sea, cannot destroy coasts, shape out or silt up estuaries, break through isthmuses, and annihilate islands, form shoals in one place and remove them from another, without the direction and position of their destroying and transporting power becoming transferred to new localities. Neither can the relative levels of the earth's crust, above and beneath the waters, vary from time to time, as they are admitted to have varied at former periods, and as it will be demonstrated that they still do, without the continents being, in the course of ages, modified, and even entirely altered, in their external configuration. Such events must clearly be accompanied by a complete change in the volume, velocity, and direction of the streams and land floods to which certain regions give passage. That we should find, therefore, cliffs where the sea once committed ravages, and from which it has now retired—estuaries where high tides once rose, but which are now dried up—valleys hollowed out by water, where no streams now flow, is no more than we should expect;—these and similar phenomena are the necessary consequences of physical causes now in operation; and, if there be no instability in the laws of nature, similar fluctuations must recur again and again in time to come.

But, however natural it may be that the force of running water in numerous valleys, and of tides and currents in many tracts of the sea, should now be *spent*, it is by no means so easy to explain why the violence of the earthquake and the fire of the volcano should also have become locally extinct, at successive periods. We can look back to the time when the marine strata, whereon the great mass of Etna rests, had no existence; and that time is extremely modern in the earth's history. This alone affords ground for anticipating that the eruptions of Etna will one day cease.

> Nec quæ sulfureis ardet fornacibus Ætna
> Ignea semper erit, *neque enim fuit ignea semper*,

are the memorable words which are put into the mouth of Pythagoras by the Roman poet, and they are followed by speculations as to the cause of volcanic vents shifting their positions. Whatever doubts the philosopher expresses as to the nature of these causes, it is assumed, as incontrovertible, that the points of eruption will hereafter vary, *because they have formerly done so.*

I have endeavoured to show, in former chapters, that this principle of reasoning has been too much set at naught by some modern schools of geology, which not only refuse to conclude that great revolutions in the earth's surface are now in progress, or that they will take place hereafter, *because* they have often been repeated in former ages, but even assume the improbability of such a conclusion, and throw the whole weight of proof on those by whom that doctrine is embraced.

Division of the subject.—Volcanic action may be defined to be "the influence exerted by the heated interior of the earth on its external covering." If we adopt this definition, without connecting it as Humboldt has done, with the theory of secular refrigeration, or the cooling down of an original heated and fluid nucleus, we may then class under a general head all the subterranean phenomena, whether of volcanos, or earthquakes, or those insensible movements of the land, by which, as will afterwards appear, large districts may be depressed or elevated, without convulsions. According to this view, I shall consider first, the volcano; secondly, the earthquake; thirdly, the rising or sinking of land in countries where there are no volcanos or earthquakes; fourthly, the probably *causes* of the changes which result from subterranean agency.

It is a very general opinion, that earthquakes and volcanos have a common origin; for both are confined to certain regions, although the subterranean movements are least violent in the immediate proximity of volcanic vents, especially where the discharge of aëriform fluids and melted rock is made constantly from the same crater. But as there are particular regions, to which both the points of eruption and the movements of great earthquakes are confined, I shall begin by tracing out the geographical boundaries of some of these, that the reader may be aware of the magnificent scale on which the agency of subterranean fire is now simultaneously developed. Over the whole of the vast tracts alluded to, active volcanic vents are distributed at intervals, and most commonly arranged in a linear direction. Throughout the intermediate spaces there is abundant evidence that the subterranean fire is at work continuously, for the ground is convulsed from time to time by earthquakes; gaseous vapours, especially carbonic acid gas, are disengaged plentifully from the soil; springs often issue at a very high temperature, and their waters are usually impregnated with the same mineral matters as are discharged by volcanos during eruptions.

DISTINCT REGIONS OF SUBTERRANEAN DISTURBANCE.

Region of the Andes.—Of these great regions, that of the Andes is one of the best defined. Respecting its southern extremity, we are still in need of more accurate information, doubts being entertained by some whether it extends into Tierra del Fuego. Captain Hall, however, had a distant view from his ship, in 1822, of appearances which seem clearly to indicate an eruption of a volcano placed near the Beagle Channel (50° 48′ S. lat., 68° W. long.) Several volcanos are said to exist in the Andes of Patagonia, and no less than nineteen points of eruption are well known in Chili, situated in a continuous line from south to north, and forming lofty mountains. The number may hereafter be greatly augmented when the country has been more carefully examined, and throughout a longer period. How long an interval of rest may entitle us to consider a volcano as extinct, is not easily determined; but we know that, in Ischia, there intervened, between two consecutive eruptions, a pause of *seventeen centuries;* and a much longer period, perhaps, elapsed between the eruptions of Vesuvius before the earliest Greek colonies settled in Campania, and the renewal of its activity in the reign of Titus. It will be necessary, therefore, to wait for at least six times as many centuries as have elapsed since the discovery of America, before any one of the dormant craters of the Andes can be presumed to be entirely spent, unless where there are some *geological* proofs that the latest eruptions must have belonged to a remote era.

From the observations of Humboldt it appears, that all the volcanos of the Andes, whether extinct or active, have burst through basalts and trachytes, or through some igneous rocks of a porphyritic structure. All the loftiest summits of the range are composed of trachyte, with which abundance of obsidian is occasionally associated, and large accumulations of pumice and tuff, the latter formed of fragments of lava and cinders agglutinated together.

Villarica, in lat. 39° 8′ S., one of the principal of the Chilian volcanos, continues burning without intermission, and is so high that it may be distinguished at the distance of 150 miles. A year never passes in this province without some slight shocks of earthquakes; and about once in a century, or oftener, tremendous convulsions occur, by which, as will be afterwards seen, the land has been shaken from one extremity to the other; and continuous tracts, including part of the bed of the Pacific, have been permanently raised from one to twenty feet or more above their former level. Hot springs are numerous in this district, as well as springs of naphtha and petroleum, and mineral waters of various kinds.

If we pursue our course northwards, we find in Peru only one active volcano as yet known; but the province is so subject to earthquakes, that scarcely a week happens without a shock, and many of these have been so considerable as to create great changes of the surface.

Proceeding further north, we find the most considerable volcanos of the Andes situated in the province of Quito, where that chain attains its highest elevation. These volcanos, occurring between the second degree of south and the third degree of north lat., are, Cayambe, Cotopaxi, Pichincha, Antisana, L'Altar, and Tunguragua. The form of Cayambe, whose summit is crossed by the line of the equator, is that of a truncated cone, which rises to the immense height of 19,625 feet. The Indians of Lican have a tradition that the mountain called L'Altar, or Capac Urcu, which means "the chief," was once the highest of those near the equator, being higher than Chimborazo, but in the reign of Ouainia Abomatha, before the discovery of America, a prodigious eruption took place, which lasted eight years, and broke it down. The fragments of trachyte, says M. Boussingault, which once formed the conical summit of this celebrated mountain, are at this day spread over the plain.* Cotopaxi is the most lofty of all the South American volcanos which have been in a state of activity in modern times, its height being 18,858 feet; and its eruptions have been more frequent and destructive than those of any other mountain. It is a perfect cone, usually covered with an enormous bed of snow, which has, however, been sometimes melted suddenly during an eruption; as in Jan. 1803, for example, when the snows were dissolved in one night.

Deluges are often caused in the Andes by the liquefaction of great masses of snow, and sometimes by the rending open, during earthquakes, of subterranean cavities filled with water. In these inundations, fine volcanic sand, loose stones, and other materials which the water meets with in its descent, are swept away, and a vast quantity of mud, called "moya," is thus formed and carried down into the lower regions. Mud derived from this source descended, in 1797, from the sides of Tunguragua, and filled valleys 1000 feet wide to the depth of 600 feet, forming barriers by which rivers were dammed up, and lakes occasioned. In these currents and lakes of moya thousands of small fish are sometimes enveloped, which, according to Humboldt, have lived and multiplied in subterranean cavities. So great a quantity of these fish were ejected from the volcano of Imbaburu in 1691, that fevers, which prevailed at the period, were attributed to the effluvia arising from the putrid animal matter.

In Quito, many important revolutions in the physical features of the country are said to have resulted, within the memory of man, from the earthquakes by which it has been convulsed. M. Boussingault declares his belief, that if a full register had been kept of all the convulsions experienced here and in other populous districts of the Andes, it would be found that the trembling of the earth had been incessant. The frequency of the movement, he thinks, is not due to volcanic explosions, but to the continual falling in of masses of rock which have been fractured and upheaved in a solid form at a comparatively recent epoch. According to the same author, the height of several mountains of the Andes has diminished in modern times.†

If we continue our investigations still father to the north, we find in the same line three volcanos in the province of Pasto, and three others in that of Popayan. In the provinces of Guatimala and Nicaragua, which

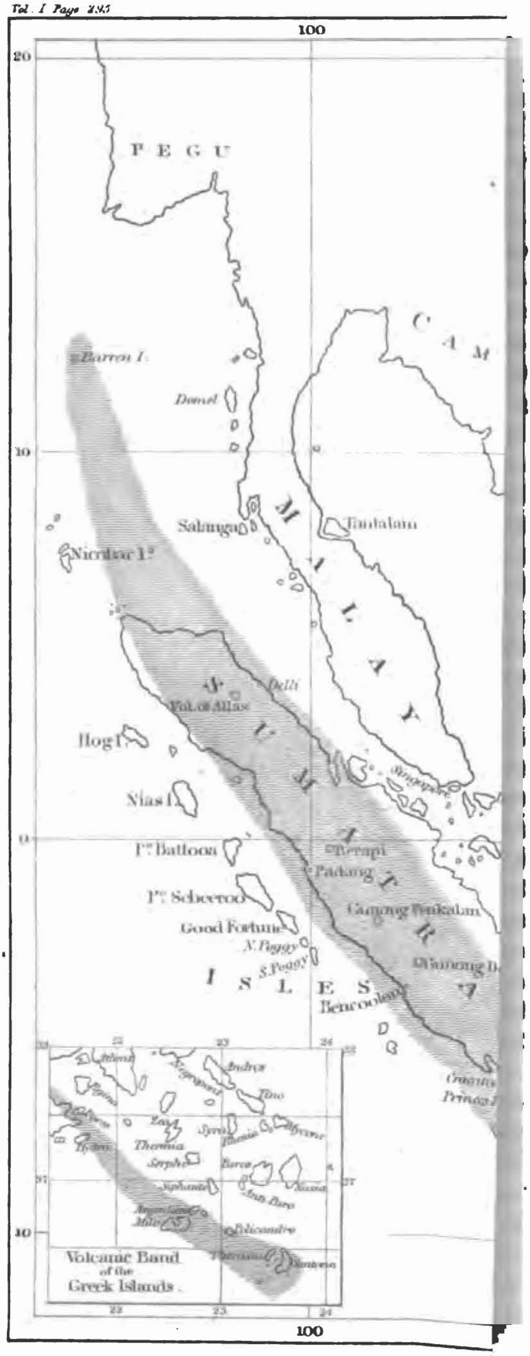
* Bull. de la Soc. Géol., tom. vi. p. 55.
† Bull. de la Soc. Géol. de France, tom. vi. p. 56.

lie between the isthmus of Panama and Mexico, there are no less than twenty-one active volcanos, all of them contained between the tenth and fifteenth degrees of north latitude.

The great volcanic chain, after having thus pursued its course for several thousand miles from south to north, turns off in a side direction in Mexico, in the parallel of the city of that name, and is prolonged in a great platform, between the eighteenth and twenty-second degrees of north latitude. This high table land is said to owe its present form to the circumstance of an ancient system of valleys, in a chain of granitic mountains, having been filled up to the depth of many thousand feet, with various volcanic products. Five active volcanos traverse Mexico from west to east—Tuxtla, Orizaba, Popocatepetl, Jorullo, and Colima. Jorullo, which is in the centre of the great platform, is no less than 120 miles from the nearest ocean—an important circumstance, as showing that the proximity of the sea is not a necessary condition, although certainly a very general characteristic, of the position of active volcanos. The extraordinary eruption of this mountain, in 1759, will be described in the sequel. If the line which connects these five vents be prolonged, in a westerly direction, it cuts the volcanic group of islands, called the Isles of Revillagigedo.

To the north of Mexico there are three, or according to some five, volcanos, in the peninsula of California, but of these we have at present no detailed account. I have before mentioned the violent earthquakes which in 1812 convulsed the valley of the Mississippi at New Madrid, for the space of 300 miles in length. As this happened exactly at the same time as the great earthquake of Caraccas, it is probable that these two points are parts of one continuous volcanic region; for the whole circumference of the intervening Caribbean Sea must be considered as a theatre of earthquakes and volcanos. On the north lies the island of Jamaica, which, with a tract of the contiguous sea, has often experienced tremendous shocks; and these are frequent along a line extending from Jamaica to St. Domingo, and Porto Rico. On the south of the same basin the shores and mountains of Colombia are perpetually convulsed. On the west, is the volcanic chain of Guatimala and Mexico, before traced out; and on the east the West India isles, where, in St. Vincent's and Guadaloupe, are active vents.

Thus it will be seen that volcanos and earthquakes occur uninterruptedly, from Chili to the north of Mexico; and it seems probable, that they will hereafter be found to extend from Cape Horn to California, or even to New Madrid, in the United States—a distance upon the whole as great as from the pole to the equator. In regard to the western limits of the region, they lie deep beneath the waves of the Pacific, and must continue unknown to us. On the east they are not prolonged, except where they include the West Indian islands, to a great distance; for there seem to be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indications of volcanic disturbances in Guiana, Brazil, and Buenos Ayres.

Canada.—Although no volcanos have been discovered in the northern regions of the new continent, we have authentic accounts of frequent earthquakes in Canada, and some of considerable violence have occurred, as that of 1663, hereafter to be described. A large part of the estuary of the St. Lawrence and the surrounding country has been shaken from time to time; and we learn from Captain Bayfield's Memoirs, that along the shores of the estuary and Gulf of St. Lawrence horizontal banks of recent shells appear at various heights, from 10 to 100 feet above high water mark, and inland breaches of sand and shingle with similar shells, as also elevated limestone rocks scooped out by the waves, and showing lines of lithodomous perforations, facts which indicate most clearly the successive upheaving of the land since the sea was inhabited by the existing species of testacea.*

Volcanic region from the Aleutian Isles to the Moluccas.—On a scale, which equals, or surpasses, that of the Andes, is another continuous line of volcanic action, which commences, on the north, with the Aleutian Isles in Russian America, and extends, first in a westerly direction for nearly 200 geographical miles, and then southwards, without interruption, throughout a space of between 60° and 70° of latitude to the Moluccas, where it branches off in different directions both towards the east and north-west.† The northern extremity of this volcanic region is the peninsula of Alaska in about 55° of latitude. From thence the line is continued through the Aleutian or Fox Islands, to Kamtschatka. In that archipelago eruptions are frequent; and a new island rose in 1814, which, according to some reports, is 3000 feet high and four miles round.‡ Langsdorf also mentions a rock of equal height, consisting of trachyte, said to have made its appearance at once from the bottom of the sea in the year 1795.§ Earthquakes of the most terrific description agitate and alter the bed of the sea and surface of the land throughout this tract. The line is continued in the southern extremity of the peninsula of Kamtschatka, where there are seven active volcanos, which, in some eruptions, have scattered ashes to immense distances. The Kurile chain of islands constitutes the prolongation of the range, where a train of volcanic mountains, nine of which are known to have been in eruption, trends in a southerly direction. In these, and in the bed of the adjoining sea, alterations of level have resulted from earthquakes since the middle of the last

* Proceedings of Geol. Soc., No. 33, p. 5, and Trans. of Lit. Soc. of Quebec, vols. i. ii.

† See map of volcanic lines which I have reduced and corrected from Von Buch's work on the Canaries.

‡ Von Hoff, vol. ii. p. 414.

§ Referred to by Daubeny, Encycl. Metr. Part. 38. p. 725.

century. The line is then continued to the south-west in the great island of Jesso, where there are active volcanic vents, as also in Nipon, the principal of the Japanese group, where the number of burning mountains is very great; slight shocks of earthquakes being almost incessant, and violent ones experienced at distant intervals. Between the Japanese and Philippine Islands, the communication is preserved by several small insular vents. Sulphur Island, in the Loo Choo archipelago, emits sulphureous vapour; and Formosa suffers greatly from earthquakes. In Luzon, the most northern and largest of the Philippines, are three active volcanos; Mindinao also was in eruption in 1764. The line is then prolonged through Sanguir and the north-eastern extremity of Celebes, by Ternate and Tidore, to the Moluccas, and, amongst the rest, Sumbawa. Here a great transverse line may be said to run from east to west. On the west it passes through the whole of Java, where there are thirty-eight large volcanic mountains, many of which continually discharge smoke and sulphureous vapours. In the volcanos of Sumatra, the same linear arrangement is preserved; but the line inclines gradually to the north-west in such a manner as to point to the active volcano in Barren Island, in the Bay of Bengal, in about the twelfth degree of north latitude. (See plate of Volcanic Band of Molucca and Sunda Islands, facing p. 295). In another direction the volcanic range is prolonged through Borneo, Celebes, Banda, and New Guinea; and farther eastward in New Britain, New Ireland, and various parts of the Polynesian archipelago. The Pacific Ocean, indeed, seems, in equatorial latitudes, to be one vast theatre of igneous action; and its innumerable archipelagos, such as the New Hebrides, Friendly and Georgian Islands, are all composed either of coralline limestones, or volcanic rocks, with active vents here and there interspersed. The abundant production of carbonate of lime in solution, would alone raise a strong presumption of the volcanic constitution of these tracts, even if there were not more positive proofs of igneous agency.

Volcanic region from the Caspian to the Azores.—If we now turn our attention to the principal region in the Old World, which, from time immemorial, has been agitated by earthquakes, and has given vent, at certain points, to subterranean fires, we find that it possesses the same general characters. This region extends from east to west for the distance of about 1000 geographical miles, from the Caspian Sea to the Azores; including within its limits the greater part of the Mediterranean, and its most prominent peninsulas. From south to north, it reaches from about the thirty-fifth to the forty-fifth degree of latitude. Its northern boundaries are Caucasus, the Black Sea, the mountains of Thrace, Transylvania, and Hungary—the Austrian, Tyrolian, and Swiss Alps—the Cevennes and Pyrenees, with the mountains which branch off from the Pyrenees westward, to the north side of the Tagus. Its western limits are the ocean, but it is impossible to determine how far it may be prolonged in that direction; neither can we assign with precision its extreme eastern limit, since the country beyond the Caspian and the Sea of Aral is little known. Capt. A. Burnes, in his recent expedition through the valley of the Oxus, found that the whole basin of that river had, a few weeks before he passed through it, been convulsed by a tremendous earthquake, which had thrown down buildings and obstructed the courses of rivers.

The great steppe of Tartary is unexplored; and we are almost equally ignorant of the physical constitution of China, in which country many violent earthquakes have been felt. The southern boundaries of the region include the most northern parts of Africa, and part of the Desert of Arabia.* We may trace, through the whole area comprehended within these extensive limits, numerous points of volcanic eruptions, hot springs, gaseous emanations, and other signs of igneous agency; while few tracts, of any extent, have been entirely exempt from earthquakes throughout the last 3000 years.

Borders of the Caspian.—To begin on the Asiatic side, we find that, on the western shores of the Caspian, in the country round Baku, there is a tract called the Field of Fire, which continually emits inflammable gas, while springs of naphtha and petroleum occur in the same vicinity, as also mud volcanos. In the chain of Elburs, to the south of this sea, is a lofty mountain, which, according to Morier, sometimes emits smoke, and at the base of which are several small craters, where sulphur and saltpetre are procured in sufficient abundance to be used in commerce. Violent subterranean commotions have been experienced along the borders of the Caspian; and, according to Engelhardt and Parrot, the bottom of that sea has, in modern times, varied in form; and they say that, near the south-coast, the Isle of Idak, north from Astrabat, formerly high land, has now become very low.† Any indications of a change in the relative levels of the land in this part of Asia, are of more than ordinary interest; because it has been supposed that the level of the Caspian is much lower than that of the Black Sea, although much doubt has recently been thrown on the observations from which this conclusion was deduced.‡

Steppes of the Caspian—A low and level tract, called the Steppe, abounding in saline plants, and composed of tertiary strata containing many shells of species now common in the adjoining sea, skirts the north-western shores of the Caspian. This plain often terminates abruptly by a line of inland cliffs, at the base of which runs a kind of beach, consisting of fragments of limestone and sand, cemented together into a conglomerate. Pallas has endeavoured to show that there is an old

* Von Hoff, vol. ii. p. 99.

† Travels in the Crimea and Caucasus, in 1815, vol. i. pp. 257. 264.—Von Hoff, vol. i. p. 137.

‡ See Book iv. chap. 19.

line of sandy country, which indicates the ancient bed of a strait, by which the Caspian was once united to the sea of Azof. On similar grounds, it is inferred that the salt lake Aral was formerly connected with the Caspian.

Tradition of deluges on the shores of the Bosphorus, &c.—The convulsions which have produced the phenomena of the steppes may be very modern in the earth's history, and yet a small portion of them only may have happened in the last twenty or thirty centuries. Remote traditions have come down to us of inundations, in which the waters of the Euxine were forced through the Thracian Bosphorus, and through the Hellespont, into the Ægean; and in the deluge of Samothrace, it appears that that small island, and the adjoining coast of Asia, were inundated. In the Ogygian also, which happened at a different time, Bœotia and Attica were overflowed. Notwithstanding the mixture of fable, and the love of the marvellous, in those rude ages, and the subsequent inventions of Greek poets and historians, it may be distinctly perceived that the floods alluded to were local and transient, and that they happened in succession near the borders of that chain of inland seas. They may, perhaps, have been nothing more than great waves, which, about fifteen centuries before our era, devastated the borders of the Black Sea, the Sea of Marmora, the Archipelago, and neighbouring coasts, in the same manner as the western shores of Portugal, Spain, and Northern Africa were inundated, during the great earthquake at Lisbon, by a wave which rose in some places, to the height of fifty or sixty feet; or as happened in Peru, in 1746, where 200 violent shocks followed each other in the space of twenty-four hours, and the ocean broke with impetuous force upon the land, destroying the town of Callao, and four other seaports, and permanently converted a considerable tract of inhabited country, which had perhaps sunk down below its former level, into a bay. Diodorus Siculus in his account of the Samothracian deluge, informs us that the inhabitants had time to take refuge in the mountains, and save themselves by flight; he also relates that, long after the event, the fishermen of the island drew up in their nets the capitals of columns, which, he says, were the remains of cities submerged by that terrible catastrophe.* These statements scarcely leave any doubt that the event consisted of a subsidence of the coast, accompanied by a series of earthquakes, and successive inroads of the sea.

In the country between the Caspian and the Black Seas, and in the chain of Caucasus, numerous earthquakes have, in modern times, caused fissures and subsidences of the soil, especially at Tiflis.† The Caucasian territories abound in hot-springs and mineral waters. So late as 1814, a

* Book v. chap. 46. See letter of M. Virlet, Bulletin de la Soc. Géol. de France, vol. ii. p. 341.

† Von Hoff, vol. ii. p. 210.

new island was raised by volcanic explosions, in the Sea of Azof; and Pallas mentions that, in the same locality, opposite old Temruk, a submarine eruption took place in 1799, accompanied with a dreadful thundering, emission of fire and smoke, and the throwing up of mire and stones. Violent earthquakes were felt at the same time at great distances from Temruk. The country around Erzerum exhibits similar phenomena, as does that around Tauris and the Lake of Urmia, in which latter we have already remarked the rapid formation of travertin. The lake of Urmia, which is about 280 English miles in circumference, resembles the Dead Sea, in having no outlet, and in being more salt than the ocean. Between the Tigris and Euphrates, also, there are numerous springs of naphtha, and frequent earthquakes agitate the country.

Syria and Palestine abound in volcanic appearances, and very extensive areas have been shaken, at different periods, with great destruction of cities and loss of lives. Continual mention is made in history of the ravages committed by earthquakes in Sidon, Tyre, Berytus, Laodicea, and Antioch, and in the island of Cyprus. The country around the Dead Sea appears evidently, from the accounts of modern travellers, to be volcanic. A district near Smyrna, in Asia Minor, was termed by the Greeks Catacecaumene, or the burnt, where there is a large arid territory, without trees, and with a cindery soil.*

Periodical alternation of Earthquakes in Syria and Southern Italy.— It has been remarked by Von Hoff, that from the commencement of the thirteenth to the latter half of the seventeenth century, there was an almost entire cessation of earthquakes in Syria and Judea; and, during this interval of quiescence, the Archipelago, together with part of the adjacent coast of Lesser Asia, as also Southern Italy and Sicily, suffered greatly from earthquakes; while volcanic eruptions were unusually frequent in the same regions. A more extended comparison, also, of the history of the subterranean convulsions of these tracts seems to confirm the opinion, that a violent crisis of commotion never visits both at the same time. It is impossible for us to declare, as yet, whether this phenomenon is constant in this and other regions, because we can rarely trace back a connected series of events farther than a few centuries; but it is well known that, where numerous vents are clustered together within a small area, as in many archipelagos for instance, two of them are never in violent eruption at once. If the action of one becomes very great for a century or more, the others assume the appearance of spent volcanos. It is, therefore, not improbable, that separate provinces of the same great range of volcanic fires may hold a relation to one deep-seated focus analogous to that which the apertures of a small group bear to some more superficial rent or cavity. Thus, for example, we may conjecture that,

* Strabo, Ed. Fal., p. 900.

at a comparatively small distance from the surface, Ischia and Vesuvius mutually communicate with certain fissures, and that each affords relief alternately to elastic fluids and lava there generated. So we may suppose Southern Italy and Syria to be connected, at a much greater depth, with a lower part of the very same system of fissures; in which case any obstruction occurring in one duct may have the effect of causing almost all the vapour and melted matter to be forced up the other, and if they cannot get vent, they may be the cause of violent earthquakes.

Grecian Archipelago.—Proceeding westwards, we reach the Grecian Archipelago, where Santorin, afterwards to be described, is the grand centre of volcanic action. To the north-west of Santorin is another volcano in the island of Milo, of recent aspect, having a very active solfatara in its central crater, and many sources of boiling water and steam. Continuing the same line, we arrive at that part of the Morea, where we learn, from ancient writers, that Helice and Bura were, in the year 373 B.C., submerged beneath the sea by an earthquake; and the walls, according to Ovid, were to be seen beneath the waters. Near the same spot, in our times (1817), Vostizza was laid in ruins by a subterranean convulsion.* At Methone, also (now Modon), in Messenia, about three centuries before our era, an eruption threw up a great volcanic mountain, which is represented by Strabo as being nearly 4000 feet in height; but the magnitude of the hill requires confirmation. Some suppose that the accounts of the formation of a hill near Trœzene, of which the date is unknown, may refer to the same event.

It was Von Buch's opinion that the volcanos of Greece were arranged in a line running N. N. W. and S. S. E., as represented in the Map, Pl. III., facing p. 295; and that they afforded the only example in Europe of active volcanos having a linear direction.† But observations made during the late French expedition to the Morea have by no means confirmed this view. On the contrary, M. Virlet announces as the result of his investigations, that there is no one determinate line of direction for the volcanic phenomena in Greece, whether we follow the points of eruptions, or the earthquakes, or any other signs of igneous agency.

Macedonia, Thrace, and Epirus, have always been subject to earthquakes, and the Ionian Isles are continually convulsed. Respecting Southern Italy, Sicily, and the Lipari Isles, it is unnecessary to enlarge here, as the existence of volcanos in that region is known to all, and I shall have occasion again to allude to them. I may mention, however, that Dr. Daubeny has traced a band of volcanic action across the Italian Peninsula, from Ischia to Mount Vultur, in Apulia, the commencement of the line being found in the hot springs of Ischia, after which it is prolonged through Vesuvius to the Lago d'Ansanto, where gases similar

* Von Hoff, vol. ii. p. 172.

† See Plate of Volcanic Bands, facing p. 295.

to those of Vesuvius are evolved. Its further extension strikes Mount Vultur, a lofty cone composed of tuff and lava, from one side of which carbonic acid and sulphuretted hydrogen are emitted.*

The north-eastern portion of Africa, including Egypt, which lies six or seven degrees south of the volcanic line already traced, has been almost always exempt from earthquakes: but the north-western portion, especially Fez and Morocco, which fall within the line, suffer greatly from time to time. The southern part of Spain also, and Portugal, have generally been exposed to the same scourge simultaneously with Northern Africa. The provinces of Malaga, Murcia, and Granada, and in Portugal, the country round Lisbon, are recorded at several periods to have been devastated by great earthquakes. It will be seen, from Michell's account of the great Lisbon shock in 1755, that the first movement proceeded from the bed of the ocean ten or fifteen leagues from the coast. So late as February 2, 1816, when Lisbon was vehemently shaken, two ships felt a shock in the ocean west from Lisbon; one of them at the distance of 120, and the other 262 French leagues from the coast,†—a fact which is the more interesting, because a line drawn through the Grecian archipelago, the volcanic region of Southern Italy, Sicily, Southern Spain, and Portugal, will, if prolonged westward through the ocean, strike the volcanic group of the Azores, which has, therefore, in all probability, a submarine connexion with the European line. How far the island of Madeira, which has been subject to violent earthquakes, and the Canary Islands, in which volcanic eruptions have been frequent, may communicate beneath the waters with the same great region, must for the present be mere matter of conjecture.

Besides the continuous spaces of subterranean disturbance, of which we have merely sketched the outline, there are other disconnected volcanic groups, of which the geographical extent is as yet very imperfectly known. Among these may be mentioned Iceland, which belongs, perhaps, to the same region as the volcano in Jan Mayen's Island, situated 5° to the north-east. With these, also, part of the nearest coast of Greenland, which is sometimes shaken by earthquakes, may be connected.

In another hemisphere the island of Bourbon belongs to the theatre of volcanic action, of which Madagascar probably forms a part, if the alleged existence of burning volcanos in that island shall, on further examination, be substantiated. In following round the borders of the Indian Ocean, to the north, we find the volcano of Gabel Tor, within the entrance of the Arabian Gulf. In the province of Cutch earthquakes are frequent, and at Mhurr, twenty-five miles from Luckput, there is an

* Daubeny on Mount Vultur, Ashmolean Memoirs. Oxford, 1835.

† Verneur, Journal des Voyages, vol. iv. p. 111. Von Hoff, vol. ii. p. 275.

active volcano, or at least a solfatara.* In Malwa, as also in Chittagong, in Bengal, there have been violent earthquakes within the historical period.

Volcanic regions of Southern Europe.—Respecting the volcanic system of Southern Europe, it may be observed, that there is a central tract where the greatest earthquakes prevail, in which rocks are shattered, mountains rent, the surface elevated or depressed, and cities laid in ruins. On each side of this line of greatest commotion there are parallel bands of country, where the shocks are less violent. At a still greater distance (as in Northern Italy, for example, extending to the foot of the Alps), there are spaces where the shocks are much rarer and more feeble, yet possibly of sufficient force to cause, by continued repetition, some appreciable alteration in the external form of the earth's crust. Beyond these limits, again, all countries are liable to slight tremors at distant intervals of time, when some great crisis of subterranean movement agitates an adjoining volcanic region; but these may be considered as mere vibrations, propagated mechanically through the external covering of the globe, as sounds travel almost to indefinite distances through the air. Shocks of this kind have been felt in England, Scotland, Northern France, and Germany—particularly during the Lisbon earthquake. But these countries cannot, on this account, be supposed to constitute parts of the southern volcanic region, any more than the Shetland and Orkney Islands can be considered as belonging to the Icelandic circle, because the sands ejected from Hecla have been wafted thither by the winds.

Lines of active and extinct Volcanos not to be confounded.—We must also be careful to distinguish between lines of extinct and active volcanos, even where they appear to run in the same direction; for ancient and modern systems may cross and interfere with each other. Already, indeed, we have proof that this is the case; so that it is not by geographical position, but by reference to the species of organic beings alone, whether aquatic or terrestrial, whose remains occur in beds interstratified with lavas, that we can clearly distinguish the relative age of volcanos of which no eruptions are recorded. Had Southern Italy been known to civilized nations for as short a period as America, we should have had no record of eruptions in Ischia; yet we might have assured ourselves that the lavas of that isle had flowed since the Mediterranean was inhabited by the species of testacea now living in the Neapolitan seas.† With this assurance it would not have been rash to include the numerous vents of that island in the modern volcanic group of Campania.

On similar grounds we may infer, without much hesitation, that the eruptions of Etna and the modern earthquakes of Calabria, are a continuation of that action, which, at a somewhat earlier period, produced the

* On the authority of Capt. A. Burnes.

† See account of Ischia, book iv. chap. 10.

submarine lavas of the Val di Noto in Sicily.* But the lavas of the Euganean hills and the Vicentin, although not wholly beyond the range of earthquakes in Northern Italy, must not be confounded with any existing volcanic system; for when they flowed, the seas were inhabited by animals almost all of them distinct from those now known to live, whether in the Mediterranean or other parts of the globe. But an examination of these topics would carry us to events anterior to the times of history; we must therefore defer their consideration to the 4th Book.

CHAPTER X.

VOLCANIC DISTRICT OF NAPLES.

History of the volcanic eruptions in the district round Naples—Early convulsions in the island of Ischia—Numerous cones thrown up there—Epomeo not an habitual volcano—Lake Avernus—The Solfatara—Renewal of the eruptions of Vesuvius, A. D. 79—Pliny's description of the phenomena (p. 306.)—Remarks on his silence respecting the destruction of Herculaneum and Pompeii—Subsequent history of Vesuvius—Lava discharged in Ischia in 1302—Pause in the eruptions of Vesuvius—Monte Nuovo thrown up (p. 309.)—Uniformity of the volcanic operations of Vesuvius and the Phlegræan Fields in ancient and modern times.

I SHALL next give a sketch of the history of some of the volcanic vents dispersed throughout the great regions before described, and consider the composition and arrangement of their lavas and ejected matter. The only volcanic region known to the ancients was that of which the Mediterranean forms a part; and even of this they have transmitted to us very imperfect records relating to the eruptions of the three principal districts, namely, that round Naples, that of Sicily and its isles, and that of the Grecian Archipelago. By far the most connected series of records throughout a long period relates to the first of these provinces; and these cannot be too attentively considered, as much historical information is indispensable in order to enable us to obtain a clear view of the connexion and alternate mode of action of the different vents in a single volcanic group.

Early convulsions in the Island of Ischia.—The Neapolitan volcanos extend from Vesuvius, through the Phlegræan Fields, to Procida and Ischia, in a somewhat linear arrangement, ranging from the north-east to the

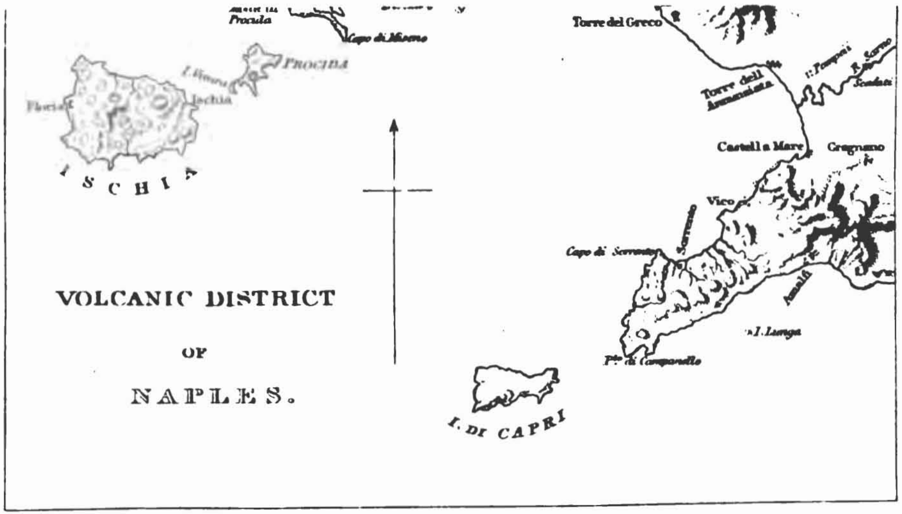
* Book iv. ch. 6.

south-west, as will be seen in the annexed Map of the Volcanic District of Naples (Plate IV.). Within the space above limited, the volcanic force is sometimes developed in single eruptions from a considerable number of irregularly scattered points; but a great part of its action has been confined to one principal and habitual vent, Vesuvius or Somma. Before the Christian era, from the remotest periods of which we have any tradition, this principal vent was in a state of inactivity. But terrific convulsions then took place from time to time in Ischia (Pithecusa), and seem to have extended to the neighbouring isle of Procida (Prochyta); for Strabo* mentions a story of Procida having been torn asunder from Ischia; and Pliny† derives its name from its having been poured forth by an eruption from Ischia.

The present circumference of Ischia along the water's edge is eighteen miles, its length from west to east about five, and its breadth from north to south three miles. Several Greek colonies which settled there before the Christian era were compelled to abandon it in consequence of the violence of the eruptions. First the Erythræans, and afterwards the Chalcidians, are mentioned as having been driven out by earthquakes and igneous exhalations. A colony was afterwards established by Hiero, king of Syracuse, about 380 years before the Christian era; but when they had built a fortress, they were compelled by an irruption to fly, and never again returned. Strabo tells us that Timæus recorded a tradition, that a little before his time, Epomeus, the principal mountain in the centre of the island, vomited fire during great earthquakes; that the land between it and the coast had ejected much fiery matter, which flowed into the sea, and that the sea receded for the distance of three stadia, and then returning, overflowed the island. This eruption is supposed by some to have been that which formed the crater of Monte Carvo on one of the higher flanks of Epomeo, above Foria, the lava-current of which may still be traced, by the aid of the scoriæ on its surface, from the crater to the sea.

To one of the subsequent eruptions in the lower parts of the isle, which caused the expulsion of the first Greek colony, Monte Rotaro has been attributed, and it bears every mark of recent origin. The cone is remarkably perfect, and has a crater on its summit precisely resembling that of Monte Nuovo; but the hill is larger, and resembles some of the more considerable cones of single eruption near Clermont in Auvergne, and, like some of them, it has given vent to a lava-stream at its base, instead of its summit. A small ravine swept out by a torrent exposes the structure of the cone, which is composed of innumerable inclined and slightly undulating layers of pumice, scoriæ, white lapilli, and enormous angular blocks of trachyte. These last have evidently been thrown out by violent explosions, like those which in 1822 launched from Vesuvius a mass of

* Lib. v. † Nat. Hist., lib. iii. c. 6.


VOLCANIC DISTRICT
OF
NAPLES.
ISCHIA
Ischia
PROCIDA
Procida
Capo di Miseno
I. DI CAPRI
Torre del Greco
Torre dell Annunziata
Castell a Mare
Gragnano
Vico
Sorrento
Capo di Sorrento
Amalfi
Pta di Campanella

augitic lava, of many tons weight, to the distance of three miles, which fell in the garden of Prince Ottajano. The cone of Rotaro is covered with the arbutus, and other beautiful evergreens. Such is the strength of the virgin soil, that the shrubs have become almost arborescent; and the growth of some of the smaller wild plants has been so vigorous that botanists have scarcely been able to recognise the species.

The eruption which dislodged the Syracusan colony is supposed to have given rise to that mighty current which forms the promontory of Zaro and Caruso. The surface of these lavas is still very arid and bristling, and is covered with black scoriæ; so that it is not without great labour that human industry has redeemed some small spots, and converted them into vineyards. Upon the produce of these vineyards the population of the island is almost entirely supported. It amounts at present to about 25,000, and is on the increase.

From the date of the great eruption last alluded to, down to our own time, Ischia has enjoyed tranquillity, with the exception of one emission of lava hereafter to be described, which, although it occasioned much local damage, does not appear to have devastated the whole country, in the manner of more ancient explosions. There are, upon the whole, on different parts of Epomeo, or scattered through the lower tracts of Ischia, twelve considerable volcanic cones, which have been thrown up since the island was raised above the surface of the deep; and many streams of lava may have flowed, like that of 'Arso' in 1302, without cones having been produced; so that this island may, for ages before the period of the remotest traditions, have served as a safety-valve to the whole Terra di Lavoro, while the fires of Vesuvius were dormant.*

Lake Avernus.—It seems also clear, that Avernus, a circular lake near Puzzuoli, about half a mile in diameter, which is now a salubrious and cheerful spot, once exhaled mephitic vapours, such as are often emitted by craters after eruptions. There is no reason for discrediting the account of Lucretius, that birds could not fly over it without being stifled, although they may now frequent it uninjured.† There must have been a time when this crater was in action; and for many centuries afterwards it may have deserved the appellation of "atri janua Ditis," emitting, perhaps, gases as destructive of animal life as those suffocating vapours given out by Lake Quilotoa, in Quito, in 1797, by which whole herds of cattle on its shores were killed,‡ or as those deleterious emanations which annihilated all the cattle in the island of Lancerote, one of the Canaries, in 1730.§ Bory St. Vincent mentions, that in the same isle birds fell life-

* For an account of the geology of Ischia, see Book iv. ch. 10.

† De Rerum Nat., vi. 740.—Forbes, on Bay of Naples, Edin. Journ. of Sci., No. iii. new series, p. 87. Jan. 1830.

‡ Humboldt, Voy., p. 317.

§ Von Buch, Uber einen vulcanischen Ausbruch auf der Insel Lanzerote.

less to the ground; and Sir William Hamilton informs us that he picked up dead birds on Vesuvius during an eruption.

Solfatara.—The Solfatara, near Puzzuoli, which may be considered as a nearly extinguished crater, appears, by the accounts of Strabo and others, to have been before the Christian era in very much the same state as at present, giving vent continually to aqueous vapour, together with sulphureous and muriatic acid gases, like those evolved by Vesuvius.

Ancient history of Vesuvius.—Such, then, were the points where the subterranean fires obtained vent, from the earliest period to which tradition reaches back, down to the first century of the Christian era; but we then arrive at a crisis in the volcanic action of this district—one of the most interesting events witnessed by man during the brief period throughout which he has observed the physical changes on the earth's surface. From the first colonization of Southern Italy by the Greeks, Vesuvius afforded no other indications of its volcanic character than such as the naturalist might infer, from the analogy of its structure to other volcanos. These were recognised by Strabo, but Pliny did not include the mountain in his list of active vents. The ancient cone was of a very regular form, terminating, not as at present, in two peaks, but with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom. On the exterior, the flanks of the mountains were clothed with fertile fields richly cultivated, and at its base were the populous cities of Herculaneum and Pompeii. But the scene of repose was at length doomed to cease, and the volcanic fire was recalled to the main channel, which, at some former unknown period, had given passage to repeated streams of melted lava, sand, and scoriæ.

Renewal of its eruptions.—The first symptom of the revival of the energies of this volcano was the occurrence of an earthquake in the year 63 after Christ, which did considerable injury to the cities in its vicinity. From that time to the year 79 slight shocks were frequent; and in the month of August of that year they became more numerous and violent, till they ended at length in an eruption. The elder Pliny, who commanded the Roman fleet, was then stationed at Misenum; and in his anxiety to obtain a near view of the phenomena, he lost his life, being suffocated by sulphureous vapours. His nephew, the younger Pliny, remained at Misenum, and has given us, in his Letters, a lively description of the awful scene. A dense column of vapour was first seen rising vertically from Vesuvius, and then spreading itself out laterally, so that its upper portion resembled the head, and its lower the trunk of the pine which characterizes the Italian landscape. This black cloud was pierced occasionally by flashes of fire as vivid as lightning, succeeded by darkness more profound than night. Ashes fell even upon the ships at Misenum, and caused a shoal in one part of the sea—the ground rocked, and the sea receded from the shores, so that many marine animals were seen on the dry sand. The appearances above described agree perfectly with those witnessed in more recent eruptions, especially those of Monte Nuovo in 1538, and of Vesuvius in 1822.

Silence of Pliny respecting the destruction of Herculaneum and Pompeii.—In all times and countries, indeed, there is a striking uniformity in the volcanic phenomena; but it is most singular that Pliny, although giving a circumstantial detail of so many physical facts, and describing the eruption, earthquake, and shower of ashes which fell at Stabiæ, makes no allusion to the sudden overwhelming of two large and populous cities, Herculaneum and Pompeii. All naturalists who have searched into the memorials of the past for records of physical events, must have been surprised at the indifference with which the most memorable occurrences are often passed by, in the works of writers of enlightened periods; as also of the extraordinary exaggeration which usually displays itself in the traditions of similar events in ignorant and superstitious ages. But no omission is more remarkable than that now under consideration; nor has the circumstance, we think, been at all explained by the suggestion that the chief object of the younger Pliny was to give Tacitus a full account of the particulars of his uncle's death. We have no hesitation in saying, that had the buried cities never been discovered, the accounts transmitted to us of their tragical end would have been discredited by the majority, so vague and general are the narratives, or so long subsequent to the event. Tacitus, the friend and contemporary of Pliny, when adverting in general terms to the convulsions, says merely that "cities were consumed or buried."*

Suetonius, although he alludes to the eruption incidentally, is silent as to the cities. They are mentioned by Martial, in an epigram, as immersed in cinders; but the first historian who alludes to them by name is Don Cassius,† who flourished about a century and a half after Pliny. He appears to have derived his information from the traditions of the inhabitants, and to have recorded, without discrimination, all the facts and fables which he could collect. He tells us, "that during the eruption a multitude of men of superhuman stature, resembling giants, appeared, sometimes on the mountain, and sometimes in the environs—that stones and smoke were thrown out, the sun was hidden, and then the giants seemed to rise again, while the sounds of trumpets were heard, &c. &c.; and finally," he relates, "two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, while all the people were sitting in the theatre." That many of these circumstances were invented would have been obvious, even without the aid of Pliny's letters; and the examina-

* Haustæ aut obrutæ urbes.—Hist., lib. i.

† Hist. Rom., lib. lxvi.

tion of Herculaneum and Pompeii enables us to prove, that none of the people were destroyed in the theatres, and, indeed, that there were very few of the inhabitants who did not escape from both cities. Yet some lives were lost, and there was ample foundation for the tale in its most essential particulars.

This case may often serve as a caution to the geologist, who has frequent occasion to weigh, in like manner, negative evidence derived from the silence of eminent writers, against the obscure but positive testimony of popular traditions. Some authors, for example, would have us call in question the reality of the Ogygian deluge, because Homer and Hesiod say nothing of it. But they were poets, not historians, and they lived many centuries after the latest date assigned to the catastrophe. Had they even lived at the time of that flood, we might still contend that their silence ought, no more than Pliny's, to avail against the authority of tradition, however much exaggeration we may impute to the traditional narrative of the event.

It does not appear that in the year 79 any lava flowed from Vesuvius; the ejected substances, perhaps, consisted entirely of lapilli, sand, and fragments of older lava, as when Monte Nuovo was thrown up in 1538. The first era at which we have authentic accounts of the flowing of a stream of lava, is the year 1036, which is the seventh eruption from the revival of the fires of the volcano. A few years afterwards, in 1049, another eruption is mentioned, and another in 1138 (or 1139), after which a great pause ensued of 168 years. During this long interval of repose, two minor vents opened at distant points. First, it is on tradition that an eruption took place from the Solfatara in the year 1198, during the reign of Frederic II., Emperor of Germany; and although no circumstantial detail of the event has reached us from those dark ages, we may receive the fact without hesitation.* Nothing more, however, can be attributed to this eruption, as Mr. Scrope observes, than the discharge of a light and scoriform trachytic lava, of recent aspect, resting upon the strata of loose tuff which covers the principal mass of trachyte.†

Volcanic eruption in Ischia, 1302.—The other occurrence is well authenticated,—the eruption, in the year 1302, of a lava-stream from a new vent on the south-east side of the Island of Ischia. During part of 1301, earthquakes had succeeded one another with fearful rapidity; and they terminated at last with the discharge of a lava-stream from a point named the Campo del Arso, not far from the town of Ischia. This lava ran quite down to the sea—a distance of about two miles; in colour it varies from iron gray to reddish black, and is remarkable for the glassy felspar

* The earliest authority, says Mr. Forbes, given for this fact, appears to be Capaccio, quoted in the Terra Tremante of Bonito.—Edin. Journ. of Sci., &c. No. I., *N. S.*, p. 127. July, 1829.

† Geol. Trans., second series, vol. ii. p. 346.

which it contains. Its surface is almost as sterile, after a period of five centuries, as if it had cooled down yesterday. A few scantlings of wild thyme, and two or three other dwarfish plants, alone appear in the interstices of the scoriæ, while the Vesuvian lava of 1767 is already covered with a luxuriant vegetation. Pontanus, whose country-house was burnt and overwhelmed, describes the dreadful scene as having lasted two months.* Many houses were swallowed up, and a partial emigration of the inhabitants followed. This eruption produced no cone, but only a slight depression, hardly deserving the name of a crater, where heaps of black and red scoriæ lie scattered around. Until this eruption, Ischia is generally believed to have enjoyed an interval of rest for about seventeen centuries; but Julius Obsequens,† who flourished A. D. 214, refers to some volcanic convulsions in the year 662 after the building of Rome (91 B. C.). As Pliny, who lived a century before Obsequens, does not enumerate this among other volcanic eruptions, the statement of the latter author is supposed to have been erroneous; but it would be more consistent, for reasons before stated, to disregard the silence of Pliny, and to conclude that some kind of subterranean commotion, probably of no great violence, happened at the period alluded to.

History of Vesuvius after 1138.—To return to Vesuvius:—the next eruption occurred in 1306; between which era and 1631 there was only one other (in 1500), and that a slight one. It has been remarked, that throughout this period Etna was in a state of such unusual activity as to lend countenance to the idea that the great Sicilian volcano may sometimes serve as a channel of discharge to elastic fluids and lava that would otherwise rise to the vents in Campania.

Formation of Monte Nuovo, 1538.—The great pause was also marked by a memorable event in the Phlegræan Fields—the sudden formation of a new mountain in 1538, of which we have received authentic accounts from contemporary writers. Frequent earthquakes, for two years preceding, disturbed the neighbourhood of Puzzuoli; but it was not until the 27th and 28th of September, 1538, that they became alarming, when not less than twenty shocks were experienced in twenty-four hours. At length, on the night of the 29th, two hours after sunset, a gulf opened between the little town of Tripergola, which once existed on the site of the Monte Nuovo, and the baths in its suburbs, which were much frequented. This watering-place contained an hospital for those who resorted thither for the benefit of the thermal springs, and it appears that there were no fewer than three inns in the principal street. A large fissure approached the town with a tremendous noise, and with the emission of flame; and began to discharge mud composed of pumice-stones and ashes mixed with water, with some blocks of solid stone. The ashes,

* Lib. vi. de Bello Neap. in Grævii Thesaur.

† Prodig. libell., c. cxiv.

by which the town was entirely overwhelmed, fell in immense quantities, even at Naples; while the neighbouring Puzzuoli was deserted by its inhabitants. The sea retired suddenly for 200 yards, and a portion of its bed was left dry. The whole coast, from Monte Nuovo to beyond Puzzuoli, was at that time upraised to the height of many feet above the bed of the Mediterranean, and has ever since remained permanently elevated. The proofs of this remarkable event will be considered at length when the phenomena of the Temple of Serapis are described.* On the 3d of October the eruption ceased, so that the hill (1. Fig. 22.), the great mass of which was thrown up in a day and a night, was accessible; and those who ascended reported that they found a funnel-shaped crater on its summit. (2. Fig. 22.)

The height of Monte Nuovo has recently been determined, by the Italian mineralogist Pini, to be 440 English feet above the level of the bay; its base is about 8000 feet, or nearly a mile and a half, in circumference. According to Pini, the depth of the crater is 421 English feet from the summit of the hill, so that its bottom is only nineteen feet above

Fig. 22.

Monte Nuovo, formed in the Bay of Baiæ, Sept. 29th, 1538.

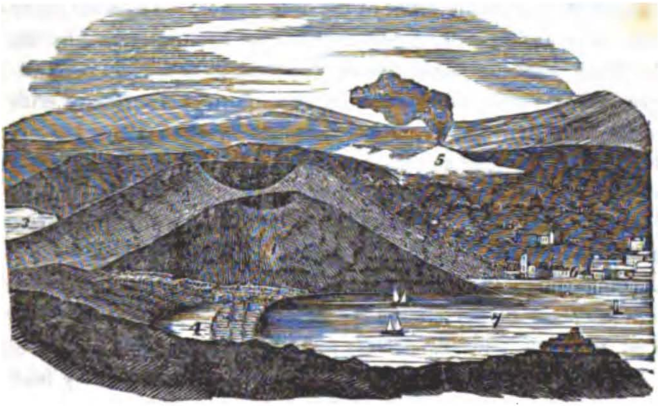
1. Cone of Monte Nuovo. 2. Brim of crater of ditto.
3. Thermal spring, called Baths of Nero, or Stufe di Tritoli.

the level of the sea. No lava flowed from this cavity, but the ejected matter consisted of pumiceous mud with some masses of trachyte, many of them schistose, and resembling clinkstone. The Monte Nuovo is declared, by the best authorities, to stand partly on the site of the Lucrine

* See chap. xvi.

Lake (4. Fig. 23.*), which was nothing more than the crater of a pre-existent volcano, and was almost entirely filled during the explosion of 1538. Nothing now remains but a shallow pool, separated from the sea by an elevated beach, raised artificially.

Fig. 23.



The Phlegræan Fields.

1. Monte Nuovo. 2. Monte Barbaro. 3. Lake Avernus.
4. Lucrine Lake. 5. The Solfatara. 6. Puzzuoli.
7. Bay of Baiæ.

Volcanos of the Phlegræan Fields.—Immediately adjoining Monte Nuovo is the larger volcanic cone of Monte Barbaro (2. Fig. 23.), the Gaurus inanis of Juvenal—an appellation given to it probably from its deep circular crater, which is about a mile in diameter. Large as is this cone, it was probably produced by a single eruption; and it does not, perhaps, exceed in magnitude some of the largest of those formed in Ischia, within the historical era. It is composed chiefly of indurated tufa, like Monte Nuovo, stratified conformably to its conical surface. This hill was once very celebrated for its wines, and is still covered with vineyards; but when the vine is not in leaf it has a sterile appearance, and, late in the year, when seen from the beautiful bay of Baiæ, it often contrasts so strongly in verdure with Monte Nuovo, which is always clothed with arbutus, myrtle, and other wild evergreens, that a stranger might well imagine the cone of older date to be that thrown up in the sixteenth century.†

* This representation of the Phlegræan Fields is reduced from part of Plate xxxi. of Sir William Hamilton's great work, "Campi Phlegræi." The faithfulness of his coloured delineations of the scenery of that country cannot be too highly praised.

† Hamilton (writing in 1770) says, "The new mountain produces as yet but a very slender vegetation."—Campi Phlegræi, p. 69. This remark was no longer applicable when I saw it, in 1828.

There is nothing, indeed, so calculated to instruct the geologist as the striking manner in which the recent volcanic hills of Ischia, and that now under consideration, blend with the surrounding landscape. Nothing seems wanting or redundant; every part of the picture is in such perfect harmony with the rest, that the whole has the appearance of having been called into existence by a single effort of creative power. Yet what other result could we have anticipated, if Nature has ever been governed by the same laws? Each new mountain thrown up—each new tract of land raised or depressed by earthquakes—should be in perfect accordance with those previously formed, if the entire configuration of the surface has been due to a long series of similar disturbances. Were it true that the greater part of the dry land originated simultaneously in its present state, at some era of paroxysmal convulsion, and that additions were afterwards made slowly and successively during a period of comparative repose; then, indeed, there might be reason to expect a strong line of demarcation between the signs of ancient and modern changes. But the very continuity of the plan, and the perfect identity of the causes, are to many a source of deception; since, by producing a unity of effect, they lead them to exaggerate the energy of the agents which operated in the earlier ages. In the absence of all historical information, they are as unable to separate the dates of the origin of different portions of our continents, as the stranger is to determine, by their physical features alone, the distinct ages of Monte Nuovo, Monte Barbaro, Astroni, and the Solfatara.

The vast scale and violence of the volcanic operations in Campania, in the olden time, has been a theme of declamation, and has been contrasted with the comparative state of quiescence of this delightful region in the modern era. Instead of inferring, from analogy, that the ancient Vesuvius was always at rest when the craters of the Phlegræan Fields were burning,—that each cone rose in succession,—and that many years, and often centuries, of repose intervened between different eruptions,—geologists seem to have generally conjectured that the whole group sprung up from the ground at once, like the soldiers of Cadmus when he sowed the dragon's teeth. As well might they endeavour to persuade us that on these Phlegræan Fields, as the the poets feigned, the giants warred with Jove, ere yet the puny race of mortals were in being.

Modern Eruptions of Vesuvius.—For nearly a century after the birth of Monte Nuovo, Vesuvius continued in a state of tranquillity. There had then been no violent eruption for 492 years; and it appears that the crater was then exactly in the condition of the present extinct volcano of Astroni, near Naples. Bracini, who visited Vesuvius not long before the eruption of 1631, gives the following interesting description of the interior: —"The crater was five miles in circumference, and about a thousand paces deep; its sides were covered with brushwood, and at the bottom there was a plain on which cattle grazed. In the woody parts wild boars frequently harboured. In one part of the plain, covered with ashes, were three small pools, one filled with hot and bitter water, another salter than the sea, and a third hot, but tasteless."* But at length these forests and grassy plains were consumed, being suddenly blown into the air, and their ashes scattered to the winds. In December, 1631, seven streams of lava poured at once from the crater, and overflowed several villages on the flanks and at the foot of the mountain. Resina, partly built over the ancient site of Herculaneum, was consumed by the fiery torrent. Great floods of mud were as destructive as the lava itself,—no uncommon occurrence during these catastrophes; for such is the violence of rains produced by the evolution of aqueous vapour, that torrents of water descend the cone, and, becoming charged with impalpable volcanic dust, and rolling along loose ashes, acquire sufficient consistency to deserve their ordinary appellation of "aqueous lavas."

A brief period of repose ensued, which lasted only until the year 1666, from which time to the present there has been a constant series of eruptions, with rarely an interval of rest exceeding ten years. During these three centuries no irregular volcanic agency has convulsed other points in this district. Brieslak remarked, that such irregular convulsions had occurred in the Bay of Naples in every second century; as, for example, the eruption of the Solfatara in the twelfth, of the lava of Arso, in Ischia, in the fourteenth, and of Monte Nuovo in the sixteenth: but the eighteenth has formed an exception to this rule, and this seems accounted for by the unprecedented number of eruptions of Vesuvius during that period; whereas, when the new vents opened, there had always been, as we have seen, a long intermittance of activity in the principal volcano.

* Hamilton's Campi Phlegræi, folio, vol. i. p. 62.; and Brieslak, Campanie, tome i. p. 186.

CHAPTER XI.

VOLCANIC DISTRICT OF NAPLES—*continued.*

Structure of the cone of Vesuvius.—BETWEEN the end of the eighteenth century and the year 1822, the great crater of Vesuvius has been gradually filled by lava boiling up from below, and by scoriæ falling from the explosions of minor mouths which were formed at intervals on its bottom and sides. In place of a regular cavity, therefore, there was a rough and rocky plain, covered with blocks of lava and scoriæ, and cut by numerous fissures, from which clouds of vapour were evolved. But this state of things was totally changed by the eruption of October, 1822, when violent explosions, during the space of more than twenty days, broke up and threw out all this accumulated mass, so as to leave an immense gulf or chasm, of an irregular, but somewhat elliptical shape, about three miles in circumference when measured along the very sinuous and irregular line of its extreme margin, but somewhat less than three-quarters of a mile in its longest diameter, which was directed from N. E. to S. W.* The depth of this tremendous abyss has been variously estimated; for from the hour of its formation it decreased daily by the dilapidation of its sides. It measured, at first, according to the account of some authors, 2000 feet in depth from the extreme part of the existing summit;† but Mr. Scrope, when he saw it, soon after the eruption, estimated its depth at less than half that quantity. More than 800 feet of the cone was carried away by the explosions, so that the mountain was reduced in height from about 4200 to 3400 feet.‡

As we ascend the sloping sides, the volcano appears a mass of loose materials—a mere heap of rubbish, thrown together without the slightest

* Account of the Eruption of Vesuvius in October, 1822, by G. P. Scrope, Esq., Journ. of Sci., &c. vol. xv. p. 175.

† Mr. Forbes, Account of Mount Vesuvius, Edin. Journ. of Sci, No. xviii. p. 195. Oct. 1828.

‡ Ibid., p. 194.

order; but on arriving at the brim of the crater, and obtaining a view of the interior, we are agreeably surprised to discover that the conformation of the whole displays in every part the most perfect symmetry and arrangement. The materials are disposed in regular strata, slightly undulating, appearing, when viewed in front, to be disposed in horizontal planes. But, as we make the circuit of the edge of the crater, and observe the cliffs by which it is encircled projecting or receding in salient or retiring angles, we behold transverse sections of the currents of lava and beds of sand and scoriæ, and recognise their true dip. We then discover that they incline outwards from the axis of the cone, at angles varying from 30° to 45°. The whole cone, in fact, is composed of a number of concentric coatings of alternating lavas, sand, and scoriæ. Every shower of ashes which has fallen from above, and every stream of lava descending from the lips of the crater, have conformed to the outward surface of the hill, so that one conical envelope may be said to have been successively folded round another, until the aggregation of the whole mountain was completed. The marked separation into distinct beds results from the different colours and degrees of coarseness in the sands, scoriæ, and lava, and the alternation of these with each other. The greatest difficulty, on the first view, is to conceive how so much regularity can be produced, notwithstanding the unequal distribution of sand and scoriæ, driven by prevailing winds in particular eruptions, and the small breadth of each sheet of lava as it first flows out from the crater.

But on a closer examination, we find that the appearance of extreme uniformity is delusive, for when a number of beds thin out gradually, and at different points, the eye does not without difficulty recognise the termination of any one stratum, but usually supposes it continuous with some other, which at a short distance may lie precisely in the same plane. The slight undulations, moreover, produced by inequalities on the sides of the hill on which the successive layers were moulded, assist the deception. As countless beds of sand and scoriæ constitute the greater part of the whole mass, these may sometimes mantle continuously round the whole cone; and even lava-streams may be of considerable breadth when first they overflow, and, since in some eruptions a considerable part of the upper portion of the cone breaks down at once, may form a sheet extending as far as the space which the eye usually takes in in a single section.

The high inclination of some of the beds, and the firm union of the particles even where there is evidently no cement, is another striking feature in the volcanic tuffs and breccias, which seems at first not very easy of explanation. But the last great eruption afforded ample illustration of the manner in which these strata are formed. Fragments of lava, scoriæ, pumice, and sand, when they fall at slight distances from the summit, are only half cooled down from a state of fusion, and are afterwards acted upon by the heat from within, and by fumeroles or small crevices in the cone through which hot vapours are disengaged. Thus heated, the ejected fragments cohere together strongly; and the whole mass acquires such consistency in a few days, that fragments cannot be detached without a smart blow of the hammer. At the same time sand and scoriæ, ejected to a greater distance, remain incoherent.*

Sir William Hamilton, in his description of the eruption of 1779, says, that jets of liquid lava, mixed with stones and scoriæ, were thrown up to the height of at least 10,000 feet, having the appearance of a column of fire.† Some of these were directed by the winds towards Ottaiano, and some of them, falling almost perpendicularly, still red-hot and liquid, on Vesuvius, covered its whole cone, part of the mountain of Somma, and the valley between them. The falling matter being nearly as vividly inflamed as that which was continually issuing fresh from the crater, formed with it one complete body of fire, which could not be less than two miles and a-half in breadth, and of the extraordinary height above mentioned, casting a heat to the distance of at least six miles around it. Dr. Clarke, also, in his account of the eruption of 1793, says that millions of red-hot stones were shot into the air full half the height of the cone itself, and then bending, fell all round in a fine arch. On another occasion he says that, as they fell, they covered nearly half the cone with fire.

The same author has also described the different appearance of the lava at its source, and at some distance from it, when it had descended into the plains below. At the point where it issued, in 1793, from an arched chasm in the side of the mountain, the vivid torrent rushed with the velocity of a flood. It was in perfect fusion, unattended with any scoriæ on its surface, or any gross materials not in a state of complete solution. It flowed with the translucency of honey, "in regular channels, cut finer than art can imitate, and glowing with all the splendour of the sun."— "Sir William Hamilton," he continues, "had conceived that no stones thrown upon a current of lava would make any impression. I was soon convinced of the contrary. Light bodies, indeed, of five, ten and fifteen pounds weight made little or no impression even at the source; but bodies of sixty, seventy, and eighty pounds were seen to form a kind of bed on the surface of the lava, and float away with it. A stone of three hundred weight, that had been thrown out by the crater, lay near the source of the current of lava: I raised it upon one end, and then let it fall in upon the liquid lava; when it gradually sunk beneath the surface, and disappeared. If I wished to describe the manner in which it acted upon the lava, I should say that it was like a loaf of bread thrown into a bowl of very thick

* Monticelli and Covelli, Storia di Fenon. del Vesuv., en 1821-2-3.

† Campi Phlegræi.

honey, which gradually involves itself in the heavy liquid, and then slowly sinks to the bottom.

"The lava, at a small distance from its source, acquires a darker tint upon its surface, is less easily acted upon, and, as the stream widens, the surface, having lost its state of perfect solution, grows harder and harder, and cracks into innumerable fragments of very porous matter, to which they give the name of scoriæ, and the appearance of which has led many to suppose that it proceeded thus from the mountain. There is, however, no truth in this. All lava, at its first exit from its native volcano, flows out in a liquid state, and all equally in fusion. The appearance of the scoriæ is to be attributed only to the action of the external air, and not to any difference in the materials which compose it, since any lava whatever, separated from its channel, and exposed to the action of the external air, immediately cracks, becomes porous, and alters its form. As we proceeded downward, this became more and more evident; and the same lava which at its original source flowed in perfect solution, undivided, and free from encumbrances of any kind, a little farther down had its surface loaded with scoriæ in such a manner, that, upon its arrival at the bottom of the mountain, the whole current resembled nothing so much as a heap of unconnected cinders from an iron-foundry." In another place he says, that "the rivers of lava in the plain resembled a vast heap of cinders, or the scoriæ of an iron-foundry, rolling slowly along, and falling with a rattling noise over one another."*

It appears that the intensity of the light and heat of the lava varies considerably at different periods of the same eruption, as in that of Vesuvius in 1819 and 1820, when Sir H. Davy remarked different degrees of vividness in the white heat at the point where the lava originated.†

When the expressions "flame" and "smoke" are used in describing volcanic appearances, they must generally be understood in a figurative sense. The clouds of apparent smoke consist usually of aqueous and other vapours, or of that impalpable dust which is formed of finely comminuted volcanic scoriæ. The columns of flame are very rarely if ever derived from inflammable gases, but consist of showers of incandescent or red-hot fragments of lava, illuminated by that vivid light which is emitted from the crater below, where the lava is said to glow with the splendour of the sun.

Dikes in the recent cone, how formed.—The inclined strata before mentioned, which dip outwards in all directions from the axis of the cone of Vesuvius, are intersected by veins or dikes of compact lava, for the most part in a vertical position.‡ In 1828 these were seen to be about seven in number, some of them not less than 400 or 500 feet in

* Otter's Life of Dr. Clarke. † Phil. Trans., 1828, p. 241.

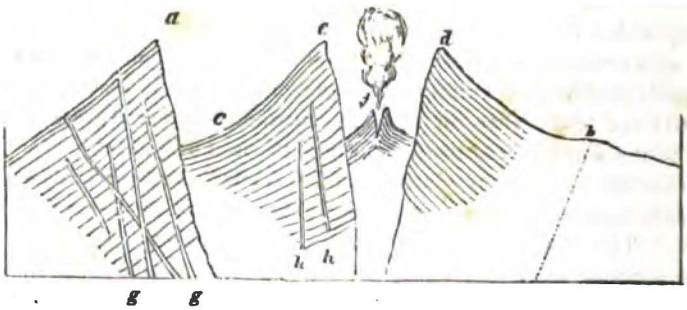
‡ See Book iv. chap. 10.

height, and thinning out before they reached the uppermost part of the cone. Being harder than the beds through which they pass, they have decomposed less rapidly, and therefore stand out in relief.*

There can be no doubt that these dikes have been produced by the filling up of open fissures with liquid lava; but of the date of their formation we know nothing further than that they are all subsequent to the year 79, and, relatively speaking, that they are more modern than all the lavas and scoriæ which they intersect. A considerable number of the upper strata, not traversed by them, must have been due to later eruptions, if the dikes were filled from below, and if lava rose in them to the surface. That the earthquakes, which almost invariably precede eruptions, occasion rents in the mass is well known; and, in 1822, three months before the lava flowed out, open fissures, evolving hot vapours, were numerous. It is clear that such rents must be injected with melted matter when the column of lava rises, so that the origin of the dikes is easily explained, as also the great solidity and crystalline nature of the rock composing them, which has been formed by lava cooling slowly under great pressure.

Section through Vesuvius and Somma.—In the annexed diagram (Fig. 24.) it will be seen that, on the side of Vesuvius opposite to that

Fig. 24.



Supposed section of Vesuvius and Somma.

a. Monte Somma, or the remains of the ancient cone of Vesuvius.

b. The Pedamentina, a terrace-like projection, encircling the base of the recent cone of Vesuvius, on the south side.

c. Atrio del Cavallo; so called from travellers leaving their horses and mules there when they prepare to ascend the cone on foot.

d, e. Crater left by eruption of 1822.

f. Small cone thrown up in 1828, at the bottom of the great crater.

g, g. Dikes intersecting Somma.

h, h. Dikes intersecting the recent cone of Vesuvius.

* When I visited Vesuvius, in Nov. 1828, I was prevented from descending into the crater by the constant ejections then thrown out. I only got sight of three of

where a portion of the ancient cone of Somma(*a*) still remains, is a projection (*b*) called the Pedamentina, which some have supposed to be part of the circumference of the ancient crater broken down towards the sea, and over the edge of which the lavas of the modern Vesuvius have poured; the axis of the present cone of Vesuvius being, according to Visconti, precisely equidistant from the escarpment of Somma and the Pedamentina. It has been objected that, if the Pedamentina and the escarpment of Somma were the remains of the original *crater*, that crater must have been many miles in diameter, and more enormous than almost any one known on the globe. In answer to this, it may be suggested, that probably the ancient mountain was higher than Vesuvius (which, comparatively speaking, is a volcano of no great height,) and that the explosions of the year 79 caused it not merely to disgorge the contents of its crater, which had long been choked up, but blew up a great part of the cone itself: so that the wall of Somma, and the ridge or terrace of the Pedamentina, were never the margin of a crater of eruption, but are the relics of a ruined and truncated cone.

It will be seen in the diagram that the slanting beds of the cone of Vesuvius become horizontal in the Atrio del Cavallo (at *c*), where the base of the new cone meets the precipitous escarpment of Somma; for when the lava flows down to this point, as happened in 1822, its descending course is arrested, and it then runs in another direction along this small valley, circling round the base of the cone. Sand and scoriæ, also, blown by the winds, collect at the base of the cone, and are then swept away by torrents; so that there is always here a flattish plain, as represented. In the same manner the small interior cone (*f*) must be composed of sloping beds, terminating in a horizontal plain; for, while this monticule was gradually gaining height by successive ejections of lava and scoriæ, in 1828, it was always surrounded by a flat pool of semi-fluid lava, into which scoriæ and sand were thrown.

The escarpment of Somma exhibits a structure precisely similar to that of the cone of Vesuvius, but the beds are intersected by a much greater number of dikes. The formation of this older cone does not belong to the historical era, and must not, therefore, be enlarged upon in this place; but I shall have occasion presently to revert to the subject, when speaking of a favourite doctrine of some modern geologists, concerning "craters

the dikes; but Signor Monticelli had previously had drawings made of the whole, which he showed me. The veins which I saw were on that side of the cone which is encircled by Somma. In March of the year before mentioned, an eruption began at the bottom of the deep gulf formed in 1822. The ejected matter had filled up nearly one-third of the original abyss in November, and the same operation was still in progress, a single black cone being seen at the bottom in almost continual activity. I found the lava of 1822 not yet cool on the north side of the cone, and evolving much heat and vapour from crevices. It was then upwards of six years since it flowed out of elevation" (Erhebungscratere), whereby, in defiance of analogy, the origin of the identical disposition of the strata and dikes in Vesuvius and Somma has been referred to a mode of operation extremely dissimilar.

Vesuvian Lavas.—The modern lavas of Vesuvius are characterised by a large proportion of augite (or pyroxene). They are often porphyritic, containing disseminated crystals of augite, leucite, or some other mineral, imbedded in a more earthy base.* In regard to the structure of these lavas on a great scale, there are no natural sections of sufficient depth to enable us to draw fair comparisons between them and the products of extinct volcanos. At the fortress near Torre del Greco a section is exposed, fifteen feet in height, of a current which ran into the sea; and it evinces, especially, in the lower part, a decided tendency to divide into rude columns. A still more striking example may be seen to the west of Torre del Annunziata, near Forte Scassato, where the mass is laid open by the sea to the depth of twenty feet. In both these cases, however, the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava-currents of Central France (those of the Vivarais, in particular), the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava irregularly prismatic; and under this there is a foundation of regular and vertical columns, but these lavas are often 100 feet or more in thickness. We can scarcely expect to discover the same phenomenon in the shallow currents of Vesuvius, where the lowest part has cooled more rapidly, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume.

Mr. Scrope mentions that, in the cliffs encircling the modern crater of Vesuvius, he saw many currents offering a columnar division, and some almost as regularly prismatic as any ranges of the older basalts; and he adds, that in some the spheroidal concretionary structure, on a large scale, was equally conspicuous.‡ Brieslak† also informs us that, in the siliceous lava of 1737, which contains augite, leucite, and crystals of felspar, he found very regular prisms in a quarry near Torre del Greco; an observation confirmed by modern authorities.§

Effects of decomposition on lavas.—The decomposition of some of the felspathic lavas, either by simple weathering, or by gaseous emanations, converts them from a hard to a soft clayey state, so that they no longer retain the smallest resemblance to rocks cooled down from a state of fusion. The exhalations of sulphuretted hydrogen and muriatic acid, which are disengaged continually from the Solfatara, also produce

* See Book iv. chap. 10.

† Journ. of Sci., vol. xv. p. 177.

‡ Voy. dans la Campanie, tome i. p. 201.

§ Mr. Forbes, Edin. Journ. of Sci., No. xviii., Oct. 1828.

curious changes on the trachyte of that nearly extinct volcano: the rock is bleached and becomes porous, fissile, and honeycombed, till at length it crumbles into a white siliceous powder.* Numerous globular concretions, composed of concentric laminæ, are also formed by the same vapours in this decomposed rock.†

They who have visited the Phlegræan Fields and the volcanic regions of Sicily, and who are aware of the many problematical appearances which igneous rocks of the most modern origin assume, especially after decomposition, cannot but be astonished at the confidence with which the contending Neptunists and Vulcanists in the last century dogmatized on the origin of certain rocks of remote antiquity. Instead of having laboured to acquire an accurate acquaintance with the aspect of known volcanic rocks, and the transmutations which they undergo subsequently to their first consolidation, the adherents of both parties seem either to have considered themselves born with an intuitive knowledge of the effects of volcanic operations, or to have assumed that they required no other analogies that those which a laboratory or furnace might supply.

Vesuvian Minerals.—A great variety of minerals are found in the lavas of Vesuvius and Somma: for so many are common to both, that it is unnecessary to separate them. Augite, leucite, felspar, mica, olivine, and sulphur, are most abundant. It is an extraordinary fact, that, in an area of three square miles round Vesuvius, a greater number of simple minerals have been found than in any spot of the same dimensions on the surface of the globe. Häuy enumerated only 380 species of simple minerals as known to him; and no less than eighty-two had been found on Vesuvius and in the tuffs on the flanks of Somma before the end of the year 1828.‡ Many of these are peculiar to that locality. Some mineralogists have conjectured that the greater part of these were not of Vesuvian origin, but thrown up in fragments from some older formation, through which the gaseous explosions burst. But none of the older rocks in Italy, or elsewhere, contain such an assemblage of mineral products; and the hypothesis seems to have been prompted by a disinclination to admit that, in times so recent in the earth's history, the laboratory of Nature could have been so prolific in the creation of new and rare compounds. Had Vesuvius been a volcano of high antiquity, formed when Nature

> Wanton'd as in her prime, and played at will
> Her virgin fancies,

it would have been readily admitted that these, or a much greater variety

* Daubeny on Volcanos, p. 169.

† Scrope, Geol. Trans., second series, vol. ii. p. 346.

‡ Monticelli and Covelli, Prodom. della Mineral. Vesuv.

of substances, had been sublimed in the crevices of lava, just as several new earthy and metallic compounds are known to have been produced by fumeroles, since the eruption of 1822. But a violent hypothesis appears to have been resorted to, in order to explain away facts which would imply the unimpaired energy of reproductive causes in our own times.

Formation of Tuffs.—The above remarks apply simply to the structure of the cone: but a small part only of the ejected matter remains so near to the volcanic orifice. A large portion of sand and scoriæ is borne by the winds and scattered over the surrounding plains: part falls into the sea; and still more is swept down by torrents into the deep, during the intervals, often protracted for many centuries, between eruptions. In this case horizontal deposits of tufaceous matter become intermixed with other kinds of sediment, and with shells and corals, so that rocks of a mixed character are formed, such as tuffs, peperinos, and volcanic conglomerates.

Flowing of lava under water.—Some of the lavas, also, of Vesuvius reach the sea, as do those of almost all volcanos; since they are generally in islands, or bordering the coast. Here they find a bottom, often levelled by operations analagous to those which form deltas; so that instead of being highly inclined, as around the cone, or in narrow bands, as in a valley, they may spread out in broad horizontal sheets. It is not improbable, as Dr. Daubeny has suggested, that they retain their fluidity for a considerable time longer beneath the sea than in the open air; for the rapidity with which heated bodies are cooled by being plunged into water arises chiefly from the conversion of the lower portions of water into steam, which steam, absorbing much heat, immediately ascends, and is reconverted into water. But under the pressure of an ocean sufficiently deep to prevent the formation of steam, the heat of the lava would be carried off more slowly, and only by the circulation of ascending and descending currents of water, those portions nearest the source of heat becoming specifically lighter, and consequently displacing the water above. This kind of circulation would take place with much less rapidity than in the atmosphere, inasmuch as the expansion of water by equal increments of heat is less considerable than that of air.*

Volcanic alluviums.—In addition to the ejections which fall on the cone, and that much greater mass which finds its way gradually to the neighbouring sea, there is a third portion, often of no inconsiderable thickness, composed of alluviums, spread over the valleys and plains at small distances from the volcano. Aqueous vapours are evolved copiously from a crater during eruptions, and often for a long time subsequently to the discharge of scoriæ and lava: these vapours are condensed in the cold atmosphere surrounding the high volcanic peak, and heavy rains are

* See Daubeny's Volcanos, p. 400.

thus caused in countries where, at the same season and under ordinary circumstances, such a phenomenon is entirely unknown. The floods thus occasioned sweep along the impalpable dust and light scoriæ, till a current of mud is produced, which is called, in Campania, "lava d' acqua," and is often more dreaded than an igneous stream (lava di fuoco), from the greater velocity with which it moves. So late as the 27th of October, 1822, one of these alluviums descended the cone of Vesuvius, and, after overspreading much cultivated soil, flowed suddenly into the villages of St. Sebastian and Massa, where, filling the streets and interior of some of the houses, it suffocated seven persons. It will therefore happen very frequently, that, towards the base of a volcanic cone, alternations will be found of lava, alluvium, and showers of ashes.

Mass enveloping Herculaneum and Pompeii.—To which of these two latter divisions the mass enveloping Herculaneum and Pompeii should be referred, has been a question of the keenest controversy; but the discussion might have been shortened, if the combatants had reflected that, whether volcanic sand and ashes were conveyed to the towns by running water, or through the air, during an eruption, the interior of buildings, so long as the roofs remain entire, together with all underground vaults and cellars, could be filled only by an *alluvium*. We learn from history, that a heavy shower of sand, pumice, and lapilla, sufficiently great to render Pompeii and Herculaneum uninhabitable, fell for eight successive days and nights in the year 79, accompanied by violent rains. We ought, therefore, to find a very close resemblance between the strata covering these towns, and those composing the minor cones of the Phlegræan Fields, accumulated rapidly, like Monte Nuovo, during a continued shower of ejected matter; with this difference, however, that the strata incumbent on the cities would be horizontal, whereas those in the cones are highly inclined, and that large angular fragments of rock, which are thrown out near the vent, would be wanting at a distance, where small lapilli only can be found. Accordingly, with these exceptions, no identity can be more perfect than the form and distribution of the matter at the base of Monte Nuovo, as laid open by the encroaching sea, and the appearance of the beds superimposed on Pompeii. That city is covered with numerous alternations of different horizontal beds of tuff and lapilli, for the most part thin, and subdivided into very fine layers. I observed the following section near the Amphitheatre, in November, 1828—(descending series).

	Feet.	Inches.
1. Black sparkling sand from the eruption of 1822, containing minute regularly formed crystals of augite and tourmaline, from		2 to 3*

* The great eruption, in 1822, caused a covering only a few inches thick on Pompeii. Several feet are mentioned by Mr. Forbes.—Ed. Journ. of Science, No. xix.

	Feet.	Inches.
2. Vegetable mould	3	0
3. Brown incoherent tuff, full of *pisolitic globules* in layers, from half an inch to three inches in thickness	1	6
4. Small scoriæ and white lapilli	0	3
5. Brown earthy tuff, with numerous pisolitic globules	0	9
6. Brown earthy tuff, with lapilli divided into layers	4	0
7. Layer of whitish lapilli	0	1
8. Gray solid tuff	0	3
9. Pumice and white lapilli	0	3
	10	4

Many of the ashes in these beds are vitrified and harsh to the touch. Crystals of leucite, both fresh and farinaceous, have been found intermixed.* The depth of the bed of ashes above the houses is variable, but seldom exceeds twelve or fourteen feet, and it is said that the higher part of the Amphitheatre always projected above the surface; though, if this were the case, it seems inexplicable that the city should never have been discovered till the year 1750. It will be observed, in the above section, that two of the brown half-consolidated tuffs are filled with small pisolitic globules. It is surprising that this circumstance is not alluded to in the animated controversy which the Royal Academy of Naples maintained with one of their members, Signor Lippi, as to the origin of the strata incumbent on Pompeii. The mode of aggregation of these globules has been fully explained by Mr. Scrope, who saw them formed in great numbers, in 1822, by rain falling during the eruption on fine volcanic sand, and sometimes also produced like hail in the air, by the mutual attraction of the minutest particles of fine damp sand. Their occurrence, therefore, agrees remarkably well with the account of heavy rain, and showers of sand and ashes, recorded in history, and is opposed to the theory of an alluvium brought from a distance by a flood of water.

Lippi entitled his work, "Fù il fuoco o l' acqua che sotterrò Pompei ed Ercolano?"† and he contended that neither were the two cities destroyed in the year 79, nor by a volcanic eruption, but purely by the agency of water charged with transported matter. His Letters, wherein he endeavoured to dispense, as far as possible, with igneous agency, even at the foot of the volcano, were dedicated, with great propriety, to Werner, and afford an amusing illustration of the polemic style in which geo-

p. 131. Jan. 1829. But he must have measured in spots where it had drifted. The dust and ashes were five feet thick at the top of the crater, and decreased gradually to ten inches at Torre del Annunziata. The size and weight of the ejected fragments diminished very regularly in the same continuous stratum, as the distance from the centre of projection was greater.

* Forbes, ibid. p. 130. † Napoli, 1816.

logical writers of that day indulged themselves. His arguments were partly of an historical nature, derived from the silence of contemporary historians, respecting the fate of the cities which, as we have already stated, is most remarkable, and partly drawn from physical proofs. He pointed out with great clearness the resemblance of the tufaceous matter in the vaults and cellars at Herculaneum and Pompeii to aqueous alluviums, and its distinctness from ejections which had fallen through the air. Nothing, he observed, but moist pasty matter could have received the impression of a woman's breast, which was found in a vault at Pompeii, or have given the cast of a statue discovered in the theatre at Herculaneum. It was objected to him, that the heat of the tuff in Herculaneum and Pompeii was proved by the carbonization of the timber, corn, papyrus-rolls, and other vegetable substances there discovered: but Lippi replied with truth, that the papyri would have been burnt up, if they had come in contact with fire, and that their being only carbonized was a clear demonstration of their having been enveloped, like fossil wood, in a sediment deposited from water. The Academicians, in their report on his pamphlet, assert, that when the Amphitheatre was first cleared out, the matter was arranged, on the steps, in a succession of concave layers, accommodating themselves to the interior form of the building, just as snow would lie if it had fallen there. This observation is highly interesting, and points to the difference between the stratification of ashes in an open building, and of mud derived from the same in the interior of edifices and cellars. Nor ought we to call the allegation in question, because it could not be substantiated at the time of the controversy, after the matter had been all removed; although Lippi took advantage of this removal, and met the argument of his antagonists by requiring them to prove the fact.

Pompeii not destroyed by lava.—There is decisive evidence that no stream of lava has ever reached Pompeii since it was first built, although the foundations of the town stand upon the old leucitic lava of Somma; several streams of which, with tuff interposed, have been cut through in excavations. At Herculaneum the case is different, although the substance which fills the interior of the houses and the vaults must have been introduced in a state of mud, like that found in similar situations in Pompeii; yet the superincumbent mass differs wholly in composition and thickness. Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more exposed to be covered, not only by showers of ashes, but by alluviums and streams of lava. Accordingly, masses of both have accumulated on each other above the city, to a depth of nowhere less than 70, and in many places of 112 feet.*

* Hamilton, Observ. on Mount Vesuvius, p. 94. London, 1774.

The tuff which envelopes the buildings consists of comminuted volcanic ashes, mixed with pumice. A mask imbedded in this matrix has left a cast, the sharpness of which was compared by Hamilton to those in plaster of Paris; nor was the mask in the least degree scorched, as if it had been imbedded in heated matter. This tuff is porous; and, when first excavated, is soft and easily worked, but acquires a considerable degree of induration on exposure to the air. Above this lowest stratum is placed, according to Hamilton, "the matter of six eruptions," each separated from the other by veins of good soil. In these soils Lippi states that he collected a considerable number of land shells—an observation which is no doubt correct; for many snails burrow in soft soils, and some Italian species descend, when they hybernate, to the depth of five feet and more from the surface. Della Torre also informs us that there is in one part of this superimposed mass a bed of true siliceous lava (*lava di pietra dura*); and as no such current is believed to have flowed till near 1000 years after the destruction of Herculaneum, we must conclude, that the origin of a large part of the covering of Herculaneum was long subsequent to the first inhumation of the place. That city, as well as Pompeii, was a seaport. Herculaneum is still very near the shore, but a tract of land, a mile in length, intervenes between the borders of the Bay of Naples and Pompeii. In both cases the gain of land is due to the filling up of the bed of the sea with volcanic matter, and not to elevation by earthquakes, for there has been no change in the relative level of land and sea. Pompeii stood on a slight eminence composed of the lavas of the ancient Vesuvius, and flights of steps led down to the water's edge. The lowermost of these steps are said to be still on an exact level with the sea.

Condition and contents of the buried cities.—After these observations on the nature of the strata enveloping and surrounding the cities, we may proceed to consider their internal condition and contents, so far at least as they offer facts of geological interest. Notwithstanding the much greater depth at which Herculaneum was buried, it was discovered before Pompeii, by the accidental circumstance of a well being sunk, in 1713, which came right down upon the theatre, where the statues of Hercules and Cleopatra were soon found. Whether this city or Pompeii, both of them founded by Greek colonies, was the most considerable, is not yet determined; but both are mentioned by ancient authors as among the seven most flourishing cities in Campania. The walls of Pompeii were three miles in circumference; but we have, as yet, no certain knowledge of the dimensions of Herculaneum. In the latter place the theatre alone is open for inspection; the Forum, Temple of Jupiter, and other buildings, having been filled up with rubbish as the workmen proceeded, owing to the difficulty of removing it from so great a depth below ground. Even the theatre is only seen by torchlight, and the most interesting information, perhaps, which the geologist obtains there, is the continual formation of stalactite in the galleries cut through the tuff; for there is a constant percolation of water charged with carbonate of lime mixed with a small portion of magnesia. Such mineral waters must, in the course of time, create great changes in many rocks, especially in lavas, the pores of which they may fill with calcareous spar, so as to convert them into amygdaloids. Some geologists, therefore, are unreasonable when they expect volcanic rocks of remote eras should accord precisely with those of modern date; since it is obvious that many of those produced in our own time will not long retain the same aspect and internal composition.

Both at Herculaneum and Pompeii, temples have been found with inscriptions commemorating the rebuilding of the edifices after they had been thrown down by an earthquake.* This earthquake happened in the reign of Nero, sixteen years before the cities were overwhelmed. In Pompeii, one-fourth of which is now laid open to the day, both the public and private buildings bear testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open. Columns are lying on the ground only half hewn from huge blocks of travertin, and the temple for which they were designed is seen half repaired. In some few places the pavement had sunk in, but in general it was undisturbed, consisting of large irregular flags of lava joined neatly together, in which the carriage-wheels have often worn ruts an inch and a-half deep. In the wider streets, the ruts are numerous and irregular; in the narrower, there are only two, one on each side, which are very conspicuous. It is impossible not to look with some interest even on these ruts, which were worn by chariot-wheels more than seventeen centuries ago; and, independently of their antiquity, it is remarkable to see such deep incisions so continuous in a stone of great hardness. We observe nothing of the kind in the oldest pavements of modern cities.

Small number of skeletons.—A very small number of skeletons have been discovered in either city; and it is clear that most of the inhabitants not only found time to escape, but also to carry with them the principal part of their valuable effects. In the barracks at Pompeii were the skeletons of two soldiers chained to the stocks, and in the vaults of a country-house in the suburbs were the skeletons of seventeen persons, who appear to have fled there to escape from the shower of ashes. They were found inclosed in an indurated tuff, and in this matrix was preserved a perfect cast of a woman, perhaps the mistress of the house, with an infant in her arms. Although her form was imprinted on the rock, nothing but the bones remained. To these a chain of gold was suspended, and on the fingers of the skeleton were rings with jewels. Against the sides of the same vault was ranged a long line of earthen amphoræ.

The writings scribbled by the soldiers on the walls of their barracks,

* Swinburne and Lalande. Paderni, Phil. Trans., vol. l. p. 619. 1758.

and the names of the owners of each house written over the doors, are still perfectly legible. The colours of fresco paintings on the stuccoed walls in the interior of buildings are almost as vivid as if they were just finished. There are public fountains decorated with shells laid out in patterns, in the same fashion as those now seen in the town of Naples; and in the room of a painter, who was perhaps a naturalist, a large collection of shells was found, comprising a great variety of Mediterranean species, in as good a state of preservation as if they had remained for the same number of years in a museum. A comparison of these remains with those found so generally in a fossil state, would not assist us in obtaining the least insight into the time required to produce a certain degree of decomposition or mineralization; for, although under favourable circumstances, much greater alteration might doubtless have been brought about in a shorter period, yet the example before us shows that an inhumation of seventeen centuries may sometimes effect nothing towards the reduction of shells to the state in which fossils are usually found.

The wooden beams in the houses at Herculaneum are black on the exterior, but when cleft open they appear to be almost in the state of ordinary wood, and the progress made by the whole mass towards the state of lignite is scarcely appreciable. Some animal and vegetable substances of more perishable kinds have of course suffered much change and decay, yet the state of conservation of these is truly remarkable. Fishing-nets are very abundant in both cities, often quite entire; and their number at Pompeii is the more interesting from the sea being now, as we stated, a mile distant. Linen has been found at Herculaneum, with the texture well defined; and in a fruiterer's shop in that city were discovered vessels full of almonds, chestnuts, walnuts, and fruit of the "carubiere," all distinctly recognisable from their shape. A loaf, also, still retaining its form, was found in a baker's shop, with his name stamped upon it. On the counter of an apothecary was a box of pills converted into a fine earthy substance; and by the side of it a small cylindrical roll, evidently prepared to be cut into pills. By the side of these was a jar containing medicinal herbs. In 1827, moist olives were found in a square glass case, and "caviare," or roe of a fish, in a state of wonderful preservation. An examination of these curious condiments has been published by Covelli, of Naples, and they are preserved hermetically sealed in the museum there.*

Papyri.—There is a marked difference in the condition and appearance of the animal and vegetable substances found in Pompeii and Herculaneum; those of Pompeii being penetrated by a gray pulverulent tuff, those in Herculaneum seeming to have been first enveloped by a paste which consolidated round them, and then allowed them to become slowly carbonized. Some of the rolls of papyrus at Pompeii still retain their

* Mr. Forbes, Edin. Journ. of Sci., No. xix. p. 130. Jan. 1829.

form; but the writing, and indeed almost all the vegetable matter, appear to have vanished, and to have been replaced by volcanic tuff somewhat pulverulent. At Herculaneum the earthy matter has scarcely ever penetrated; and the vegetable substance of the papyrus has become a thin friable black matter, almost resembling in appearance the tinder which remains when stiff paper has been burnt, in which the letters may still be sometimes traced. The small bundles of papyri, composed of five or six rolls tied up together, had sometimes lain horizontally, and were pressed in that direction, but sometimes they had been placed in a vertical position. Small tickets were attached to each bundle, on which the title of the work was inscribed. In one case only have the sheets been found with writing on both sides of the pages. So numerous are the obliterations and corrections, that many must have been original manuscripts. The variety of hand-writings is quite extraordinary: nearly all are written in Greek, but there are a few in Latin. They were almost all found in a suburban villa, in the library of one private individual; and the titles of four hundred of those least injured, which have been read, are found to be unimportant works, but all entirely new, chiefly relating to music, rhetoric, and cookery. There are two volumes of Epicurus "On Nature," and the others are mostly by writers of the same school, only one fragment having been discovered, by an opponent of the Epicurean system, Chrysippus.*

Probability of future discoveries of MSS.—In the opinion of some antiquaries, not one hundredth part of the city has yet been explored; and the quarters hitherto cleared out, at a great expense, are those where there was the least probability of discovering manuscripts. As Italy could already boast her splendid Roman amphitheatres and Greek temples, it was a matter of secondary interest to add to their number those in the dark and dripping galleries of Herculaneum; and having so many of the masterpieces of ancient art, we could have dispensed with the inferior busts and statues which could alone have been expected to reward our researches in the ruins of a provincial town. But from the moment that it was ascertained that rolls of papyrus preserved in this city could still be deciphered, every exertion ought to have been steadily and exclusively directed towards the discovery of other libraries. Private dwellings should have been searched, before so much labour and expense were consumed in examining public edifices. A small portion of that zeal and enlightened spirit which prompted the late French and Tuscan expedition to Egypt might, long ere this, in a country nearer home, have snatched from oblivion some of the lost works of the Augustan age, or of eminent

* In one of the manuscripts which was in the hands of the interpreters when I visited the museum, the author indulges in the speculation that all the Homeric personages were allegorical—that Agamemnon was the ether, Achilles the sun, Helen the earth, Paris the air, Hector the moon, &c.

Greek historians and philosophers. A single roll of papyrus might have disclosed more matter of intense interest than all that was ever written in hieroglyphics.*

Stabiæ.—Besides the cities already mentioned, Stabiæ, a small town about six miles from Vesuvius, and near the site of the modern Castel-a-Mare (see Map of Volcanic District of Naples, facing p. 304,) was overwhelmed during the eruption of 79. Pliny mentions that, when his uncle was there, he was obliged to make his escape, so great was the quantity of falling stones and ashes. In the ruins of this place a few skeletons have been found, buried in volcanic ejections, together with some antiquities of no great value, and rolls of papyrus, which, like those of Pompeii, were illegible.

Torre del Greco overflowed by lava.—Of the towns hitherto mentioned, Herculaneum alone has been overflowed by a stream of melted matter; but this did not, as we have seen, enter or injure the buildings which were previously enveloped or covered over with tuff. But burning torrents have often taken their course through the streets of Torre del Greco, and consumed or inclosed a large portion of the town in solid rock. It seems probable that the destruction of three thousand of its inhabitants, in 1631, which some accounts attribute to boiling water, was principally due to one of those alluvial floods which we before mentioned: but, in 1737, the lava itself flowed through the eastern side of the town, and afterwards reached the sea; and, in 1794, another current, rolling over the western side, filled the streets and houses, and killed more than four hundred persons. The main street is now quarried through this lava, which supplied building stones for new houses erected where others had been annihilated. The church was half buried in a rocky mass, but the upper portion served as the foundation of a new edifice.

The number of the population at present is estimated at fifteen thousand; and a satisfactory answer may readily be returned to those who inquire how the inhabitants can be so "inattentive to the voice of time and the warnings of nature,"† as to rebuild their dwellings on a spot so often devastated. No neighbouring site unoccupied by a town, or which would not be equally insecure, combines the same advantages of proximity to the capital, to the sea, and to the rich lands on the flanks of Vesuvius. If the present population were exiled, they would immediately be

* During my stay at Naples, in 1828, the Neapolitan government, after having discontinued operations for many years, cleared out a small portion of Herculaneum, near the sea, where the covering was least thick. After this expense had been incurred, it was discovered that the whole of the ground had been previously examined, near a century before, by the French Prince d'Elbœuf, who had removed every thing of value! Such is the want of system with which operations have always been, and still are, carried on here, that we may expect similar blunders to be made continually.

† Sir H. Davy, Consolations in Travel, p. 66.

replaced by another, for the same reason that the Maremma of Tuscany and the Campagna di Roma will never be depopulated, although the malaria fever commits more havoc in a few years than the Vesuvian lavas in as many centuries. The district around Naples supplies one, amongst innumerable examples, that those regions where the surface is most frequently renewed, and where the renovation is accompanied, at different intervals of time, by partial destruction of animal and vegetable life, may nevertheless be amongst the most habitable and delightful on our globe.

I have already made a similar remark when speaking of tracts where aqueous causes are now most active; and the observation applies as well to parts of the surface which are the abode of aquatic animals, as to those which support terrestrial species. The sloping sides of Vesuvius give nourishment to a vigorous and healthy population of about eighty thousand souls; and the surrounding hills and plains, together with several of the adjoining isles, owe the fertility of their soil to matter ejected by prior eruptions. Had the fundamental limestone of the Apennines remained uncovered throughout the whole area, the country could not have sustained a twentieth part of its present inhabitants. This will be apparent to every geologist who has marked the change in the agricultural character of the soil the moment he has passed the utmost boundary of the volcanic ejections, as when, for example, at the distance of about seven miles from Vesuvius, he leaves the plain and ascends the declivity of the Sorrentine Hills.

Concluding remarks.—Yet, favoured as this region has been by Nature from time immemorial, the signs of the changes imprinted on it during the period that it has served as the habitation of man, may appear in after-ages to indicate a series of unparalleled disasters. Let us suppose that at some future time the Mediterranean should form a gulf of the great ocean, and that the tidal current should encroach on the shores of Campania, as it now advances upon the eastern coast of England; the geologist will then behold the towns already buried, and many more which will evidently be entombed hereafter, laid open in the steep cliffs, where he will discover buildings superimposed above each other, with thick intervening strata of tuff or lava—some unscathed by fire, like those of Herculaneum and Pompeii; others half melted down, as in Torre del Greco; and many shattered and thrown about in strange confusion, as in Tripergola. Among the ruins will be seen skeletons of men, and impressions of the human form stamped in solid rocks. Nor will the signs of earthquakes be wanting. The pavement of part of the Domitian Way, and the Temple of the Nymphs, submerged at high tide, will be uncovered at low water, the columns remaining erect and uninjured. Other temples which had once sunk down, like that of Serapis, will be found to have been upraised again by subsequent movements. If they who study these phenomena, and speculate on their causes, assume that there were periods when the laws of Nature differed from those established in their own time, they will scarcely hesitate to refer the wonderful monuments in question to those primeval ages. When they consider the numerous proofs of reiterated catastrophes to which the region was subject, they may, perhaps, commiserate the unhappy fate of beings condemned to inhabit a planet during its nascent and chaotic state, and feel grateful that their favoured race has escaped such scenes of anarchy and misrule.

Yet what was the real condition of Campania during those years of dire convulsion? "A climate where heaven's breath smells sweet and wooingly—a vigorous and luxuriant nature unparalleled in its productions—a coast which was once the fairy land of poets, and the favourite retreat of great men. Even the tyrants of the creation loved this alluring region, spared it, adorned it, lived in it, died in it."* The inhabitants, indeed, have enjoyed no immunity from the calamities which are the lot of mankind; but the principal evils which they have suffered must be attributed to moral, not to physical, causes—to disastrous events over which man might have exercised a control, rather than to the inevitable catastrophes which result from subterranean agency. When Spartacus encamped his army of 10,000 gladiators in the old extinct crater of Vesuvius, the volcano was more justly a subject of terror to Campania, than it has ever been since the rekindling of its fires.

CHAPTER XII.

ETNA—SKAPTAR JOKUL—JORULLO.

External physiognomy of Etna—Lateral cones—Their successive obliteration—Early eruptions of Etna—Monti Rossi in 1669—Great Fissure of S. Lio—Towns overflowed by lava—Part of Catania destroyed (p. 336.)—Mode of advance of a current of lava—Excavation of a church under lava—Subterranean caverns—Linear direction of cones formed in 1811 and 1819—Flood produced in 1755 by the melting of snow during an eruption—A glacier covered by lava on Etna—Volcanic eruptions in Iceland (p. 341.)—New island thrown up in 1783—Lava currents of Skaptár Jokul in same year—Their immense volume—Eruption of Jorullo in Mexico (p. 345.)—Humboldt's Theory of the convexity of the Plain of Malpais.

External physiognomy of the cone.—Having entered into a detailed historical account of the changes in the volcanic district round Naples, I

* Forsyth's Italy, vol. ii.

shall allude in a more cursory manner to some of the circumstances of principal interest in the history of other volcanic mountains. After Vesuvius, our most authentic records relate to Etna, which rises near the sea in solitary grandeur to the height of nearly 11,000 feet,* the mass being chiefly composed of volcanic matter ejected above the surface of the water. The base of the cone is almost circular, and eighty-seven English miles in circumference; but if we include the whole district over which its lavas extend, the circuit is probably twice that extent.

Divided into three regions.—The cone is divided by nature into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The first of these, comprising the delightful country around the skirts of the mountain, is well cultivated, thickly inhabited, and covered with olives, vines, corn, fruit trees, and aromatic herbs. Higher up, the woody region encircles the mountain—an extensive forest, six or seven miles in width, affording pasturage for numerous flocks. The trees are of various species, the chestnut, oak, and pine being most luxuriant; while in some tracts are groves of cork and beech. Above the forest is the desert region, a waste of black lava and scoriæ; where, on a kind of plain, rises the cone to the height of about 1100 feet, from which sulphureous vapours are continually evolved. The most grand and original feature in the physiognomy of Etna is the multitude of minor cones which are distributed over its flanks, and which are most abundant in the woody region. These, although they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain, would, nevertheless, be deemed hills of considerable altitude in almost any other region.

Cones produced by lateral eruptions.—Without enumerating numerous monticules of ashes thrown out at different points, there are about eighty of these secondary volcanos, of considerable dimensions; fifty-two on the west and north, and twenty-seven on the east side of Etna. One of the largest, called Monte Minardo, near Bronte, is upwards of 700 feet in height, and a double hill near Nicolosi, called Monti Rossi, formed in 1669, is 450 feet high, and the base two miles in circumference: so that it somewhat exceeds in size Monte Nuovo, before described. Yet it ranks only as a cone of the second magnitude, amongst those produced by the lateral eruptions of Etna. On looking down from the lower bor-

* In 1815, Captain Smyth ascertained, trigonometrically, that the height of Etna was 10,874 feet. The Catanians, disappointed that their mountain had lost nearly 2000 feet of the height assigned to it by Recupero, refused to acquiesce in the decision. Afterwards, in 1824, Sir J. Herschel, not being aware of Captain Smyth's conclusions, determined, by careful barometrical measurement, that the height was 10,872½ feet. This singular agreement of results so differently obtained was spoken of by Herschel as "a happy accident;" but Dr. Wollaston remarked that "it was one of those accidents which would not have happened to two fools."

ders of the desert region, these volcanos present us with one of the most delightful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which is generally broken down. There are, indeed, few objects in nature more picturesque than a wooded volcanic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines; while those at a lower elevation are adorned with chestnuts, oaks, beech, and holm.

Successive obliteration of these cones.—The history of the eruptions of Etna, imperfect and interrupted as it is, affords, nevertheless, a full insight into the manner in which the whole mountain has successively attained its present magnitude and internal structure. The principal cone has more than once fallen in and been reproduced. In 1444 it was 320 feet high, and fell in after the earthquakes of 1537. In the year 1693, when a violent earthquake shook the whole of Sicily and killed 60,000 persons, the cone lost so much of its height, says Boccone, that it could not be seen from several places in Valdemone, from which it was before visible. The greater number of eruptions happen either from the great crater, or from lateral openings in the desert region. When hills are thrown up in the middle zone, and project beyond the general level, they gradually lose their height during subsequent eruptions; for when lava runs down from the upper parts of the mountain, and encounters any of these hills, the stream is divided, and flows round them so as to elevate the gently sloping grounds from which they rise. In this manner a deduction is often made at once of twenty or thirty feet, or even more, from their height. Thus, one of the minor cones, called Monte Peluso, was diminished in altitude by a great lava stream which encircled it in 1444; and another current has recently taken the same course—yet this hill still remains four or five-hundred feet high.

There is a cone called Monte Nucilla, near Nicolosi, round the base of which several successive currents have flowed, and showers of ashes have fallen, since the time of history, till at last, during an eruption in 1536, the surrounding plain was so raised, that the top of the cone alone was left projecting above the general level. Monte Nero, situated above the Grotta dell' Capre, was in 1766 almost submerged by a current; and Monte Capreolo afforded, in the year 1669, a curious example of one of the last stages of obliteration: for a lava stream, descending on a high ridge which had been built up by the continued superposition of successive lavas, flowed directly into the crater, and nearly filled it. The lava, therefore, of each new lateral cone tends to detract from the relative height of lower cones above their base; so that the flanks of Etna, sloping with a gentle inclination, envelope in succession a great multitude of minor volcanos, while new ones spring up from time to time; and this has given to the older parts of the mountain, as seen in some sections, 2000 or 3000 feet perpendicular, a complex and highly interesting internal structure.

Early eruptions of Etna.—Etna appears to have been in activity from the earliest times of tradition; for Diodorus Siculus mentions an eruption which caused a district to be deserted by the Sicani before the Trojan war. Thucydides informs us, that in the sixth year of the Peloponnesian war, or in the spring of the year 425 B.C., a lava stream ravaged the environs of Catania, and this, he says, was the third eruption which had happened in Sicily since the colonization of that island by the Greeks.* The second of the three eruptions alluded to by the historian took place in the year 475 B.C., and was that so poetically described by Pindar, two years afterwards, in his first Pythian ode:—

κιων
Δ' ουρανια συνεχει
Νιφοεσσ' Αἰτνα, πανετες
Χιονος ὀξειας τιθηνα·

In these and the seven verses which follow, a graphic description is given of Etna, such as it appeared five centuries before the Christian era, and such as it has been seen when in eruption in modern times. The poet is only making a passing allusion to the Sicilian volcano, as the mountain under which Typhœus lay buried, yet by a few touches of his master hand every striking feature of the scene has been faithfully portrayed. We are told of "the snowy Etna, the pillar of heaven,—the nurse of everlasting frost, in whose deep caverns lie concealed the fountains of unapproachable fire—a stream of eddying smoke by day—a bright and ruddy flame by night; and burning rocks rolled down with loud uproar into the sea."

Eruption of 1669—*Monti Rossi formed.*—The great eruption which happened in the year 1669 is the first which claims particular attention. An earthquake had levelled to the ground all the houses in Nicolosi, a town situated near the lower margin of the woody region, about twenty miles from the summit of Etna, and ten from the sea at Catania. Two gulfs then opened near that town, from whence sand and scoriæ were thrown up in such quantity, that, in the course of three or four months, a double cone was formed, called Monti Rossi, about 450 feet high. But the most extraordinary phenomenon occurred at the commencement of the convulsion in the plain of S. Lio. A fissure six feet broad, and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was

* Book iii., at the end.

Fig. 25.

Minor cones on the flanks of Etna.

1. Monti Rossi, near Nicolosi, formed in 1669.
2. Vampeluso ?*

from north to south, and its length twelve miles. It emitted a most vivid light. Five other parallel fissures of considerable length afterwards opened one after the other, and emitted smoke, and gave out bellowing sounds which were heard at the distance of forty miles. This case seems to present the geologist with an illustration of the manner in which those continuous dikes of vertical porphyry were formed which are seen to traverse some of the older lavas of Etna; for the light emitted from the great rent of S. Lio appears to indicate that the fissure was filled to a certain height with incandescent lava probably to the height of an orifice not far distant from Monti Rossi, which at that time opened and poured out a lava current. When the melted matter in such a rent has cooled, it must become a solid wall or dike, intersecting the older rocks of which the mountain is composed.

The lava current above alluded to soon reached in its course a minor cone called Mompiliere, at the base of which it entered a subterranean grotto, communicating with a suite of those caverns which are so common in the lavas of Etna. Here it appears to have melted down some of the vaulted foundations of the hill, so that the whole of that cone became slightly depressed and traversed by numerous open fissures.

Part of Catania destroyed.—The lava, after overflowing fourteen towns and villages, some having a population of between 3000 and 4000 inhabitants, arrived at length at the walls of Catania. These had been purposely raised to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was sixty feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. The

* The hill which I have here introduced was called by my guide Vampolara, but the name given in the text is the nearest to this which I find in Gemmellaro's Catalogue of Minor Cones.

wall, however, was not thrown down, but was discovered long afterwards, by excavations made in the rock by the Prince of Biscari; so that the traveller may now see the solid lava curling over the top of the rampart as if still in the very act of falling.

This great current had performed a course of fifteen miles before it entered the sea, where it was still six hundred yards broad and forty feet deep. It covered some territories in the environs of Catania, which had never before been visited by the lavas of Etna. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava streams, was by the occasional fissuring of the solid walls. A gentleman of Catania, named Pappalardo, desiring to secure the city from the approach of the threatening torrent, went out with a party of fifty men whom he had dressed in skins to protect them from the heat, and armed with iron crows and hooks. They broke open one of the solid walls which flanked the current near Belpasso, and immediately forth issued a rivulet of melted matter, which took the direction of Essentially Paternò; but the inhabitants of that town, being alarmed for their safety, took up arms and put a stop to farther operations.*

As another illustration of the solidity of the walls of an advancing lava stream, I may mention an adventure related by Recupero, who, 1766, had ascended a small hill formed of ancient volcanic matter, to behold the slow and gradual approach of a fiery current, two miles and a-half broad; when suddenly two small threads of liquid matter issuing from a crevice detached themselves from the main stream, and ran rapidly towards the hill. He and his guide had just time to escape, when they saw the hill, which was fifty feet in height, surrounded, and in a quarter of an hour melted down into the burning mass, so as to flow on with it.

But it must not be supposed that this complete fusion of rocky matter coming in contact with lava is of universal, or even common, occurrence. It probably happens when fresh portions of incandescent matter come successively in contact with fusible materials. In many of the dikes which intersect the tuffs and lavas of Etna, there is scarcely any perceptible alteration effected by heat on the edges of the horizontal beds, in contact with the vertical and more crystalline mass. On the site of Mompiliere, one of the towns overflowed in the great eruption above described, an excavation was made in 1704; and by immense labour the workmen reached, at the depth of thirty-five feet, the gate of the principal church, where there were three statutes, held in high veneration. One of these, together with a bell, some money, and other articles, were extracted in a good state of preservation from beneath a great arch formed by the lava. It seems very extraordinary that any works of art, not encased with tuff, like those in Herculaneum, should have escaped fusion in hollow spaces

* Ferrara, Descriz. dell' Etna, p. 108.

left open in this lava current, which was so hot at Catania eight years after it entered the town, that it was impossible to hold the hand in some of the crevices.

Subterranean caverns on Etna.—Mention was made of the entrance of a lava stream into a subterranean grotto, whereby the foundations of a hill were partially undermined. Such underground passages are among the most curious features on Etna, and appear to have been produced by the hardening of the lava, during the escape of great volumes of elastic fluids, which are often discharged for many days in succession, after the crisis of the eruption is over. Near Nicolosi, not far from Monti Rossi, one of these great openings may be seen, called the Fossa della Palomba, 625 feet in circumference at its mouth, and 78 feet deep. After reaching the bottom of this, we enter another dark cavity, and then others in succession, sometimes descending precipices by means of ladders. At length the vaults terminate in a great gallery ninety feet long, and from fifteen to fifty broad, beyond which there is still a passage, never yet explored; so that the extent of these caverns remains unknown.* The walls and roofs of these great vaults are composed of rough and bristling scoriæ, of the most fantastic forms.

Eruption of 1811.—I shall now proceed to offer some observations on the two last eruptions in 1811 and 1819.† It appears, from the relation of Signor Gemmellaro, who witnessed the phenomena, that the great crater in 1811 first testified, by its loud detonations, that the lava had ascended to near the summit of the mountain. A violent shock was then felt, and a stream broke out from the side of the cone, at no great distance from its apex. Shortly after this had ceased to flow, a second stream burst forth at another opening, considerably below the first; then a third still lower, and so on till seven different issues had been thus successively formed, all lying upon the same straight line. It has been supposed that this line was a perpendicular rent in the internal framework of the mountain, which rent was probably not produced at one shock, but prolonged successively downwards, by the lateral pressure and intense heat of the internal column of lava, as it subsided by gradual discharge through each vent.‡

Eruption of 1819.—In 1819 three large mouths or caverns opened very near those which were formed in the eruptions of 1811, from which flames, red-hot cinders, and sand, were thrown up with loud explosions. A few minutes afterwards another mouth opened below, from which flames and smoke issued; and finally a fifth, lower still, whence a torrent of lava flowed, which spread itself with great velocity over the deep and

* Ferrara, Descriz. dell' Etna. Palermo, 1818.

† Since this was written for the first edition of this work, another eruption has occurred. In 1832 the lava flowed down on the west side of Etna to within two miles of Bronte.

‡ Scrope on Volcanos, p. 153.

broad valley called "Val del Bove." This stream flowed two miles in the first twenty-four hours, and nearly as far in the succeeding day and night. The three original mouths at length united into one large crater, and sent forth lava, as did the inferior apertures, so that an enormous torrent poured down the "Val del Bove." When it arrived at a vast and almost perpendicular precipice, at the head of the valley of Calanna, it poured over in a cascade, and, being hardened in its descent, made an inconceivable crash as it was dashed against the bottom. So immense was the column of dust raised by the abrasion of the tufaceous hill over which the hardened mass descended, that the Catanians were in great alarm, supposing a new eruption to have burst out in the woody region, exceeding in violence that near the summit of Etna.

Mode of advance of the lava.—Of the cones thrown up during this eruption, not more than two are of sufficient magnitude to be numbered among those eighty which were before described as adorning the flanks of Etna. The surface of the lava which deluged the "Val del Bove" consists of rocky and *angular blocks*, tossed together in the utmost disorder. Nothing can be more rugged, or more unlike the smooth and even superficies which those who are unacquainted with volcanic countries may have pictured to themselves, in a mass of matter which had consolidated from a liquid state. Mr. Scrope observed this current in the year 1819, slowly advancing down a considerable slope, at the rate of about a yard an hour, nine months after its first emission. The lower stratum being arrested by the resistance of the ground, the upper or central part gradually protruded itself, and being unsupported, fell down. This in its turn was covered by a mass of more liquid lava, which swelled over it from above. The current had all the appearance of a huge heap of rough and large cinders rolling over and over upon itself by the effect of an extremely slow propulsion from behind. The contraction of the crust as it solidified, and the friction of the scoriform cakes against one another, produced a crackling sound. Within the crevices a dull red heat might be seen by night, and vapour issuing in considerable quantity was visible by day.*

Flood produced by the melting of snow by lava.—The erosive and transporting power of running water is rarely exerted on Etna with great force, the rain which falls being immediately imbibed by the porous lavas; so that, vast as is the extent of the mountain, it feeds only a few small rivulets, and these, even, are dry throughout the greater portion of the year. The enormous rounded boulders, therefore, of trachyte and basalt, a line of which can be traced from the sea, from near Giardini, by Mascali, and Zafarana, to the "Val del Bove," would offer a perplexing problem to the geologist, if history had not preserved the memorials of a

* Scrope on Volcanos, p. 102.

tremendous flood which happened in this district in the year 1755. It appears that two streams of lava flowed in that year, on the 2d of March, from the highest crater: they were immediately precipitated upon an enormous mass of snow which then covered the whole mountain, and was extremely deep near the summit. The sudden melting of this frozen mass, by a fiery torrent three miles in length, produced a frightful inundation, which devastated the sides of the mountain for eight miles in length, and afterwards covered the lower flanks of Etna, where they were less steep, together with the plains near the sea, with great deposits of sand, scoriæ, and blocks of lava.

Many absurd stories circulated in Sicily respecting this event, such as that the water was boiling, and that it was vomited from the highest crater; that it was as salt as the sea, and full of marine shells; but these were mere inventions, to which Recupero, although he relates them as tales of the mountaineers, seem to have attached rather too much importance.

Floods of considerable violence have also been produced on Etna by the fall of heavy rains, aided, probably, by the melting of snow. By this cause alone, in 1761, sixty of the inhabitants of Acicatena were killed, and many of their houses swept away.*

Glacier covered by a lava stream.—A remarkable discovery was made on Etna in 1828 of a great mass of ice, preserved for many years, perhaps for centuries, from melting, by the singular accident of a current of red-hot lava having flowed over it. The following are the facts in attestation of a phenomenon which must at first sight appear of so paradoxical a character. The extraordinary heat experienced in the south of Europe, during the summer and autumn of 1828, caused the supplies of snow and ice which had been preserved in the spring of that year, for the use of Catania and the adjoining parts of Sicily and the island of Malta, to fail entirely. Great distress was consequently felt for want of a commodity regarded in those countries as one of the necessaries of life rather than an article of luxury, and the abundance of which contributes in some of the larger cities to the salubrity of the water and the general health of the community. The magistrates of Catania applied to Signor M. Gemmellaro, in the hope that his local knowledge of Etna might enable him to point out some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor were they disappointed; for he had long suspected that a small mass of perennial ice at the foot of the highest cone was part of a large and continuous glacier covered by a lava current. Having procured a large body of workmen, he quarried into this ice, and proved the superposition of the lava for several hundred yards, so as completely to satisfy himself that nothing but the subsequent flowing of

* Ferrara, Descriz. dell' Etna, p. 116.

the lava over the ice could account for the position of the glacier. Unfortunately for the geologist, the ice was so extremely hard, and the excavation so expensive, that there is no probability of the operations being renewed.

On the first of December, 1828, I visited this spot, which is on the south-east side of the cone, and not far above the Casa Inglese; but the freshs now had already nearly filled up the new opening, so that it had only the appearance of the mouth of a grotto. I do not, however, question the accuracy of the conclusion of Signor Gemmellaro, who being well acquainted with all the appearances of drift snow in the fissures and cavities of Etna, had recognised, even before the late excavations, the peculiarity of the position of the ice in this locality. We may suppose that at the commencement of the eruption, a deep mass of drift snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ is well known to be an extremely bad conductor of heat; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches thick over the snow, which effectually prevents the heat of the sun from penetrating.

Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had consolidated, we may then readily conceive that a glacier thus protected, at the height of ten thousand feet above the level of the sea, would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below. When I visited the great crater in the beginning of winter (December 1st, 1828), I found the crevices in the interior encrusted with thick ice, and in some cases hot vapours were actually streaming out between masses of ice and the rugged and steep walls of the crater.

After the discovery of Signor Gemmellaro, it would not be surprising to find in the cones of the Icelandic volcanos, which are covered for the most part with perpetual snow, repeated alternations of lava streams and glaciers.

Volcanic eruptions in Iceland.—With the exception of Etna and Vesuvius, the most complete chronological records of a series of eruptions are those of Iceland; for their history reaches as far back as the ninth century of our era; and, from the beginning of the twelth century, there is clear evidence that during the whole period, there has never been an interval of more than forty, and very rarely one of twenty years, without either an eruption or a great earthquake. So intense is the energy of the volcanic action in this region, that some eruptions of Hecla have lasted six years without ceasing. Earthquakes have often skaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels, and the appearance of new lakes.* New islands have often been thrown up near the coast, some of which still exist, while others have disappeared, either by subsidences or the action of the waves.

In the interval between eruptions, innumerable hot springs afford vent to subterranean heat, and solfataras discharge copious streams of inflammable matter. The volcanos in different parts of this island are observed, like those of the Phlegræan Fields, to be in activity by turns, one vent often serving for a time as a safety-valve to the rest. Many cones are often thrown up in one eruption, and in this case they take a linear direction, running generally from north-east to south-west, from the north-eastern part of the island, where the volcano Krabla lies, to the promontory Reykianas.

New island thrown up in 1783.—The convulsions of the year 1783 appear to have been more tremendous than any recorded in the modern annals of Iceland; and the original Danish narrative of the catastrophe, drawn up in great detail, has since been substantiated by several English travellers, particularly in regard to the prodigious extent of country laid waste, and the volume of lava produced.† About a month previous to the eruption on the main land, a submarine volcano burst forth in the sea in lat. 63° 25′ N., long. 23° 44′ W. at a distance of thirty miles in a south-west direction from Cape Reykianas, and ejected so much pumice, that the ocean was covered with that substance to the distance of 150 miles, and ships were considerably impeded in their course. A new island was thrown up, consisting of high cliffs, within which fire, smoke, and pumice were emitted from two or three different points. This island was claimed by his Danish Majesty, who denominated it Nyöe, or the New Island; but before a year had elapsed, the sea resumed its ancient domain, and nothing was left but a reef of rocks from five to thirty fathoms under water.

Great eruption of Skaptár Jokul.—Earthquakes, which had long been felt in Iceland, became violent on the 11th of June, when Skáptar Jokul, distant nearly 200 miles from Nyöe, threw out a torrent of lava which flowed down into the river Skaptâ, and completely dried it up. The channel of the river was between high rocks, in many places from 400 to 600 feet in depth, and near 200 in breadth. Not only did the lava fill

* Von Hoff, vol. ii. p. 393.

† The first narrative of the eruption was drawn up by Stephensen, then Chief Justice in Iceland, appointed Commissioner by the King of Denmark, for estimating the damage done to the country, that relief might be afforded to the sufferers. Henderson was enabled to correct some of the measurements given by Stevensen, of the depth, width, and length of the lava currents, by reference to the MS. of Mr. Paulson, who visited the tract in 1794, and examined the lava with attention. (Journal of a Residence in Iceland, &c. p. 229.) Some of the principal facts are also corroborated by Dr. Hooker, in his "Tour in Iceland," vol. ii. p. 128.

up this great defile to the brink, but it overflowed the adjacent fields to a considerable extent. The burning flood, on issuing from the confined rocky gorge, was then arrested for some time by a deep lake, which formerly existed in the course of the river, between Skaptardal and Aa, which it entirely filled. The current then advanced again, and reaching some ancient lava full of subterraneous caverns, penetrated and melted down part of it; and in some places, where the stream could not gain vent, it blew up the rock, throwing fragments to the height of more than 150 feet. On the 18th of June, another ejection of liquid lava rushed from the volcano, which flowed down with amazing velocity over the surface of the first stream. By the damming up of the mouths of some of the tributaries of the Skaptâ, many villages were completely overflowed with water, and thus great destruction of property was caused. The lava, after flowing for several days, was precipitated down a tremendous cataract called Stapafoss, where it filled a profound abyss, which that great waterfall had been hollowing out for ages, and, after this, the fiery current again continued its course.

On the 3d of August, fresh floods of lava still pouring from the volcano, a new branch was sent of in a different direction; for the channel of the Skaptâ was now so entirely choked up, and every opening to the west and north so obstructed, that the melted matter was forced to take a new course, so that it ran in a south-east direction, and discharged itself into the bed of the river Hverfisfliot, where a scene of destruction scarcely inferior to the former was occasioned. These Icelandic lavas (like the ancient streams which are met with in Auvergne, and other provinces of Central France) are stated by Stephensen to have accumulated to a prodigious depth in narrow rocky gorges; but when they came to wide alluvial plains, they spread themselves out into broad burning lakes, sometimes from twelve to fifteen miles wide, and one hundred feet deep. When the "fiery lake" which filled up the lower portion of the valley of the Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills from whence the Skaptâ takes its rise. This affords a parallel case to one which can be shown to have happened at a remote era in the volcanic region of the Vivarais in France, where lava issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up the channel of the river Ardèche.

The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont Dor in Auvergne, where more modern lava currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterwards, in 1794, he found columns of smoke still rising from parts of the lava, and several rents filled with hot water.*

Although the population of Iceland was very much scattered, and did not exceed 50,000, no less than twenty villages were destroyed, besides those inundated by water; and more than 9000 human beings perished, together with an immense number of cattle, partly by the depredations of the lava, partly by the noxious vapours which impregnated the air, and, in part, by the famine caused by showers of ashes throughout the island, and the desertion of the coasts by the fish.

Immense volume of the lava.—But the extraordinary volume of the melted matter produced in this eruption deserves the particular attention of the geologist. Of the two branches, which flowed in nearly opposite directions, the greatest was fifty, and the lesser forty miles in length. The extreme breadth which the Skaptâ branch attained in the low countries was from twelve to fifteen miles, that of the other about seven. The ordinary height of both currents was 100 feet, but in narrow defiles it sometimes amounted to 600. A more correct idea will be formed of the dimensions of the two streams, if we consider how striking a feature they would now form in the geology of England, had they been poured out on the bottom of the sea after the deposition, and before the elevation of our secondary and tertiary rocks. The same causes which have excavated valleys through parts of our marine strata, once continuous, might have acted with equal force on the igneous rocks, leaving, at the same time, a sufficient portion undestroyed to enable us to discover their former extent. Let us, then, imagine, the termination of the Skaptâ branch of lava to rest on the escarpment of the inferior and middle oolite, where it commands the vale of Gloucester. The great platform might be 100 feet thick, and from ten to fifteen miles broad, exceeding any which can be found in Central France. We may also suppose great tabular masses to occur at intervals, capping the summit of the Cotswold Hills between Gloucester and Oxford, by Northleach, Burford, and other towns. The wide valley of the Oxford clay would then occasion an interruption for many miles; but the same rocks might recur on the summit of Cumnor and Shotover Hills, and all the other oolitic eminences of that district. On the chalk of Berkshire, extensive plateaus, six or seven miles wide, would again be formed; and, lastly, crowning the highest sands of Highgate and Hampstead, we might behold some remnants of the current 500 or 600 feet in thickness, causing those hills to rival, or even to surpass, in height, Salisbury Craigs and Arthur's Seat.

The distance between the extreme points here indicated would not exceed ninety miles in a direct line; and we might then add, at the distance of nearly two hundred miles from London, along the coast of Dorsetshire

* Henderson's Journal, &c. p. 228.

and Devonshire for example, a great mass of igneous rocks, to represent those of contemporary origin, which were produced beneath the level of the sea, where the island of Nyöe rose up.

Volume of ancient and modern flows of lava compared.—Yet, gigantic as must appear the scale of these modern volcanic operations, we must be content to regard them as perfectly insignificant in comparison to currents of primeval ages, if we embrace the theoretical views of some geologists of great celebrity. Thus, we are informed by Professor Brongniart, in his last work, that "aux époques géognostiques anciennes, tous les phénomènes géologiques se passoient dans des dimensions *centuples* de celles qu'ils présentent aujourd'hui.* Had Skaptár Jokul, therefore, been a volcano of the olden time, it would have poured forth lavas, at a single eruption, a hundred times more voluminous than those which were witnessed by the present generation in 1783. But this can never have been intended by M. Brongniart; for were we to multiply the two currents before described by a hundred, and first assume that their height and breadth remain the same, they would stretch out to the length of 9000 miles, or about half as far again as from the pole to the equator. If, on the other hand, we suppose their length and breadth to remain the same, and multiply their height in an equal proportion, the mean elevation of the volcanic mass becomes ten thousand feet, and its greatest more than double that of the Himalaya mountains. It will immediately be granted that, among the older formations, no igneous rock of such colossal magnitude has yet been met with; nay, it would be most difficult to point out a mass of ancient date distinctly referable to a single eruption, which should even rival in volume the matter poured out from Skaptár Jokul in 1783.

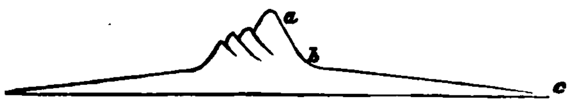
Eruption of Jorullo in 1759.—As another example of the stupendous scale of modern volcanic eruptions, I may mention that of Jorullo in Mexico, in 1759. The great region to which this mountain belongs has already been described. The plain of Malpais forms part of an elevated platform, between 2000 and 3000 feet above the level of the sea, and is bounded by hills composed of basalt, trachyte, and volcanic tuff, clearly indicating that the country had previously, though probably at a remote period, been the theatre of igneous action. From the era of the discovery of the New World to the middle of the last century, the district had remained undisturbed, and the space, now the site of the volcano, which is thirty-six leagues distant from the nearest sea, was occupied by fertile fields of sugar-cane and indigo, and watered by the two brooks Cuitimba and San Pedro. In the month of June, 1759, hollow sounds of an alarming nature were heard, and earthquakes succeeded each other for two months, until, in September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic

* Tableau des Terrains qui composent l'Ecorce du Globe, p. 52. Paris, 1829.

cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm which ran in the direction from N. N. E. to S. S. W. The least of these cones was 300 feet in height; and Jorullo, the central volcano, was elevated 1600 feet above the level of the plain. It sent forth great streams of basaltic lava, containing included fragments of granitic rocks, and its ejections did not cease till the month of February, 1760.

Humboldt visited the country more than forty years after this occurrence, and was informed by the Indians, that when they returned, long after the catastrophe, to the plain, they found the ground uninhabitable from the excessive heat. When he himself visited the place, there appeared, around the base of the cones, and spreading from them, as from a centre, over an extent of four square miles, a mass of matter of a convex form, about 550 feet high at its junction with the cones, and gradually sloping from them in all directions towards the plain. This mass was

Fig. 26.



a, Summit of Jorullo; b, c, inclined plane sloping at an angle of 6° from the base of the cones.

still in a heated state, the temperature in the fissures being on the decrease from year to year, but in 1780 it was still sufficient to light a cigar at the depth of a few inches. On this slightly convex protuberance, the slope of which must form an angle of about 6° with the horizon, were thousands of flattish conical mounds, from six to nine feet high, which, as well as large fissures traversing the plain, acted as fumeroles, giving out clouds of sulphuric acid and hot aqueous vapour. The two small rivers before mentioned disappeared during the eruption, losing themselves below the eastern extremity of the plain, and reappearing as hot springs at its western limit.

Cause of the convexity of the plain of Malpais.—Humboldt attributed the convexity of the plain to inflation from below; supposing the ground, for four square miles in extent, to have risen up in the shape of a bladder to the elevation of 550 feet above the plain in the highest part. But this theory is by no means borne out by the facts described; and it is the more necessary to scrutinize closely the proofs relied on, because the opinion of Humboldt appears to have been received as if founded on direct observation, and has been made the groundwork of other bold and extraordinary theories. Mr. Scrope has suggested that the phenomena may be accounted for far more naturally, by supposing that lava flowing simultaneously from the different orifices, and principally from Jorullo, united into a sort of pool or lake. As they were poured forth on a surface previously flat, they would, if their liquidity was not very great, remain thickest and deepest near their source, and diminish in bulk from thence towards the limits of the space which they covered. Fresh supplies were probably emitted successively during the course of an eruption *which lasted a year;* and some of these, resting on those first emitted, might only spread to a small distance from the foot of the cone, where they would necessarily accumulate to a great height.

The showers, also, of loose and pulverulent matter from the six craters, and principally from Jorullo, would be composed of heavier and more bulky particles near the cones, and would raise the ground at their base, where, mixing with rain, they might have given rise to the stratum of black clay which is described as covering the lava. The small conical mounds (called "hornitos," or little ovens) may resemble those five or six small hillocks which existed in 1823 on the Vesuvian lava, and sent forth columns of vapour, having been produced by the disengagement of elastic fluids heaving up small dome-shaped masses of lava. The fissures mentioned by Humboldt as of frequent occurrence, are such as might naturally accompany the consolidation of a thick bed of lava, contracting as it congeals; and the disappearance of rivers is the usual result of the occupation of the lower part of a valley or plain by lava, of which there are many beautiful examples in the old lava-currents of Auvergne. The heat of the "hornitos" is stated to have diminished from the first; and Mr. Bullock, who visted the spot many years after Humboldt, found the temperature of the hot spring very low,—a fact which seems clearly to indicate the gradual congelation of a subjacent bed of lava, which from its immense thickness may have been enabled to retain its heat for half a century. The reader may be reminded, that when we thus suppose the lava near the volcano to have been, together with the ejected ashes, more than 500 feet in depth, we merely assign a thickness which the current of Skaptár Jokul attained in some places in 1783.

Hollow sound of the plain when struck.—Another argument adduced in support of the theory of inflation from below, was, the hollow sound made by the steps of a horse upon the plain; which, however, proves nothing more than that the materials of which the convex mass is composed are light and porous. The sound called "rimbombo" by the Italians is very commonly returned by *made ground* when struck sharply; and has been observed not only on the sides of Vesuvius and other volcanic cones where there is a cavity below, but in plains such as the Campagna di Roma, composed in a great measure of tuff and porous volcanic rocks. The reverberation, however, may perhaps be assisted by grottos and caverns, for these may be as numerous in the lavas of Jorullo as in many of those of Etna; but their existence would lend no countenance to the hypothesis of a great arched cavity, four square miles in extent, and in the centre 550 feet high.*

* See Scrope on Volcanos, p. 267.

No recent eruptions of Jorullo.—In a former edition I stated that I had been informed by Captain Vetch, that in 1819 a tower at Guadalaxara was thrown down by an earthquake, and that ashes, supposed to have come from Jorullo, fell at the same time at Guanaxuato, a town situated 140 English miles from the volcano. There appears, however, to have been a mistake in the statement; for Mr. Burkart, a German director of mines, who examined Jorullo in 1827, ascertained that there had been no eruption there since Humboldt's visit in 1803. He went to the bottom of the crater, and observed a slight evolution of sulphurous acid vapours, but the "hornitos" had entirely ceased to send forth steam. During the twenty-four years intervening between his visit and that of Humboldt, vegetation had made great progress on the flanks of the new hills, the rich soil of the surrounding country was once more covered with luxuriant crops of sugar-cane and indigo, and there was an abundant growth of natural underwood on all the uncultivated tracts.*

CHAPTER XIII.

Volcanic archipelagos—The Canaries—Eruptions in Teneriffe—Cones thrown up in Lancerote in 1730–36—Pretended distinction between ancient and modern lavas—Recent oolitic travertin in Lancerote—Submarine volcanos (p. 352.)—Graham Island formed in 1831—Von Buch's Theory of "Elevation Craters" considered (p. 357.)—Santorin and its contiguous isles—Isle of Palma, a supposed "Crater of Elevation"—Barren Island in the Bay of Bengal (p. 361.)—Mineral composition of volcanic products (p. 372.)—Speculations respecting igneous rocks produced at great depths by modern volcanic eruptions.

Volcanic archipelagos.—In our chronological sketch of the changes which have happened within the traditionary and historical period in the volcanic district round Naples, we described the renewal of the fires of a central and habitual crater, and the almost entire cessation of a series of irregular eruptions from minor and independent vents. Some volcanic archipelagos offer interesting examples of the converse of this phenomenon; the great habitual vent having become almost sealed up, and eruptions of great violence now proceeding, either from different points in the bed of the ocean, or from adjoining islands, where, as formerly in Ischia,

* Leonhard and Bronn's Neues Jahrbuch, 1835, p. 36.

new cones and craters are formed from time to time. Of this state of things the Canary Islands now afford an example.

Peak of Teneriffe.—The highest crater of the Peak of Teneriffe has been in the state of a solfatara ever since it has been known to Europeans; but several eruptions have taken place from the sides of the mountain; one in the year 1430, which formed a small hill, and another in 1704 and the two following years, accompanied with great earthquakes, when the lava overflowed a town and harbour. Another eruption happened in June, 1798, not far from the summit of the peak. But these lateral emissions of lava, at distant intervals, may be considered as of a subordinate kind, and subsidiary to the great discharge which has taken place in the contiguous isles of Palma and Lancerote; and the occasional activity of the peak may be compared to the irregular eruptions before mentioned, of the Solfatara, of Arso in Ischia, and of Monte Nuovo, which have broken out since the renewal of the Vesuvian fires in 79.

Eruption in Lancerote, 1730 *to* 1736.—The effects of one of these insular eruptions in the Canaries, which happened in Lancerote, between the years 1730 and 1736, were very remarkable; and a detailed description has been published by Von Buch, who had an opportunity, when he visited that island in 1815, of comparing the accounts transmitted to us of the event, with the present state and geological appearances of the country.* On the first of September, 1730, the earth split open on a sudden two leagues from Yaira. In one night a considerable hill of ejected matter was thrown up; and a few days later, another vent opened, and gave out a lava-stream, which overran Chinanfaya and other villages. It flowed first rapidly, like water, but became afterwards heavy and slow, like honey. On the 7th of September an immense rock was protruded from the bottom of the lava, with a noise like thunder, and the stream was forced to change its course from N. to N.W., so that St. Catalina and other villages were overflowed.

Whether this mass was protruded by an earthquake, or was a mass of ancient lava, blown up like that before mentioned in 1783 in Iceland, is not explained.

On the 11th of September more lava flowed out, and covered the village of Maso entirely, and, for the space of eight days, precipitated itself with a horrible roar into the sea. Dead fish floated on the waters in indescribable multitudes, or were thrown dying on the shore. After a brief interval of repose, three new openings broke forth immediately from the site of the consumed St. Catalina, and sent out an enormous quantity of lapilli, sand, and ashes. On the 28th of October, the cattle throughout

* This account was principally derived by Von Buch from the MS. of Don Andrea Lorenzo Curbeto, Curate of Yaira, the point where the eruption began —Uebe einen vulcanischen Ausbruch auf der Insel Lanzerote.

the whole country dropped lifeless to the ground, suffocated by putrid vapours, which condensed and fell down in drops. On the 1st of December a lava stream reached the sea, and formed an island, round which dead fish were strewed.

Number of cones thrown up.—It is unnecessary here to give the details of the overwhelming of other places by fiery torrents, or of a storm which was equally new and terrifying to the inhabitants, as they had never known one in their country before. On the 10th of January, 1731, a high hill was thrown up, which, on the same day, precipitated itself back again into its own crater; fiery brooks of lava flowed from it to the sea. On the 3d of February a new cone arose. Others were thrown up in March, and poured forth lava-streams. Numerous other volcanic cones were subsequently formed in succession, till at last their number amounted to about thirty. In June, 1731, during a renewal of the eruptions, all the banks and shores in the western part of the island were covered with dying fish, of different species, some of which had never before been seen. Smoke and flame arose from the sea, with loud detonations. These dreadful commotions lasted without interruption for *five successive years*, so that a great emigration of the inhabitants became necessary.

Their linear direction.—As to the height of the new cones, Von Buch was assured that the formerly great and flourishing St. Catalina lay buried under hills 400 feet in height; and he observes that the most elevated cone of the series rose 600 feet above its base, and 1378 feet above the sea, and that several others were nearly as high. The new vents were all arranged *in one line*, about two geographical miles long, and in a direction nearly east and west. If we admit the probability of Von Buch's conjecture, that these vents opened along the line of a cleft, it seems necessary to suppose that this subterranean fissure was only prolonged upwards to the surface by degrees, and that the rent was narrow at first, as is usually the case with fissures caused by earthquakes. Lava and elastic fluids might escape from some point on the rent where there was least resistance, till, the first aperture becoming obstructed by ejections and the consolidation of lava, other orifices burst open in succession, along the line of the original fissure. Von Buch found that each crater was lowest on that side on which lava had issued; but some craters were not breached, and were without any lava-streams. In one of these were open fissures, out of which hot vapours rose, which in 1815 raised the thermometer to 145° Fahrenheit, and was probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour; yet they could not be pure steam, for the crevices were encrusted on either side by siliceous sinter (an opal-like hydrate of silica of a white colour), which extended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and how open fissures may be filled up laterally by mineral matter, sublimed from volcanic exhalations. The lavas of this eruption covered nearly a third of the whole island, often forming on slightly inclined planes great horizontal sheets several square leagues in area, resembling very much the basaltic plateaus of Auvergne.

Pretended distinction between ancient and modern lavas.—One of the new lavas was observed to contain masses of olivine of an olive-green colour, resembling those which occur in one of the lavas of the Vivarais. Von Buch supposes the great crystal of olivine to have been derived from a previously existing basalt melted up by the new volcanos; but he gives no sufficient data to bear out such a conjecture. The older rocks of the island consist, in a great measure, of that kind of basaltic lava called dolerite, sometimes columnar, and partly of common basalt and amygdaloid. Some recent lavas assumed, on entering the sea, a prismatic form, and so much resembled the older lavas of the Canaries, that the only geological distinction which Von Buch appears to have been able to draw between them was, that they did not alternate with conglomerates, like the ancient basalts. Some modern writers have endeavoured to discover, in the abundance of these conglomerates, a proof of the dissimilarity of the volcanic action in ancient and modern times; but this character is more probably attributable to the difference between submarine operations and those on the land. All the blocks and imperfectly rounded fragments of lava, transported, during the intervals of eruption, by rivers and torrents, into the adjoining sea, or torn by the continued action of the waves from cliffs which are undermined, must accumulate in stratified breccias and conglomerates, and be covered again and again by other lavas. This is now taking place on the shores of Sicily, between Catania and Trezza, where the sea breaks down and covers the shore with blocks and pebbles of the modern lavas of Etna; and on parts of the coast of Ischia, where numerous currents of trachyte are in like manner undermined in lofty precipices. So often then as an island is raised in a volcanic archipelago by earthquakes from the deep, the fundamental and (relatively to all above) the oldest lavas will often be distinguishable from those formed by subsequent eruptions on dry land, by their alternation with beds of sandstone and fragmentary rocks.

The supposed want of identity then between the volcanic phenomena of different epochs resolves itself into the marked difference between the operations simultaneously in progress, above and below the waters. Such, indeed, is the source, as was before stated in the First Book (chap. v.), of many of our strongest theoretical prejudices in geology. No sooner do we study and endeavour to explain submarine appearances, than we feel, to use a common expression, out of our element; and, unwilling to concede that our extreme ignorance of processes now continually going on can be the cause of our perplexity, we take refuge in a "pre-existent order of nature."

Recent formation of oolitic travertin in Lancerote.—Throughout a considerable part of Lancerote, the old lavas are covered by a thin stratum of limestone, from an inch to two feet in thickness. It is of a hard stalactitic nature, sometimes oolitic, like the Jura limestone, and contains fragments of lava and terrestrial shells, chiefly helices and spiral bulimi. Von Buch imagines, that this remarkable superstratum has been produced by the furious north-west storms, which in winter drive the spray of the sea in clouds over the whole island; from whence calcareous particles may be deposited stalactitically. If this explanation be correct, and it seems highly probable, the fact is interesting, as attesting the quantity of matter held in solution by the sea-water, and ready to precipitate itself in the form of solid rock. At the bottom of such a sea, impregnated, as in the neighbourhood of all active volcanos, with mineral matter in solution, lavas must be converted into calcareous amygdaloids, a form in which the igneous rocks so frequently appear in the older European formations. I may mention that recent crevices in the rocks of Trezza, one of the Cyclopian isles at the foot of Etna, are filled with a kind of travertin, as high as the spray of the sea reaches; and included in this hard veinstone I have seen fragments, and even entire specimens, of recent shells, perhaps thrown up by the waves.

Recent eruption in Lancerote.—From the year 1736 to 1815, when Von Buch visited Lancerote, there had been no eruption; but, in August, 1824, a crater opened near the port or Rescif, and formed, by its ejections, in the space of twenty-four hours, a considerable hill. Violent earthquakes preceded and accompanied this eruption.*

Submarine volcanos.—Although we have every reason to believe that volcanic eruptions as well as earthquakes are common in the bed of the sea, it was not to be expected that many opportunities would occur to scientific observers of witnessing the phenomena. The crews of vessels have sometimes reported that they have seen in different places sulphureous smoke, flame, jets of water, and steam, rising up from the sea, or they have observed the waters greatly discoloured, and in a state of violent agitation, as if boiling. New shoals have also been encountered, or a reef of rocks just emerging above the surface, where previously there was always supposed to have been deep water. On some few occasions the gradual formation of an island by a submarine eruption has been observed, as that of Sabrina, in the year 1811, off St. Michael's, in the Azores. The throwing up of ashes in that case, and the formation of a cone about 300 feet in height, with a crater in the centre, closely resembled the phenomena usually accompanying a volcanic eruption on land. Sabrina was soon washed away by the waves. Previous eruptions in the same part

* Férussac, Bulletin des Sci. Nat., tome v. p. 45. 1825. The volcano was still burning when the account here cited was written.

of the sea were recorded to have happened in 1691 and 1720. The rise of Nyöe, also, a small island off the coast of Iceland, in 1783, has already been alluded to, and another volcanic isle was produced by an eruption near Reikiavig, on the same coast, in June, 1830.*

Graham Island,† 1831.—We have still more recent and minute information respecting the appearance, in 1831, of a new volcanic island in the Mediterranean, between the S.W. coast of Sicily and that projecting part of the African coast where ancient Carthage stood. The site of the island was not any part of the great shoal, or bank, called "Nerita," as was first asserted, but a spot where Captain W. H. Smyth had found, in his survey a few years before, a depth of more than 100 fathoms' water.‡

The position of the island (lat. 37° 8′ 30″ N., long. 12° 42′ 15″ E.) was about thirty miles S.W. of Sciacca in Sicily, and thirty-three miles N. E. of Pantellaria.§ On the 28th of June, about a fortnight before the eruption was visible, Sir Pulteney Malcolm, in passing over the spot in his ship, felt the shocks of an earthquake, as if he had struck on a sand-bank; and the same shocks were felt on the west coast of Sicily, in a direction from S. W. to N. E. About the 10th of July, John Corrao, the captain of a Sicilian vessel, reported that, as he passed near the place, he saw a column of water like a water-spout, sixty feet high, and eight hundred yards in circumference, rising from the sea, and soon afterwards a dense steam in its place, which ascended to the height of 1800 feet. The same Corrao, on his return from Gergenti, on the 18th of July, found a small island, twelve feet high, with a crater in its centre, ejecting volcanic matter, and immense columns of vapour, the sea around being covered with floating cinders and dead fish. The scoriæ were of a chocolate colour, and the water which boiled in the circular basin was of a dingy red. The eruption continued with great violence to the end of the same month, at which time the island was visited by several persons, and, among others, by Captain Swinburne, R. N., and M. Hoffmann, the Prussian geologist. It was then from fifty to ninety feet in height, and three-quarters of a mile in circumference. By the 4th of August it became, according to some accounts, above 200 feet high, and three miles in circumference; after which it began to diminish in size by the action

* Journ. de Géol., tome i.

† In a former edition, I selected the name of Sciacca out of seven which had been proposed; but the Royal and Geographical Societies have now adopted Graham Island, a name given by Captain Senhouse, R. N., the first who succeeded in landing on it. The seven rival names are, Nerita, Ferdinanda, Hotham, Graham, Corrao, Sciacca, Julia. As the isle was visible for only about three months, this is an instance of a wanton multiplication of synonyms, which has scarcely ever been outdone even in the annals of zoology and botany.

‡ Phil. Trans. 1832, p. 255.

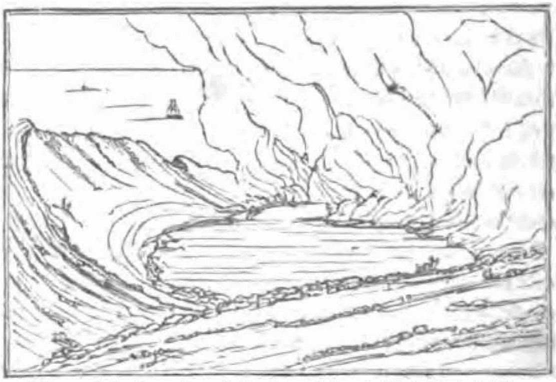
§ Journ. of Roy. Geograph. Soc. 1830–31.

Fig. 27.

Form of the cliffs of Graham Island, as seen from S. S. E., distant one mile, 7th August, 1831.*

of the waves, and was only two miles round on the 25th of August; and on the 3d of September, when it was carefully examined by Captain Wodehouse, only three-fifths of a mile in circumference, its greatest height being then 107 feet. At this time the crater was about 780 feet in circumferenee. On the 29th of September, when it was visited by Mons. C. Prevost, its circumference was reduced to about 700 yards.

Fig. 28.



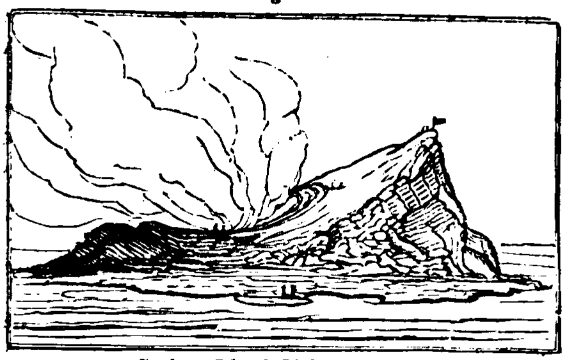
View of the interior of Graham Island, 29th Sept. 1831.

It was composed entirely of incoherent ejected matter, scoriæ, pumice, and lapilli, forming regular strata, some of which are described as having been parallel to the steep inward slope of the crater, while the rest were inclined outwards, like those of Vesuvius.† When the arrangement of the ejected materials has been determined by their falling continually on two steep slopes, that of the external cone and that of the crater, which is always a hollow inverted cone, a transverse section would probably resemble that given in Fig. 30, p. 355. But when I visited Vesuvius in 1828, I saw no beds of scoriæ inclined towards the axis of the cone (see Fig. 24, p. 318). Such may have once existed; but the explosions, or subsidences, or whatever causes produced the great crater of 1822, had possibly destroyed them.

* Phil. Trans., part ii., 1832, reduced from drawings by Captain Wodehouse, R. N.

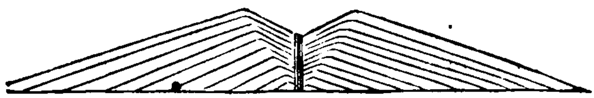
† See memoir by M. C. Prevost, Ann. des Sci. Nat., tom. xxiv.

Fig. 29.



Graham Island, 29*th Sept.* 1831.*

Fig. 30.



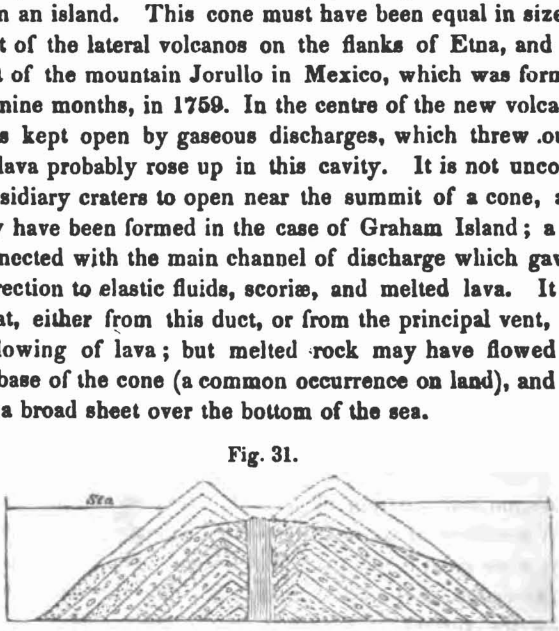
Few of the pieces of stone thrown out from Graham Island exceeded a foot in diameter. Some fragments of dolomitic limestone were intermixed; but these were the only non-volcanic substances. During the month of August, there occurred on the S. W. side of the new island a violent ebullition and agitation of the sea, accompanied by the constant ascension of a column of dense white steam, indicating the existence of a second vent at no great depth from the surface. Towards the close of October, no vestige of the crater remained, and the island was nearly levelled with the surface of the ocean, with the exception, at one point, of a small monticule of sand and scoriæ. It was reported that, at the commencement of the year following (1832), there was a depth of 150 feet where the island had been: but this account was quite erroneous; for in the early part of that year Captain Swinburne found a shoal and discoloured water there, and towards the end of 1833 a dangerous reef existed, of an oval figure, about three-fifths of a mile in extent. In the centre was a black rock, of the diameter of about twenty-six fathoms, from nine to eleven feet under water; and round this rock are banks of black volcanic stones and loose sand. At the distance of sixty fathoms from this central mass, the depth increased rapidly. There was also a second shoal at the distance of 450 feet S. W. of the great reef, with fifteen feet water over it, also composed of rock surrounded by deep sea.

* In the annexed sketch (Fig. 29.), drawn by M. Joinville, who accompanied M. C. Prevost, the beds seem to slope towards the centre of the crater; but I am informed by Mr. Prevost that these lines were not intended by the artist to represent the dip of the beds.

We can scarcely doubt that the rock in the middle of the larger reef is solid lava which rose up in the principal crater, and that the second shoal marks the sight of the submarine eruption observed in August, 1831, to the S.W. of the island.

From the whole of the facts above detailed, it appears that a hill 800 feet or more in height was formed by a submarine volcanic vent, of which the upper part (only about 200 feet high) emerged above the waters, so as to form an island. This cone must have been equal in size to one of the largest of the lateral volcanos on the flanks of Etna, and about half the height of the mountain Jorullo in Mexico, which was formed in the course of nine months, in 1759. In the centre of the new volcano a large cavity was kept open by gaseous discharges, which threw out scoriæ; and fluid lava probably rose up in this cavity. It is not uncommon for small subsidiary craters to open near the summit of a cone, and one of these may have been formed in the case of Graham Island; a vent, perhaps, connected with the main channel of discharge which gave passage in that direction to elastic fluids, scoriæ, and melted lava. It does not appear that, either from this duct, or from the principal vent, there was any overflowing of lava; but melted rock may have flowed from the flanks or base of the cone (a common occurrence on land), and may have spread in a broad sheet over the bottom of the sea.

Fig. 31.



The dotted lines in the annexed figure are an imaginary restoration of the upper part of the cone, now removed by the waves: the strong lines represent the part of the volcano which is still under water. In the centre is a great column, or dike, of solid lava, 200 feet in diameter, supposed to fill the space by which the gaseous fluids rose; and on each side of the dike is a stratified mass of scoriæ and fragmentary lava. The solid nucleus of the reef where the black rock is now found, withstands the movements of the sea; while the surrounding loose tuffs are cut away to a somewhat lower level. In this manner the lava, which was the lowest part of the island, or to speak more correctly, which scarcely ever rose above the level of the sea when the island existed, has now become the highest point in the reef.

No appearances observed, either during the eruption or since the island disappeared, give the least support to the opinion promulgated by some writers, that part of the ancient bed of the sea had been lifted up bodily.

The solid products, says Dr. John Davy, whether they consisted of sand, light cinders, or vesicular lava, differed more in form than in composition. The lava contained augite; and the specific gravity was 2.07 and 2.70. When the light spongy cinder, which floated on the sea, was reduced to fine powder by trituration, and the greater part of the entangled air got rid of, it was found to be of the specific gravity 2.64; and that of some of the sand which fell in the eruption was 2.75;* so that the materials equalled ordinary granites in weight and solidity. The only gas evolved in any considerable quantity was carbonic acid.†

Theory of Elevation Craters.‡—Before quitting the subject of submarine volcanos, it will be necessary to say something of an opinion which has been promulgated by Leopold Von Buch, respecting what he has termed elevation craters (Erhebungscratere.) He has attempted to explain, by a novel hypothesis, the origin of certain large cavities, and the peculiar conical disposition of the masses of volcanic matter which surround them.

According to this view, such cones as the ancient Vesuvius (or Somma), and the greater part even of the modern Vesuvius, as well as the nucleus of Etna, and many other mountains of similar form, have not derived the actual arrangement of their materials from successive eruptions as above described (p. 314); but their mode of origin is thus explained: Beds of pumice, breccia, trachyte, basalt, scoriæ, and other substances were first accumulated in a horizontal position, and then lifted up by the force of pent-up vapours, which burst open a cavity in the middle of the upraised mass. By this elevation the beds were so tilted as to dip outwards, in every direction from the central cavity or crater, at various angles of between twelve and thirty-five degrees. In this way, says Von Buch, Monte Nuovo itself originated, being formed of the same marine pumiceous tuff which occurs at Posilippo and the country round Naples. He supposes that, previously to 1538, this tuff stretched uninterruptedly to the site of Monte Nuovo in nearly horizontal beds, until, at that period, it was upheaved and made to constitute a hill more than 400 feet in height, with a crater of nearly equal depth in the centre. In the unbroken walls surrounding the crater appear the upper ends of the beds of tuff, which are there seen to be inclined every where from within outwards.§

* Phil. Trans. 1832, p. 243. † Ibid. p. 249.

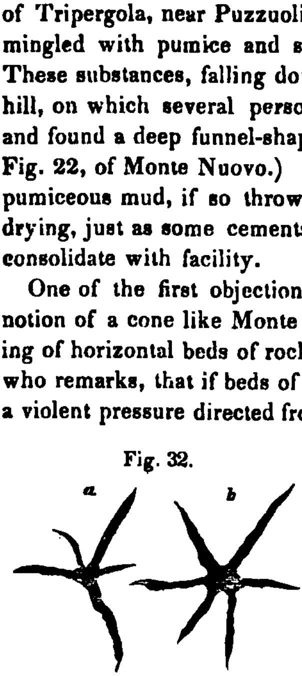
‡ The view which I now give of the theory of elevation craters, although more full, is substantially the same which I published in the first edition, printed in 1829, after I had examined Vesuvius and Etna, and compared them with Mont Dor and the Plomb du Cantal. The late Professor Hoffmann of Berlin set out on his travels through Italy and Sicily in 1829, with a strong expectation of finding every where the clearest illustrations of the "Erhebungscratere;" but when he had explored the Lake Albano, near Rome, as well as Vesuvius, Etna, Stromboli, and the other Lipari Islands, he was compelled reluctantly to abandon the doctrine. (Bulletin de la Soc. Géol. de France, tom. iii. p. 170.) An examination of the same countries led M. C. Prevost, as it had done Mr. Scrope and myself, to similar conclusions.

§ Poggendorf's Annalen, 1836, p. 181.

Before the publication of these opinions it had always been inferred, from the accounts of eye-witnesses, that Monte Nuovo was produced, in 1538, in the same manner as Graham Island in 1831. Those who beheld the eruption relate that a gulf opened on the site of the small town of Tripergola, near Puzzuoli, close to the sea, from which jets of mud, mingled with pumice and stones, were vomited for a day and a night. These substances, falling down on all sides of the vent, caused a conical hill, on which several persons ascended a few days after the eruption, and found a deep funnel-shaped crater on the summit. (Seè p. 309, and Fig. 22, of Monte Nuovo.) There is no difficulty in conceiving that the pumiceous mud, if so thrown out, may have set into a kind of stone on drying, just as some cements, composed of volcanic ashes, are known to consolidate with facility.

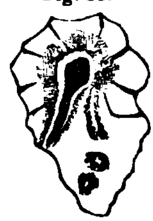
One of the first objections which naturally suggest themselves to the notion of a cone like Monte Nuovo being the effect of the sudden uplifting of horizontal beds of rock, has been well stated by Mons. C. Prevost, who remarks, that if beds of solid and non-elastic materials had yielded to a violent pressure directed from below upwards, we should find not simply a deep empty cavity, but an irregular opening where many rents converged, and these rents would be seen to break through the walls of the crater. They would also be widest at top and diminish downwards. (See Fig. 32. *a. b.*)* But not a single fissure of this kind is observable in the interior of Monte Nuovo, where the walls of the crater are quite continous and entire.

Fig. 32.



Isle of Palma.—As the theory of elevation craters was first invented for the Canary Islands, it will be desirable to give them our first consideration; and when treating of this subject we must not forget how much we are indebted to the talents and zeal of Leopold Von Buch for his faithful description of these islands, as well as for his numerous other works on Geology.

Fig. 33.

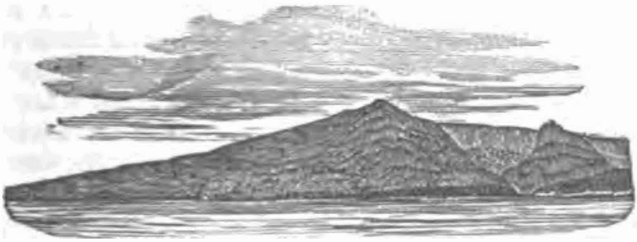


Isle of Palma.

Nearly in the centre of Palma is an immense circular cavity, called the Caldera or basin, which forms the hollow axis of the entire island. A lofty mountain ridge runs round this axis, and presents in all directions, towards the Caldera, a perpendicular precipice of no less than four thousand feet in height, while on the outside the slope is gentle towards the sea. The middle of the Caldera is more than 2000 feet above the level of the ocean; the surrounding borders ("cumbre," or "crest" in Spanish,) are

* Mém. de la Soc Géol. de France, tom. ii. p. 91.

Fig. 34.



View of the Isle of Palma, and of the Caldera in its centre.

of various heights, attaining at one point an elevation of 7234 feet. The diameter of the Caldera is about six miles; and so steep are the cliffs by which it is environed, that there is not a single pathway down the rocks; and the only entrance is by the ravine, or "baranco," which runs from the great circus down to the sea, intersecting all the rocks of which the island is composed. In this section are exposed strata of tuff, alternating with beds of basalt; and below are conglomerates, composed of fragments of granite, quartz, syenite, and other crystalline rocks, some of which appear in one place in situ. Volcanic dikes, or veins, are seen cutting through all these formations in the precipice on each side of the baranco, and these increase in number as we pass up the gorge, and approach nearer to the Caldera. The veins often cross one another, and at length form a perfect net-work. In the cliffs encircling the Caldera itself are various volcanic rocks, traversed by basaltic dikes, most of which are perpendicular, and appear to hold together the more incoherent masses through which they cut. The sloping sides of the island, which has much the appearance of a flattened and hollow cone, are furrowed by numerous minor ravines, in which beds of red and yellow scoriæ are exposed to view. The ravines are deep near the sea, but they terminate before reaching the Caldera.

From this description I find it impossible to draw any other inference than that we have here the remains of a great volcanic mountain, formed by successive eruptions, the first of which burst through granitic rocks. A great cone having, in the course of ages, been built up, the higher parts of it were afterwards destroyed, and the central crater enlarged by gaseous explosions; at the same time that a falling in, or engulfment, of large masses may have taken place. But, according to the theory of "elevation craters," we are called upon to suppose, that a series of horizontal beds of volcanic matter were first accumulated over each other, to the enormous depth of more than 4000 thousand feet, after which the expansive force was directed on a given point with such extraordinary energy, as to lift up bodily the whole mass, so that it rose in some parts to the height of 7000 feet above the sea, while a great void or cavity was formed in the middle. Yet, notwithstanding this prodigious effort of gaseous explosions, concentrated on so small a point, the beds, instead of being shattered, contorted, and thrown into the utmost disorder, have acquired that regular and symmetrical arrangement which characterizes the flanks of the large cone of Etna! Earthquakes, when they act on extensive tracts of country, may certainly elevate and depress them without deranging considerably the relative position of hills, valleys, and ravines. But if the aëriform fluids should break through a mere point, as it were, of the earth's crust, and that, too, where the beds were not composed of soft yielding clay, or incoherent sand, but in great part of solid trachyte and basalt, thousands of feet thick, is it possible to conceive that such masses of rock could be heaved up, so as to attain the height of 7000 feet, or more, without being fissured and fractured in every direction?

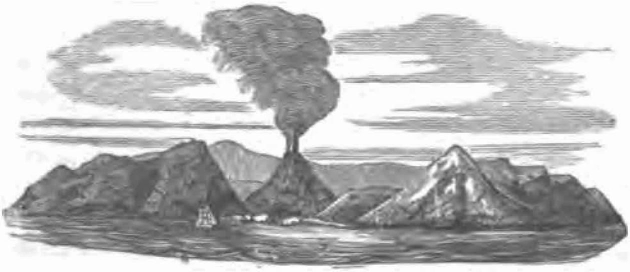
But there is another difficulty which the advocates of "elevation craters" appear to have overlooked. Numerous dikes or veins of igneous rock are observed in the walls of the craters of Palma, Somma, Stromboli, and other volcanic masses. It is agreed on all hands that such dikes were once fissures, at first empty and afterwards filled up with melted matter. It must also be conceded that the fluid was introduced at different periods, for after the cooling and consolidation of some dikes, new rents have occasionally been made into which other lavas have entered and solidified. Now these phenomena imply the successive rise of lava from the interior towards the surface, precisely in the region where the height of the volcanic mountain is greatest, and where, in perfect accordance with the eruption theory, the quantity of igneous rock and tuff are in excess. It cannot be said in reply, that the dikes were all produced at once during the upheaving of the mass, or, in other words, that fissures were both caused and filled at the moment when the uplifting force was exerted, and when the cone and crater were formed; for had this been the case, there would have been a large quantity of melted matter ready to flow down into the crater, which would then have been partially choked up, at the same time that the fissures would have been left partially empty.

Great Canary.—The form of the Great Canary is very analogous to that of Palma, there being here also a caldera and a principal ravine leading out of it, on the south side. The rocks are tuff, conglomerate, basalt, and trachyte. In some of the borders of the island are marls and conglomerates containing *recent* marine shells, from 300 to 400 feet above the level of the sea, and presenting an appearance, says Von Buch, as if the level of the ocean had subsided at successive periods. These are doubtless the effects of *elevation*, and at the base of Etna marine strata are in like manner discoverable; but their occurrence does not prove an upheaving of that kind from which cones and craters would result. It is also stated that between masses of basalt in the Great Canary,* marine shells have been found, 500 or 600 feet above the sea, all of which is what we should now expect to arise on the flanks of Stromboli. For a great number of alternating beds of lava, and deposits containing shells mixed with volcanic sand and scoriæ, may have accumulated on the flanks of that half-submerged cone, and may, one day, be raised up in the same manner as continents and islands have risen from the deep.

Teneriffe.—The Peak of Teneriffe rises out of a valley surrounded by precipitous cliffs, which vary in height from 1000 to 1800 feet, and which are given as an exemplification of the "Erhebungscratere." The Peak stands, says Von Buch, like a tower encircled by its fosse and bastion. The volcanic rocks resemble, in general, those found in the other Canary Islands.

Barren Island.—Barren Island, in the Bay of Bengal, is also proposed as a striking illustration of the Erhebungscratere; and here, it is said, we have the advantage of being able to contrast the ancient crater of elevation with a cone and crater of eruption in its centre. When seen from the ocean, this island presents, on almost all sides, a surface of bare rocks, rising, with a moderate acclivity, towards the interior; but at one point there is a cleft, by which we can penetrate into the centre, and there discover that it is occupied by a great circular basin, filled by the

Fig. 35.



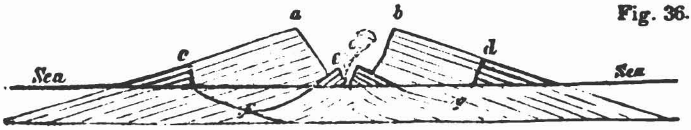
Cone and Crater of Barren Island, in the Bay of Bengal.

waters of the sea, and bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The summit of this cone is 1690 French feet in height, corresponding to that of the circular border which incloses the basin; so that it can be seen from the sea only through the ravine, which precisely resembles the deep gorge of the caldera of the Isle of Palma, and of which an equivalent, more or less decided in its characters, is said to occur in all elevation craters. It is most probable that the exterior inclosure of Barren Island, *c*, *d*, (Fig. 36.)

* See Berthelot and Webb, cited by De Beaumont, Descrip. Géol. de la France, tom. iii. p. 254.

is nothing more than the remains of a truncated cone, *c*, *a*, *b*, *d*, a great portion of which has been carried away, partly by the action of the waves, and partly by explosions which preceded the formation of the new interior cone, *f*, *e*, *g*.

Fig. 36.



Supposed section of Barren Island in the Bay of Bengal.

Santorin.—We may next consider the island of Santorin, in the Grecian Archipelago, as its structure has been frequently appealed to by both parties during the controversy now under consideration.

The three islands of Santorin, Therasia, and Aspronisi surround an almost circular gulf of about two leagues in diameter from south to north, and a league and a-half from east to west. The island of Santorin itself forms more than two-thirds of the circuit, and is composed entirely of volcanic matter, with the exception of its southern part, which rises to three

Fig. 37.

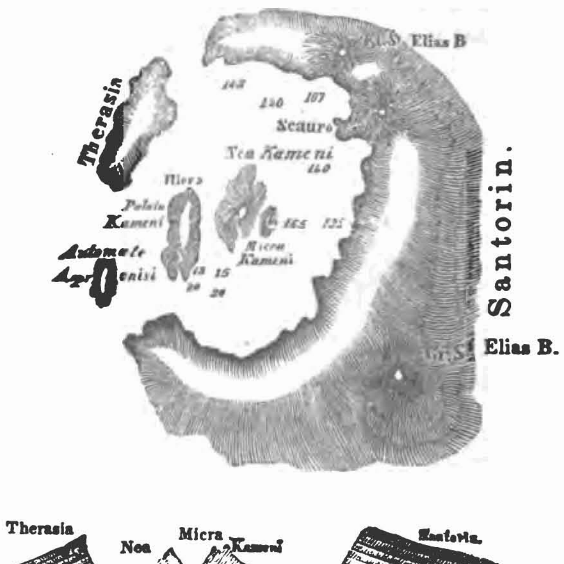


Chart and section of Santorin and the contiguous islands in the Grecian Archipelago.

times the height of the igneous rocks in the island, and is formed of granular limestone and argillaceous schist.* This mountainous part is the original and fundamental nucleus of the isle; and, according to M. Bory

* Virlet. Bull. de la Soc. Géol. de France, tom. iii. p. 103.

de St. Vincent, its strata have the same direction as those of the other isles of the Grecian archipelago, from N. N.W. to S.S.E. Their inclination and fractures have no relation to the position of the newer volcanic rocks, of which the remainder of the group of islands is exclusively composed. The volcanic mass, which must be considered as quite an independent formation, consists of alternating beds of trachytic lava, tuff, and conglomerate, which dip on every side from the centre of the gulf to the circumference. Towards the gulf they present uniformly a high and steep escarpment, the precipices in Santorin rising to the height of more than 800 feet, and plunging at once into a sea from 800 to 1000 feet deep. Each of the islands is capped by an enormous mass of white tufaceous conglomerate, from forty to fifty feet in thickness; which is not pumice, as has often been stated. The beds of lava and tuff, above mentioned, are accumulated in great numbers one upon another, and of unequal thickness; although disposed with great regularity, when viewed as a whole, they are found to be discontinuous, as in Vesuvius, when any particular mass is traced to some distance.

Before discussing the merits of the theory proposed to account for the structure of this volcanic group, it will be desirable to give a brief sketch of its history, so far as it is known. Pliny relates that the separation of Therasia from Thera, or Santorin, took place after a violent earthquake, in the year 233 before the Christian era. From this work, and other authorities, we also learn that the year 196 B.C. gave birth, in the middle of the gulf, to Hiera, or the Sacred Isle, still called Hiera-Nisos, or sometimes Palaia Kameni (Old Burnt Island). There seems to have been no eruption then, but simply an upheaving of solid lava. In the year 19 of our era, Thia (the Divine) made its appearance above the surface of the waters. This small island has no longer a separate existence, having been joined to Hiera, from which it was only 250 paces distant: Hiera itself increased in size in 726 and in 1427. In 1573, the small island of Micra-Kameni appeared, a small cone and crater, 100 feet high, raised by successive ejections.

On the 27th of September, 1650, there was an eruption three or four miles north of Santorin, altogether outside of the gulf, immediately after violent earthquakes. It gave rise to no new islet, but greatly elevated the bottom of the sea on the spot. The eruption lasted three months; many houses on Santorin were destroyed; and the vapours of sulphur and hydrogen killed more than fifty persons, and more than 1000 domesticated animals. A wave fifty feet high broke upon the rocks of the Isle of Nio, about four leagues distant, and advanced 350 yards into the interior of the island of Sikino, which is seven leagues off. The sea also broke upon Santorin, overthrew two churches, and exposed to view a village on each side of the mountain of St. Stephen, both of which must have been overwhelmed by showers of volcanic matter during some former eruption.*

Lastly, in 1707 and 1709, Nea Kameni was produced between Palaia and Micra (old and lesser) Kamenis. This isle was composed originally of two distinct parts; the first which rose was called the White Island—a mass of pumice, extremely porous. Goree the Jesuit, who was then in Santorin, says that the rock "cut like bread," and that, when the inhabitants landed on it, they found a multitude of full-grown fresh oysters adhering to it, which they eat.† This island was afterwards covered, in great part, by the matter ejected from the crater of the second island, produced at the same time, called "Black Island," being composed partly of brown trachyte. This volcano, now named Nea (or New) Kameni, continued in eruption, at intervals, during 1711 and 1712, and formed a cone 330 feet above the level of the sea: there are now, therefore, two channels of direct communication between the atmosphere and volcanic foci beneath the group of Santorin; namely, the craters of New and Little Kameni.

A curious fact is mentioned by M. Virlet, respecting the supposed slow and progressive rise of a solid ridge at the bottom of the sea. Twenty years ago there was a depth of fifteen fathoms of water between the lesser Kameni and the port of Phira in Santorin. In 1830, when MM. Virlet and Bory visited the spot, there was only a depth of between three and four fathoms; and they found that the bottom consisted of a hard rock, probably trachyte, measuring about eight hundred yards from E. to W. and five hundred only from N. to S. Beyond this the sea deepens rapidly on all sides. From these facts, and from information obtained on the spot, M. Virlet infers that the bed of the sea is rising gradually, and that, in all probability, a new island may one day appear without commotion above the surface. He suggests that the solid crust of rock now slowly rising may resemble a cork carried up by the fermentation of the liquor on which it floats.‡

After the explanation before offered§ of the mode in which the semicircular escarpment of Somma originated, it is almost needless to say that I regard the three islands which encircle the gulf of Santorin as nothing more than the ruins of a great volcanic cone, the summit of which, like that of the ancient Vesuvius, or of Barren Island, has been destroyed; and as to the small volcanic islets thrown up since the historical era, in the centre of the gulf, they may be compared to the modern cone, or rather cones, of Vesuvius.

* Virlet, Bull. de la Soc. Géol. de France, tom. iii. p. 103.

† Phil. Trans., No. 332.

‡ See M. Virlet's Memoir, before cited.

§ Ante, p. 318.

Von Buch supposes that a solid dome of trachyte is now rising in the centre of the bay, and that the expansive force from below will, one day, burst an opening, and cause the uplifted rocks to dip on all sides from within outwards.* It would be an unprofitable task to speculate on the mode in which the water may now be shoaling in the centre of the gulf of Santorin, or on the possible forms which the uplifted mass may assume. Undoubtedly the porous mass of white pumice upheaved in 1707 (see p. 364), implies the partial elevation of solid matter, and may be compared perhaps to the solid crust of scoriæ, which is often capable of supporting heavy weights on the surface of lava currents still in motion. Such data are far too scanty and obscure to form a solid foundation for the theory now under discussion.

It is naturally objected by M. Virlet, that if a mass like Santorin, which, including its submarine foundations, must be from 1700 to 2000 feet in thickness, was suddenly and violently heaved up from a horizontal position, we might expect to find the rocks traversed every where with rents which would diverge from the principal centre of movement to the circumference of the circular area. But these rents are wanting, as are all signs of the shattering and dislocation of the mass. At the same time he adduces a fact which must surely prove conclusive against the notion of the island's having been formed in any other mode than that by which an ordinary cone is accumulated. In examining the various currents of lava (the existence of which was unknown to Von Buch, who had not visited Santorin), it was found that the vesicles, or pores which abound in them, are lengthened in the several directions in which they would naturally be drawn out, if the melted matter had flowed towards different points of the compass from the summit of a conical mountain, of which the present islands were the base. The force of this argument will be appreciated by those who are aware that bubbles of confined gas in a fluid in motion assume an oval form, and that the direction of the longer axis coincides always with that of the stream. It is also observed by M. Virlet, that the deep stratum of white tufaceous conglomerate by which all the islands are uniformly covered, may well be supposed to have resulted from heavy showers of ejected matter which fell during that paroxysmal explosion by which the great cone was originally blown up, truncated, and emptied in its interior.

The manner in which the external walls were separated into three distinct islands is easily conceived. The principal breaches are to the N. W., the quarter most exposed to the waves and currents. On this side, the earthquake of 233 B.C., mentioned by Pliny, may have caused a fissure, which allowed the waves and currents to penetrate and sweep away the incoherent tuffs and conglomerates, just as they washed away Graham

* Poggendorf's Annalen, 1836, p. 183.

Island; and if there happened to be little or no lava at certain points, the waves would in such places readily force a passage.*

The dimensions of the Gulf of Santorin, or the Caldera of the Isle of Palma, are not greater than we may suppose to result from the truncation and evacuation of ordinary volcanic cones. We shall afterwards see that Papandayang, formerly one of the loftiest volcanos in Java, lost, in 1772, about four thousand feet of its former height.† During an eruption in 1444, accompanied by a tremendous earthquake, the summit of Etna was destroyed, and an enormous crater was left, from which lava flowed. The segment of that crater may still be seen near the Casa Inglese, and, when complete, it must have measured several miles in diameter. The cone was afterwards repaired; but this might not so easily have happened, had the summit of Etna, like Stromboli or Santorin, been placed in a deep sea; for in that case the vent might have become choked up with strata of sand and conglomerate, swept in by waves and currents; and these obstructions, by augmenting the repressive force, would have increased the violence of subsequent explosions. There is, unquestionably, a much greater probability, when the volcanic vent communicates with the atmosphere, that a channel will be kept open by elastic fluids, whereby currents of lava may escape without resistance, and without causing any violent commotion. Let us suppose the large Etnean crater of 1444 to have been choked up, and again truncated down to the upper margin of the woody region; a circular basin would thus have been formed, thirty Italian miles in circumference, exceeding by five or six miles the circuit of the Gulf of Santorin. Yet we know, by numerous sections, that the strata of trachyte, basalt, and trachytic breccia, would, in that part of the great cone of Etna, dip on all sides off from the centre, at a gentle angle, to every point of the compass, except where irregularities were occasioned, at certain points, by the occurrence of the small buried cones before mentioned. If this gulf were, then, again choked up, and the vent obstructed, so that new explosions of great violence should truncate the cone once more down to the inferior border of the forest zone of Etna, the circumference of the gulf would be fifty Italian miles.‡ Yet even then the ruins of the cone of Etna might form a circular island, entirely composed of volcanic rocks, sloping gently outward on all sides, at a very slight angle; and this island might be between seventy and eighty English miles in its exterior circuit, rivalling Palma in fertility; while the circular bay within might be between forty and fifty miles round.

If a difference in size alone were a sufficient reason for seeking a difference in origin, we should then be called upon to refer the innermost cone of Vesuvius, thrown up in 1828, to a mode of action distinct from

* Virlet, Ibid.

† See chap. xvi.

‡ For the measurements of different parts of the cone of Etna, see Trattato dei Boschi del' Etna, Scuderi, Acti dell' Acad. Gion. de Catan., vol. i.

that by which the larger cone of the year 79 was formed; and the shape and structure of this, again, might be attributed to a series of operations distinct from those to which the outermost cone and escarpment of Somma were due. It is extraordinary that, after the identity of the form and structure of Vesuvius and Somma had been so clearly demonstrated by M. Necker,* one of these cones should actually have been considered by some of the followers of Von Buch as an "Erhebungscratere," and the other as a cone of eruption. (See Fig. 24, p. 318.)

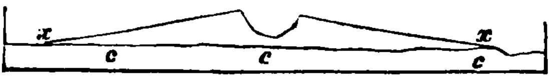
Had there been any foundation for the theory, that violent explosions of gas could exert the power of raising up horizontal strata symmetrically round a central cavity, numerous examples would, ere this, have been adduced of strata *other than volcanic* elevated in this way round some active volcano. But where do we find an instance of inner cones with craters like those of Vesuvius, Santorin, Barren Island, and others, encircled by precipices of rocks exclusively of lacustrine or marine origin, and in which the strata have the quaqua-versal dip, characteristic of all cones of eruption? If such could be pointed out, we might undoubtedly be forced to concede, that the cone and crater-like configuration may be the result of two distinct modes of formation. It is not pretended that, on the whole face of the globe, a single example of this kind can be pointed out. Are we then called upon to believe that, whenever elastic fluids generated in the subterranean regions burst through horizontal strata, so as to upheave them in the peculiar manner before adverted to, they always select, as if from choice, those spots of comparatively insignificant area where a certain quantity of volcanic matter happens to lie; while they carefully avoid purely lacustrine and marine strata, although they often lie immediately contiguous? Why, on the southern borders of the Limagne d'Auvergne, where several eruptions burst through, and elevated the horizontal marls and limestones, did these fresh-water beds never acquire, in any instance, a conical and crateriform disposition? We have no hesitation, therefore, in adhering to the opinion, that all the central cavities of the volcanic mountains alluded to by Von Buch, are simply craters of paroxysmal explosion, as they have been very properly termed by Mr. Scrope. This class of craters, or cup-shaped hollows, have usually been formed where the earth's crust happened to be composed of volcanic matter; but not always. Elastic fluids have sometimes burst through rents in other rocks, and have shattered them for a certain space, and blown their contents into the air. Thus in the volcanic region of the Eifel, explosions, sometimes unaccompanied by the emission of lava, have excavated craters in strata of sandstone and shale; but they have not raised the strata all round the central cavity. The distinctness of these

* Mémoire sur le Mont Somma, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tom. ii. part i. p. 155.

phenomena from those appealed to in corroboration of the "Erhebungs-cratere" will be pointed out in the Fourth Book.*

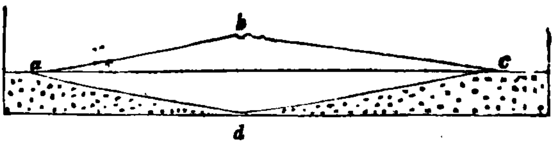
An attempt has been made to adduce the ancient volcanos of Central France, the Mont Dor, and the Plomb du Cantal, as illustrations of elevation craters, but it has been found necessary to resort to a very complicated hypothesis in order to reconcile their form and structure to the conditions required by the elevation theory. M. Prevost had remarked that the thickness of volcanic matter is much more considerable in the centre of these masses than at their circumference, for at the centre there are sections several hundred yards deep of trachyte and turfaceous breccias, while round the borders there are only thin deposits of tuff and basalt covering the fundamental rocks, which in the case of the Mont Dor are granite, in the Cantal tertiary marl and limestone, and granitic schist.† These fundamental rocks are themselves quite exposed at the surface, as at *x* (Fig. 38.), as soon as we recede from the borders of the volcanic region. We cannot, therefore, admit the actual configuration of Mont Dor

Fig. 38.



and the Cantal to have been the effect of a violent upheaval of volcanic materials, previously horizontal, unless we are prepared to suppose that these materials first filled deep basins or hollows of a nearly circular form, of which *a*, *d*, *c* (Fig. 39,) may be taken as a section, and afterwards the

Fig. 39.



elevating force must have been applied precisely at the point where the thickness of igneous rock was greatest, or at *d*, and with such energy as to invert the original position of the cone, and to cause the mass to occupy the space *a*, *b*, *c*, instead of *a*, *d*, *c*.

These consequences were proposed as fatal objections; but Monsieur Elie de Beaumont, while fully admitting them, denies that they invalidate Von Buch's theory. He assumes that in Auvergne, Cantal, and Velay, deep depressions did actually exist just in the spots where the three volcanic mountains of Mont Dor, Cantal, and Mezen now rise. Eruptions took place at scattered points near the margin or on the sides of these depressions, so that trachyte, basalt, pumice, and scoriæ were emitted from

* See Index, "Eifel."

† Mém. de la Soc. Géol. de France, tom. ii. p. 91.

different vents. The fused materials flowed down, and the ejected fragments and scoriæ were washed by the rains, so as to accumulate in greatest thickness towards the central or deepest part of each basin. In this manner the conical or lenticular forms of the future volcanic mountains were first cast as it were in a mould, sunk in granitic or tertiary rocks, until the time arrived when the gaseous power was so directed against the volcanic accumulations, that they were rent and thrust up, and made to present a convexity upwards instead of downwards. During this upheaval the beds acquired their actual dip on every side away from the principal point of elevation. It is not stated whether the concavity *a*, *b*, *c*, (Fig. 39.) which must have been occasioned by the uplifting of the igneous rocks, and their removal to *a*, *b*, *c*, remains at present an empty space, or whether the space has since been occupied by other matter, and if so, by what. Nor is any reason assigned why, in every instance, the lowest point of each basin, whether composed of granite or other rock, should happen to be the point of maximum elevation during a subsequent process of subterranean expansion. We might, perhaps, believe in one fortuitous coincidence of this kind, and grant that the deepest part of a pre-existing basin happened to be the point of least resistance in the whole neighbourhood, or might even imagine that it remained so after it was loaded by the weight of a thousand feet or more of solid basalt and breccia. But how can we suppose that in several, nay, in hundreds of cases, the gaseous explosion should break forth precisely where some original depression was deepest, and where the surface was afterwards loaded with the greatest mass of volcanic matter?

In cones and craters which we have seen produced, or which have been augmented in size by eruptions of lava and scoriæ, we know that the largest and heaviest fragments fall nearest to the principal vent, and that this is one cause of the conical form of the heap. We know also that lava currents are often insufficient in volume or fluidity to extend far from the point where they issue, and hence many currents stop short before approaching the circumference of a large cone. This is another obvious cause of the peculiar shape of volcanic mountains, and the inclined position of their component beds of rock. In direct defiance of such striking analogy, we are told that we must look for the point of eruption, not where lava and scoriæ are now accumulated in the greatest abundance, but anywhere and everywhere rather than at that point!

It has been said that the sheets of trachyte and basalt on the Mont Dor and Cantal are too broad and too thick to have congealed on a slope which formed an angle of more than three degrees with the horizon, and that these ancient igneous rocks are more compact and less cellular than modern lava, and that the bubbles of gas inclosed in them would have been drawn out into more lengthened forms if they had flowed down an inclined plane steeper than that above alluded to. It is also affirmed that modern lava streams, when they run down the sides of a cone, form only a narrow stream or thread of melted matter. In reply I may observe, that the number of accurate observations on the effects of modern eruptions is too scanty to enable a geologist to insist on such points of discordance, although we know enough to show that some of them have been exaggerated. We learn from Mr. Abich, who witnessed the eruption of Vesuvius in 1833 and 1834, that lava consolidated on a very steep slope, and that the beds flowing one over another preserved their parallelism from top to bottom of the cone, without any visible difference of thickness. He denies that they evinced any tendency to run off the cone, and states, as indeed others had stated, that the amount of declivity on which lava is capable of becoming fixed or congealed, depends almost entirely on the degree of its original fluidity, which is exceedingly variable.* Sir W. Hamilton had related that on Vesuvius, in 1779 and 1793, the lava thrown up in jets into the air was still red hot when it fell down again upon the cones, which it invested with one complete body of fire. (See p. 316.) From such showers may result continuous envelopes, if not of lava, at least of solid scoriæ, the half-melted fragments being known to cohere together into one mass, as they cool around the vent. It is also stated that in some eruptions large portions of the upper rim of the crater broke down suddenly, so that a broad sheet of lava descended the flanks of the cone.

The sections seen on the flanks of Mont Dor and Cantal are not sufficiently numerous to enable a geologist to trace with certainty the continuity of the same flows, and to prove their precise identity at distant points. The number of different beds is extremely great, especially near the centre and summit of each mountain; and we see tuffs alternating again and again with basalt and trachyte. Often on the opposite sides of the same valley in the Cantal the tuffs and lavas by no means coincide, bed for bed.

As to the texture of the more ancient igneous rocks, it may be admitted that they are generally more compact; yet they are sometimes very porous, and occasionally exhibit signs of having been in motion. On the other hand some modern lavas of Etna are extremely compact. This character may probably be modified in part by mineralogical composition, and the degree of fluidity of different varieties of lava and the quantity of gas contained in them, as well as by the declivity of the surface on which they cool. That the ancient lavas of France should differ in many respects, and particularly in composition, from those now flowing from Vesuvius and Etna, is natural, since we are told that the active volcanos of the Andes produce lavas quite distinct from those of Europe, both ancient and modern. According to Von Buch, the American volcanic

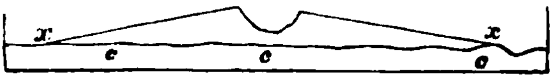
* Bulletin de la Soc. Géol. de France, tom. vii. p. 40.

rocks contain generally albite instead of common felspar as a principal ingredient.*

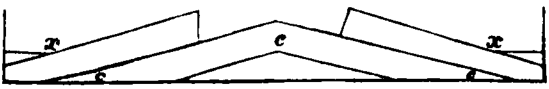
But may not some large volcanic cones have been subjected to a certain amount of forcible elevation produced by the local earthquakes generally felt during and before eruptions? This may be conceded, for we frequently see that the same force which drives lava up the central vent has power to rend the cone, and may, therefore, in some cases, tilt the beds so as to raise them and increase their original slope. Some cones, therefore, may have had their central mass successively upheaved to a certain extent, while they were thickened outwardly by new showers of scoriæ and lava streams. But although this theory of elevation and partial dislocation accompanying successive eruptions may be called in to explain certain phenomena, it may be regarded only as a subsidiary and subordinate hypothesis, eruptions alone without upheaval being the principal and often the sole cause of volcanic cones and craters.

It remains to consider how far the analogy of certain tracts which have a dome-shaped configuration, and have been called valleys of elevation, lend any support to the elevation-crater theory. The meaning attached to the term valleys of elevation will be fully understood by studying the 21st and 22d chapters of the Fourth Book. It is not disputed that horizontal strata have in this case been upheaved, in such a manner as to dip off in all directions from a central nucleus; but generally this phenomenon is only a modified form of that kind of linear upheaval to which mountain chains owe their origin. Such protuberances, therefore, are in their normal form elliptical, rather than circular, although occasionally they resemble or may even be identical in outward shape with certain volcanic cones. But the analogy fails in many essential particulars. The volcanic mass (Fig. 38.) is thickest towards the centre, and thins out round the circumference at *x x*.; but in the Elevation Valley (Fig. 40.)

Volcanic Mountain. Fig. 38.



Elevation Valley Fig. 40.



there is no such thinning out of the formations found in the middle of the elevated tract. In the one case (Fig. 38.) the fundamental rock *c* makes its appearance at the surface at *x*, *x*; but in the other, on the contrary

* Poggendorf's Annalen, 1836, p. 190.

(Fig. 40.) the strata forming the nucleus *c* are removed farthest from the surface below, *x*, *x*. In both instances there may be a central depression, but in the Elevation Valley it is caused partly by fracture and partly by denudation; and if the central mass or nucleus happens to be composed of some hard rock, there is then a ridge or eminence in the middle instead of a depression. Sometimes a steep escarpment surrounds the valley of elevation, but not always, and when such cliffs exist they are principally due to denudation. They are, moreover, usually intersected by open ravines, caused by cross fractures and faults running at right angles to the longest diameter of the ellipse, which cross fractures are wanting, as before observed, in the so-called craters of elevation.

Mineral Composition of Volcanic Products.—The mineral called felspar forms in general more than half of the mass of modern lavas. When it is in great excess, lavas are called trachytic; they consist generally of a base of compact felspar, in which crystals of glassy felspar are disseminated.* When augite (or pyroxene) predominates, lavas are termed basaltic. But others of an intermediate composition occur, which from their colour have been called gray-stones. The abundance of quartz, forming distinct crystals or concretions, characterizes the granitic and other ancient rocks, now generally considered by geologists as of igneous origin: whereas that mineral is rarely exhibited in a separate form in recent lavas, although silica enters largely into their composition. Hornblende, so common in hypogene rocks, or those commonly called "primary," is rare in modern lava; nor does it enter largely into rocks of any age in which augite abounds. It should, however, be stated, that the experiments of M. Gustavus Rose have made it very questionable, whether the minerals called hornblende and augite can be separated as distinct species, as their different varieties seem to pass into each other, whether we consider the characters derived from their angles of crytallization, their chemical composition, or their specific gravity. The difference in form of the two substances may be explained by the different circumstances under which they have been produced; the form of hornblende being the result of slower cooling. Crystals of augite have been met with in the scoriæ of furnaces, but never those of hornblende; and crystals of augite have been obtained by melting hornblende in a platina crucible, but hornblende itself has not been formed artificially.† Mica occurs plentifully in some recent trachytes, but is rarely present where augite is in excess.

Frequency of eruptions, and nature of subterranean igneous rocks.—When we speak of the igneous rocks of our own times, we mean that small portion which, in violent eruptions, is forced up by elastic fluids to the surface of the earth,—the sand, scoriæ, and lava, which cool in the

* See Glossary, at the end of the first volume.

† Bulletin de la Soc. Géol. de France, tom. ii. p. 206.

open air. But we cannot obtain access to that which is congealed far beneath the surface under great pressure, equal to that of many hundred, or many thousand atmospheres.

During the last century, about fifty eruptions are recorded of the five European volcanic districts, of Vesuvius, Etna, Volcano, Santorin, and Iceland; but many beneath the sea in the Grecian Archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others, on the contrary, like that of Skaptár Jokul, in 1783, poured out melted matter for five or six years consecutively; which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there happen on the earth about two thousand eruptions in the course of a century, or about twenty every year.

However inconsiderable, therefore, may be the superficial rocks which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones must be as insignificant, when contrasted to the products of fire in the nether regions, as are the deposits formed in shallow estuaries when compared to submarine formations accumulating in the abysses of the ocean. In regard to the characters of these volcanic rocks, formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that the rocks are heavier and less porous than ordinary lavas, and more crystalline, although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages, a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions; for this is seen to be the case in many lava currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic regions; and the fissures will be often injected with similar matter, so that dikes of crystalline rock will traverse masses of similar composition. It is also clear, that no organic remains can be included in such masses, as also that these deep-seated igneous formations, considered in mass, must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks included in the midst of them.

If by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may then, perhaps, study in some mountain chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.

CHAPTER XIV.

EARTHQUAKES AND THEIR EFFECTS.

Earthquakes and their effects—Deficiency of ancient accounts—Ordinary atmospheric phenomena—Changes produced by earthquakes in modern times considered in chronological order—Earthquake in Chili, 1835—Isle of Santa Maria raised ten feet—Chili, 1822—Extent of country elevated (p. 381.)—Aleppo and Ionian Isles—Earthquake of Cutch in 1819—Subsidence in the delta of the Indus (p. 383.)—Island of Sumbawa in 1815—Town of Tomboro submerged—Earthquake of Caraccas in 1812—South Carolina in 1811—Changes in the valley of the Mississippi (p. 388.)—Aleutian Islands in 1806—Reflections on the earthquakes of the nineteenth century—Earthquake in Quito, Quebec, &c.—Java, 1786—Sinking down of large tracts—Japan isles, 1783.

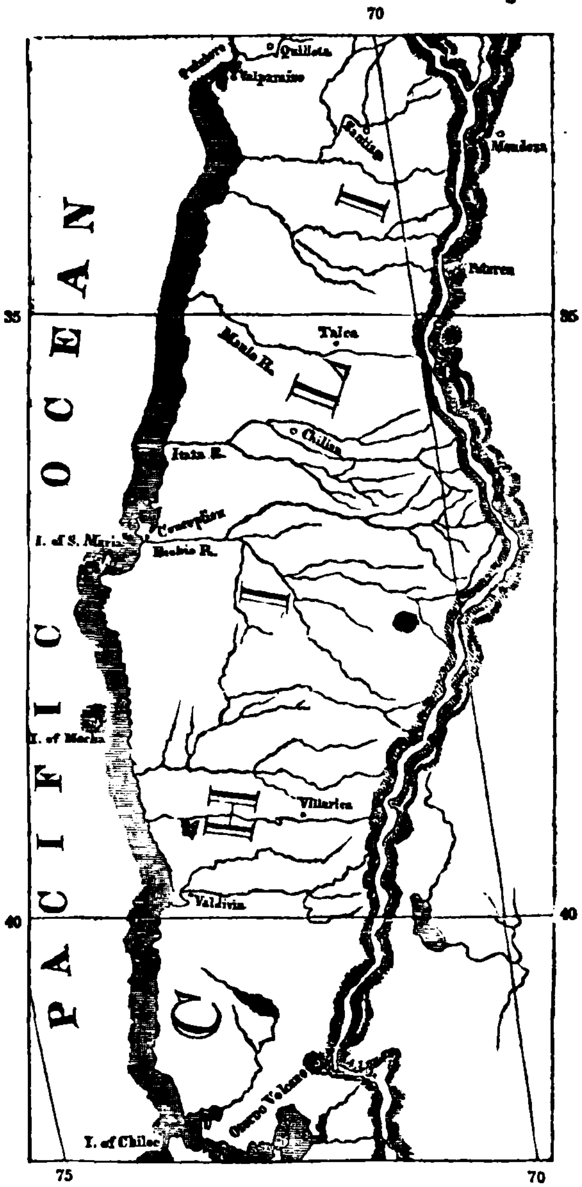
In the sketch before given of the geographical boundaries of volcanic regions, I stated, that although the points of eruption are but thinly scattered, constituting mere spots on the surface of those vast districts, yet the subterranean movements extend simultaneously over immense areas. We may now proceed to consider the changes which these movements produce on the surface, and in the internal structure of the earth's crust.

Deficiency of ancient accounts.—It is only within the last century and a-half, since Hooke first promulgated his views respecting the connexion between geological phenomena and earthquakes, that the permanent changes effected by these convulsions have excited attention. Before that time the narrative of the historian was almost exclusively confined to the number of human beings who perished, the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulfing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical interest, to be passed over in silence. But no researches were made expressly with a view of ascertaining the amount of depression or elevation of the ground, or any particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts; and how much reason we have to regret this deficiency of information appears from this, that in every instance where a spirit of scientific inquiry has animated the eye-witnesses of these events, facts calculated to throw light on former modifications of the earth's structure are recorded.

Phenomena attending earthquakes.—As I shall confine myself almost entirely, in the following notice of earthquakes, to the changes brought about by them in the configuration of the earth's crust, I may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, that it may be unnecessary to advert to them again. Irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons, or in countries where such phenomena are almost unknown; a reddening of the sun's disk, and a haziness in the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphureous and mephitic vapours; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder; animals uttering cries of distress, and evincing extraordinary alarm, being more sensitive than men of the slightest movement; a sensation like sea-sickness, and a dizziness in the head, experienced by men: these, and other phenomena, which are still more remotely connected with our present subject as geologists, have recurred again and again at distant ages, and in all parts of the globe.

I shall now begin the enumeration of earthquakes with the latest authentic narratives, and so carry back the survey retrospectively, that I may bring before the reader, in the first place, the minute and circumstantial details of modern times, and thus enable him, by observing the extraordinary amount of change within the last 150 years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

Fig. 41.


70
Quillota
Valparaiso
Mendoza
Talca
Maule R.
Chilian
Itata R.
I. of S. Maria
I. of Mocha
Villarica
Valdivia
I. of Chiloe
PACIFIC OCEAN
CHILI
35
40
75
70

EARTHQUAKES OF THE NINETEENTH CENTURY.*

Chili, 1835.—The latest earthquake by which the position of solid land is known to have been permanently altered, is that which occurred in South America, on the 20th of February, 1835. It was felt at all places between Copiapo and Chiloe, from north to south, and from Mendoza to Juan Fernandez, from east to west. "Vessels," says Mr. Caldcleugh, "navigating the Pacific, within 100 miles of the coast, experienced the shock with considerable force."† Conception, Talcahuano, Chillan, and other towns were thrown down. From the account of Captain Fitz Roy, R. N., who was then employed in surveying the coast, we learn that after the shock the sea retired in the bay of Conception, and the vessels grounded, even those which had been lying in seven fathoms water; all the shoals were visible, and soon afterwards a wave rushed in and then retreated, and was followed by two other waves. The vertical height of these waves does not appear to have been much greater than from sixteen to twenty feet, although they rose to much greater heights when they broke upon a sloping beach.

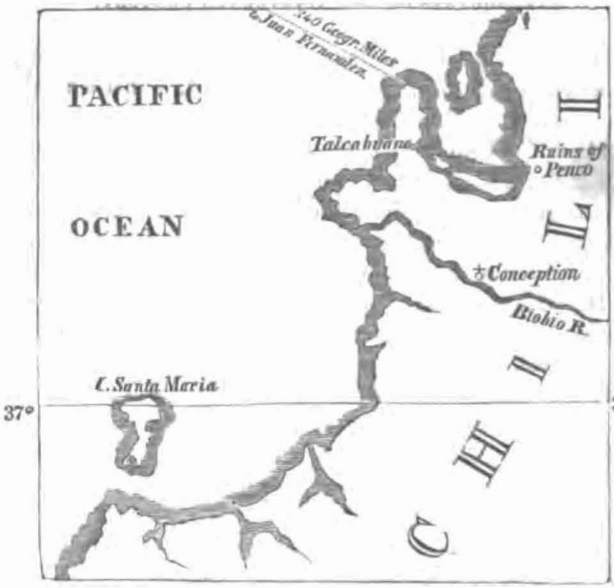
According to Mr. Caldcleugh, a great number of the volcanos of the Chilian Andes were in a state of unusual activity, both during the shocks and for some time preceding and after the convulsion, and lava was seen to flow from the crater of Osorno. (See Map. Fig. 41, p. 376.) The island of Juan Fernandez, distant 360 miles from Chili, was violently shaken at the same time, and devastated by a great wave. Flames rose there from the sea about a mile from the shore, and illumined the whole island during the night, although it was afterwards ascertained that there was a depth of sixty-nine fathoms water in the spot where the flames had appeared.‡

"At Conception," says Captain Fitz Roy, "the earth opened and closed rapidly in numerous places. The direction of the cracks was not uniform, though generally from south-east to north-west. The earth was not quiet for three days after the great shock, and more than three hun-

* Since the publication of the first edition of this work, numerous accounts of recent earthquakes have been published; but as they do not illustrate any new principle, I cannot insert them all, as they would enlarge too much the size of my work. Among the most violent may be mentioned those of March, 1829, near Alicant in Murcia—that of Sept. 1827, at Lahore, East Indies—of Jan. 15, 1832, which destroyed Foligno, in Italy,—June 24, 1830, in China, in Tayming, North of Houan—March 9, 1830, in the Caucasus at Kislier—April 1833, Manilla—1833, Isle of Lissa in Adriatic, and Opus. Von Hoff has published, from time to time, in Poggendorf's Annalen, lists of the earthquakes which have happened since 1821; and, by consulting these, the reader will perceive that every month is signalized by one or many convulsions in some part of the globe.

† Phil. Trans., 1836, p. 21. ‡ Ibid. p. 25.

Fig. 42.



dred shocks were counted between the 20th of February and the 4th of March. The loose earth of the valley of the Biobio was everywhere parted from the solid rocks which bound the plain, there being an opening between them from an inch to a foot in width.

"For some days after the 20th of February, the sea at Talcahuano," says Captain Fitz Roy, "did not rise to the usual marks by four or five feet vertically. When walking on the shore, even at high water, beds of dead muscles, numerous chitons, and limpets, and withered sea-weed, still adhering, though lifeless, to the rocks on which they had lived, everywhere met the eye." But this difference in the relative level of the land and sea gradually diminished, till in the middle of April the water rose again to within two feet of the former high water mark. It might be supposed that these changes of level merely indicated a temporary disturbance in the set of the currents or in the height of the tides at Talcahuano; but on considering what occurred in the neighbouring island of Santa Maria, Captain Fitz Roy concluded that the land had been raised four of five feet in February, and that it had returned in April to within two or three feet of its former level.

Santa Maria, the island just alluded to, is about seven miles long and two broad, and about twenty-five miles south-west of Conception. (See Map, Fig. 42.) The phenomena observed there are most important. "It appeared," says Captain Fitz Roy, who visited Santa Maria twice, the first time at the end of March, and afterwards in the beginning of April, "that the southern extremity of the island had been raised eight feet, the middle nine, and the northern end upwards of ten feet. On steep rocks, where vertical measures could be correctly taken, beds of dead muscles were found ten feet above high water mark. One foot lower than the highest bed of muscles, a few limpets and chitons were seen adhering to the rock where they had grown. Two feet lower than the same, dead muscles, chitons, and limpets were abundant."

"An extensive rocky flat lies around the northern parts of Santa Maria. Before the earthquake this flat was covered by the sea, some projecting rocks only showing themselves. Now, the whole flat is exposed, and square acres of it are covered with dead shell-fish, the stench arising from which is abominable. By this elevation of the land the southern port of Santa Maria has been almost destroyed—little shelter remaining there, and very bad landing." The surrounding sea is also stated to have become shallower in exactly the same proportion as the land had risen; the soundings having diminished a fathom and a-half everywhere around the island.

At Tubal, also, to the south-east of Santa Maria, the land was raised six feet, at Mocha two feet, but no elevation could be ascertained at Valdivia, northward of Conception.

Ischia, 1828.—On the 2d of February the whole island of Ischia was shaken by an earthquake, and in the October following I found all the houses in Casamicciol still without their roofs. On the sides of a ravine between that town and Forio, I saw masses of greenish tuff, which had been thrown down. The hot-spring of Rita, which was nearest the centre of the movement, was ascertained by M. Covelli to have increased in temperature, showing, as he observes, that the explosion took place below the reservoirs which heat the thermal waters.*

Bogota, 1827.—On the 16th of November, 1827, the plain of Bogota was convulsed by an earthquake, and a great number of towns were thrown down. Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphureous vapour and destroyed the fish. Popayan, which is distant two hundred geographical miles S. S. W. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow.† It is worthy of remark, that in all such cases the ancient gravel bed of a river is deserted, and a new one formed at a lower level; so that a want of relation in the position of alluvial beds to the existing water-courses may be no test of the high antiquity of such deposits, at least in countries habitually convulsed by earthquakes. Extraordinary

* Biblioth. Univ., Oct. 1828, p. 157.; and Férussac, Bulletin, &c., tome xi. p. 227.
† Phil. Mag., July, 1828, p. 37.

rains accompanied the shocks before mentioned; and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On the 19th of November, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of 1200 miles from north to south. St. Jago, Valparaiso, and some other places, were greatly injured. When the district round Valparaiso was examined on the morning after the shock, it was found that the whole line of coast, for the distance of above one hundred miles, was raised above its former level.* At Valparaiso the elevation was three feet, and at Quintero about four feet. Part of the bed of the sea, says Mrs. Graham, remained bare and dry at high water, "with beds of oysters, muscles, and other shells, adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia."†

An old wreck of a ship, which before could not be approached, became accessible from the land, although its distance from the original sea-shore had not altered.‡ It was observed, that the water-course of a mill, at the distance of about a mile from the sea, gained a fall of fourteen inches, in little more than one hundred yards; and from this fact it is inferred that the rise in some parts of the inland country was far more considerable than on the borders of the ocean.§ Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a-half inland. Cones of earth, about four feet high, were thrown up in several districts, by the forcing up of water mixed with sand through funnel-shaped hollows,—a phenomenon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili of which the foundations were on rock were less damaged than such as were built on alluvial soil.

Mr. Cruckshanks, an English botanist, who resided in the country during the earthquake, has informed me that some rocks of greenstone at Quintero, a few hundred yards from the beach, which had always been under water till the shock of 1822, have since been uncovered when the tide is at half-ebb; and he states that, after the earthquake, it was the general belief of the fishermen and inhabitants of the Chilian coast, *not* that the land had risen, but that the ocean had permanently retreated.

Dr. Meyen, a Prussian traveller, who visited Valparaiso in 1831, says that on examining the rocks both north and south of the town, nine years after the event, he found in corroboration of Mrs. Graham's account, that remains of animals and sea-weed, the *Lessonia* of Bory de St. Vincent, which has a firm ligneous stem, still adhered to those rocks which in

* See Geol. Trans., vol. i., second series; and also Journ. of Sci., 1824, vol. xvii. p. 40.

† Geol. Trans., vol. i., second series, p. 415. ‡ Ibid.

§ Journ. of Sci., vol. xvii. p. 42.

1822 had been elevated above high-water mark.* According to the same author, the whole coast of central Chili was raised about four feet, and banks of marine shells were laid dry on many parts of the coast. He observed similar banks, elevated at unknown periods, in several places, especially at Copiapo, where the species all agree with those now living in the ocean. Mr. Freyer also, who resided some years in South America, has confirmed these statements;† but Mr. Cuming, a gentleman well known by his numerous discoveries in conchology, and who resided at Valparaiso during and after the earthquake, could detect no proofs of the rise of the land, nor any signs of a change of level. On the contrary, he remarked, that the water at spring-tides rose after the earthquake to the same point, on a wall near his house, which it had reached before the shocks. The opinions of this gentleman well deserve attention from those who may have opportunities of minutely investigating the Chilian coast; but after considering his objections to Mrs. Graham's account, even before the late convulsion, I felt satisfied with the proofs of elevation in 1822. Had I still cherished any scepticism, it would have been removed by the coincidence of the facts related by Captain Fitz Roy; a shaving occurred in 1835, thirteen years afterwards, in another part of the same country.‡

Extent of country elevated.—The area over which this permanent alteration of level is conjectured to have extended, in 1822, is 100,000 square miles.§ The whole country, from the foot of the Andes to a great distance under the sea, is supposed to have been raised, the greatest rise being at the distance of about two miles from the shore. "The rise upon the coast was from two to four feet:—at the distance of a mile inland it must have been from five to six, or seven feet."‖ The soundings in the harbour of Valparaiso have been materially changed by this shock, and the bottom has become shallower. The shocks continued up to the end of September, 1823; even then, forty-eight hours seldom passed without one, and sometimes two or three were felt during twenty-four hours. Mrs. Graham observed, after the earthquake of 1822, that, besides the beach newly raised above high-water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea.¶

In order to give some idea of the enormous amount of change which this single convulsion may have occasioned, let us assume that the extent of country moved was correctly estimated at 100,000 square miles,—an

* Reise um die erde; and see Dr. Meyen's letter cited Foreign Quart. Rev. No. 33. p. 13., 1836.

† Geol. Soc. Proceedings, No. 40. p. 179., Feb. 1835.

‡ Cuming, Geol. Proceedings, No. 42. p. 213.

§ Journ. of Sci., vol. xvii.

‖ Ibid., pp. 40. 45.

¶ Geol. Trans., vol. i., second series, p. 415.

extent just equal to half the area of France, or about five-sixths of the area of Great Britain and Ireland. If we suppose the elevation to have been only three feet on an average, it will be seen that the mass of rock added to the continent of America by the movement, or, in other words, the mass previously below the level of the sea, and after the shocks permanently above it, must have contained fifty-seven cubic miles in bulk; which would be sufficient to form a conical mountain two miles high (or about as high as Etna), with a circumference at the base of nearly thirty-three miles. We may take the mean specific gravity of the rock at 2.655,—a fair average, and a convenient one in such computations, because at such a rate a cubic yard weighs two tons. Then, assuming the great Pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, six million tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled 100,000 pyramids.

But it must always be borne in mind that the weight of rock here alluded to constituted but an insignificant part of the whole amount which the volcanic forces had to overcome. The whole thickness of rock between the surface of Chili and the subterranean foci of volcanic action, may be many miles or leagues deep. Say that the thickness was only two miles, even then the mass which changed place and rose three feet, being 200,000 cubic miles in volume, must have exceeded in weight 363 million pyramids.

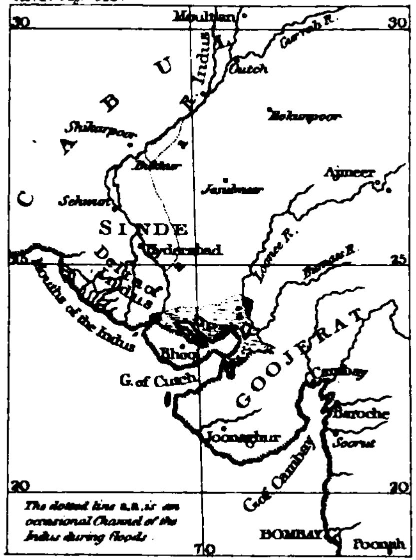
It may be useful to consider these results in connexion with others already obtained from a different source, and to compare the working of two antagonist forces—the levelling power of running water, and the expansive energy of subterranean heat. How long, it may be asked, would the Ganges require, according to data before explained, to transport to the sea a quantity of solid matter equal to that added to the land by the Chilian earthquake? The discharge of mud in one year by the Ganges equalled the weight of sixty pyramids. In that case it would require seventeen centuries and a half before the river could bear down from the continent into the sea a mass equal to that gained by the Chilian earthquake. In about half that number of centuries, perhaps, the united waters of the Ganges and Burrampooter might accomplish the operation.

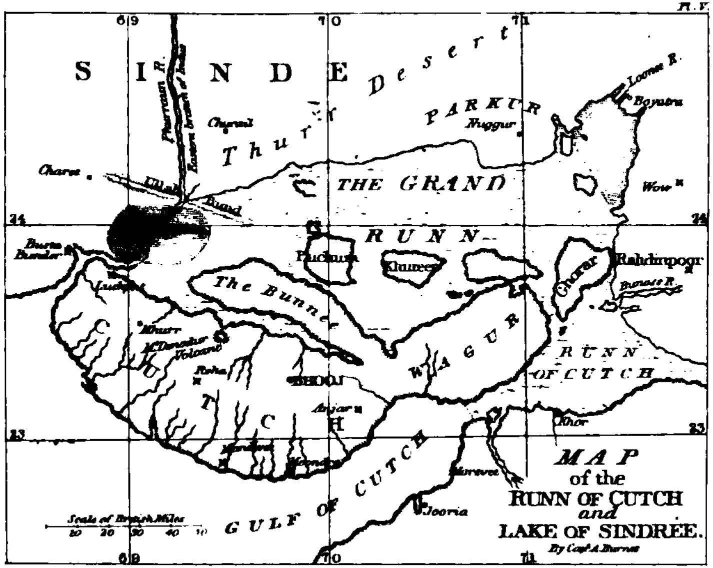
Aleppo, 1822.—*Ionian Isles*, 1820.—When Aleppo was destroyed by an earthquake in 1822, two rocks are reported to have risen from the sea near the island of Cyprus;* and a new rocky island was observed in 1820 not far from the coast of Santa Maura, one of the Ionian Islands, after violent earthquakes.†

Cutch, 1819.—A violent earthquake occurred at Cutch, in the delta of the Indus, June 16, 1819. (See annexed Map, Plate V.) The principal

* Journ. of Sci., vol. xiv. p. 450.

† Von Hoff, vol. ii. p. 180.





MAP
of the
RUNN OF CUTCH
and
LAKE OF SINDREE.
By Capt. A. Burnes

SINDREE, ON THE EASTERN BRANCH OF THE INDUS.

SINCE SUBMERGED BY THE EARTHQUAKE OF 1819.

From a sketch taken on the spot by Captain Grindlay, in 1808.

town, Bhooj, was converted into a heap of ruins, and its stone buildings were thrown down. The shock extended to Ahmedabad, where it was very destructive; and at Poonah, four hundred miles farther, it was feebly felt. At the former city, the great mosque erected by Sultan Ahmed nearly 450 years before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visted that point. At Anjar, the fort, with its tower and guns, were hurled to the ground in one common mass of ruin. The shocks continued some days until the 20th; when, thirty miles north-west from Bhooj, the volcano called Denodur is said to have burst out in eruption, and the convulsions ceased.

Subsidence in the Delta of the Indus.—Although the ruin of towns was great, the face of nature in the inland country, says Captain Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. The estuary, or inlet of the sea, was, before the earthquake, fordable at Luckput, being only about a foot deep when the tide was at ebb, and at flood tide never more than six feet; but it was deepened at the fort of Luckput, after the shock, to more than *eighteen feet at low water.** On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded one or two feet, it had become from four to ten feet deep. By these and other remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, become again practicable.

Fort and village submerged.†—The fort and village of Sindree, on the eastern arm of the Indus, above Luckput, are stated by the same writer to have been overflowed; and, after the shock, the tops of the houses and wall were alone to be seen above the water, for the houses, although submerged, were not cast down. Had they been situated, therefore, in the interior, where so many forts were levelled to the ground, their site would, perhaps, have been regarded as having remained comparatively unmoved. Hence we may suspect that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

A more recent survey of Cutch by Capt. A. Burnes, who was not in communication with Capt. Macmurdo, confirms the facts above enumerated, and adds many important details.‡ That officer examined the delta of the Indus in 1826 and 1828, and from his account it appears that,

* Macmurdo, Ed. Phil. Journ., vol. iv. p. 106.

† I am indebted to Captain Burnes for the accompanying engraving (Pl. VI.) of the Fort of Sindree, as it appeared eleven years before the earthquake.

‡ This Memoir is now in the Library of the Royal Asiatic Society of London.

when Sindree subsided, in June, 1819, the sea flowed in by the eastern mouth of the Indus, and in a few hours converted a tract of land, 2000 square miles in area, into an inland sea, or lagoon. Neither the rush of the sea into this new depression, nor the movement of the earthquake, threw down entirely the small fort of Sindree, one of the four towers, the north western still continuing to stand; and the day after the earthquake, the inhabitants, who had ascended to the top of this tower, saved themselves in boats.*

Elevation of the Ullah Bund.—Immediately after the shock, the inhabitants of Sindree saw, at the distance of five miles and a-half from their village, a long elevated mound, where previously there had been a low and perfectly level plain. (See Map, Pl. V.) To this uplifted tract they gave the name of "Ullah Bund," or the "Mound of God," to distinguish it from several artificial dams previously thrown across the eastern arm of the Indus.

Extent of country raised.—It has been already ascertained that this new-raised country is *upwards of fifty miles* in length from east to west, running parallel to that line of subsidence before mentioned which caused the grounds around Sindree to be flooded. The range of this elevation extends from Puchum Island towards Gharee; its breadth from north to south is conjectured to be in some parts *sixteen miles*, and its greatest ascertained height above the original level of the delta is ten feet,—an elevation which appears to the eye to be very uniform throughout.

For several years after the convulsion of 1819, the course of the Indus was very unsettled, and at length, in 1826, the river threw a vast body of water into its eastern arm, that called the Phurraun, above Sinde; and forcing its way in a more direct course to the sea, burst through all the artificial dams which had been thrown across its channel, and at length cut right through the "Ullah Bund," whereby a natural section was obtained. In the perpendicular cliffs thus laid open, Captain Burnes found that the upraised lands consisted of clay filled with shells. The new channel of the river where it intersected the "bund" was eighteen feet deep, and during the swells in 1826 it was two or three hundred yards in width; but in 1828 the channel was still further enlarged. The Indus, when it first opened this new passage, threw such a body of water into the new meer, or salt lagoon, of Sindree, that it became fresh for many months; but it had recovered its saltness in 1828, when the supply of river water was less copious, and finally it became more salt than the sea, in consequence, as the natives suggested to Captain Burnes, of the saline particles with which the "Runn of Cutch" is impregnated.

* I have been enabled, from personal communication with Captain Burnes, to add several particulars to my former account of this earthquake.

In 1828 Captain Burnes went in a boat to the ruins of Sindree, where a single remaining tower was seen in the midst of a wide expanse of sea. The tops of the ruined walls still rose two or three feet above the level of the water; and standing on one of these, he could behold nothing in the horizon but water, except in one direction, where a blue streak of land to the north indicated the Ullah Bund. This scene presents to the imagination a lively picture of the revolutions now in progress on the earth—a waste of waters where a few years before all was land, and the only land visible consisting of ground uplifted by a recent earthquake.

The Runn of Cutch, above alluded to, is a flat region of a very peculiar character, and no less than 7000 square miles in area; a greater superficial extent than Yorkshire, or about one-fourth the area of Ireland. It is not a desert of moving sand, nor a marsh, but evidently the dried-up bed of an inland sea, which for a great part of every year has a hard and dry bottom uncovered by weeds or grass, and only supporting here and there a few tamarisks. But during the monsoons, when the sea runs high, the salt water driven up from the Gulf of Cutch and the creeks at Luckput overflows a large part of the Runn, especially after rains, when the soaked ground permits the sea-water to spread rapidly. The Runn is also liable to be overflowed occasionally in some parts by river-water; and it is remarkable that the only portion which was ever highly cultivated (that anciently called Sayra) is now permanently submerged. The surface of the Runn is sometimes encrusted with salt about an inch in depth, in consequence of the evaporation of the sea-water. Islands rise up in some parts of the waste, and the boundary lines form bays and promontories.

The natives have a tradition that, about three centuries ago, the countries of Cutch and Sinde were separated by the sea, thus giving rise to the district called the Runn. Towns far inland are still pointed out as having once been ancient ports; and it is said that ships were wrecked and engulfed by the great catastrophe. In confirmation of this account it was observed, in 1819, that, in the jets of black muddy water thrown out of fissures in that region, there were cast up numerous pieces of wrought iron and ship-nails.* Cones of sand six or eight feet in height are said to have been thrown up on these lands.†

We must not conclude without alluding to a *moral* phenomenon connected with this tremendous catastrophe, which we regard as highly deserving the attention of geologists. It is stated by Captain Burnes, that "these wonderful events passed *unheeded* by the inhabitants of Cutch;" for the region convulsed, though once fertile, had for a long period been reduced to sterility by want of irrigation, so that the natives were indifferent as to its fate. Now it is to this profound apathy which all but

* Captain Burnes's Account.

† Capt. Macmurdo's Memoir, Ed. Phil. Journ., vol. iv. p. 106.

highly civilized nations feel, in regard to physical events not having an immediate influence on their worldly fortunes, that we must ascribe the extraordinary dearth of historical information concerning changes of the earth's surface, which modern observations show to be by no means of rare occurrence in the ordinary course of nature.

To the east of the line of this earthquake lies Oojain (called Ozene in the *Peryplus Maris Erythr.*) Ruins of an ancient city are there found, a mile north of the present, buried in the earth to the depth of from fifteen to sixteen feet, which inhumation is known to have been the consequence of a tremendous catastrophe in the time of the Rajah Vicramaditya.*

Island of Sumbawa, 1815.—In April, 1815, one of the most frightful eruptions recorded in history occurred in the mountain Tomboro, in the island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of 970 geographical miles in a direct line; and at Ternate, in an opposite direction, at the distance of 720 miles. Out of a population of twelve thousand, only twenty-six individuals survived on the island. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air, tore up the largest trees by the roots, and covered the whole sea with floating timber.† Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, forty miles east of the volcano, and rendered it, as well as many other dwellings in the town, uninhabitable. On the side of Java the ashes were carried to the distance of 300 miles, and 217 towards Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumatra formed, on the 12th of April, a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable powder, it was of considerable weight when compressed, a pint of it weighing twelve ounces and three-quarters. Along the sea coast of Sumbawa, and the adjacent isles, the sea rose suddenly to the height of from two to twelve feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

* Von Hoff, vol. ii. p. 454.; for further particulars, see book iii. chap. xiv.

† Raffle's Java, vol. i. p. 28.

The town called Tomboro, on the west side of the volcano of Sumbawa, was overflowed by the sea, which encroached upon the shore so that the water remained permanently eighteen feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was apparent, in spite of the ashes, which would naturally have caused the limits of the coast to be extended.

The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca Islands, Java, a considerable portion of Celebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again.*

In conclusion, I may remind the reader, that but for the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of the geologist. They mention, that similar effects, though in a less degree, had, about seven years before, accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumatra; but no particulars of that great catastrophe are recorded.†

Caraccas, 1812.—On the 26th of March, 1812, several violent shocks of an earthquake were felt in Caraccas. The surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which ten thousand of the inhabitants were buried. On the 5th of April, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from 300 to 360 feet of its height by subsidence; but this was an opinion not founded on any measurement. On the 27th of April, a volcano in St. Vincent's threw out ashes; and on the 30th, lava flowed from its crater into the sea, while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo, near Valencia, as also at Porto Cabello, through openings in the earth; and in the Lake Maracaybo the water sank. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.‡

* Raffles's Hist. of Java, vol. i. p. 25.—Ed. Phil. Journ., vol. iii. p. 389.

† Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

‡ Humboldt's Pers. Nar., vol. iv. p. 12; and Ed. Phil. Journ., vol. i. p. 272, 1819.

South Carolina, 1811.—*New Madrid*.—Previous to the destruction of La Guayra and Caraccas, in 1812, South Carolina was convulsed by earthquakes; and the shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed to such a degree as to create lakes and islands. Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near the Little Prairie, became covered with water three or four feet deep; and when the water disappeared, a stratum of sand was left in its place. Large lakes of twenty miles in extent were formed in the course of an hour, and others were drained. The grave-yard at New Madrid was precipitated into the bed of the Mississippi; and it is stated that the ground whereon the town is built, and the river bank for fifteen miles above, sank eight feet below their former level.* The neighbouring forest presented for some years afterwards "a singular scene of confusion; the trees standing inclined in every direction, and many having their trunks and branches broken."†

The inhabitants relate that the earth rose in great undulations; and when these reached a certain fearful height, the soil burst, and vast volumes of water, sand, and pit-coal were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in an alluvial soil, seven years after. The people in the country, although inexperienced in such convulsions, had remarked that the chasms in the earth were in a direction from S. W. to N. E.; and they accordingly felled the tallest trees; and laying them at right angles to the chasms, stationed themselves upon them. By this invention, when chasms opened more than once under these trees, several persons were prevented from being swallowed up.‡ At one period during this earthquake, the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waves. The motion of some of the shocks was horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal. If this be often the case, those shocks which injure cities least may produce the greatest alteration of level.

Aleutian Islands, 1806.—In the year 1806, a new island, in the form of a peak, with some low conical hills upon it, rose from the sea among the Aleutian Islands, east of Kamtschatka. According to Langsdorf,§ it was four geographical miles in circumference; and Von Buch infers, from its magnitude, and from its not having again subsided below the level of the sea, that it did not consist merely of ejected matter, but of a

* Cramer's Navigator, p. 243. Pittsburgh, 1821.

† Long's Exped. to the Rocky Mountains, iii. p. 184.

‡ Silliman's Journ., Jan. 1829.

§ Bemerkungen auf einer Reise um die Welt., bd. ii. s. 209.

solid rock of trachyte upheaved.* Another extraordinary eruption happened in the spring of the year 1814, in the sea near Unalaschka, in the same archipelago. A new isle was then produced of considerable size, and with a peak three thousand feet high, which remained standing for a year afterwards, though with somewhat diminished height.

Although it is not improbable that earthquakes accompanying these tremendous eruptions may have heaved up part of the bed of the sea, yet the circumstance of the islands not having disappeared like Sabrina (see p. 352.) may have arisen from the emission of lava. If Jorullo, for example, in 1759, had risen from a shallow sea to the height of 1600 feet, instead of attaining that elevation above the Mexican plateau, the massive current of basaltic lava which poured out from its crater would have enabled it to withstand, for a long period, the action of a turbulent sea.

Reflections on the earthquakes of the nineteenth century.—We are now about to pass on to the events of the eighteenth century; but, before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of the last thirty years. New rocks have risen from the waters; the temperature of a thermal spring has been raised; the coast of Chili has been twice permanently elevated; a considerable tract in the delta of the Indus has sunk down, and some of its shallow channels have become navigable; an adjoining part of the same district, upwards of fifty miles in length and sixteen in breadth, has been raised about ten feet above its former level; the town of Tomboro has been submerged, and twelve thousand of the inhabitants of Sumbawa have been destroyed. Yet, with a knowledge of these terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world, have now ceased? If, in the face of so many striking facts, he persists in maintaining this favourite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose:

> Si fractus illabatur orbis,
> Impavidum ferient ruinæ.

EARTHQUAKES OF THE EIGHTEENTH CENTURY.

Quito, 1797.—On the morning of February 4th, 1797, the volcano of Tunguragua in Quito, and the surrounding district, for forty leagues from

* Neue Allgem. Geogr. Ephemer., bd. iii. s. 348.

south to north, and twenty leagues from west to east, experienced an undulating movement, which lasted four minutes. The same shock was felt over a tract of 170 leagues from south to north, from Piura to Popayan; and 140 from west to east, from the sea to the river Napo. In the smaller district first mentioned, where the movement was more intense, every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open in several places; and streams of water and fœtid mud, called "moya," poured out, overflowing and wasting every thing. In valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet; and the mud deposit barred up the course of the river, so as to form lakes, which in some places continued for more than eighty days. Flames and suffocating vapours escaped from the lake Quilotoa, and killed all the cattle on its shores. The shocks continued all February and March; and on the fifth of April they recurred with almost as much violence as at first. We are told that the form of the surface in the district most shaken was entirely altered, but no exact measurements are given whereby we may estimate the degree of elevation or subsidence.* Indeed it would be difficult, except in the immediate neighbourhood of the sea, to obtain any certain standard of comparison, if the levels were really as much altered as the narrations imply.

Cumana, 1797.—In the same year, on the 14th of December, the small Antilles experienced subterranean movements, and four-fifths of the town of Cumana was shaken down by a vertical shock. The form of the shoal of Mornerouge, at the mouth of the river Bourdones, was changed by an upheaving of the ground.†

Quebec, 1791.—We learn from Captain Bayfield's memoirs, that earthquakes are very frequent on the shore of the estuary of the St. Lawrence, of force sufficient at times to split walls and throw down chimneys. Such were the effects experienced in December, 1791, in St. Paul's Bay, about fifty miles N. E. from Quebec; and the inhabitants say, that about every twenty-five years a violent earthquake returns, which lasts forty days. In the History of Canada, it is stated that, in 1663, a tremendous convulsion lasted six months, extending from Quebec to Tadeausac—a distance of about 130 miles. The ice on the river was broken up, and many landslips caused.‡

Caraccas, 1790.—In the Caraccas, near where the Caura joins the Orinoco, between the towns San Pedro de Alcantara and San Francisco de Aripao, an earthquake, on St. Matthew's day, 1790, caused a sinking

* Cavanilles, Journ. de Phys., tome xlix. p. 230. Gilbert's Annalen, bd. vi. p. 67. Humboldt's Voy., p. 317.

† Humboldt's Voy., Relat. Hist. part i. p. 309.

‡ Macgregor's Travels in America.

in of the granitic soil, and left a lake eight hundred yards in diameter, and from eighty to one hundred in depth. It was a portion of the forest of Aripao which subsided, and the trees remained green for several months under water.*

Sicily, 1790.—On the 18th of March in the same year, at S. Maria di Niscemi, some miles from Terranuova, near the south coast of Sicily, the ground gradually sank down for a circumference of three Italian miles, during seven shocks; and, in one place, to the depth of thirty feet. It continued to subside to the end of the month. Several fissures sent forth sulphur, petroleum, steam, and hot water; and a stream of mud, which flowed for two hours, and covered a space sixty feet long, and thirty broad. This happened far from both the ancient and modern volcanic district, in a group of strata consisting chiefly of blue clay.†

Java, 1786.—About the year 1786, an earthquake was felt at intervals, for the period of four months, in the neighbourhood of Batur, in Java, and an eruption followed. Various rents were formed, which emitted a sulphureous vapour; separate tracts sunk away, and were swallowed by the earth. Into one of these the rivulet Dotog entered, and afterwards continued to follow a subterraneous course. The village of Jampang was buried in the ground, with thirty-eight of its inhabitants, who had not time to escape. We are indebted to Dr. Horsfield for having verified the above mentioned facts.‡

Japan Isles, 1783.—In the province of Simano, in the Isle of Nifon, the volcanic mountain of Asamayama, situated north-east of the town of Komoro, was in violent eruption August 1, 1783. The eruption was preceded by a frightful earthquake; gulfs are said to have opened every where, and many towns to have been swallowed up, while others were subsequently buried by lava.§

* Humboldt's Voy., Relat. Hist., part ii. p. 632.

† Ferrara, Camp. fl., p. 51.

‡ Batav. Trans., vol. viii. p. 141.

§ Humboldt, Fragmens Asiatiques, &c., tom. i. p. 229.

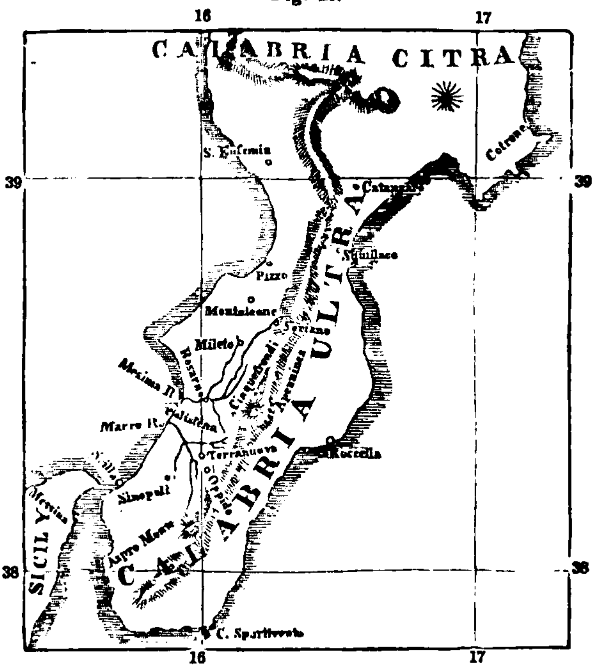
CHAPTER XV.

EARTHQUAKE IN CALABRIA, 1783.

Earthquake in Calabria, February 5, 1783—Shocks continued to the end of the year 1786—Authorities—Area convulsed—Geological structure of the district—Difficulty of ascertaining changes of level (p. 396.)—Subsidence of the quay at Messina—Shift or fault in the Round Tower of Terranuova—Movement in the stones of two obelisks—Opening and closing of fissures—Large edifices engulfed—Dimensions of new caverns and fissures (p. 401.) Gradual closing in of rents—Bounding of detached masses into the air—Landslips—Buildings transported entire to great distances (p. 405.)—New Lakes—Currents of Mud—Funnel-shaped hollows in alluvial plains—Fall of cliffs, and shore near Scilla inundated—State of Stromboli and Etna during the shocks—How earthquakes contribute to the formation of valleys (p. 409.)—Concluding remarks.

Calabria, 1783.—OF the numerous earthquakes which have occurred in different parts of the globe, during the last hundred years, that of Calabria, in 1783, is almost the only one of which the geologist can be said to have such a circumstantial account as to enable him fully to appreciate the changes which this cause is capable of producing in the lapse of ages.

Fig. 42.



The shocks began in February, 1783, and lasted for nearly four years, to the end of 1786. Neither in duration, nor in violence, nor in the extent of territory moved, was this convulsion remarkable, when contrasted with many experienced in other countries, both during the last and present century; nor were the alterations which it occasioned in the relative level of hill and valley, land and sea, so great as those effected by some subterranean movements in South America, in later times. The importance of the earthquake in question arises from the circumstance, that Calabria is the only spot hitherto visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information, to enable them to collect and describe with accuracy the physical facts which throw light on geological questions.

Authorities.—Among the numerous authorities, Vivenzio, physician to the King of Naples, transmitted to the court a regular statement of his observations during the continuance of the shocks; and his narrative is drawn up with care and clearness.* Francesco Antonio Grimaldi, then secretary of war, visited the different provinces at the king's command, and published a most detailed description of the permanent changes in the surface.† He measured the length, breadth, and depth of the different fissures and gulfs which opened, and ascertained their number in many provinces. His comments, moreover, on the reports of the inhabitants, and his explanations of their relations, are judicious and instructive. Pignataro, a physician residing at Monteleone, a town placed in the very centre of the convulsions, kept a register of the shocks, distinguishing them into four classes, according to their degree of violence. From his work, it appears that, in the year 1783, the number was 949, of which 501 were shocks of the first degree of force; and in the following year there were 151, of which 98 were of the first magnitude.

Count Ippolito, also, and many others, wrote descriptions of the earthquake; and the Royal Academy of Naples, not satisfied with these and other observations, sent a deputation from their own body into Calabria, before the shocks had ceased, who were accompanied by artists instructed to illustrate by drawings the physical changes of the district, and the state of ruined towns and edifices. Unfortunately these artists were not very successful in their representations of the condition of the country, particularly when they attempted to express, on a large scale, the extraordinary revolutions which many of the great and minor river-courses underwent. But many of the plates published by the Academy are valuable; and as they are little known, I shall frequently avail myself of them to illustrate the facts about to be described.‡

* Istoria de' Tremuoti della Calabria del 1783.

† Descriz. de' Tremuoti Accad. nelle Calabria nel 1783. Napoli, 1784.

‡ Istoria de' Fenomeni del Tremoto, &c. nell' An. 1783, posta in luce dalla Real. Accad. &c. di Nap. Napoli, 1784. fol.

In addition to these Neapolitan sources of information, our countryman, Sir William Hamilton, surveyed the district, not without some personal risk, before the shocks had ceased; and his sketch, published in the Philosophical Transactions, supplies many facts that would otherwise have been lost. He has explained in a rational manner many events which, as related in the language of some eyewitnesses, appeared marvellous and incredible. Dolomieu also examined Calabria during the catastrophe, and wrote an account of the earthquake, correcting a mistake into which Hamilton had fallen, who supposed that a part of the tract shaken had consisted of volcanic tuff. It is, indeed, a circumstance which enhances the geological interest of the commotions which so often modify the surface of Calabria, that they are confined to a country where there are neither ancient nor modern rocks of volcanic or trappean origin; so that at some future time, when the era of disturbance shall have passed by, the cause of former revolutions will be as latent as in parts of Great Britain now occupied exclusively by ancient marine formations.

Extent of the area convulsed.—The convulsion of the earth, sea, and air extended over the whole of Calabria Ultra, the south-east part of Calabria Citra, and across the sea to Messina and its environs; a district lying between the 38th and 39th degrees of latitude. The concussion was perceptible over a great part of Sicily, and as far north as Naples; but the surface over which the shocks acted so forcibly as to excite intense alarm did not generally exceed five hundred square miles in area. The soil of that part of Calabria is composed chiefly, like the southern part of Sicily, of calcareo-argillaceous strata of great thickness, containing marine shells. This clay is sometimes associated with beds of sand and limestone. For the most part these formations resemble in appearance and consistency the Subapennine marls, with their accompanying sands and sandstones; and the whole group bears considerable resemblance, in the yielding nature of its materials, to most of our tertiary deposits in France and England. Chronologically considered, however, the Calabrian formations are comparatively of very modern date, and abound in fossil shells referrible to species now living in the Mediterranean.

We learn from Vivenzio that, on the 20th and 26th of March, 1783, earthquakes occurred in the islands of Zante, Cephalonia, and St. Maura; and in the last mentioned island several public edifices and private houses were overthrown, and many people destroyed. It has been already shown that the Ionian Islands fall within the line of the same great volcanic region as Calabria; so that both earthquakes were probably derived from a common source, and it is not improbable that the bed of the whole intermediate sea was convulsed.

If the city of Oppido, in Calabria, be taken as a centre, and round that centre a circle be described, with a radius of twenty-two miles, this space will comprehend the surface of the country which suffered the greatest alteration, and where all the towns and villages were destroyed. The first shock, of February 5th, 1783, threw down, in two minutes, the greater part of the houses in all the cities, towns, and villages, from the western flanks of the Apennines in Calabria Ultra to Messina in Sicily, and convulsed the whole surface of the country. Another occurred on the 28th of March, with almost equal violence. The granitic chain which passes through Calabria from north to south, and attains the height of many thousand feet, was shaken but slightly by the first shock, but more rudely by some which followed.

Some writers have asserted that the wave-like movements which were propagated through the recent strata, from west to east, became very violent when they reached the point of junction with the granite, as if a reaction was produced where the undulatory movement of the soft strata was suddenly arrested by the more solid rocks. But the statement of Dolomieu on this subject is most interesting, and, perhaps, in a geological point of view, the most important of all the observations which are recorded.*

The Apennines, he says, which consist in great part of hard and solid granite, with some micaceous and argillaceous schists, form bare mountains with steep sides, and exhibit marks of great degradation. At their base newer strata are seen of sand and clay, mingled with shells; a marine deposit containing such ingredients as would result from the decomposition of granite. The surface of this newer (*tertiary*) formation constitutes what is called the plain of Calabria—a platform which is flat and level, except where intersected by narrow valleys or ravines, which rivers and torrents have excavated sometimes to the depth of six hundred feet. The sides of these ravines are almost perpendicular; for the superior stratum, being bound together by the roots of trees, prevents the formation of a sloping bank. The usual effect of the earthquake, he continues, was to disconnect all those masses which either had not sufficient bases for their bulk, or which were supported only by lateral adherence. Hence it follows that throughout almost the whole length of the chain the soil which adhered to the granite at the base of the mountains Caulone, Esope, Sagra, and Aspramonte, slid over the solid and steeply inclined nucleus, and descended somewhat lower, leaving almost uninterruptedly from St. George to beyond St. Christina, a distance of from nine to ten miles, a chasm between the solid granitic nucleus and the sandy soil. Many lands slipping thus were carried to a considerable distance from their former position, so as entirely to cover others; and disputes arose as to whom the property which had thus shifted its place should belong.

* Dissertation on the Calabrian Earthquake, &c., translated in Pinkerton's Voyages and Travels, vol. v.

From this account of Dolomieu we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact than at a greater distance from the mountains; phenomena very common in other parts of Italy at the junction of the Apennine and Subapennine formations.

The surface of the country often heaved, like the billows of a swelling sea, which produced a swimming in the head, like sea-sickness. It is particularly stated, in almost all the accounts, that just before each shock the clouds appeared motionless; and, although no explanation is offered of this phenomenon, it is obviously the same as that observed in a ship at sea when it pitches violently. The clouds seem arrested in their career as often as the vessel rises in a direction contrary to their course; so that the Calabrians must have experienced precisely the same motion on the land.

Trees, supported by their trunks, sometimes bent during the shocks to the earth, and touched it with their tops. This is mentioned as a well-known fact by Dolomieu; and he assures us that he was always on his guard against the spirit of exaggeration in which the vulgar are ever ready to indulge when relating these wonderful occurrences.

I shall now consider, in the first place, that class of physical changes produced by the earthquake which are connected with alterations in the relative level of the different parts of the land; and afterwards describe those which are more immediately connected with the derangement of the regular drainage of the country, and where the force of running water co-operated with that of the earthquake.

Difficulty of ascertaining changes of level.—In regard to alterations of relative level, none of the accounts establish that they were on a considerable scale; but it must always be remembered that, in proportion to the area moved is the difficulty of proving that the general level has undergone any change, unless the sea-coast happens to have participated in the principal movement. Even then it is often impossible to determine whether an elevation or depression even of several feet has occurred, because there is nothing to attract notice in a band of shingle and sand of unequal breadth above the level of the sea running parallel to a coast; such bands generally marking the point reached by the waves during spring tides, or the most violent tempests. The scientific investigator has not sufficient topographical knowledge to discover whether the extent of beach has diminished or increased; and he who has the necessary local information scarcely ever feels any interest in ascertaining the amount of the rise or fall of the ground. Add to this the great difficulty of making correct observations, in consequence of the enormous waves which roll in upon a coast during an earthquake, and efface every landmark near the shore.

Subsidence of the Quay at Messina.—It is evidently in seaports alone that we can look for very accurate indications of slight changes of level; and when we find them, we may presume that they would not be rare at other points, if equal facilities of comparing relative altitudes were afforded. Grimaldi states (and his account is confirmed by Hamilton and others), that at Messina, in Sicily, the shore was rent; and the soil along the port, which before the shock was perfectly level, was found afterwards to be inclined towards the sea,—the sea itself near the "Banchina" becoming deeper, and its bottom in several places disordered. The quay also sunk down about fourteen inches below the level of the sea, and the houses in its vicinity were much fissured. (*Phil. Trans.* 1783.)

Among various proofs of partial elevation and depression in the interior, the Academicians mention; in their Survey, that the ground was sometimes on the same level on both sides of new ravines and fissures, but sometimes there had been a considerable shifting, either by the upheaving of one side, or the subsidence of the other. Thus, on the sides of long rents in the territory of Soriano, the stratified masses had altered their relative position to the extent of from eight to fourteen palms (six to ten and a-half feet).

Polistena.—Similar shifts in the strata are alluded to in the territory of Polistena, where there appeared innumerable fissures in the earth. One of these was of great length and depth; and in parts the level of the corresponding sides was greatly changed. (See Fig. 44.)

Fig. 44.

Deep fissure near Polistena, caused by the earthquake of 1783.

Terranuova.—In the town of Terranuova some houses were seen uplifted above the common level, and others adjoining sunk down into the earth. In several streets the soil appeared thrust up, and abutted against the walls of houses; a large circular tower of solid masonry, part of which had withstood the general destruction, was divided by a vertical rent, and one side was upraised, and the foundations heaved out of the ground. It was compared by the Academicians to a great tooth half extracted from the alveolus, with the upper part of the fangs exposed. (See Fig. 45.)

Fig. 45.

Shift or "fault" in the round tower of Terranuova in Calabria, occasioned by the earthquake of 1783.

Along the line of this shift, or "fault," as it would be termed technically by miners, the walls were found to adhere firmly to each other, and to fit so well, that the only signs of their having been disunited was the want of correspondence in the courses of stone on either side of the rent.

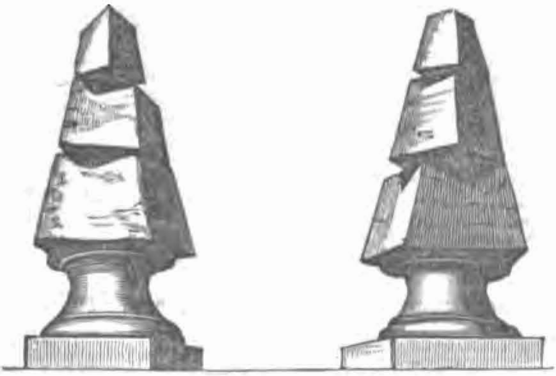
Dolomieu saw a stone well in the convent of the Augustins at Terranuova, which had the appearance of having been driven out of the earth. It resembled a small tower eight or nine feet in height, and a little inclined. This effect, he says, was produced by the consolidation and consequent sinking of the sandy soil in which the well was dug.

In some walls which had been thrown down, or violently shaken, in Monteleone, the separate stones were parted from the mortar, so as to leave an exact mould where they had rested; whereas in other cases the mortar was ground to dust between the stones.

It appears that the wave-like motions, and those which are called vorticose or whirling in a vortex, often produced effects of the most capricious kind. Thus in some streets of Monteleone, every house was thrown down but one; in others, all but two; and the buildings which were spared were often scarcely in the least degree injured.

In many cities of Calabria, all the most solid buildings were thrown down, while those which were slightly built escaped; but at Rosarno, as also at Messina in Sicily, it was precisely the reverse, the massive edifices being the only ones that stood. Two obelisks (Fig. 46.) placed at the extremities of a magnificent façade in the convent of S. Bruno, in a small town called Stefano del Bosco, were observed to have undergone a movement of a singular kind. The shock which agitated the building is described as having been horizontal and vorticose. The pedestal of each obelisk remained in its original place; but the separate stones above were turned partially round, and removed sometimes nine inches from their position without falling.

Fig. 46.

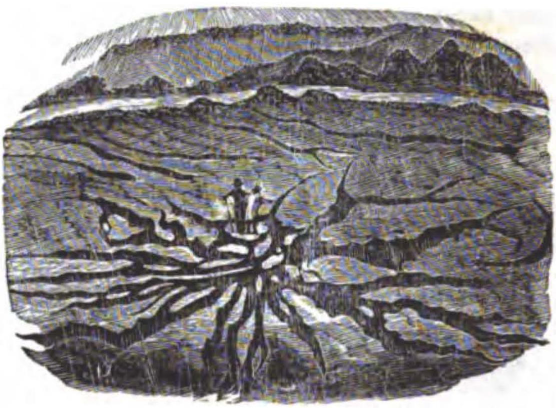


Shift in the stones of two obelisks in the Convent of S. Bruno.

Fissures.—It appears evident that a great part of the rending and fissuring of the ground was the effect of a violent motion from below upwards; and in a multitude of cases where the rents and chasms opened and closed alternately, we must suppose that the earth was by turns heaved up, and then let fall again. We may conceive the same effect to be produced on a small scale, if, by some mechanical force, a pavement composed of large flags of stone should be raised up, and then allowed to fall suddenly, so as to resume its original position. If any small pebbles happened to be lying on the line of contact of two flags, they would fall into the opening when the pavement rose, and be swallowed up, so that no trace of them would appear after the subsidence of the stones. In the same manner, when the earth was upheaved, large houses, trees, cattle, and men were engulfed in an instant in chasms and fissures; and when the ground sank down again, the earth closed upon them, so that no vestige of them was discoverable on the surface. In many instances, individuals were swallowed up by one shock, and then thrown out again alive, together with large jets of water, by the shock which immediately succeeded.

At Jerocarne, a country which, according to the Academicians, was *lacerated* in a most extraordinary manner, the fissures ran in every direction "like cracks on a broken pane of glass" (see Fig. 47.); and, as a great portion of them remained open after the shocks, it is very possible that this country was permanently upraised. It was usual, as we learn from Dolomieu, for the chasms and fissures throughout Calabria to run parallel to the course of some pre-existing gorges in their neighbourhood.

Fig. 47.



Fissures near Jerocarne, in Calabria, caused by the earthquake of 1783.

Houses engulfed.—In the vicinity of Oppido, the central point from which the earthquake diffused its violent movements, many houses were swallowed up by the yawning earth, which closed immediately over them. In the adjacent district, also, of Cannamaria, four farm-houses, several oil-stores, and some spacious dwelling-houses were so completely engulfed in one chasm, that not a vestige of them was afterwards discernible. The same phenomenon occurred at Terranuova, S. Christina, and Sinopoli. The Academicians state particularly, that when deep abysses had opened in the argillaceous strata of Terranuova, and houses had sunk into them, the sides of the chasms closed with such violence, that, on excavating afterwards to recover articles of value, the workmen found the contents and detached parts of the buildings jammed together so as to become one compact mass. It is unnecessary to accumulate examples of similar occurrences; but so many are well authenticated during this earthquake in Calabria, that we may, without hesitation, yield assent to the accounts of catastrophes of the same kind repeated again and again in history, where whole towns are declared to have been engulfed, and nothing but a pool of water or tract of sand left in their place.

Chasm formed near Oppido.—On the sloping side of a hill near Oppido a great chasm opened; and, although a large quantity of soil was precipitated into the abyss, together with a considerable number of olive-trees and part of a vineyard, a great gulf remained after the shock, in the form of an amphitheatre, 500 feet long and 200 feet deep. (See Fig. 48.)

Fig. 48.

Chasm formed by the earthquake of 1783 *near Oppido, in Calabria.*

Dimensions of new fissures and chasms.—According to Grimaldi, many fissures and chasms, formed by the first shock of February 5th, were greatly widened, lengthened, and deepened by the violent convulsions of March 28th. In the territory of San Fili this observer found a new ravine, half a mile in length, two feet and a half broad, and twenty-five feet deep; and another of similar dimensions in the territory of Rosarno. A ravine *nearly a mile long*, 105 feet broad, and thirty feet deep, opened in the district of Plaisano, where, also, two gulfs were caused—one in a place called Cerzulle, three-quarters of a mile long, 150 feet broad, and above *one hundred feet deep*; and another at La Fortuna, nearly a quarter of a mile long, above thirty feet in breadth, and no less than 225 feet deep.

In the district of Fosolano three gulfs opened: one of these measured 300 feet square, and above thirty feet deep; another was nearly half a mile long, fifteen feet broad, and above thirty feet deep; the third was 750 feet square. Lastly, a calcareous mountain, called Zefirio, at the southern extremity of the Italian peninsula, was cleft in two for the length of nearly half a mile, and an irregular breadth of many feet. Some of these chasms were in the form of a crescent. The cut (Fig. 49, p. 402,) represents one by no means remarkable for its dimensions, which remained open by the side of a small pass over the hill of St. Angelo, near Soriano. The small river Mesima is seen in the foreground.

Formation of new lakes.—In the vicinity of Seminara, a lake was suddenly formed by the opening of a great chasm, from the bottom of which water issued. This lake was called Lago del Tolfilo. It extended 1785 feet in length, by 937 in breadth, and 52 in depth. The inhabitants, dreading the miasma of this stagnant pool, endeavoured, at great

Fig. 49.

Chasm in the hill of St. Angelo, near Soriano, in Calabria, caused by the earthquake of 1783.

cost, to drain it by canals, but without success, as it was fed by springs issuing from the bottom of the deep chasm. A small circular subsidence occurred not far from Polistena, of which a representation is given (Fig. 50.).

Fig. 50.

Circular pond near Polistena, in Calabria, caused by the earthquake of 1783.

Gradual closing in of fissures.—Sir W. Hamilton was shown several deep fissures in the vicinity of Mileto, which, although not one of them was above a foot in breadth, had opened so wide during the earthquake as to swallow up an ox and nearly one hundred goats. The Academicians also found, on their return through districts which they had passed at the commencement of their tour, that many rents had, in that short interval, gradually closed in, so that their width had diminished several feet, and the opposite walls had sometimes nearly met. It is natural that this should happen in argillaceous strata, while, in more solid rocks, we may expect that fissures will remain open for ages. Should this be ascertained to be a general fact in countries convulsed by earthquakes, it may afford a satisfactory explanation of a common phenomenon in mineral veins. Such veins often retain their full size so long as the rocks consist of limestone, granite, or other indurated materials; but they contract their dimensions, become mere threads, or are even entirely cut off, where masses of an argillaceous nature are interposed. If we suppose the filling up of fissures with metallic and other ingredients to be a process requiring ages for its completion, it is obvious that the opposite walls of rents, where strata consist of yielding materials, must collapse or approach very near to each other before sufficient time is allowed for the accretion of a large quantity of veinstone.

Thermal waters augmented.—It is stated by Grimaldi, that the thermal waters of St. Eufemia, in Terra di Amato, which first burst out during the earthquake of 1638, acquired, in February, 1783, an augmentation both in quantity and degree of heat. This fact appears to indicate a connexion between the heat of the interior and the fissures caused by the Calabrian earthquakes, notwithstanding the absence of volcanic rocks, either ancient or modern, in that district.

Bounding of detached masses into the air.—The violence of the movement of the ground upwards was singularly illustrated by what the Academicans call the "sbalzo," or bounding into the air, to the height of several yards, of masses slightly adhering to the surface. In some towns, a great part of the pavement stones were thrown up, and found lying with their lower sides uppermost. In these cases, we must suppose that they were propelled upwards by the momentum which they had acquired; and that the adhesion of one end of the mass being greater than that of the other, a rotatory motion had been communicated to them. When the stone was projected to a sufficient height to perform somewhat more than a quarter of a revolution in the air, it pitched down on its edge, and fell with its lower side uppermost.

Effects of earthquakes on the excavation of valleys.—The next class of effects to be considered, are those more immediately connected with the formation of valleys, in which the action of water was often combined with that of the earthquake. The country agitated was composed, as before stated, chiefly of argillaceous strata, intersected by deep narrow valleys, sometimes from five to six hundred feet deep. As the boundary cliffs were in great part vertical, it will readily be conceived that, amidst the various movements of the earth, the precipices overhanging rivers, being without support on one side, were often thrown down. We find, indeed, that inundations produced by obstructions in river-courses are among the most disastrous consequences of great earthquakes in all parts of the world; for the alluvial plains in the bottoms of valleys are usually the most fertile and well-peopled parts of the whole country; and whether the site of a town is above or below a temporary barrier in the channel of a river, it is exposed to injury by the waters either of a lake or flood.

Landslips.—From each side of the deep valley or ravine of Terranuova, enormous masses of the adjoining flat country were detached, and cast down into the course of the river, so as to give rise to great lakes. Oaks, olive-trees, vineyards, and corn, were often seen growing at the bottom of the ravine, as little injured as their former companions, which still continued to flourish in the plain above, at least five hundred feet higher, and at the distance of about three-quarters of a mile. In one part of this ravine was an enormous mass, two hundred feet high, and about four hundred feet at its base, which had been detached by some former earthquake. It is well attested, that this mass travelled down the ravine nearly four miles, having been put in motion by the earthquake of the 5th of February. Hamilton, after examining the spot, declared that this phenomenon might be accounted for by the declivity of the valley, the great abundance of rain which fell, and the great weight of the alluvial matter which pressed behind it. Dolomieu also alludes to the fresh impulse derived from other masses falling, and pressing upon the rear of those first set in motion.

The first account sent to Naples of the two great slides or landslips above alluded to, which caused a great lake near Terranuova, was couched in these words:—"Two mountains on the opposite sides of a valley walked from their original position until they met in the middle of the plain, and there joining together, they intercepted the course of a river," &c. The expressions here used resemble singularly those applied to phenomena, probably very analogous, which are said to have occurred at Fez, during the great Lisbon earthquake, as also in Jamaica and Java at other periods.

Not far from Soriano, which was levelled to the ground by the great shock of February, a small valley, containing a beautiful olive-grove, called Fra Ramondo, underwent a most extraordinary revolution. Innumerable fissures first traversed the river-plain in all directions, and absorbed the water until the argillaceous substratum became soaked, so that a great part of it was reduced to a state of fluid paste. Strange alterations in the outline of the ground were the consequence, as the soil to a great depth was easily moulded into any form. In addition to this change, the ruins of the neighbouring hills were precipitated into the hollow; and while many olives were uprooted, others remained growing on the fallen masses, and inclined at various angles. (See Fig. 51.) The small river Caridi was entirely concealed for many days; and when at length it reappeared, it had shaped for itself an entirely new channel.

Fig. 51.

Changes of the surface at Fra Ramondo, near Soriano, in Calabria.

1. Portion of a hill covered with olives thrown down.
2. New bed of the river Caridi. 3. Town of Soriano.

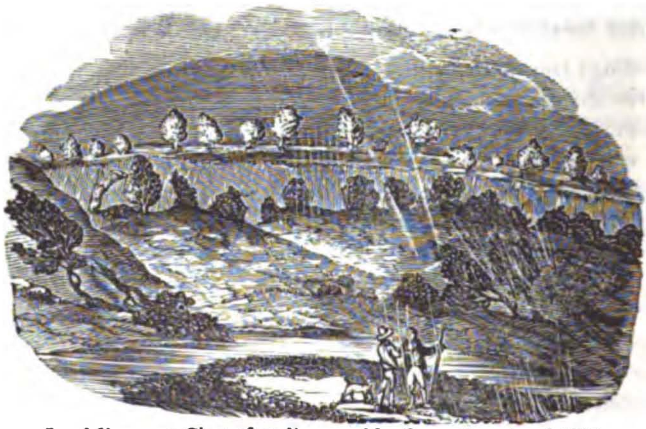
Buildings transported entire to great distances.—Near Seminara, an extensive olive-ground and orchard were hurled to a distance of two hundred feet, into a valley sixty feet in depth. At the same time a deep chasm was riven in another part of the high platform from which the orchard had been detached, and the river immediately entered the fissure, leaving its former bed completely dry. A small inhabited house, standing on the mass of earth carried down into the valley, went along with it entire, and without injury to the inhabitants. The olive trees, also, continued to grow on the land which had slid into the valley, and bore the same year an abundant crop of fruit.

Two tracts of land on which a great part of the town of Polistena stood, consisting of some hundreds of houses, were detached into a contiguous ravine, and nearly across it, about half a mile from their original site; and what is most extraordinary, several of the inhabitants were dug out from the ruins alive and unhurt.

Two tenements, near Mileto, called the Macini and Vaticano, about a mile long, and half a mile broad, were carried for a mile down a valley. A thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance. According to Hamilton, the surface removed had been long undermined by rivulets, which were afterwards in full view on the bare spot deserted by the tenements. The earthquake seems to have opened a passage in the adjoining argillaceous hills, which admitted water charged with loose soil into the subterranean channels of the rivulets immediately under the tenements, so that the foundations of the ground set in motion by the earthquake were loosened. Another example of subsidence, where the edifices were not destroyed, is mentioned by Grimaldi, as having taken place in the city of Catanzaro, the capital of the province of that name. The houses in the quarter called San Giuseppe subsided with the ground to various depths from two to four feet, but the buildings remained uninjured.

It would be tedious, and our space would not permit us, to follow the different authors through their local details of landslips produced in minor valleys; but they are highly interesting, as showing to how great an extent the power of rivers to widen valleys, and to carry away large portions of soil towards the sea, is increased where earthquakes are of periodical occurrence. Among other territories, that of Cinquefrondi was greatly convulsed, various portions of soil being raised or sunk, and innumerable fissures traversing the country in all directions. (See Fig. 52.) Along the flanks of a small valley in this district there appears to have been an almost uninterrupted line of landslips.

Fig. 52.



Landslips near Cinquefrondi, caused by the earthquake of 1783.

Number of new formed lakes.—Vivenzio states, that near Sitizzano a valley was nearly filled up to a level with the high grounds on each side, by the enormous masses detached from the boundary hills, and cast down into the course of two streams. By this barrier a lake was formed of great depth, about two miles long and a mile broad. The same author mentions that, upon the whole, there were fifty lakes occasioned during the convulsions: and he assigns localities to all of these. The government surveyors enumerated 215 lakes, but they included in this number many small ponds.

Currents of mud.—Near S. Lucido, among other places, the soil is described as having been "dissolved," so that large torrents of mud inundated all the low grounds, like lava. Just emerging from this mud, the tops only of trees and of the ruins of farmhouses were seen. Two miles from Laureana, the swampy soil in two ravines became filled with calcareous matter, which oozed out from the ground immediately before the first great shock. This mud, rapidly accumulating, began, ere long, to roll onward, like a flood of lava, into the valley, where the two streams uniting, moved forward with increased impetus from east to west. It now presented a breadth of 225 feet by fifteen in depth, and, before it ceased to move, covered a surface equal in length to an Italian mile. In its progress it overwhelmed a flock of thirty goats, and tore up by the roots many olive and mulberry trees, which floated like ships upon its

Fig. 53.

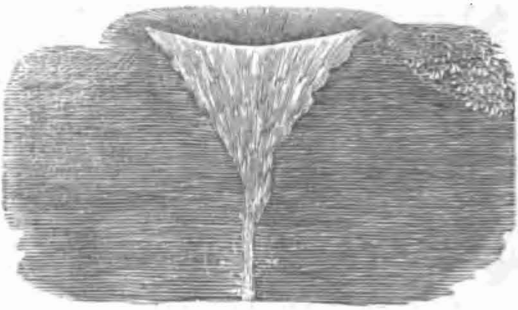
Circular hollows in the plain of Rosarno, formed by the earthquake of 1783.

surface. When this calcareous lava had ceased to move, it gradually became dry and hard, during which process the mass was lowered seven feet and a half. It contained fragments of earth of a ferruginous colour, and emitting a sulphureous smell.

Cones of sand thrown up.—Many of the appearances exhibited in the alluvial plains indicate clearly the alternate rising and sinking of the ground. The first effect of the more violent shocks was usually to dry up the rivers, but they immediately afterwards overflowed their banks. Along the alluvial plains, and in marshy places, an immense number of cones of sand were thrown up. These appearances Hamilton explains, by supposing that the first movement raised the fissured plain from below upwards, so that the rivers and stagnant waters in bogs sank down, or at least were not upraised with the soil. But when the ground returned with violence to its former position, the water was thrown up in jets through fissures.*

Formation of circular hollows.—In the report of the Academy, we find that some plains were covered with circular hollows, for the most part about the size of carriage-wheels, but often somewhat larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but, in general, they were filled with dry sand, sometimes with a concave surface, and at other times convex. (See Fig. 53, p. 407.) On digging down, they found them to be funnel-shaped, and the moist loose sand in the centre marked the tube up which the water spouted. The annexed cut (Fig. 54.) represents a section of one of these inverted cones when the water had disappeared, and nothing but dry micaceous sand remained.

Fig. 54.



Section of one of the circular hollows formed in the plain of Rosarno.

Fall of the sea cliffs.—Along the sea-coast of the Straits of Messina, near the celebrated rock of Scilla, the fall of huge masses detached from the bold and lofty cliffs overwhelmed many villas and gardens. At Gian Greco a continuous line of cliff, for a mile in length, was thrown down. Great agitation was frequently observed in the bed of the sea during the shocks, and, on those parts of the coast where the movement was most violent, all kinds of fish were taken in abundance, and with unusual facility. Some rare species, as that called Cicirelli, which usually lie buried in the sand, were taken on the surface of the waters in great quantity. The sea is said to have boiled up near Messina, and to have been agitated as if by a copious discharge of vapours from its bottom.

Shore near Scilla inundated.—The Prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of the 5th of February, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and

* Phil. Trans., vol. lxxiii. p. 180.

suddenly a great mass was torn from the contiguous Mount Jaci, and thrown down with a dreadful crash upon the plain. Immediately afterwards, the sea, rising more than twenty feet above the level of this low tract, rolled foaming over it, and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing with it some of the people and animals it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged Prince, with 1430 of his people, was destroyed.

State of Stromboli and Etna during the shocks.—The inhabitants of Pizzo remarked that, on the 5th of February, 1783, when the first great shock afflicted Calabria, the volcano of Stromboli, which is in full view of that town, and at the distance of about fifty miles, smoked less, and threw up a less quantity of inflamed matter, than it had done for some years previously. On the other hand, the great crater of Etna is said to have given out a considerable quantity of vapour towards the beginning, and Stromboli towards the close, of the commotions. But as no eruption happened from either of these great vents during the whole earthquake, the sources of the Calabrian convulsions, and of the volcanic fires of Etna and Stromboli, appear to be very independent of each other; unless, indeed, they have the same mutual relation as Vesuvius and the volcanos of the Phlegræan Fields and Ischia, a violent disturbance in one district serving as a safety-valve to the other, and both never being in full activity at once.

Excavations of valleys.—It is impossible for the geologist to consider attentively the effect of this single earthquake of 1783, and to look forward to the alterations in the physical condition of the country to which a continued series of such movements will hereafter give rise, without perceiving that the formation of valleys by running water can never be understood, if we consider the question independently of the agency of earthquakes. It must not be imagined that rivers only begin to act when a country is already elevated far above the level of the sea, for their action must of necessity be most powerful while land is *rising* or *sinking* by successive movements. Whether Calabria is now undergoing any considerable change of relative level, in regard to the sea, or is, upon the whole, nearly stationary, is a question which our observations, confined almost entirely to the last half century, cannot possibly enable us to determine. But we know that strata, containing species of shells identical with those now living in the contiguous parts of the Mediterranean, have been raised in that country, as they have in Sicily, to the height of several thousand feet.

Now, those geologists who grant that the present course of Nature in the inanimate world, has continued the same since the existing species of animals were in being, will not feel surprise that the Calabrian streams and rivers have cut out of such comparatively modern strata a great system of valleys, varying in depth from fifty to six hundred feet, and often several miles wide, if they consider how numerous must have been the earthquakes which lifted those recent marine strata to so prodigious a height. Some speculators, indeed, who disregard the analogy of existing Nature, and who are always ready to assume that her forces were more energetic in by-gone ages, may dispense with a long series of movements, and suppose that Calabria "rose like an exhalation" from the deep, after the manner of Milton's Pandemonium. But such an hypothesis would deprive them of that peculiar removing force required to form a regular system of deep and wide valleys; for *time*, which they are so unwilling to assume, is essential to the operation. Time must be allowed in the intervals between distinct convulsions, for running water to clear away the ruins caused by landslips, otherwise the fallen masses will serve as buttresses, and prevent the succeeding earthquake from exerting its full power. The sides of the valley must be again cut away by the stream, and made to form precipices and overhanging cliffs, before the next shock can take effect in the same manner.

Possibly the direction of the succeeding shock may not coincide with that of the valley, a great extent of adjacent country being equally shaken. Still it will usually happen that no permanent geographical change will be produced except in valleys. In them alone will occur landslips from the boundary cliffs, and these will frequently divert the stream from its accustomed course, causing the original ravine to become both wider and more tortuous in its direction.

If a single convulsion of extreme violence should agitate at once an entire hydrographical basin, or if the shocks should follow each other too rapidly, the previously existing valleys would be annihilated, instead of being modified and enlarged. Every stream might in that case be compelled to begin its operations anew, and to shape out new channels, instead of continuing to deepen and widen those already excavated. But if the subterranean movements have been intermittent; and if sufficient periods have always intervened between the severer shocks to allow the drainage of the country to be nearly restored to its original state, then are both the kind and degree of force supplied by which running water may hollow out valleys of any depth or size consistent with the elevation above the sea which the districts drained by them may have attained.

When we read of the drying up and desertion of the channels of rivers, the accounts most frequently refer to their deflection into some other part of the same alluvial plain, perhaps several miles distant. Under certain circumstances, a change of level may undoubtedly force the water to flow over into some distinct hydrographical basin; but even then it will fall immediately into some other system of valleys already formed.

We learn from history that, ever since the first Greek colonists settled in Calabria, that region has been subject to devastation by earthquakes;

and, for the last century and a-half, ten years have seldom elapsed without a shock: but the severer convulsions have not only been separated by intervals of twenty, fifty, or one hundred years, but have not affected precisely the same points when they recurred. Thus the earthquake of 1783, although confined within the same geographical limits as that of 1638, and not very inferior in violence, visited, according to Grimaldi, very different districts. The points where the local intensity of the force is developed being thus perpetually varied, more time is allowed for the removal of separate mountain masses thrown into river channels by each shock.

When chasms and deep hollows open at the bottom of valleys, they must often be filled with those "mud lavas" before described; and these must be extremely analagous to the enormous ancient deposits of mud which are seen in many countries, as in the basin of the Tay, Isla, and North Esk rivers, for example, in Scotland—alluvions hundreds of feet thick, which are neither stratified nor laminated like the ordinary sediment which subsides from water. Whenever a landslip blocks up a river, these currents of mud will be arrested, and accumulate to an enormous depth.

The portion of the Calabrian valleys formed within the last three thousand years may be inconsiderable in amount, compared to that previously formed, just as the lavas which have flowed from Etna since the historical era constitute but a small proportion of the whole cone. But as a continued series of such eruptions as man has witnessed would reproduce another cone like Etna, so a sufficient number of earthquakes like that of 1783 would enable torrents and rivers to re-excavate all the Calabrian valleys, if they were now to be entirely obliterated. It must be evident that more change is effected in two centuries in the width and depth of the valleys of that region, than in many thousand years in a country as undisturbed by earthquakes as Great Britain. For the same reason, therefore, that he who desises to comprehend the volcanic phenomena of Central France will repair to Vesuvius, Etna, or Hecla, so they who aspire to explain the mode in which valleys are formed, must visit countries where earthquakes are of frequent occurrenee. For we may be assured, that the power which uplifted our more ancient tertiary strata of marine origin to more than a thousand feet above the level of the sea, co-operated at some former epoch with the force of rivers in the removal of large portions of rock and soil, just as the elevatory power which has upraised new strata to the height of several thousand feet in the south of Italy has caused those formations to be already intersected by deep valleys and ravines.

Number of persons who perished during the earthquake.—The number of persons who perished during the earthquake in the two Calabrias and Sicily is estimated by Hamilton at about forty thousand, and about twenty thousand more died by epidemics, which were caused by insufficient nourishment, exposure to the atmosphere, and malaria, arising from the new stagnant lakes and pools.

By far the greater number were buried under the ruins of their houses; but many were burnt to death in the conflagrations which almost invariably followed the shocks. These fires raged the more violently in some cities, such as Oppido, from the immense magazines of oil which were consumed.

Many persons were engulfed in deep fissures, especially the peasants, when flying across the open country, and their skeletons may perhaps be buried in the earth to this day, at the depth of several hundred feet.

When Dolomieu visited Messina after the shock of February 5th, he describes the city as still presenting, at least at a distance, an imperfect image of its ancient splendour. Every house was injured, but the walls were standing: the whole population had taken refuge in wooden huts in the neighbourhood, and all was solitude and silence in the streets: it seemed as if the city had been desolated by the plague, and the impression made upon his feelings was that of melancholy and sadness. "But when I passed over to Calabria, and first beheld Polistena, the scene of horror almost deprived me of my faculties; my mind was filled with mingled compassion and terror; nothing had escaped; all was levelled with the dust; not a single house or piece of wall remained; on all sides were heaps of stone so destitute of form, that they gave no conception of there ever having been a town on the spot. The stench of the dead bodies still rose from the ruins. I conversed with many persons who had been buried for three, four, and even for five days; I questioned them respecting their sensations in so dreadful a situation, and they agreed that, of all the physical evils they endured, thirst was the most intolerable; and that their mental agony was increased by the idea that they were abandoned by their friends, who might have rendered them assistance."*

It is supposed that about a fourth part of the inhabitants of Polistena, and of some other towns, were buried alive, and might have been saved had there been no want of hands; but in so general a calamity, where each was occupied with his own misfortunes, or those of his family, aid could rarely be obtained. Neither tears, nor supplications, nor promises of high rewards, were listened to. Many acts of self-devotion, prompted by parental and conjugal tenderness, or by friendship, or the gratitude of faithful servants, are recorded; but individual exertions were, for the most part, ineffectual. It frequently happened, that persons in search of those most dear to them could hear their moans,—could recognise their

* Dissertation on the Calabrian Earthquake, &c., translated in Pinkerton's Voyages and Travels, vol. v.

voices,—were certain of the exact spot where they lay buried beneath their feet, yet could afford them no succour. The piled mass resisted all their strength, and rendered their efforts of no avail.

At Terranuova, four Augustin monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support an immense pile of ruins, made their cries heard for the space of four days. One only of the brethren of the whole convent was saved, and "of what avail was his strength to remove the enormous weight of rubbish which had overwhelmed his companions?" He heard their voices die away gradually; and when afterwards their four corpses were disinterred, they were found clasped in each other's arms. Affecting narratives are preserved of mothers saved after the fifth, sixth, and even seventh day of their interment, when their infants or children had perished with hunger.

It might have been imagined that the sight of sufferings such as these would have been sufficient to awaken sentiments of humanity and pity in the most savage breasts, but nothing could exceed the atrocity of conduct and moral depravity displayed by the Calabrian peasants: they abandoned the farms, and flocked in great numbers into the towns—not to rescue their countrymen from a lingering death, but to plunder. They dashed through the streets, fearless of danger, amid tottering walls and clouds of dust, trampling beneath their feet the bodies of the wounded and half buried, and often stripping them, while yet living, of their clothes.*

Concluding remarks.—But to enter more fully into these details would be foreign to the purpose of the present work, and several volumes would be required to give the reader a just idea of the sufferings which the inhabitants of many populous districts have undergone during the earthquakes of the last 140 years. A bare mention of the loss of life—as that fifty or a hundred thousand souls perished in one catastrophe—conveys to the reader no idea of the extent of misery inflicted: we must learn, from the narratives of eye-witnesses, the various forms in which death was encountered, the numbers who escaped with loss of limbs or serious bodily injuries, and the multitude who were suddenly reduced to penury and want. It has been often remarked, that the dread of earthquakes is strongest in the minds of those who have experienced them most frequently; whereas, in the case of almost every other danger, familiarity with peril renders men intrepid. The reason is obvious—scarcely any part of the mischief apprehended in this instance is imaginary; the first shock is often the most destructive; and, as it may occur in the dead of the night, or if by day, without giving the least warning of its approach, no forethought can guard against it; and when the convulsion has begun, no skill, or courage, or presence of mind, can point out the path of safety. During the intervals, of uncertain duration, between the more fatal

* Dolomieu, Ibid.

shocks, slight tremors of the soil are not unfrequent; and as these sometimes precede more violent convulsions, they become a source of anxiety and alarm. The terror arising from this cause alone is of itself no inconsiderable evil.

Although sentiments of pure religion are frequently awakened by these awful visitations, yet we more commonly find that an habitual state of fear, a sense of helplessness, and a belief in the futility of all human exertions, prepare the minds of the vulgar for the influence of a demoralizing superstition.

Where earthquakes are frequent, there can never be perfect security of property under the best government; industry cannot be assured of reaping the fruits of its labour; and the most daring acts of outrage may occasionally be perpetrated with impunity, when the arm of the law is paralysed by the general consternation. It is hardly necessary to add, that the progress of civilization and national wealth must be retarded by convulsions which level cities to the ground, destroy harbours, render roads impassable, and cause the most cultivated valley-plains to be covered with lakes, or the ruins of adjoining hills.

Those geologists who imagine that, at remote periods, ere man became a sojourner on earth, the volcanic agency was more energetic than now, should be careful to found their opinion on strict geological evidence, and not permit themselves to be biassed, as they have often been, by a notion, that the disturbing force would probably be mitigated for the sake of man.

I shall endeavour to point out in the sequel, that the general tendency of subterranean movements, when their effects are considered for a sufficient lapse of ages, is eminently beneficial, and that they constitute an essential part of that mechanism by which the integrity of the habitable surface is preserved, and the very existence and perpetuation of dry land secured. Why the working of this same machinery should be attended with so much evil, is a mystery far beyond the reach of our philosophy, and must probably remain so until we are permitted to investigate, not our planet alone and its inhabitants, but other parts of the moral and material universe with which they may be connected. Could our survey embrace other worlds, and the events, not of a few centuries only, but of periods as indefinite as those with which geology renders us familiar, some apparent contradictions might be reconciled, and some difficulties would doubtless be cleared up. But even then, as our capacities are finite, while the scheme of the universe may be infinite, both in time and space, it is presumptuous to suppose that all sources of doubt and perplexity would ever be removed. On the contrary, they might, perhaps, go on augmenting in number; for it has been justly said, that the greater the circle of light, the greater the boundary of darkness by which it is surrounded.*

* Sir H. Davy, Consolations in Travel, p. 246.

CHAPTER XVI.

EARTHQUAKES OF THE EIGHTEENTH CENTURY—*continued.*

Earthquake of Guatimala, 1773—Java, 1772—Truncation of a lofty cone—St. Domingo, 1770—Colombia, 1766—Lisbon, 1755—Shocks felt throughout Europe, Northern Africa, and the West Indies—Great wave (p. 414.)—Conception Bay, 1750—Permanent elevation—Peru, 1746—Kamtschatka, 1737—Java, 1699 (p. 417.)—Rivers obstructed by landslips—Subsidence in Sicily, 1693—Moluccas, 1693—Jamaica, 1692—Large tracts engulfed—Portion of Port Royal sunk—Amount of change in the last 140 years—Elevation and subsidence of land in Bay of Baiæ (p. 426.)—Evidence of the same afforded by the Temple of Serapis.

In the preceding chapters we have considered a small part of those earthquakes only which have occurred during the last fifty years, of which accurate and authentic descriptions happen to have been recorded. We may next proceed to examine some of earlier date, respecting which information of geological interest has been obtained.

Mexico, June, 1773.—The town of Guatimala was founded, in 1742, on the side of a volcano, in a valley about three miles wide, opening to the South Sea; nine years afterwards it was destroyed by an earthquake, and again, in 1773, during an eruption of the volcano. The ground on which the town stood gaped open in deep fissures, until at length, after five days, an abyss opened, and the city, with all its riches, and eight thousand families, was swallowed up. Every vestige of its former existence was entirely obliterated, and the spot is now indicated by a frightful desert, four leagues distant from the present town.*

Java, 1772—*Truncation of a lofty cone.*—In the year 1772, Papandayang, formerly one of the loftiest volcanos in the island of Java, was in eruption. Before all the inhabitants on the declivities of the mountain could save themselves by flight, the ground began to give way, and a great part of the volcano fell in and disappeared. It is estimated that an extent of ground of the mountain itself and its immediate environs, fifteen miles long and full six broad, was by this commotion swallowed up in the bowels of the earth. Forty villages were destroyed, some being engulfed and some covered by the substances thrown out on this occasion, and 2957 of the inhabitants perished. A proportionate number of cattle were also killed, and most of the plantations of cotton, indigo, and coffee in the adjacent districts were buried under the volcanic matter. This catastrophe appears to have resembled, although on a grander scale, that of the ancient Vesuvius in the year 79. The cone was reduced in height

* Von Hoff—Dodsley's Ann. Regist., vol. xvi. p. 149.

from nine thousand to about five thousand feet; and, as vapours still escape from the crater on its summit, a new cone may one day rise out of the ruins of the ancient mountain, as the modern Vesuvius has risen from the remains of Somma.*

Caucasus, 1772.—About the year 1772, an earthquake convulsed the ground in the province at Beshtau, in the Caucasus, so that part of the hill Metshuka sunk into an abyss.†

St. Domingo, 1770.—During a tremendous earthquake which destroyed a great part of St. Domingo, innumerable fissures were caused throughout the island, from which mephitic vapours emanated and produced an epidemic. *Hot springs* burst forth in many places where there had been no water before; but after a time they ceased to flow.‡

Colombia, 1766.—On the 21st of October, 1766, the ground was agitated at once at Cumana, at Caraccas, at Maraycabo, and on the banks of the rivers Casenare, the Meta, the Orinoco, and the Ventuario. These districts were much fissured, and great fallings in of the earth took place in the mountain Paurari: Trinidad was violently shaken. A small island in the Orinoco, near the rock Aravacoto, sunk down and disappeared.§ At the same time the ground was raised in the sea near Cariaco, where the Point Del Gardo was enlarged. A rock also rose up in the river Guarapica, near the village of Maturin.‖ The shocks continued in Colombia hourly for fourteen months.

Hindostan, 1762.—The town of Chittagong, in Bengal, was violently shaken by an earthquake, on the 2d of April 1762, the earth opening in many places, and throwing up water and mud of a sulphureous smell. At a place called Bardavan a large river was dried up; and at Bakar Churak, near the sea, a tract of ground sunk down, and 200 people with all their cattle were lost. Unfathomable chasms are described as remaining open in many places after the shocks, and towns which subsided several cubits were overflowed with water; among others, Deep Gong, which was submerged to the depth of seven cubits. Two volcanos are said to have opened in the Secta Cunda hills. The shock was also felt at Calcutta.¶

Lisbon, 1755.—In no part of the volcanic region of southern Europe has so tremendous an earthquake occurred in modern times as that which

* Dr. Horsfield, Batav. Trans., vol. viii. p. 26. Dr. H. informs me that he has seen this truncated mountain: and, though he did not ascend it, he has conversed with those who have examined it. Raffles's account (History of Java, vol. i.) is derived from Horsfield.

† Pallas's Travels in Southern Russia.

‡ Essai sur l'Hist. Nat. de l'Isle de St. Domingue, Paris, 1776.

§ Humboldt's Personal Narrative, vol. iv. p. 45; and Saggio di Storia Americana, vol. ii. p. 6.

‖ Humboldt, Voy. Relat. Hist., part i. p. 307; and part ii. p. 23.

¶ Dodsley's Ann. Regist., 1763. For other particulars see Phil. Trans., vol. liii.

began on the 1st of November, 1755, at Lisbon. A sound of thunder was heard underground, and immediately afterwards a violent shock threw down the greater part of that city. In the course of about six minutes, sixty thousand persons perished. The sea first retired and laid the bar dry; it then rolled in, rising fifty feet or more above its ordinary level. The mountains of Arrabida, Estrella, Julio, Marvan, and Cintra, being some of the largest in Portugal, were impetuously shaken, as it were, from their very foundations; and some of them opened at their summits, which were split and rent in a wonderful manner, huge masses of them being thrown down into the subjacent valleys.* Flames are related to have issued from these mountains, which are supposed to have been electric; they are also said to have smoked; but vast clouds of dust may have given rise to this appearance.

Subsidence of the Quay.—The most extraordinary circumstance which occurred at Lisbon during the catastrophe was the subsidence of a new quay, built entirely of marble at an immense expense. A great concourse of people had collected there for safety, as a spot where they might be beyond the reach of falling ruins; but, suddenly, the quay sank down with all the people on it, and not one of the dead bodies ever floated to the surface. A great number of boats and small vessels anchored near it, all full of people, were swallowed up, as in a whirlpool.† No fragments of these wrecks ever rose again to the surface, and the water in the place where the quay had stood is stated, in many accounts, to be unfathomable; but Whitehurst says he ascertained it to be one hundred fathoms.‡

In this case, we must either suppose that a certain tract sank down into a subterranean hollow, which would cause a "fault" in the strata to the depth of six hundred feet, or we may infer, as some have done, from the entire disappearance of the substances engulfed, that a chasm opened and closed again. Yet, in adopting this latter hypothesis, we must suppose that the upper part of the chasm, to the depth of one hundred fathoms, remained open.

Area over which the earthquake extended.—The great area over which this Lisbon earthquake extended is very remarkable. The movement was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even the West Indies, felt the shock on the same day. A seaport, called St. Ubes, about twenty miles south of Lisbon, was engulfed. At Algiers and Fez, in Africa, the agitation of the earth was equally violent; and at the distance of eight leagues from Morocco, a village with the inhabitants, to the number of about eight or

* Hist. and Philos. of Earthquakes, p. 317.

† Rev. C. Davy's Letters, vol. ii. Letter ii. p. 12, who was at Lisbon at the time, and ascertained that the boats and vessels said to have been swallowed were missing.

‡ On the Formation of the Earth, p. 55.

ten thousand persons, together with all their cattle, were swallowed up. Soon after the earth closed again over them.

Shocks felt at sea.—The shock was felt at sea, on the deck of a ship to the west of Lisbon, and produced very much the same sensation as on dry land. Off St. Lucar, the captain of the ship Nancy felt his vessel so violently shaken, that he thought she had struck the ground; but, on heaving the lead, found a great depth of water. Captain Clark, from Denia, in latitude 36° 24′ N., between nine and ten in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. Another ship, forty leagues west of St. Vincent, experienced so violent a concussion, that the men were thrown a foot and a-half perpendicular up from the deck. In Antigua and Barbadoes, as also in Norway, Sweden, Germany, Holland, Corsica, Switzerland, and Italy, tremors and slight oscillations of the ground were felt.

Rate at which the movement travelled.—The agitation of lakes, rivers, and springs, in Great Britain, was remarkable. At Loch Lomond in Scotland, for example, the water, without the least apparent cause, rose against its banks, and then subsided below its usual level. The greatest perpendicular height of this swell was two feet four inches. It is said that the movement of this earthquake was undulatory, and that it travelled at the rate of twenty miles a minute, its velocity being calculated by the intervals between the time when the first shock was felt at Lisbon, and its time of occurrence at other distant places.*

Great wave and retreat of the sea.—A great wave swept over the coast of Spain, and it is said to have been sixty feet high at Cadiz. At Tangier, in Africa, it rose and fell eighteen times on the coast. At Funchal, in Madeira, it rose full fifteen feet perpendicular above high-water mark, although the tide, which ebbs and flows there seven feet, was then at half ebb. Besides entering the city, and committing great havoc, it overflowed other seaports in the island. At Kinsale, in Ireland, a body of water rushed into the harbour, whirled round several vessels, and poured into the market-place.

It was before stated that the sea first retired at Lisbon; and this retreat of the ocean from the shore, at the commencement of an earthquake and its subsequent return in a violent wave, is a common occurrence. In order to account for the phenomenon, Michell imagined a subsidence at the bottom of the sea, from the giving way of the roof of some cavity in consequence of a vacuum produced by the condensation of steam. Such condensation, he observes, might be the first effect of the introduction of a large body of water into fissures and cavities already filled with

* Michell on the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. p. 566. 1760.

steam, before there has been sufficient time for the heat of the incandescent lava to turn so large a supply of water into steam, which being soon accomplished causes a greater explosion.

Another proposed explanation is, the sudden rise of land, which would cause the sea to abandon immediately the ancient line of coast; and if the shore, after being thus heaved up, should fall again to its original level, the ocean would return. This theory, however, will not account for the facts observed during the Lisbon earthquake; for the retreat preceded the wave, not only on the coast of Portugal, but also at the island of Madeira, and several other places. If the upheaving of the coast of Portugal had caused the retreat, the motion of the waters, when propagated to Madeira, would have produced a wave previous to the retreat. Nor could the motion of the waters at Madeira have been caused by a different local earthquake; for the shock travelled from Lisbon to Madeira in two hours, which agrees with the time which it required to reach other places equally distant.*

The following is, perhaps, the most probable solution of the problem which has yet been offered:—Suppose a portion of the bed of the sea to be suddenly upheaved, the first effect will be to raise over the elevated part a body of water, the momentum of which will carry it much above the level it will afterwards assume, causing a draught or receding of the water from the neighbouring coasts, followed immediately by the return of the displaced water, which will also be impelled by its momentum, much farther and higher on the coast than its former level.†

St. Domingo, 1751.—On the fifteenth of September, 1751, an earthquake began in several of the West India Islands; and on the twenty-first of November, a violent shock destroyed the capital of St. Domingo, Port au Prince. Part of the coast, twenty leagues in length, sank down, and has ever since formed a bay of the sea.‡

Chili, 1750.—On the twenty-fourth of May, 1750, the ancient town of Conception, otherwise called Penco, was totally destroyed by an earthquake, and the sea rolled over it. (See plan of the Bay, Fig. 42, p. 378.) The ancient port was rendered entirely useless, and the inhabitants built another town ten miles from the sea-coast, in order to be beyond the reach of similar inundations.

Proofs of elevation of twenty-four feet.—During a late survey of Conception Bay, Captains Beechy and Belcher discovered that the ancient harbour, which formerly admitted all large merchant vessels which went round the Cape, is now occupied by a reef of sandstone, certain points of which project above the sea at low water, the greater part being very

* Michell, Phil. Trans., vol. li. p. 614.

† Quarterly Review, No. 86, p. 459.

‡ Hist. de l'Acad. des Sciences. 1752. Paris.

shallow. A tract of a mile and a-half in length, where, according to the report of the inhabitants, the water was formerly four or five fathoms deep, is now a shoal: consisting, as our hydrographers found, of hard sandstone, so that it cannot be supposed to have been formed by recent deposits of the river Biobio, an arm of which carries down loose micaceous sand into the same side of the bay. Besides, it is a well-known fact that ever since the shock of 1750, no vessels have been able to approach within a mile and a half of the ancient port of Penco. (See Map, p. 378.) That shock, therefore, uplifted the bed of the sea to the height of twenty-four feet at least, and, most probably, the adjoining coast shared in the elevation; for an enormous bed of shells of the same species as those now living in the bay, are seen raised above high-water mark along the beach, filled with micaceous sand like that which the Biobio now conveys to the bay. These shells, as well as others, which cover the adjoining hills of mica-schist to the height of 1000 to 1500 feet, have lately been examined by experienced conchologists in London, and identified with those taken at the same time in a living state from the bay and its neighbourhood.*

Ulloa, therefore, was perfectly correct in his statement that, at various heights above the sea between Talcahuano and Conception, "mines were found of various sorts of shells used for lime of the very same kinds as those found in the adjoining sea." Among them he mentions the great muscle called Choros, and two others, which he describes. Some of these, he says, are entire, and others broken; they occur at the bottom of the sea, in four, six, ten, or twelve fathom water, where they adhere to a sea-plant called Cochayuyo. They are taken in dredges, and have no resemblance to those found on the shore or in shallow water; yet beds of them occur at various heights on the hills. "I was the more pleased with the sight," he adds, "as it appeared to me a convincing proof of the universality of the deluge, although I am not ignorant that some have attributed their position to other causes; but an unanswerable confutation of their subterfuge is, that the various sorts of shells which compose these strata, both in the plains and mountains, are the very same with those found in the bay."† Perhaps the diluvian theory of this distinguished navigator, the companion of Condamine, may account for his never having recorded even reports of changes in the relative level of land and sea on the shores of South America. He could not, however, have given us a relation of the rise of the reef above alluded to; for the destruction of Penco happened a few years after the publication of his Voyages.

If we duly consider these facts, so recently brought to light, as well as

* Captain Belcher has shown me these shells, and the collection has been examined by Mr. Broderip.

† Ulloa's Voyage to South America, vol. ii. book viii. ch. vi.

the elevations before mentioned of the coast of Chili in 1822 and 1835, we shall be less sceptical than Raspe, in regard to an event for which Hooke had cited Purchas's Travels. In that passage it was stated, that "a certain sea-coast in a province of South America, called Chili, was, during a violent earthquake, propelled upwards with such force and velocity, that some ships on the sea were grounded in it, and the sea receded to a distance." Raspe, being himself of opinion that all the continents had been upraised gradually by earthquakes from the sea, admitted that the circumstance was not impossible; but he complains that Purchas had interpolated the account of the earthquake (which happened, probably, at the close of the seventeenth century) into Da Costa's History of the West Indies.*

Peru, 1746.—Peru was visited, on the 28th of October, 1746, by an earthquake, which is declared to have been more tremendous and extensive than even that of Lisbon in 1755. In the first twenty-four hours, two hundred shocks were experienced. The ocean twice retired and returned impetuously upon the land: Lima was destroyed, and part of the coast near Callao was converted into a bay; four other harbours, among which were Cavalla and Guanape, shared the same fate. There were twenty-three ships and vessels, great and small, in the harbour of Callao, of which nineteen were sunk; and the other four, among which was a frigate called St. Fermin, were carried by the force of the waves to a great distance up the country. The number of the inhabitants in this city amounted to four thousand. Two hundred only escaped, twenty-two of whom were saved on a small fagment of the fort of Vera Cruz, which remained as the only memorial of the site of the town after this dreadful inundation.

A volcano in Lucanas burst forth the same night, and such quantities of water descended from the cone that the whole country was overflowed; and in the mountain near Patao, called Conversiones de Caxamarquilla, three other volcanos burst out, and frightful torrents of water swept down their sides.†

Kamtschatka, 1737, &c.—There are records of earthquakes in Kamtschatka and the Kurile Isles, in 1737,—in Martinique, in 1727,—Iceland, 1725,—Teneriffe, 1706,—during which the shape of the ground both above and beneath the level of the sea was greatly changed.

Java, 1699.—On the 5th of January, 1699, a terrible earthquake visited Java, and no less than 208 considerable shocks were reckoned. Many houses in Batavia were overturned, and the flame and noise of a volcanic eruption were seen and heard in that city, which were afterwards found to proceed from Mount Salak,‡ a volcano six days' journey

* De Novis Insulis, p. 120. 1753.

† Ulloa's Voyage, vol. ii. book vii. chap. vii.

‡ Misspelt Sales in Hooke's Account.

distant. Next morning the Batavian river, which has its rise from that mountain, became very high and muddy, and brought down abundance of bushes and trees, half burnt. The channel of the river being stopped up, the water overflowed the country round the gardens about the town, and some of the streets, so that fishes lay dead in them. All the fish in the river, except the carps, were killed by the mud and turbid water. A great number of drowned buffalos, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down by the current; and, "notwithstanding," observes one of the writers, "that a crocodile is amphibious, several of them were found dead among the rest."*

It is stated, that seven hills bounding the river sank down, by which is merely meant, as by similar expressions in the description of the Calabrian earthquakes, seven great landslips. These hills, descending some from one side of the valley and some from the other, filled the channel, and the waters then finding their way under the mass, flowed out thick and muddy. The Tangaran river was also dammed up by nine hills, and in its channels were large quantities of drift trees. Seven of its tributaries also are said to have been "covered up with earth." A high tract of forest land, between the two great rivers before mentioned, is described as having been changed into an open country, destitute of trees, the surface being spread over with a fine red clay. This part of the account may, perhaps, merely refer to the sliding down of woody tracts into the valleys, as happened to so many extensive vineyards and olive grounds in Calabria, in 1783. The close packing of large trees in the Batavian river is represented as very remarkable, and it attests in a striking manner the destruction of soil bordering the valleys which had been caused by floods and landslips.†

Quito, 1698.—In Quito, on the 19th of July, 1698, during an earthquake, a great part of the crater and summit of the volcano Carguairazo fell in, and a stream of water and mud issued from the broken sides of the hill.‡

Sicily, 1693.—Shocks of earthquakes spread over all Sicily in 1693, and on the 11th of January the city of Catania and forty-nine other places were levelled to the ground, and about one hundred thousand people killed. The bottom of the sea, says Vicentino Bonajutus, sank down considerably, both in ports, inclosed bays, and open parts of the coast, and water bubbled up along the shores. Numerous long fissures of various breadths were caused, which threw out sulphureous water; and one of them, in the plain of Catania (the delta of the Simeto), at the distance of four miles from the sea, sent forth water as salt as the sea. The stone buildings of a street in the city of Noto, for the length of half a mile, sank

* Hooke's Posthumous Works, p. 437. 1705. † Phil. Trans. 1700.
‡ Humboldt, Atl. Pit., p. 106.

into the ground, and remained hanging on one side. In another street, an opening large enough to swallow a man and horse appeared.*

Moluccas, 1693.—The small isle of Sorea, which consists of one great volcano, was in eruption in the year 1693. Different parts of the cone fell, one after the other, into a deep crater, until almost half the space of the island was converted into a fiery lake. Most of the inhabitants fled to Banda; but great pieces of the mountain continued to fall down, so that the lake of lava became wider; and finally the whole population was compelled to emigrate. It is stated that, in proportion as the burning lake increased in size, the earthquakes were less vehement.†

Jamaica, 1692.—In the year 1692, the island of Jamaica was visited by a violent earthquake; the ground was swelled and heaved like a rolling sea, and was traversed by numerous cracks, two or three hundred of which were often seen at a time opening and then closing rapidly again. Many people were swallowed up in these rents; some the earth caught by the middle, and squeezed to death; the heads of others only appeared above ground; and some were first engulfed, and then cast up again with great quantities of water. Such was the devastation, that even at Port Royal, then the capital, where more houses are said to have been left standing than in the whole island beside, three-quarters of the buildings, together with the ground they stood on, sank down with their inhabitants entirely under water.

Subsidence in the harbour.—The large store-houses on the harbour side subsided, so as to be twenty-four, thirty-six, and forty-eight feet under water; yet many of them appear to have remained standing, for it is stated that, after the earthquake, the mast-heads of several ships wrecked in the harbour, together with the chimney-tops of houses, were just seen projecting above the waves. A tract of land round the town, about a thousand acres in extent, sank down in less than one minute, during the first shock, and the sea immediately rolled in. The Swan frigate, which was repairing in the wharf, was driven over the tops of many buildings, and then thrown upon one of the roofs, through which it broke. The breadth of one of the streets is said to have been doubled by the earthquake.

According to Mr. De la Beche, the part of Port Royal described as having sunk, was built upon newly formed land, consisting of sand in which piles had been driven; and the *settlement* of this loose sand, charged with the weight of heavy houses, may have given rise to the subsidences alluded to.‡ There can be no doubt that a waving motion of the earth, accompanied by an inroad of the sea, might affect loose sand, while solid rock might remain unmoved; but, after attentively considering the

* Phil. Trans. 1693-4. † Ibid. 1693.

‡ Manual of Geol., p. 133, second edition.

original documents, and conversing with persons who, ninety years after, saw some of the submerged houses, I am inclined to believe that there were various and unequal subsidences of the land at Port Royal, independently of any sliding and undermining of the sands.

At several thousand places in Jamaica, the earth is related to have opened. On the north of the island, several plantations, with their inhabitants, were swallowed up, and a lake appeared in their place, covering about a thousand acres, which afterwards dried up, leaving nothing but sand and gravel, without the least sign that there had ever been a house or a tree there. Several tenements at Yallowes were buried under landslips; and one plantation was removed half a mile from its place, the crops continuing to grow upon it uninjured. Between Spanish Town and Sixteen-mile Walk, the high and perpendicular cliffs bounding the river fell in, stopped the passage of the river, and flooded the latter place for nine days, so that the people "concluded it had been sunk as Port Royal was." But the flood at length subsided, for the river had found some new passage at a great distance.

Mountains shattered.—The Blue and other of the highest mountains are declared to have been strangely torn and rent. They appeared shattered, and half-naked, no longer affording a fine green prospect, as before, but stripped of their woods and natural verdure. The rivers on these mountains first ceased to flow for about twenty-four hours, and then brought down into the sea, at Port Royal and other places, several hundred thousand tons of timber, which looked like floating islands on the ocean. The trees were in general barked, most of their branches having been torn off in the descent. It is particularly remarked in this, as in the narratives of so many earthquakes, that fish were taken in great numbers on the coast during the shocks. The correspondents of Sir Hans Sloane, who collected with care the accounts of eye-witnesses of the catastrophe, refer constantly to *subsidences*, and some supposed the whole of Jamaica to have sunk down.*

Reflections on the amount of change in the last one hundred and forty years.—I have now only enumerated the earthquakes of the last 140 years, respecting which facts illustrative of geological inquiries are on record. Even if my limits permitted, it would be a tedious and unprofitable task to examine all the obscure and ambiguous narratives of similar events of earlier epochs; although, if the places were now examined by geologists well practised in the art of interpreting the monuments of physical changes, many events which have happened within the historical era might still be determined with precision. It must not be imagined that, in the above sketch of the occurrences of a short period, I have given an account of all, or even the greater part, of the mutations which

* Phil. Trans. 1694.

the earth has undergone by the agency of subterranean movements. Thus, for example, the earthquake of Aleppo, in the present century, and of Syria, in the middle of the eighteenth, would doubtless have afforded numerous phenomena, of great geological importance, had those catastrophes been described by scientific observers. The shocks in Syria, in 1759, were protracted for three months, throughout a space of ten thousand square leagues; an area, compared to which that of the Calabrian earthquake of 1783 was insignificant. Accon, Saphat, Balbeck, Damascus, Sidon, Tripoli, and many other places, were almost entirely levelled to the ground. Many thousands of the inhabitants perished in each; and, in the valley of Balbeck alone, twenty thousand men are said to have been victims to the convulsion. In the absence of scientific accounts, it would be as irrelevant to our present purpose to enter into a detailed account of such calamities, as to follow the track of an invading army, to enumerate the cities burnt or rased to the ground, and reckon the number of individuals who perished by famine or the sword.

Deficiency of historical records.—If such, then, be the amount of ascertained changes in the last 140 years, notwithstanding the extreme deficiency of our records during that brief period, how important must we presume the physical revolutions to have been in the course of thirty or forty centuries, during which some countries habitually convulsed by earthquakes have been peopled by civilized nations! Towns engulfed during one earthquake may, by repeated shocks, have sunk to enormous depths beneath the surface, while the ruins remain as imperishable as the hardest rocks in which they are enclosed. Buildings and cities, submerged, for a time, beneath seas or lakes, and covered with sedimentary deposits, must, in some places, have been re-elevated to considerable heights above the level of the ocean. The signs of these events have, probably, been rendered visible by subsequent mutations, as by the encroachments of the sea upon the coast, by deep excavations made by torrents and rivers, by the opening of new ravines, and chasms, and other effects of natural agents, so active in districts agitated by subterranean movements.

If it be asked why, if such wonderful monuments exist, so few have hitherto been brought to light, we reply—because they have not been searched for. In order to rescue from oblivion the memorials of former occurrences, the inquirer must know what he may reasonably expect to discover; and under what peculiar local circumstances. He must be acquainted with the action and effect of physical causes, in order to recognise, explain, and describe correctly the phenomena when they present themselves.

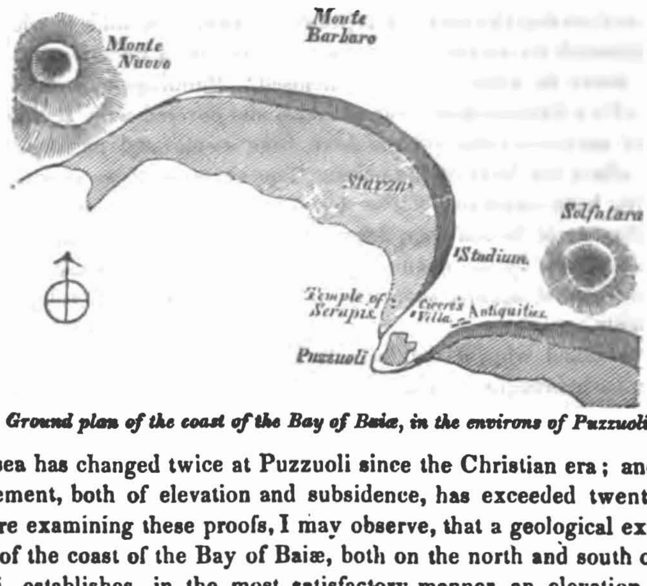
The best known of the great volcanic regions, of which the boundaries were sketched in the ninth chapter, is that which includes Southern Europe, Northern Africa, and Central Asia; yet nearly the whole, even of this region, must be laid down in a geological map, as "Terra Incognita." Even Calabria may be regarded as unexplored, as also Spain, Portugal, the Barbary States, the Ionian Isles, the Morea, Asia Minor, Cyprus, Syria, and the countries between the Caspian and Black Seas. We are, in truth, beginning to obtain some insight into one small spot of that great zone of volcanic disturbance, the district around Naples; a tract by no means remarkable for the violence of the earthquakes which have convulsed it.

If, in this part of Campania, we are enabled to establish, that considerable changes in the relative level of land and sea have taken place since the Christian era, it is all that we could have expected; and it is to recent antiquarian and geological research, not to history, that we are principally indebted for the information. I shall now proceed to lay before the reader some of the results of modern investigations in the Bay of Baiæ and the adjoining coast.

PROOFS OF ELEVATION AND SUBSIDENCE IN THE BAY OF BAIÆ.

Temple of Jupiter Serapis.—This celebrated monument of antiquity affords, in itself alone, unequivocal evidence that the relative level of land

Fig. 55.



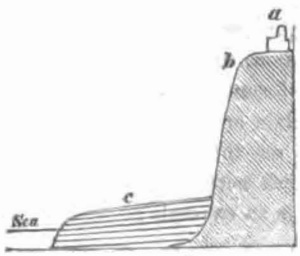
Ground plan of the coast of the Bay of Baiæ, in the environs of Puzzuoli.

and sea has changed twice at Puzzuoli since the Christian era; and each movement, both of elevation and subsidence, has exceeded twenty feet. Before examining these proofs, I may observe, that a geological examination of the coast of the Bay of Baiæ, both on the north and south of Puzzuoli, establishes, in the most satisfactory manner, an elevation, at no remote period, of more than twenty feet, and, at one point, of more than thirty feet; and the evidence of this change would have been complete, even if the temple had, to this day, remained undiscovered.

Coast south of Puzzuoli.—If we coast along the shore from Naples to Puzzuoli, we find, on approaching the latter place, that the lofty and precipitous cliffs of indurated tuff, resembling that of which Naples is built, retire slightly from the sea; and that a low level tract of fertile land, of a very different aspect, intervenes between the present sea-beach, and what was evidently the ancient line of coast.

The inland cliff may be seen opposite the small island of Nisida, about two miles and a half southeast of Puzzuoli,* where, at the height of thirty-two feet above the level of the sea, Mr. Babbage observed an ancient mark, such as might have been worn by the waves; and, upon further examination, discovered that, along that line, the face of the perpendicular rock, consisting of very hard tuff, was covered with barnacles (*Balanus sulcatus*, Lamk.), and drilled by boring testacea. Some of the hollows of the Lithodomi contained the shells; while others were filled with the valves of a species of Arca.† Nearer to Puzzuoli, the inland cliff is eighty feet high, and as perpendicular as if it was still undermined by the waves. At its base, a new deposite, constituting the fertile tract above

Fig. 56.



a. Antiquities on hill S. E. of Puzzuoli.
b. Ancient cliff now inland.
c. Terrace composed of recent submarine deposit.

alluded to, attains a height of about twenty feet above the sea; and, since it is composed of regular sedimentary deposits, containing marine shells, its position proves that, subsequently to its formation, there has been a change of more than twenty feet in the relative level of land and sea.

The sea encroaches on these new incoherent strata; and as the soil is valuable, a wall has been built for its protection: but when I visited the spot in 1828, the waves had swept away part of this rampart, and exposed to view a regular series of strata of tuff, more or less argillaceous, alternating with beds of pumice and lapilli, and containing great abundance of marine shells, of species now common on this coast, and amongst them

* See Map, Pl. IV. Fig. 2, facing page 304.

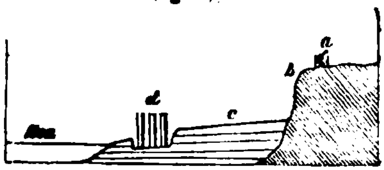
† Mr. Babbage examined this spot in company with Mr. Head, in June, 1828, and has shown me numerous specimens of the shells collected here, and in the Temple of Serapis.

Cardium rusticum, Ostrea edulis, Donax trunculus (Lamk.), and others. The strata vary from about a foot to a foot and a-half in thickness, and one of them contains abundantly remains of works of art, tiles, squares of mosaic pavement of different colours, and small sculptured ornaments, perfectly uninjured. Intermixed with these I collected some teeth of the pig an ox. These fragments of building occur below as well as above strata containing marine shells. Puzzuoli itself stands chiefly on a promontory of the older tufaceous formation, which cuts off the new deposit, although I detected a small patch of the latter in a garden under the town.

From the town the ruins of a mole, called Caligula's Bridge, run out into the sea. This mole consists of a number of piers and arches; and Mr. Babbage found, on the sixth pier, perforations of lithodomi four feet above the level of the sea; and near the termination of the mole, on the last pier but one, marks of the same ten feet above the level of the sea, together with great numbers of balani and flustra.

Coast north of Puzzuoli.—If we then pass to the north of Puzzuoli, and examine the coast between that town and Monte Nuovo, we find a repetition of analogous phenomena. The sloping sides of Monte Barbaro slant down within a short distance of the coast, and terminate in an inland cliff of moderate elevation, to which the geologist perceives at once that the sea must, at some former period, have extended. Between this cliff and the sea is a low plain or terrace, called La Starza, corresponding to that before described on the south-east of the town; and as the sea encroaches rapidly, fresh sections of the strata may readily be obtained, of which the annexed is an example:

Fig. 57.



a. Remains of Cicero's villa, N. side of Puzzuoli.*
b. Ancient cliff, now inland.
c. Terrace composed of recent submarine deposits.
d. Temple of Serapis.

Section on the shore north of the town of Puzzuoli:—

	Ft.	In.
1. Vegetable soil - - - - - - - - - - - - - -	1	0

* The spot here indicated on the summit of the cliff, is that from which Hamilton's view, plate 26, Campi Phlegræi, is taken, and on which, he observes, Cicero's villa, called the Academia, anciently stood.

	Ft.	In.
2. Horizontal beds of pumice and scoriæ, with broken fragments of unrolled bricks, bones of animals, and marine shells - - - - -	1	6
3. Beds of lapilli, containing abundance of marine shells, principally Cardium rusticum, Donax trunculus, Lam., Ostrea edulis, Triton cutaceum, Lam., and Buccinum serratum, Brocchi, the beds varying in thickness from one to eighteen inches - - - - - - -	10	0
4. Argillaceous tuff, containing bricks and fragments of buildings not rounded by attrition - - - - - - - - - - - - -	1	6

The thickness of many of these beds varies greatly as we trace them along the shore, and sometimes the whole group rises to a greater height than at the point above described. The surface of the tract which they compose appears to slope gently upwards towards the base of the old cliffs.

Now, if these appearances presented themselves on the eastern or southern coast of England, a geologist would naturally endeavour to seek an explanation in some local depression of high water mark, in consequence of a change in the set of the tides and currents: for towns have been built, like ancient Brighton, on sandy tracts intervening between the old cliff and the sea, and, in some cases, they have been finally swept away by the return of the ocean. On the other hand, the inland cliff at Lowestoffe, in Suffolk, remains, as was before stated, at some distance from the shore, and the low green tract called the Ness may be compared to the low flat called La Starza, near Puzzuoli.* But there are scarce any tides in the Mediterranean; and, to suppose that sea to have sunk generally from twenty to twenty-five feet since the shores of Campania were covered with sumptuous buildings, is an hypothesis obviously untenable. The observations, indeed, made during modern surveys on the moles and cothons (docks) constructed by the ancients in various ports of the Mediterranean, have proved that there has been no sensible variation of level in that sea during the last two thousand years.†

Thus we arrive, without the aid of the celebrated temple, at the conclusion, that the recent marine deposit at Puzzuoli was upraised in modern times above the level of the sea, and that not only this change of position, but the accumulation of the modern strata, was posterior to the destruction of many edifices, of which they contain the imbedded remains. If we now examine the evidence afforded by the temple itself, it appears, from the most authentic accounts, that the three pillars now standing erect continued, down to the middle of the last century, half buried in the new marine strata before described. The upper part of the columns, being concealed by bushes, had not attracted, until the year 1749, the notice of antiquaries; but, when the soil was removed in 1750, they were seen to

* See p. 256.

† On the authority of Captain W. H. Smyth, R. N.

form part of the remains of a splendid edifice, the pavement of which was still preserved, and upon it lay a number of columns of African breccia and of granite. The original plan of the building could be traced distinctly; it was of a quadrangular form, seventy feet in diameter, and the roof had been supported by forty-six noble columns, twenty-four of granite, and the rest of marble. The large court was surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still used for medicinal purposes, issues now just behind the building, and the water, it is said, of this spring was conveyed by marble ducts into the chambers.

Many antiquaries have entered into elaborate discussions as to the deity to which this edifice was consecrated; but Signor Carelli, who has written the last able treatise on the subject,* endeavors to show that all the religious edifices of Greece were of a form essentially different; that the building, therefore, could never have been a temple; that it corresponded to the public bathing-rooms at many of our watering-places; and, lastly, that if it had been a temple, it could not have been dedicated to Serapis, the worship of the Egyptian god being strictly prohibited, at the time when this edifice was in use, by the senate of Rome.

Perforation of the columns by Lithodomous shells.—It is not for the geologist to offer an opinion on these topics; and I shall, therefore, designate this valuable relic of antiquity by its generally received name, and proceed to consider the memorials of physical changes inscribed on the three standing columns in most legible characters by the hand of Nature. (See Frontispiece, Vol. I.†) These pillars, which have been carved each out a single block of marble, are forty-two feet in height. An horizontal fissure nearly intersects one of the columns; the other two are entire. They are all slightly out of the perpendicular, inclining somewhat to the south-west, that is, towards the sea.‡ Their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone, about nine feet in height, where the marble has been pierced by a species of marine perforating bivalve—*Lithodomus*, Cuv.§ The holes of these animals are pear-shaped, the external opening being minute, and gradually increasing downwards. At the bottom of the cavities, many shells are still found, notwithstanding the great numbers that have been taken out by visitors; in many the valves of a species of arca,

* Dissertazione sulla Sagra Architettura degli Antichi.

† This view of the present state of the temple has been reduced from that of the Canonico Andrea de Jorio, Ricerche sul Tempio di Serapide, in Puzzuoli. Napoli, 1820.

‡ This appears from the measurement of Captain Basil Hall, R. N., Proceedings of Geol. Soc., No. 38, p. 114. The fact of the three standing columns having been each formed out of a single stone, was first pointed out to me by Mr. James Hall, and is important, as helping to explain why they were not shaken down.

§ Modiola lithophaga, Lam. Mytilus lithophagus, Linn.

an animal which conceals itself in small hollows, occur. The perforations are so considerable in depth and size, that they manifest a long-continued abode of the lithodomi in the columns; for, as the inhabitant grows older and increases in size, it bores a large cavity, to correspond with the increasing magnitude of its shell. We must, consequently, infer a long-continued immersion of the pillars in sea-water, at a time when the lower part was covered up and protected by strata of tuff and the rubbish of buildings; the highest part, at the same time, projecting above the waters, and being consequently weathered, but not materially injured.

On the pavement of the temple lie some columns of marble, which are perforated in the same manner in certain parts; one, for example, to the length of eight feet, while, for the length of four feet, it is uninjured. Several of these broken columns are eaten into, not only on the exterior, but on the cross fracture, and, on some of them, other marine animals have fixed themselves.* All the granite pillars are untouched by lithodomi. The platform of the temple, which is not perfectly even, is at present about one foot below high-water mark (for there are small tides in the Bay of Naples); and the sea, which is only one hundred feet distant, soaks through the intervening soil. The upper part of the perforations, then, are at least twenty-three feet above high-water mark; and it is clear, that the columns must have continued for a long time in an erect position, immersed in salt water. After remaining for many years submerged, they must have been upraised to the height of about twenty-three feet above the level of the sea.

Temples and Roman roads under water.—So far the information derived from the temple corroborates that before obtained from the new strata in the plain of La Starza, and proves nothing more. But, as the temple could not have been built originally at the bottom of the sea, it must have first sunk down below the waves, and afterwards have been elevated. Of such subsidences there are numerous independent proofs in the Bay of Baiæ. Not far from the shore, to the north-west of the Temple of Serapis, are the ruins of a temple of Neptune, and a Temple of the Nymphs, now under water. The columns of the former edifice stand erect in five feet water, their upper portions just rising to the surface of the sea. The pedestals are doubtless buried in the mud; so that if this part of the bottom of the bay should hereafter be elevated, the exhumation of this temple might take place after the manner of that of Serapis. Both these buildings probably participated in the movement which raised the Starza; but either they were deeper under water than the Temple of Serapis, or they were not raised up again to so great a height. There are also two Roman roads under water in the bay, one reaching from Puzzuoli towards the Lucrine Lake, which may still be seen, and the

* Serpula contortuplicata, Linn., and Vermilia triquetra, Lam. These species, as well as the Lithodomus, are now inhabitants of the neighbouring sea.

other near the Castle of Baiæ. The ancient mole, too, of Puzzuoli, before alluded to, has the water up to a considerable height of the arches; whereas Brieslak justly observes, it is next to certain that the piers must formerly have reached the surface before the springing of the arches;* so that, although the phenomena before described prove that this mole has been uplifted ten feet above the level at which it once stood, it is still evident that it has not yet been restored to its original position.

A modern writer also reminds us, that these effects are not so local as some would have us believe; for on the opposite side of the Bay of Naples, on the Sorrentine coast, which, as well as Puzzuoli, is subject to earthquakes, a road, with some fragments of Roman buildings, is covered to some depth by the sea. In the island of Capri, also, which is situated some way at sea, in the opening of the bay of Naples, one of the palaces of Tiberius is now covered with water.† They who have attentively considered the effects of earthquakes, before enumerated, as having occurred during the last 140 years, will not feel astonished at these signs of alternate elevation and depression of the bed of the sea and the adjoining coast during the course of eighteen centuries; but, on the contrary, they will be very much astonished if future researches fail to bring to light similar indications of change in almost all regions of volcanic disturbances.

That buildings should have been submerged, and afterwards upheaved, without being entirely reduced to a heap of ruins, will appear no anomaly, when we recollect that, in the year 1819, when the delta of the Indus sank down, the houses within the fort of Sindree subsided beneath the waves, without being overthrown. In like manner, in the year 1692, the buildings around the harbour of Port Royal, in Jamaica, descended suddenly to the depth of between thirty and fifty feet under the sea without falling. Even on small portions of land transported to a distance of a mile, down a declivity, tenements, like those near Mileto, in Calabria, were carried entire. At Valparaiso buildings were left standing, when their foundations, together with a long tract of the Chilian coast, were permanently upraised to the height of several feet in 1822. It is true that, in the year 1750, when the bottom of the sea in the harbour of Penco was suddenly uplifted to the extraordinary elevation of twenty-four feet above its former level, the buildings of that town were thrown down; but we might still suppose that a great portion of them would have escaped, had the walls been supported on the exterior and interior with a deposit, like that which surrounded and filled to the height of ten or twelve feet the Temple of Serapis at Puzzuoli.

* Voy. dans la Campanie, tome ii. p. 162.

† Mr. Forbes, Physical Notices of the Bay of Naples. Ed. Journ. of Sci., No. II., new series, p. 280. October 1829. When I visited Puzzuoli, and arrived at the above conclusions, I knew nothing of Mr. Forbes's observations, which I first saw on my return to England the year following.

Periods when the Temple of Serapis sank and rose.—The next subject of inquiry is the era when these remarkable changes took place in the Bay of Baiæ. It appears that in the Atrium of the Temple of Serapis, inscriptions were found in which Septimius Severus and Marcus Aurelius record their labours in adorning it with precious marbles.* We may, therefore, conclude, that it existed at least down to the third century of our era in its original position; and it may have been built at the close of the second century. On the other hand, we have evidence that the marine deposit forming the flat land, called La Starza, was still covered by the sea in the year 1530, or just eight years anterior to the tremendous explosion of Monte Nuovo. Mr. Forbes has lately pointed out the distinct testimony of an old Italian writer, Loffredo, in confirmation of this important point.† Writing in 1580, Loffredo declares that, fifty years previously, the sea washed the base of the hills which rise from the flat land before alluded to; and at that time he expressly tells us, that a person *might have fished* from the site of those ruins which are now called the Stadium. (See Fig. 55, p. 426.) Hence it follows, that the subsidence of the ground happened at some period between the third century, when the temple was still standing, and the beginning of the sixteenth century, when its site was still submerged.

Now, in this interval the only two events which are recorded in the imperfect annals of the dark ages are, the eruption of the Solfatara in 1198, and an earthquake in 1488, by which Puzzuoli was ruined. It is at least highly probable, that earthquakes, which preceded the eruption of the Solfatara, which is very near the temple (See Fig. 55, p. 426), caused a subsidence, and the pumice and other matters ejected from that volcano might have fallen in heavy showers into the sea, and would thus immediately have covered up the lower part of the columns, and preserved them from the action of the sea and from lithodomous perforations. The waves might afterwards have thrown down many pillars, and formed strata of broken fragments of buildings, intermixed with volcanic ejections, and thus have caused those strata, containing works of art and shells, which extend for several miles along the coast. Mr. Babbage, after carefully examining several incrustations of carbonate of lime, such as the waters of the hot spring might have deposited, adhering to the walls and columns of the temple at different heights, as also the distinct marks of ancient lines of water level, visible below the zone of lithophagous perforations, has come to the conclusion, and, I think, proved, that the subsidence of the building was not sudden, or at one period only, but gradual, and by successive movements.‡

As to the re-elevation of the depressed tract, that may also have occur-

* Brieslak, Voy. dans la Campanie, tom. ii. p. 167.

* Ed. Journ. of Science, new series, No. II. p. 281.

† Proceedings of Geol. Soc., No. 36. March 1834.

red at different periods, since earthquakes are not unfrequent in this country. Jorio cites two authentic documents in illustration of this point. The first, dated Oct. 1503, is a deed, written in Italian, by which Ferdinand and Isabella grant to the University of Puzzuoli a portion of land, "where the sea is drying up" (Che va seccando el mare); the second, a document in Latin, dated May 23, 1511, or nearly eight years after, by which Ferdinand grants to the city a certain territory around Puzzuoli, where the ground *is dried up* from the sea (desiccatum).*

It is perfectly evident, however, from Loffredo's statement, that the principal elevation of the low tract called La Starza took place after the year 1530, and some time before the year 1580; and from this alone we might have suspected that the change happened in the year 1538, when Monte Nuovo was formed. But, fortunately, we are not left in the slightest doubt that such was the date of this remarkable event. Sir William Hamilton has given us two original letters describing the eruption of 1538, the first of which, by Falconi, dated 1538, contains the following passages.† "It is now two years since there have been frequent earthquakes at Puzzuoli, Naples, and the neighbouring parts. On the day and in the night before the eruption (of Monte Nuovo), above twenty shocks, great and small, were felt. The eruption began on the 29th of September, 1538. It was on a Sunday, about one o'clock in the night, when flames of fire were seen between the hot baths and Tripergola. In a short time the fire increased to such a degree, that it burst open the earth in this place, and threw up so great a quantity of ashes and pumice stones, mixed with water, as covered the whole country. The next morning (after the formation of Monte Nuovo) the poor inhabitants of Puzzuoli quitted their habitations in terror, covered with the muddy and black shower which continued the whole day in that country—flying from death, but with death painted in their countenances. Some with their children in their arms, some with sacks full of their goods; others leading an ass, loaded with their frightened family, towards Naples; others carrying quantities of birds of various sorts, that had fallen dead at the beginning of the eruption; others, again, with fish which they had found, and which were to be met with in plenty on the shore, the sea having *left them dry for a considerable time.* I accompanied Signor Moramaldo to behold the wonderful effects of the eruption. The sea had retired on the side of Baiæ, *abandoning a considerable tract*, and the shore appeared almost entirely dry, from the quantity of ashes and broken pumice stones thrown up by the eruption. I saw two springs *in the newly discovered ruins:* one before the house that was the queen's, of hot and salt water," &c.

So far Falconi; the other account is by Pietro Giacomo di Toledo,

* Sul Tempio di Serap. chap. viii. † Campi Phlegræi, p. 70.

which begins thus:—"It is now two years since this province of Campagna has been afflicted with earthquakes, the country about Puzzuoli much more so than any other parts: but the 27th and 28th of the month of September last, the earthquakes did not cease day or night in the town of Puzzuoli: that plain which lies between Lake Avernus, the Monte Barbaro, and the sea, was *raised a little*, and many cracks were made in it, from some of which issued water; at the same time the sea immediately adjoining the plain *dried up about two hundred paces*, so that the fish were left on the sand a prey to the inhabitants of Puzzuoli. At last, on the 29th of the same month, about two o'clock in the night, the earth opened," &c. Now, both these accounts, written immediately after the birth of Monte Nuovo, agree in expressly stating that the sea retired, and one mentions that its bottom was upraised. To this elevation we have already seen that Hooke, writing at the close of the seventeenth century, alludes as to a well-known fact.* The preposterous theories, therefore, that have been advanced in order to dispense with the elevation of the land, in the face of all this historical and physical evidence, are not entitled to a serious refutation.

Encroachments of the sea in the Bay of Baiæ.—The flat land, when first upraised, must have been more extensive than now, for the sea encroaches somewhat rapidly, both to the north and south-east of Puzzuoli. The coast has, of late years, given way more than a foot in a twelvemonth; and I was assured, by fishermen in the bay, that it has lost ground near Puzzuoli, to the extent of thirty feet, within their memory. It is, probably, this gradual encroachment, which has led many authors to imagine that the level of the sea is slowly rising in the Bay of Baiæ; an opinion by no means warranted by such circumstances. In the course of time, the whole of the low land will, perhaps, be carried away, unless some earthquake shall remodify the surface of the country, before the waves reach the ancient coast-line; but the removal of this narrow tract will by no means restore the country to its former state, for the old tufaceous hills, and the interstratified current of trachytic lava which has flowed from the Solfatara, must have participated in the movement of 1538; and these will remain upraised, even though the sea may regain its ancient limits.

In 1828, excavations were made below the marble pavement of the Temple of Serapis, and another costly pavement of mosaic was found, at the depth of five feet or more below the other. The existence of these two pavements, at different levels, seems clearly to imply some subsidence previously to all the changes already alluded to, which had rendered it necessary to construct a new floor at a higher level. But to these and other circumstances bearing on the history of the Temple antecedently to

* Ante, p. 46.

the revolutions already explained, I shall not refer at present, trusting that future investigations will set them in a clearer light.

Permanence of the ocean's level.—In concluding this subject, I may observe, that the interminable controversies to which the phenomena of the Bay of Baiæ gave rise, have sprung from an extreme reluctance to admit that the land, rather than the sea, is subject alternately to rise and fall. Had it been assumed that the level of the ocean was invariable, on the ground that no fluctuations have as yet been clearly established, and that, on the other hand, the continents are inconstant in their level, as has been demonstrated by the most unequivocal proofs again and again, from the time of Strabo to our own times, the appearances of the Temple at Puzzuoli could never have been regarded as enigmatical. Even if contemporary accounts had not distinctly attested the upraising of the coast, this explanation should have been proposed in the first instance as the most natural, instead of being now adopted unwillingly when all others have failed.

To the strong prejudices still existing in regard to the mobility of the land, we may attribute the rarity of such discoveries as have been recently brought to light in the Bay of Baiæ and the Bay of Conception. A false theory, it is well known, may render us blind to facts which are opposed to our prepossessions, or may conceal from us their true import when we behold them. But it is time that the geologist should, in some degree, overcome those first and natural impressions which induced the poets of old to select the rock as the emblem of firmness—the sea as the image of inconstancy. Our modern poet, in a more philosophical spirit, saw in the sea "The image of Eternity," and has finely contrasted the fleeting existence of the successive empires which have flourished and fallen on the borders of the ocean with its own unchanged stability.

——— Their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play:
Time writes no wrinkle on thine azure brow;
Such as creation's dawn beheld, thou rollest now.

CHILDE HAROLD, Canto iv.

CHAPTER XVII.

ELEVATION AND SUBSIDENCE OF LAND WITHOUT EARTHQUAKES.

Changes in the relative level of land and sea in regions not volcanic—Opinion of Celsius that the waters of the Baltic Sea and Northern Ocean were sinking—Objections raised to his opinion—Proofs of the stability of the sea-level in the Baltic—Playfair's hypothesis that the land was rising in Sweden—Opinion of Von Buch (p. 441.)—Marks cut on the rocks—Survey of these in 1820—Facility of detecting slight alterations in level of sea on coast of Sweden—Shores of the ocean also rising—Area upheaved (p. 444.)—Shelly deposits of Uddevalla—Of Stockholm, containing fossil shells characteristic of the Baltic—Whether subsidence in Sweden—Fishing-hut buried under marine strata (p. 447.)—Sinking of land in Greenland—Bearing of these facts on geological phenomena.

We have now considered the phenomena of volcanos and earthquakes according to the division of the subject before proposed (p. 291), and have next to turn our attention to those slow and insensible changes in the relative level of land and sea which take place in countries remote from volcanos, and where no violent earthquakes have occurred within the period of human observation. Early in the last century the Swedish naturalist, Celsius, expressed his opinion that the waters, both of the Baltic and Northern Ocean, were gradually subsiding. From numerous observations he inferred, that the rate of depression was about forty Swedish inches in a century.* In support of this position, he alleged that there were many rocks both on the shores of the Baltic and the ocean known to have been once sunken reefs, and dangerous to navigators, but which were in his time above water—that the waters of the Gulf of Bothnia had been gradually converted into land, several ancient ports having been changed into inland cities, small islands joined to the continent, and old fishing-grounds deserted as being too shallow, or entirely dried up. Celsius also maintained, that the evidence of the change rested not only on modern observations, but on the authority of ancient geographers, who had stated that Scandinavia was formerly an island. This island, he argued, must, in the course of centuries, by the gradual retreat of the sea, have become connected with the continent; an event which he supposed to have happened after the time of Pliny, and before the ninth century of our era.

To this argument it was objected that the ancients were so ignorant of the geography of most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an

* The Swedish measure scarcely differs from ours; the foot being divided into twelve inches, and being less than ours by three-eighths of an inch only.

island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked, that if the land which connected Scandinavia with the main continent was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have risen above the sea at the latter period, the rate of depression could not have been uniform, as was pretended; for it ought to have fallen much more rapidly between the ninth and eighteenth centuries.

Many of the proofs relied on by Celsius and his followers were immediately controverted by several philosophers, who saw clearly that a fall of the sea in any one region could not take place without a general sinking of the waters over the whole globe; they denied that this was the fact, or that the depression was universal, even in the Baltic. In proof of the stability of the level of that sea, they appealed to the position of the island of Saltholm, not far from Copenhagen. This island is so low that, in autumn and winter, it is permanently overflowed; and it is only dry in summer, when it serves for pasturing cattle. It appears from documents of the year 1280, that Saltholm was then also in the same state, and exactly on a level with the mean height of the sea, instead of having been about twenty feet under water, as it ought to have been, according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after six or even eight hundred years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level of the sea in the year 1000; and after eight centuries its relative position remains exactly the same.*

Several of the examples of the gain of land and shallowing of the sea pointed out by Celsius, and afterwards by Linnæus, who embraced the same opinions, were ascribed by others to the deposition of sediment at points where rivers entered; and, undoubtedly, Celsius had not sufficiently distinguished between changes due to these causes, and such as would arise if the waters of the ocean itself were diminishing. Many large rivers descending from a mountainous country, at the head of the Gulf of Bothnia, enter the sea charged with sand, mud, and pebbles, and it was said that in these places the low land had advanced rapidly, especially near Torneo. At Piteo also, half a mile had been gained in forty-five years; at Luleo,† no less than a mile in twenty-eight years; facts which might all be admitted consistently with the assumption that the level of the Baltic has remained unchanged, like that of the Adriatic, during a

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, Geschichte, &c. vol. i. p. 439.

† Piteo, Luleo, and Obo are spelt, in many English maps, Pitea, Lulea, Abo; but the *e* is not sounded in the Swedish diphthong *ao* or *å*.

period when the plains of the Po and the Adige have greatly extended their area.

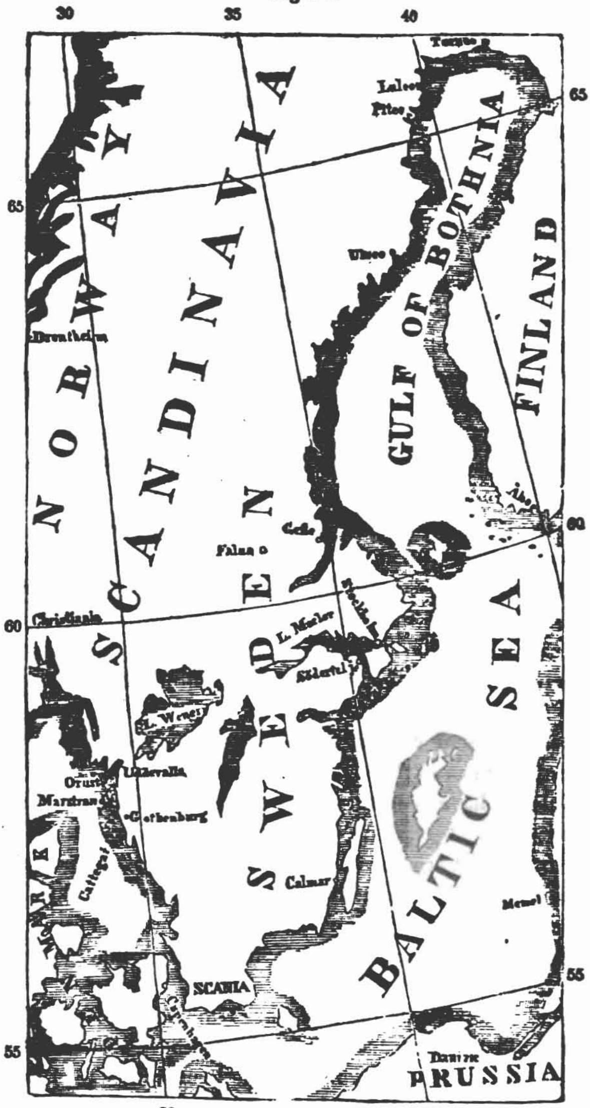
It was also alleged that certain insular rocks, once entirely covered with water, had at length protruded themselves above the waves, and grown, in the course of a century and a-half, to be eight feet high. The following attempt was made to explain away this phenomenon:—In the Baltic, large erratic blocks, as well as sand and smaller stones which lie on shoals, are liable every year to be frozen into the ice, where the sea freezes to the depth of five or six feet. On the melting of the snow in spring, when the sea rises about half a fathom, numerous ice-lands float away, bearing up these rocky fragments so as to convey them to a distance; and if they are driven by the waves upon shoals, they may convert them into islands by depositing the blocks; if stranded upon low islands, they may considerably augment their height.

Browallius, also, and some other Swedish naturalists, affirmed that some islands were lower than formerly; and that by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious proof of the permanency of the water-level, at some points at least, for many centuries. On the Finland coast were some large pines, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that they had stood there for four hundred years. Now, according to the Celsian hypothesis, the sea had sunk about fifteen feet during that period, in which case the germination and early growth of these pines must have been, for many seasons, below the level of the water. In like manner it was asserted, that the lower walls of many ancient castles, such as those of Sonderburg and Åbo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea.

In reply to this last argument, Colonel Hällstrom, a Swedish engineer, well acquainted with the Finland coast, assured me, that the base of the walls of the castle of Åbo is now ten feet above the water, so that there may have been a considerable rise of the land at that point since the building was erected.

Playfair, in his "Illustrations of the Huttonian Theory," in 1802, admitted the sufficiency of the proofs adduced by Celsius, but attributed the change of level to the movement of the land, rather than to a diminution of the waters. He observed, "that in order to depress or elevate the absolute level of the sea, by a given quantity, in any one place, we must depress or elevate it by the same quantity over the whole surface of the earth; whereas no such necessity exists with respect to the elevation

Fig. 58.


NORWAY
SCANDINAVIA
SWEDEN
GULF OF BOTHNIA
FINLAND
BALTIC SEA
PRUSSIA
SCANIA
Drontheim
Christiania
Falun
Gefle
Umeo
Pitea
Lulea
Tornea
Abo
Stockholm
L. Maeler
L. Wener
Uddevalla
Orust
Marstrand
Gothenburg
Cattegat
Calmar
Memel
Dantzic
30
35
40
65
60
55

or depression of the land."* The hypothesis of the rising of the land, he adds, "agrees well with the Huttonian theory, which holds that our continents are subject to be acted upon by the expansive forces of the mineral regions; that by these forces they have been actually raised up, and are sustained by them in their present situation."†

In the year 1807, Von Buch, after returning from a tour in Scandinavia, announced his conviction, "that the whole country, from Frederickshall in Sweden to Åbo in Finland, and perhaps as far as St. Petersburgh, was slowly and insensibly rising." He also suggested "that Sweden may rise more than Norway, and the northern more than the southern part."‡ He was led to these conclusions principally by information obtained from the inhabitants, and pilots, and in part by the occurrence of marine shells of recent species, which he had found at several points on the coast of Norway above the level of the sea. He also mentions the marks set on the rocks. Von Buch, therefore, has the merit of being the first geologist who, after a personal examination of the evidence, declared in favour of the rise of land in Scandinavia.

The attention excited by this subject in the early part of the last century, induced many philosophers in Sweden to endeavour to determine, by accurate observations, whether the standard level of the Baltic was really subject to periodical variations; and under their direction, lines or grooves, indicating the ordinary level of the water on a calm day, together with the date of the year, were chiselled out upon the rocks. In 1820-21, all the marks made before those years were examined by the officers of the pilotage establishment of Sweden; and in their report to the Royal Academy of Stockholm they declared, that on comparing the level of the sea at the time of their observations with that indicated by the ancient marks, they found that the Baltic was lower relatively to the land in certain places, but the amount of change during equal periods of time had not been every where the same. During their survey, they cut new marks for the guidance of future observers, several of which I had an opportunity of examining fourteen years after (in the summer of 1834), and in that interval the land appeared to me to have risen at certain places north of Stockholm four or five inches. I also convinced myself, during my visit to Sweden, after conversing with many civil engineers, pilots, and fishermen, and after examining some of the ancient marks, that the evidence formerly adduced in favour of the change of level, both on the coasts of Sweden and Finland, was full and satisfactory.§ The alteration

* Sect. 393. † Sect. 398. ‡ Transl. of his Travels, p. 387.

§ In former editions I expressed many doubts as to the validity of the proofs of a gradual rise of land in Sweden. A detailed statement of the observations which I made in 1834, and which led me to change my opinion, will be found in the Philosophical Transactions for 1835, part i.

of level evidently diminishes as we proceed from the northern parts of the Gulf of Bothnia towards the south, being slight around Stockholm, and not in the least degree perceptible in Scania, the southernmost province of Sweden. Some writers have indeed represented the rate of depression of the waters at Stockholm as very considerable, because certain houses in that city which are built on piles have sunk down within the memory of persons still living, so as to be out of the perpendicular; and this in consequence of the tops of the piles giving way, and decaying, owing to a fall of the waters which has exposed them to be alternately wet and dry. The houses alluded to are situated on the borders of Lake Maeler, a large lake, the outlet of which joins the Baltic in the middle of Stockholm. This lake is certainly lower than formerly; but the principal cause of the change is not the elevation of the land, but the removal of two old bridges built on piles, which formerly obstructed the discharge of the fresh water into the sea. Another cause is the opening, in the year 1819, of a new canal at Södertelje, a place south of Stockholm, by means of which a new line of communication was formed between Lake Maeler and the Baltic.*

It will naturally be asked, whether the mean level of a sea like the Baltic can ever be determined so exactly as to permit us to appreciate a variation of level, amounting only to one or two feet. In reply, I may observe, that, except near the Cattegat, there are no tides in the Baltic; and it is only when particular winds have prevailed for several days in succession, or at certain seasons when there has been an unusually abundant influx of river water, or when these causes have combined, that this sea is made to rise two or three feet above its standard level. The fluctuations due to these causes are nearly the same from year to year; so that the pilots and fishermen believe, and apparently with reason, that they can mark a deviation, even of a few inches, from the ordinary or mean height of the waters.

There are, moreover, peculiarities in the configuration of the shores of Norway and Sweden, which facilitate, in a remarkable degree, the appreciation of slight changes in the relative level of land and water. It has often been said, that there are two coasts, an inner and an outer one; the inner being the shore of the mainland; the outer one, a fringe of countless rocky islands of all dimensions, called the skär (*skair*). Boats and small vessels make their coasting voyages within this skär; for here they may sail in smooth water, even when the sea without is strongly agitated. But the navigation is very intricate, and the pilot must possess a perfect acquaintance with the breadth and depth of every narrow channel, and the position of innumerable sunken rocks. If on such a coast the land rises

* See Professor Johnston's Paper, Ed. New Phil. Journ., No. 29, July 1833; and my remarks, Phil. Trans., 1835, p. 12.

one or two feet in the course of half a century, the minute topography of the skär is entirely altered. To a stranger, indeed, who revisits it after an interval of many years, its general aspect remains the same; but the inhabitant finds that he can no longer penetrate with his boat through channels where he formerly passed; and he can tell of countless other changes in the height and breadth of isolated rocks, now exposed, but once only seen through the clear water.

The rocks of gneiss, mica-schist, and quartz, are usually very hard on this coast, slow to decompose, and, when protected from the breakers, remaining for ages unaltered in their form. Hence it is easy to mark the stages of their progressive emergence by the aid of natural and artificial marks imprinted on them. Besides the summits of *fixed* rocks, there are numerous erratic blocks of vast size strewed over the shoals and islands in the skär, which have been probably drifted by ice in the manner before suggested.* All these are observed to have increased in height and dimensions within the last half century. Some, which were formerly known as dangerous sunken rocks, are now only hidden when the water is highest. On their first appearance, they usually present a smooth, bare, rounded protuberance, a few feet or yards in diameter; and a single sea-gull often appropriates to itself this resting-place, resorting there to devour its prey. Similar points, in the mean time, have grown to long reefs, and are constantly whitened by a multitude of sea fowl; while others have been changed from a reef, annually submerged, to a small islet, on which a few lichens, a fir-seedling, and a few blades of grass, attest that the shoal has at length been fairly changed into dry land. Thousands of wooded islands around show the greater alterations which time can work. In the course of centuries also, the spaces intervening between the existing islands may be laid dry, and become grassy plains encircled by heights well clothed with lofty firs. This last step of the process, by which long fiords and narrow channels, once separating wooded islands, are deserted by the sea, has been exemplified within the memory of living witnesses on several parts of the coast.

Had the apparent fall of the waters been observed in the Baltic only, we might have endeavoured to explain the phenomenon by local causes affecting that sea alone. For instance, the channel by which the Baltic discharges its surplus waters into the Atlantic, might be supposed to have been gradually widened and deepened by the waves and currents, in which case a fall of the water, like that before alluded to in Lake Maeler, might have occurred. But the lowering of level would in that case have been uniform and universal, and the waters could not have sunk at Torneo, while they retained their former level at Copenhagen. Such an explanation is also untenable on other grounds; for it is a fact, as Celsius long

* See pp. 174. 439.

ago affirmed, that the alteration of level extends to the western shores of Sweden, bordering the ocean. The signs of elevation observed between Uddevalla and Gothenburg are as well established as those on the shores of the Bothnian Gulf. Among the places where they may be studied, are the islands of Marstrand and Gulholmen, the last-mentioned locality being one of those particularly pointed out by Celsius.

The inhabitants there and elsewhere affirm, that the rate of the sinking of the sea (or elevation of land) varies in different and adjoining districts, being greatest at points where the coast is low. But in this they are deceived; for they measure the amount of rise by the area gained, which is most considerable where the land descends with a gentle slope into the sea. In the same manner, some advocates of the Celsian theory formerly appealed to the increase of lands near the mouths of rivers, not sufficiently adverting to the fact, that if the bed of the sea is rising, the change will always be most sensible where the bottom has been previously rendered shallow; whereas, at a distance from these points, where the scarped granitic cliffs plunge at once into deep water, a much greater amount of elevation is necessary to produce an equally conspicuous change.

As to the area in northern Europe which is subject to this slow upheaving movement, we have not as yet sufficient data for estimating it correctly. It seems probable, however, that it reaches from Gothenburg to Torneo, and from thence to the North Cape, the rate of elevation increasing always as we proceed farther northwards. The two extremities of this line are more than a thousand geographical miles distant from each other; and as both terminate in the ocean, we know not how much farther the motion may be prolonged under water. As to the breadth of the tract, its limits are equally uncertain, though it evidently extends across the widest parts of the Gulf of Bothnia, and may probably stretch far into the interior, both of Sweden and Finland. Now, if the elevation continue, a larger part of the Gulf of Bothnia will be turned into land, as also more of the ocean off the west coast of Sweden between Gothenburg and Uddevalla; and, on the other hand, if the change has been going on for thousands of years at the rate of several feet in a century, large tracts of what is now land must have been submarine at periods comparatively modern. It is natural therefore to inquire whether there are any signs of the recent sojourn of the sea on districts now inland? The answer is most satisfactory. Near Uddevalla and the neighbouring coastland, we find upraised deposits of shells belonging to species such as now live in the ocean; while on the opposite or eastern side of Sweden, near Stockholm, Gefle, and other places bordering the Bothnian Gulf, there are analogous beds containing shells of species characteristic of the Baltic.

Von Buch announced, in 1807, that he had discovered in Norway and at Uddevalla in Sweden, beds of shells of existing species, at considerable heights above the sea. Since that time, other naturalists have confirmed his observation; and, according to Ström, deposits occur at an elevation of more than 400 feet above the sea in the northern part of Norway. M. Alex. Brongniart, when he visited Uddevalla, ascertained that one of the principal masses of shells, that of Capellbacken, is raised more than 200 feet above the sea, resting on rocks of gneiss, all the species being identical with those now inhabiting the contiguous ocean. The same naturalist also stated that on examining with care the surface of the gneiss, immediately above the ancient shelly deposit, he found barnacles (*balani*) adhering to the rocks, showing that the sea had remained there for a long time. I was fortunate enough to be able to verify this observation by finding, in the summer of 1834, at Kured, about two miles north of Uddevalla, and at the height of more than 100 feet above the sea, a surface of gneiss newly laid open by the partial removal of a mass of shells used largely in the district for making lime and repairing the roads. So firmly did these barnacles adhere to the gneiss that I broke off portions of the rock with the shells attached. The face of the gneiss was also encrusted with small zoophytes (*Cellepora?* Lam.), but had these or the barnacles been exposed in the atmosphere ever since the elevation of the rocks above the sea, they would probably have decomposed and been obliterated.

The town of Uddevalla stands at the head of a narrow creek overhung by steep and barren rocks of gneiss, of which all the adjacent country is composed, except in the low grounds and bottoms of valleys, where strata of sand, clay, and marl frequently hide the fundamental rocks. To these newer and horizontal deposits the fossil shells above mentioned belong, and similar marine remains are found at various heights above the sea on the opposite island of Orust. The extreme distance from the sea to which such fossils extend is as yet unknown, but they have been already found at Trollhättan in digging the canal there, and still farther inland on the northern borders of lake Wener, fifty miles from the sea, at an elevation of 200 feet, near Lake Rogvarpen.

To pass to the Baltic: I observed near its shores at Södertelje, sixteen miles S.W. of Stockholm, strata of sand, clay, and marl, more than 100 feet high, and containing shells of species now inhabiting the Bothnian Gulf. These consist partly of marine and partly of freshwater species; but they are few in number, the brackishness of the water appearing to be very unfavourable to the development of testacea. The most abundant species are the common cockle, and the common muscle and periwinkle of our shores (*Cardium edule*, *Mytilus edulis*, and *Littorina littorea*), together with a small tellina (*T. Baltica*), and a few minute univalves allied to *Paludina ulva*. These live in the same waters as a *Lymneus*, a *Neritina* (*N. fluviatilis*), and some other freshwater shells.

But the marine mollusks of the Baltic above mentioned, although very numerous in individuals, are dwarfish in size, scarcely ever attaining a third of the average dimensions which they acquire in the salter waters of the ocean. By this character alone a geologist would generally be able to recognise an assemblage of Baltic fossils as distinguished from those derived from a deposit in the ocean. The absence also of oysters, barnacles, whelks, scallops, limpets (*ostrea*, *balanus*, *buccinum*, *pecten*, *patella*), and many other forms abounding alike in the sea near Uddevalla, and in the fossilliferous deposits of modern date on that coast, supplies an additional negative character of the greatest value, distinguishing assemblages of Baltic from those of oceanic shells. Now the strata containing Baltic shells are found in many localities near Stockholm, Upsala, and Gefle, and will probably be discovered every where around the borders of the Bothnian Gulf; for I have seen similar remains brought from Finland, in marl resembling that found near Stockholm. The utmost distance to which these deposits have yet been traced inland, is on the southern shores of Lake Maeler, at a place seventy miles from the sea.*

As no accurate observations on the rise of the Swedish coast refer to periods more remote than a century and a-half from the present time, and as traditional information, and that derived from ancient buildings on the coast, do not enable the antiquary to trace back any monuments of change for more than five or six centuries, we cannot declare whether the rate of the upheaving force is uniform during very long periods. In those districts where the fossil shells are found at the height of more than 200 feet above the ocean, as at Uddevalla, Orust, and Lake Rogvarpen, the present rate of rise seems less than four feet in a century. Even at that rate it would have required five thousand years to lift up those deposits. But as the movement is now very different in different places, it may also have varied much in intensity at different periods.

Whether any of the land in Norway is now rising must be determined by future investigations. Marine fossil shells, of recent species, have been collected from inland places near Drontheim; but Mr. Everest, in his "Travels through Norway," informs us that the small island of Munkholm, which is an insulated rock in the harbour of Drontheim, affords conclusive evidence of the land having in that region remained stationary for the last eight centuries. The area of this isle does not exceed that of a small village, and by an official survey, its highest point has been determined to be twenty-three feet above the mean high water mark, that is, the mean between neap and spring tides. Now, a monastery was founded there by Canute the Great, A.D. 1028, and thirty-three years before that time it was in use as a common place of execution. According to the assumed average rate of rise in Sweden (about forty inches in a century), we should be obliged to suppose that this island had been three feet eight inches below high-water mark when it was originally chosen as the site of the monastery.

But we have not only to learn whether the motion proceeds always at

* Phil. Trans., 1835, part i.

the same rate, but also whether it has been uniformly *in one direction*. The level of the land may oscillate; and for centuries there may be a depression, and afterwards a re-elevation, of the same district. This idea is rendered the more probable by the proofs lately brought to light by two Danish investigators, Dr. Pingel and Captain Graah, of the sinking down of part of the west coast of Greenland, for a space of more than 600 miles from north to south. The observations alluded to were made by Captain Graah during a survey of Greenland in 1823–24; and afterwards in 1828–29; those by Dr. Pingel were made in 1830–32. It appears from various signs and traditions, that the coast has been subsiding for the last four centuries from the Firth called Igalliko in lat. 60° 43′ N. to Disco Bay, extending to nearly the 69th degree of north latitude. Ancient buildings on low rocky islands and on the shore of the mainland have been gradually submerged, and experience has taught the aboriginal Greenlander never to build his hut near the water's edge. In one case, the Moravian settlers have been obliged more than once to move inland the poles upon which their large boats were set, and the old poles still remain beneath the water as silent witnesses of the change.*

Some phenomena in the neighbourhood of Stockholm, appear to me only explicable on the supposition of the alternate rising and sinking of the ground since the country was inhabited by man. In digging a canal, in 1819, at Södertelje, about sixteen miles to the south of Stockholm, to unite Lake Maeler with the Baltic, marine strata, containing fossil shells of Baltic species, were passed through. At a depth of about sixty feet, they came down upon what seems to have been a buried fishing-hut, constructed of wood, in a state of decomposition, which soon crumbled away on exposure to the air. The lowest part, however, which had stood on a level with the sea, was in a more perfect state of preservation. On the floor of this hut was a rude fireplace, consisting of a ring of stones, and within this were cinders and charred wood. On the outside lay boughs of the fir, cut as with an axe, with the leaves or needles still attached. It seems impossible to explain the position of this buried hut, without imagining, as in the case of the Temple of Serapis (see p. 426), first, a subsidence to the depth of more than sixty feet, then a re-elevation. During the period of submergence, the hut must have become covered over with gravel and shelly marl, under which not only the hut, but several vessels also were found, of a very antique form, and having their timbers fastened together by wooden pegs instead of nails.†

The probable cause of these movement, whether of elevation or depression, will be more appropriately discussed in the following chapters,

* See Proceedings of Geol. Soc., No. 42, p. 208. I also conversed with Dr. Pingel on the subject at Copenhagen in 1834.

† See the paper before referred to, Phil. Trans., 1835, part i.

when the origin of subterranean heat is considered. But I may remark here, that the rise of Scandinavia has naturally been regarded as a very singular and scarcely credible phenomenon, because no region on the globe has been more free within the times of authentic history from violent earthquakes. In common, indeed, with our own island, and with almost every spot on the globe, some movements have been, at different periods, experienced, both in Norway and Sweden. But some of these, as for example during the Lisbon earthquake in 1755, may have been mere vibrations of the earth's crust prolonged from a great distance. Others, however, have been sufficiently local to indicate a source of disturbance immediately under the country itself. Notwithstanding these shocks Scandinavia has, upon the whole, been as tranquil in modern times, and as free from subterranean convulsions, as any region of equal extent on the globe. There is also another circumstance which has made the change of level in Sweden appear anomalous, and has for a long time caused the proofs of the fact to be received with reluctance. Volcanic action, as we have seen, is usually intermittent: and the variations of level to which it has given rise have taken place by starts, not by a prolonged and insensible movement similar to that experienced in Sweden.

Yet, when we are once assured of the reality of the gradual rise of a large region, it enables us to account for many geological appearances otherwise very difficult of explanation. There are large continental tracts and high table lands where the strata are nearly horizontal, bearing no marks of having been thrown up by violent convulsions, nor by a series of movements, such as those which occur in the Andes, and cause the earth to be rent open, and raised or depressed from time to time, while large masses are engulfed in subterranean cavities. The result of a series of such earthquakes might be to produce in a great lapse of ages a country of shattered, inclined, and perhaps vertical strata. But a movement like that of Scandinavia would cause the bed of the sea, and all the strata recently formed in it, to be upheaved so gradually, that it would merely seem as if the ocean had formerly stood at a higher level, and had slowly and tranquilly sunk down into its present bed.

The fact also of a very gradual and insensible elevation of land may explain many geological monuments of denudation, on a grand scale. If, for example, instead of the hard granitic rocks of Norway and Sweden, a large part of the bed of the Atlantic, consisting chiefly of soft strata, should rise up, century after century, at the rate of about half an inch, or an inch, in a year, how easily might oceanic currents, such as those described in the sixth chapter, sweep away the thin film of matter thus brought up annually within the sphere of aqueous denudation! The tract, when it finally emerged, might present table lands and ridges of horizontal strata, with intervening valleys and vast plains, where originally, and during its period of submergence, the surface was level and nearly uniform.

These speculations relate to superficial changes; but others must be continually in progress in the subterranean regions. The foundations of the country, thus gradually uplifted in Sweden, must be undergoing important modifications. Whether we ascribe these to the expansion of solid matter by continually increasing heat, or to the liquefaction of rock, or to the crystallization of a dense fluid, or the accumulation of pent-up gases, in whatever conjectures we indulge, we can never doubt for a moment, that at some unknown depth the structure of the globe is in our own times becoming changed from day to day, throughout a space probably more than a thousand miles in length, and several hundred in breadth.

CHAPTER XVIII.

CAUSES OF EARTHQUAKES AND VOLCANOS.

Intimate connexion between the causes of volcanos and earthquakes—Supposed original state of fusion of the planet—Universal fluidity not proved by spheroidal figure of the earth—Heat in mines increasing with the depth (p. 452.)—Objections to the supposed intense heat of a central fluid—Whether chemical changes may produce volcanic heat (p. 456.)—Currents of electricity circulating in the earth's crust—Theory of an unoxidated metallic nucleus (p. 460.)—The metallic oxides when heated may be deoxidated by hydrogen.

It will hardly be questioned, after the description before given of the phenomena of earthquakes and volcanos, that both of these agents have, to a certain extent, a common origin; and I may now, therefore, proceed to inquire into their probable causes. But first, it may be well to recapitulate some of those points of relation and analogy which lead naturally to the conclusion, that they spring from a common source.

The regions convulsed by violent earthquakes include within them the site of all the active volcanos. Earthquakes, sometimes local, sometimes extending over vast areas, often precede volcanic eruptions. The subterranean movement and the eruption return again and again, at irregular intervals of time, and with unequal degrees of force, to the same spots. The action of either may continue for a few hours, or for several consecutive years. Paroxysmal convulsions are usually followed, in both cases, by long periods of tranquillity. Thermal and mineral springs are abundant in countries of earthquakes and active volcanos. Lastly, hot springs situated in districts considerably distant from volcanic vents have been observed to have their temperature suddenly raised, and the volume of their water augmented, by subterranean movements.

All these appearances are evidently more or less connected with the passage of heat from the interior of the earth to the surface; and where there are active volcanos, there must exist, at some unknown depth below, enormous masses of matter intensely heated, and, in many instances, in a constant state of fusion. We have first, then, to inquire, whence is this heat derived?

It has long been a favourite conjecture, that the whole of our planet was originally in a state of igneous fusion, and that the central parts still retain a great portion of their primitive heat. Some have imagined, with the late Sir W. Herschel, that the elementary matter of the earth may have been first in a gaseous state, resembling those nebulæ which we behold in the heavens, and which are of dimensions so vast, that some of them would fill the orbits of the remotest planets of our system. It is conjectured that such aëriform matter (for in many cases the nebulous appearance cannot be referred to clusters of very distant stars), if concentrated, might form solid spheres; and others have imagined that the evolution of heat, attendant on condensation, might retain the materials of the new globes in a state of igneous fusion.

Without dwelling on such speculations, which can only have a distant bearing on geology, we may consider how far the spheroidal form of the earth affords sufficient ground for presuming that its primitive condition was one of universal fluidity. The discussion of this question would be superfluous, were the doctrine of original fluidity less popular; for it may well be asked, why the globe should be supposed to have had a pristine shape different from the present one?—why the terrestrial materials, when first called into existence, or assembled together in one place, should not have been subject to rotation, so as to assume at once that form which alone could retain their several parts in a state of equilibrium?

Let us, however, concede that the statical figure may be a modification of some other pre-existing form, and suppose the globe to have been at first a perfect and quiescent sphere, covered with an uniform ocean—what would happen when it was made to turn round on its axis with its present velocity? "A centrifugal force," says Sir J. Herschel, "would in that case be generated, whose general tendency would be to urge the water at every point of the surface to *recede* from the *axis*. A rotation might indeed be conceived so swift as to flirt the whole ocean from the surface, like water from a mop. But this would require a far greater velocity than what we now speak of. In the case supposed, the *weight* of the water would still keep it *on* the earth; and the tendency to recede from the axis *could* only be satisfied, therefore, by the water leaving the poles, and flowing towards the equator; there heaping itself up in a ridge, and being retained in opposition to its weight or natural tendency towards the centre by the pressure thus caused. This, however, could not take place without laying dry the polar regions, so that protuberant land would appear at the poles, and a zone of ocean be disposed around the equator. This would be the first or immediate effect. Let us now see what would afterwards happen, if things were allowed to take their natural course.

"The sea is constantly beating on the land, grinding it down, and scattering its worn-off particles and fragments, in the state of sand and pebbles, over its bed. Geological facts afford abundant proof that the existing continents have all of them undergone this process, even more than once, and been entirely torn in fragments, or reduced to powder, and submerged and reconstructed. Land, in this view of the subject, loses its attribute of fixity. As a mass it might hold together in opposition to forces which the water freely obeys; but in its state of successive or simultaneous degradation, when disseminated through the water, in the state of sand or mud, it is subject to all the impulses of that fluid. In the lapse of time, then, the protuberant land would be destroyed, and spread over the bottom of the ocean, filling up the lower parts, and tending continually to re-model the surface of the solid nucleus, in correspondence with the *form of equilibrium*. Thus, after a sufficient lapse of time, in the case of an earth in rotation, the polar protuberances would gradually be cut down and disappear, being transferred to the equator (as being *then* the *deepest sea*), till the earth would assume by degrees the form we observe it to have—that of a flattened or *oblate* ellipsoid.

"We are far from meaning here to trace the process *by which* the earth really assumed its actual form; all we intend is to show that this is the form to which, under a condition of a rotation on its axis, it must *tend*, and which it would attain even if originally and (so to speak) perversely constituted otherwise."*

In this passage, the author has contemplated the superficial effects of aqueous causes only; he might have added that every stream of lava which flowed out of a volcano would be impelled, in a slight degree, towards the equatorial regions, in obedience to the same power; and if the volcanic action should extend to great depths, so as to melt, one after another, different parts of the earth, the whole interior might at length be remodelled under the influence of similar changes, due to causes which may all be operating at this moment. The statical figure, therefore, of the terrestrial spheroid (of which the longest diameter exceeds the shortest by about twenty-five miles), may have been the result of gradual and even of existing causes, and not of a primitive, universal, and simultaneous fluidity.

Experiments made with the pendulum, and observations on the manner

* Herschel's Astronomy, chap. iii.

in which the earth attracts the moon, have shown that our planet is not an empty sphere, but that it must rather increase in density from the surface towards the centre; and it has also been inferred that the equatorial protuberance is continued inwards, that is to say, that layers of equal density are arranged elliptically, and symmetrically, from the exterior to the centre. The inequalities, however, in the moon's motion, on which this opinion is founded, are so extremely slight, that it can be regarded as little more than a probable conjecture.

The mean density of the earth has been computed by Laplace to be about 5½, or more than five times that of water. Now the specific gravity of many of our rocks is from 2½ to 3, and the greater part of the metals range between that density and 21. Hence some have imagined that the terrestrial nucleus may be metallic—that it may correspond, for example, with the specific gravity of iron, which is about 7. But here a curious question arises in regard to the form which materials, whether fluid or solid, might assume, if subjected to the enormous pressure which must obtain at the earth's centre. Water, if it continued to decrease in volume according to the rate of compressibility deduced from experiment, would have its density doubled at the depth of ninety-three miles, and be as heavy as mercury at the depth of 362 miles. Dr. Young computed that, at the earth's centre, steel would be compressed into one-fourth, and stone into one-eighth of its bulk.* It is more than probable, however, that after a certain degree of condensation, the compressibility of bodies may be governed by laws altogether different from those which we can put to the test of experiment; but the limit is still undetermined, and the subject is involved in such obscurity, that we cannot wonder at the variety of notions which have been entertained respecting the nature and conditions of the central nucleus. Some have conceived it to be fluid, others solid; some have imagined it to have a cavernous structure, and have even endeavoured to confirm this opinion by appealing to observed irregularities in the vibrations of the pendulum in certain countries.

Central Heat.—The hypothesis of internal fluidity calls for the more attentive consideration, as it has been found that the heat in mines augments in proportion as we descend. Observations have been made, not only on the temperance of the air in mines, but on that of the rocks, and on the water issuing from them. The mean rate of increase, calculated from results obtained in six of the deepest coal miles in Durham and Northumberland, is 1° Fahr. for a descent of forty-four English feet.† A series of observations, made in several of the principal lead and silver mines in Saxony, gave 1° Fahr. for every sixty-five feet. In this case,

* Young's Lectures, and Mrs. Somerville's Connexion of the Physical Sciences, p. 90.

† Ed. Journal of Sci., April, 1832.

the bulb of the thermometer was introduced into cavities purposely cut in the solid rock at depths varying from two hundred to above nine hundred feet. But in other mines of the same country, it was necessary to descend thrice as far for each degree of temperature.*

A thermometer was fixed in the rock of the Dolcoath mine, in Cornwall, by Mr. Fox, at the great depth of 1380 feet, and frequently observed during eighteen months; the mean temperature was 68° Fahr., that of the surface being 50°, which gives 1° for every seventy-five feet.

Kupffer, after an extensive comparison of the results in different countries, makes the increase 1° F. for about every thirty-seven English feet;† and Cordier considers that it would not be overstated at 1° Cent. for every twenty-five metres, or about 1° F. for every forty-five feet.‡

Some writers have endeavoured to refer these phenomena (which, however discordant as to the ratio of increasing heat, appear all to point one way), to the condensation of air constantly descending from the surface into the mines. For the air under pressure would give out latent heat, on the same principle as it becomes colder when rarified in the higher regions of the atmosphere. But besides that the quantity of heat is greater than could be supposed to flow from this source, the argument has been answered in a satisfactory manner by Mr. Fox, who has shown, that in the mines of Cornwall the ascending have generally a higher temperature than the descending aërial currents. The difference between them was found to vary from 9° to 17° Fahr.: a proof, that instead of imparting heat, these currents actually carry off a large quantity from the mines.§

If we adopt M. Cordier's estimate of 1° Fahr. for every 45 feet of depth as the mean result, and assume, with the advocates of central fluidity, that the increasing temperature is continued downwards, we should reach the ordinary boiling point of water at about two miles below the surface, and at the depth of about twenty-four miles should arrive at the melting point of iron, a heat sufficient to fuse almost every known substance. The temperature of melted iron was estimated at 21,000° Fahr. by Wedgwood; but his pyrometer gives, as is now demonstrated, very erroneous results. It has been ascertained by Professor Daniell, that the point of fusion is 2786° Fahr.‖

* Cordier, Mém. de l'Instit., tom. vii.

† Pog. Ann. tom. xv. p. 159.

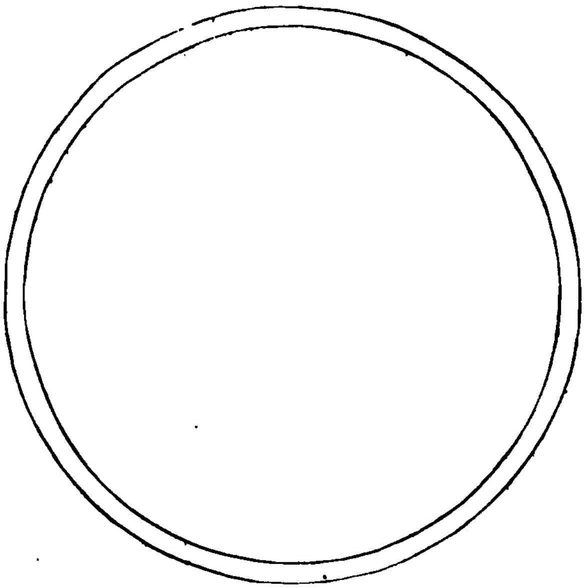
‡ Cordier, Mém. de l'Instit., tom. vii.

§ Phil. Mag. and Ann., Feb. 1830.

‖ The heat was measured in Wedgwood's pyrometer by the contraction of pure clay, which is reduced in volume when heated, first by the loss of its water of combination, and afterwards on the application of more intense heat, by incipient vitrification. The expansion of platina is the test employed by Mr. Daniell, in his pyrometer, and this has been found to yield uniform and consistent results, such as are in perfect harmony with conclusions drawn from various other independent sources. The instrument for which the author received the Rumford Medal from the Royal Society in 1833, is described in the Phil. Trans. 1830, part ii., and 1331, part ii.

By adopting the least correct of these two results the melting point of our ordinary rocks would be farther removed from the surface; but this difference does not affect the probability of the theory now under consideration. According to Mr. Daniell's scale, we ought to encounter the internal melted matter before penetrating through a thickness represented by that of the outer circular line in the annexed diagram (Fig. 59.);

Fig. 59.



Section of the earth in which the breadth of the outer boundary line represents a thickness of 25 miles; the space between the circles including the breadth of the lines, 200 miles.

whereas, if the other scale be correct, we should meet with it at some point between the two circles; the space between them, together with the lines themselves, representing a crust of two hundred miles in depth. In either case, we must be prepared to maintain, that a temperature many times greater than that sufficient to melt the most refractory substances known to us, is sustained at the centre of the globe; while a comparatively thin crust, resting upon the fluid, remains unmelted; or is even, according to M. Cordier, increasing in thickness, by the continual addition of new internal layers solidified during the process of refrigeration.

The mathematical calculations of Fourier, on the passage of heat through conducting bodies, have been since appealed to in support of these views; for he has shown that it is compatible with theory that the present temperature of the surface might coexist with an intense heat, at a certain depth below. But his reasoning seems to be confined to the conduction of heat through solid bodies; and the conditions of the problem are wholly altered when we reason about a fluid nucleus, as we must do, if it be assumed that the heat augments from the surface to the interior, according to the rate observed in mines. For when the heat of the lower portion of a fluid is increased, a circulation begins thoughout the mass, by the ascent of hotter, and the descent of colder currents. And this circulation, which is quite distinct from the mode in which heat is propagated through solid bodies, must evidently occur in the supposed central ocean, if the laws of fluids and of heat are the same there as upon the surface.

In Mr. Daniell's recent experiments for obtaining a measure of the heat of bodies, at their point of fusion, he invariably found that it was impossible to raise the heat of a large crucible of melted iron, gold, or silver, a single degree beyond the melting point, so long as a bar of the respective metals was kept immersed in the fluid portions. So in regard to other substances, however great the quantities fused, their temperature could not be raised while any solid pieces immersed in them remained unmelted; every accession of heat being instantly absorbed during their liquefaction. These results are, in fact, no more than the extension of a principle previously established, that so long as a fragment of ice remains in water, we cannot raise the temperature of the water above 32° F.

If, then, the heat of the earth's centre amount to 450,000° F., as M. Cordier deems highly probable, that is to say, about twenty times the heat of melted iron, even according to Wedgwood's scale, and upwards of 160 times according to the improved pyrometer, it is clear that the upper parts of the fluid mass could not long have a temperature only just sufficient to melt rocks. There must be a continual tendency towards a uniform heat; and until this were accomplished, by the interchange of portions of fluid of different densities, the surface could not begin to consolidate. Nor, on the hypothesis of primitive fluidity, can we conceive any crust to have been formed until *the whole* planet had cooled down to about the temperature of incipient fusion.

It cannot be objected that hydrostatic pressure would prevent a tendency to equalization of temperature; for, as far as observations have yet been made, it is found that the waters of deep lakes and seas are governed by the same laws as a shallow pool; and no experiments indicate that solids resist fusion under high pressure. The arguments, indeed, now controverted, always proceed on the admission that the internal nucleus is in a state of fusion.

It may be said that we may stand upon the hardened surface of a lava current while it is still in motion,—nay, may descend into the crater of Vesuvius after an eruption, and stand on the scoriæ while every crevice shows that the rock is red-hot two or three feet below us; and at a somewhat greater depth, all is, perhaps, in a state of fusion. May not, then, a much more intense heat be expected at the depth of several hundred yards, or miles? The answer is,—that, until a great quantity of heat has been given off, either by the emission of lava, or in a latent form by the evolution of steam and gas, the melted matter continues to boil in the crater of a volcano. But ebullition ceases when there is no longer a sufficient supply of heat from below, and then a crust of lava may form on the top, and showers of scoriæ may then descend upon the surface, and remain unmelted. If the internal heat be raised again, ebullition will recommence, and soon fuse the superficial crust. So in the case of the moving current, we may safely assume that no part of the liquid beneath the hardened surface is much above the temperature sufficient to retain it in a state of fluidity.

It may assist us in forming a clearer view of the doctrine now controverted, if we consider what would happen were a globe of homogeneous composition placed under circumstances analogous, in regard to the distribution of heat, to those above stated. If the whole planet, for example, were composed of water covered with a spheroidal crust of ice fifty miles thick, and with an interior ocean having a central heat about two hundred times that of the melting point of ice, or 6400° F.; and if, between the surface and the centre, there was every intermediate degree of temperature between that of melting ice and that of the central nucleus;—could such a state of things last for a moment? If it must be conceded, in this case, that the whole spheroid would be instantly in a state of violent ebullition, that the ice (instead of being strengthened annually by new internal layers) would soon melt, and form part of an atmosphere of steam—on what principle can it be maintained that analogous effects would not follow, in regard to the earth, under the conditions assumed in the theory of central heat?

M. Cordier admits that there must be tides in the internal melted ocean; but their effect, he says, has become feeble, although originally, when the fluidity of the globe was perfect, the rise and fall of these ancient land tides could not have been less than from thirteen to sixteen feet. Now granting, for a moment, that these tides have become so feeble as to be incapable of lifting up every six hours the fissured shell of the earth, may we not ask whether, during eruptions, jets of lava ought not to be thrown up from the craters of volcanos, when the tides rise?—and whether the same phenomena would not be conspicuous in Stromboli, where there is always lava boiling in the crater? Ought not the fluid, if connected with the interior ocean, to disappear entirely on the ebbing of its tides?

Whether chemical changes may produce volcanic heat.—Having now explained the reasons which have induced me to question the hypothesis of central heat as the pirmary source of volcanic action, it remains to consider what has been termed the chemical theory of volcanos. It is well known that many, perhaps all, of the substances of which the earth is composed are continually undergoing chemical changes. To what depth these processes may be continued downwards must, in a great degree, be matter of conjecture; but there is no reason to suspect that, if we could descend to a great distance from the surface, we should find elementary substances differing essentially from those with which we are acquainted.

Playfair has, indeed, attempted to deduce, from an observation of Pallas, that we can, by the aid of geology, see, as it were, into the interior as far as thirty miles or more; for Pallas had described, in the peninsula of Tauris, a series of parallel strata as regular as the leaves of a book, inclined at an angle of 45° to the horizon, and exposed in a continuous section eighty-six English miles long. The height of the range of hills composed of these strata does not exceed twelve hundred feet; but if we measure the thickness of the stratified mass by a line perpendicular to its stratification, the height of the uppermost bed above the undermost must have been originally more than sixty miles; and, even allowing, says Playfair, that the strata had shifted during their elevation, we may still suppose a thickness of thirty miles. But, if a deception to the extent of one-half is allowed for, on the score of shifting, it may well be asked why the same cause might not have produced a much greater amount of error? I shall point out, in another place, that, besides the probability of a shifting of the beds during elevation, there may also have been an original deviation from horizontality in the strata, which might cause them to assume the appearance of having been deposited in an ocean many leagues in depth, when, in fact, they may have been accumulated in a sea only a few hundred fathoms deep.*

Nevertheless, since we discover in mountain chains strata thousands of feet thick, which must have been formed at the bottom of the sea, but are now raised to the height of three or four miles above it, we may fairly speculate on the probability of rocks, such as are now on the surface, existing at the depth of several leagues below.

We may next recal to mind that all the solid, fluid, and gaseous bodies which enter into the composition of the earth, consist of a very small number of elementary substances variously combined: the total number of elements at present known is less than sixty; and not half of these enter into the composition of the more abundant inorganic productions.

Some portions of the compounds above alluded to are daily resolved into their elements; and these, on being set free, are always passing into new combinations. These processes are by no means confined to the surface, and are almost always accompanied by the evolution of heat, which is intense in proportion to the rapidity of the combinations. At the same time, there is a development of electricity.

* Book iv. chap. xii.

It is well known that mixtures of sulphur and iron, sunk in the ground, and exposed to moisture, give out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that are near. The following experiment was first made by Lemery:—Let a large quantity of clean iron filings be mixed with a still larger proportion of sulphur, and as much water as is necessary to make them into a firm paste. Let the mixture be then buried in the earth, and the soil pressed down firmly upon it. In a few hours it will grow warm, and swell so as to raise the ground; sulphurous vapours will make their way through the crevices, and sometimes flames appear. There is rarely an explosion; but, when this happens, the fire is vivid, and, if the quantity of materials is considerable, the heat and fire both continue for a long time.*

The spontaneous combustion of beds of bituminous shale, and of refuse coal thrown out of mines, is also generally due to the decomposition of pyrites; and it is the contact of water, not of air, which brings about the change. A smouldering heat results from the various new combinations, which immediately take place when the sulphur and other substances are set free. Similar effects are often produced in mines where no coaly matter is present, where substances capable of being decomposed by water are heaped together.

On what principle heat is generated, when two or more bodies having a strong affinity for each other unite suddenly, is wholly unexplained; but it is a singular fact that, while chemical combination causes heat, the disunion of elements does not produce the opposite effect, or a corresponding degree of cold. It may be said that decomposition is usually brought about by the combination of one or more of the elements with a new substance, and this concomitant agency might be supposed to neutralize or counterbalance any frigorific effects which might otherwise be sensible. But this explanation is, in many cases, wholly inapplicable; as, for example, when the voltaic pile is used for decomposition, or in the more striking instance of the well-known detonating powder, the iodine of nitrogen, which explodes with violence in the open air, the instant it is touched by a cold substance. The two elements into which this binary compound is resolved fly off in a gaseous form, and do not unite with any other body, the iodine rising in a purple vapour, while the nitrogen may be collected separately. Yet sudden as is the process by which their union is broken, we find that heat and light, instead of cold, are generated.

Electricity a source of volcanic heat.—It has already been stated, that chemical changes develope electricity; which, in its turn, becomes a powerful disturbing cause. As a chemical agent, says Davy, its silent and slow operation in the economy of nature is much more important

* Daubeny's Volcanos, p. 356.

than its grand and impressive operation in lightning and thunder. It may be considered, not only as directly producing an infinite variety of changes, but as influencing almost all which take place; it would seem, indeed, that chemical attraction itself is only a peculiar form of the exhibition of electrical attraction.*

Now that it has been demonstrated that magnetism and electricity are always associated, and are perhaps only different conditions of the same power, the phenomena of terrestrial magnetism have become of no ordinary interest to the geologist. Soon after the first great discoveries of Oersted in electro-magnetism, Ampere suggested that all the phenomena of the magnetic needle might be explained by supposing currents of electricity to circulate constantly in the shell of the globe in directions parallel to the magnetic equator. This theory has acquired additional consistency the farther we have advanced in science; and according to the experiments of Mr. Fox, on the electro-magnetic properties of metalliferous veins, some trace of electric currents seems to have been detected in the interior of the earth.†

Some philosophers ascribe these currents to the chemical action going on in the superficial parts of the globe to which air and water have the readiest access; while others refer them, in part at least, to thermo-electricity excited by the solar rays on the surface of the earth during its rotation; successive parts of the land and sea being exposed to the influence of the sun, and then cooled again in the night. That this idea is not a mere speculation, is proved by the correspondence of the diurnal variations of the magnet with the apparent motion of the sun; and by the greater amount of variation in summer than in winter, and during the day than in the night. M. de la Rive, although conceding that such minor variations of the needle may be due to thermo-electricity, contends that the general phenomena of terrestrial magnetism must be attributed to currents far more intense; which, though liable to secular fluctuations, act with much greater constancy and regularity than the causes which produce the diurnal variations.‡ The remark seems just; yet it is difficult to assign limits to the accumulated influence even of a very feeble force constantly acting on the whole surface of the earth. This subject, however, must evidently remain obscure, until we become acquainted with the causes which give a determinate direction to the supposed electric currents. Already the experiments of Faraday on the rotation of magnets have led him to speculate on the manner in which the earth, when once it had become magnetic, might produce electric currents within itself, in consequence of its diurnal rotation.§

Before leaving the consideration of thermo-electricity, I may remark,

* Consolations in Travel, p. 271. † Phil. Trans. 1830, p. 399.

‡ Biblioth. Univers., 1833, Electricité.

§ Phil. Trans., 1832, p. 176.; also pp. 172, 173, &c.

that it may be generated by great inequalities of temperature, arising from a partial distribution of volcanic heat. Wherever, for example, masses of rock occur of great horizontal extent, and of considerable depth, which are, at one point in a state of fusion (as beneath some active volcano); at another, red hot; and at a third, comparatively cold—strong thermo-electric action may be excited.

Some, perhaps, may object, that this is reasoning in a circle; first to introduce electricity as one of the primary causes of volcanic heat, and then to derive the same heat from thermo-electric currents. But there must, in truth, be much reciprocal action between the agents now under consideration; and it is very difficult to decide which should be regarded as the prime mover, or to see where the train of changes, once begun, would terminate.

In the ordinary operations of nature, it is in the atmosphere alone that we observe the action of electricity; and it is probable that a moment never passes without a flash of lightning striking some part of the earth. The electric fluid shatters rocks, and instantaneously melts substances which are commonly regarded as infusible. The air is supposed to derive a great part of this electricity directly from the earth;* and M. Necker seems to have succeeded in establishing that there is a connexion between the direction of the curves of equal magnetic intensity and the *strike* of the principal mountain chains.† Some, also, attribute the electricity of the air to the evaporation of sea-water by the sun: for it can be shown, by experiment, that the conversion of salt water into vapour is accompanied by the excitement of electricity; and the process alluded to takes place on so vast a scale,—the measure of the quantity of evaporation being the constant flow of all the rivers of the earth, exclusive of the rain which falls directly into the ocean,—that a feeble action of this kind may become very powerful by accumulation.

During volcanic eruptions, vivid lightnings are almost invariably seen in the clouds of vapour which ascend from the crater; and, as there are always one or more eruptions going on in some part of the globe, we are here presented with another perpetual source of derangement. How far subterranean electric currents may possess the decomposing power of the voltaic pile is a question for those alone who are farthest advanced in the career of discovery in a rapidly progressive science; but such a power would at once supply us with a never-failing source of chemical action, from which volcanic heat might be derived.

Theory of an unoxidated metallic nucleus.—When Sir H. Davy first discovered the metallic bases of the earths and alkalies, he threw out the idea that those metals might abound in an unoxidized state in the subter-

* Faraday, Phil. Trans., 1832, p. 177.

† Biblioth. Univers., tom. xliii. p. 166.

ranean regions to which water must occasionally penetrate. Whenever this happened, gaseous matter would be set free, the metals would combine with the oxygen of the water, and sufficient heat might be evolved to melt the surrounding rocks. This hypothesis was at first very favourably received both by the chemist and the geologist; for silica, alumina, lime, soda, and oxide of iron,—substances of which lavas are principally composed,—would all result from the contact of the inflammable metals alluded to with water. But whence this abundant store of unsaturated metals in the interior? It was assumed that, in the beginning of things, the nucleus of the earth was mainly composed of inflammable metals, and that oxidation went on with intense energy at first; till, at length, when a superficial crust of oxides had been formed, the chemical action became more and more languid.

It must be confessed, that this assumption was not less arbitrary than that first suggested by Leibnitz, of an original igneous fluid; for a particular mineral condition of a primitive solid nucleus is, to say the least, as bold a speculation as a newly created mass of incandescent matter. It would, perhaps, be more philosophical to begin by inquiring, whether any existing causes may have the power of deoxidating the earthy and alkaline compounds formed from time to time by the action of water upon the metallic bases; so that the previous state of things might, under favourable circumstances, be restored, a permanent chemical action sustained, and a continual circle of operation kept up. It has been suggested to me, by Mr. Daniell, that we have, in hydrogen, precisely such a deoxidating agent as would be required. It is well known to chemists, that the metallization of the most difficultly reduced oxides may be effected by hydrogen brought into contract with them at a red heat; and it is more than probable that the production of potassium itself, in the common gun-barrel process, is due to the power of nascent hydrogen derived from the water which the hydrated oxide contains. According to the recent experiments, also, of Faraday, it would appear that every case of metallic reduction by voltaic agency, from saline solutions, in which water is present, is due to the secondary action of hydrogen upon the oxide; both of these being determined to the negative pole, and then reacting upon one another.

It has never been disputed that intense heat might be produced by the occasional contact of water with the metallic bases; and it is quite certain that, during the process of saturation, vast volumes of hydrogen must be evolved. The hydrogen, thus generated, might permeate the crust of the earth in different directions, and be stored up for ages in fissures and caverns, sometimes in a liquid form, under the necessary pressure. Whenever, at any subsequent period, in consequence of the changes effected by earthquakes in the shell of the earth, this gas happened to come in contact with metalic oxides at a high temperature, the reduction of these oxides would be the necessary result.

Recapitulation.—In the next chapter I shall inquire more particularly into the manner in which the phenomena of earthquakes and volcanos accord with the hypothesis of a continued generation of heat by chemical action. But, first, it may be desirable to recapitulate, in a few words, the conclusions already obtained.

1st. The primary causes of the volcano and the earthquake are, to a great extent, the same, and must be connected with the passage of heat from the interior to the surface.

2dly. This heat has been referred, by many, to a supposed state of igneous fusion of the central parts of the planet when it was first created, of which a part still remains in the interior, but is always diminishing in intensity.

3dly. The spheroidal figure of the earth, adduced in support of this theory, does not of necessity imply an universal and simultaneous fluidity in the beginning; for supposing the original figure of our planet had been strictly spherical—which, however, is a gratuitous assumption, resting on no established analogy—still the statical figure must have been assumed, if sufficient time be allowed, by the gradual operation of the centrifugal force, acting on the materials brought successively within its action by aqueous and igneous causes.

4thly. It appears, from experiment, that the heat in mines increases progressively with their depth; and if the ratio of increase be continued uniformly from the surface to the interior, the whole globe, with the exception of a small external shell, must be fluid, and the central parts must have a temperature many times higher than that of melted iron.

5thly. But the theory adopted by M. Cordier and others, which maintains the actual existence of such a state of things, seems wholly inconsistent with the laws which regulate the circulation of heat through fluid bodies. For, if the central heat were as intense as is represented, there must be a circulation of currents, tending to equalize the temperature of the resulting fluid, and the solid crust itself would be melted.

6thly. Instead of an original central heat, we may, perhaps, refer the heat of the interior to chemical changes constantly going on in the earth's crust; for the general effect of chemical combination is the evolution of heat and electricity, which, in their turn, becomes sources of new chemical changes.

7thly. The existence of currents of electricity in the shell of the earth has been deduced from the phenomena of terrestrial magnetism; from the connexion between the diurnal variations of the magnet and the apparent motion of the sun; from observations on the electro-magnetic properties of metalliferous veins; and, lastly, from atmospheric electricity, which is continually passing between the air and the earth.

8thly. Subterranean electric currents may exert a slow decomposing power like that of the voltaic pile, and thus become a constant source of chemical action, and consequently, of volcanic heat.

9thly. It has been suggested, that the metals of the earths and alkalies may exist in an unoxidized state in the subterranean regions, and that the occasional contact of water with these metals must produce intense heat. The hydrogen, evolved during the process of saturation, may, on coming afterwards in contact with the heated metallic oxides, reduce them again to metals; and this circle of action may be one of the principal means by which internal heat, and the stability of the volcanic energy, are preserved.

CHAPTER XIX.

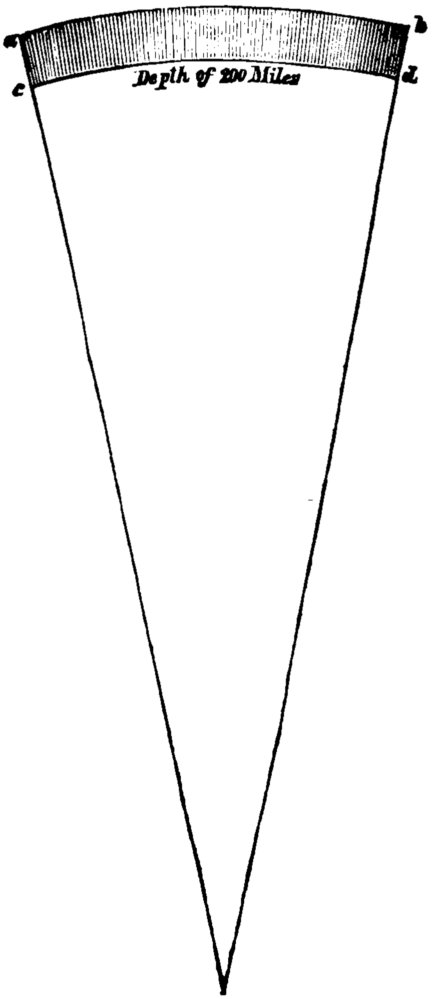
CAUSES OF EARTHQUAKES AND VOLCANOS—*continued.*

Heat of the interior of the earth—Causes of earthquakes—Expansive power of condensed gases—How land may be permanently elevated—Expansion of rocks by heat (p. 468.)—Subsidence of land—Volcanic eruptions—Geysers of Iceland—Whether decomposition of water a source of volcanic heat—Almost all volcanos near the sea (p. 473.)—Many subterranean changes now unseen; therefore many geological phenomena obscure—Average annual number of earthquakes—Elevatory movements alone not opposed to the levelling force of running water—The sinking in of the earth's crust must exceed the forcing out of the same by earthquakes (p. 478.)—Whether earthquakes have diminished in energy—Conservative influence of volcanic action.

When we reflect that the largest mountains are but insignificant protuberances upon the surface of the earth, and that these mountains are nevertheless composed of different parts which have been formed in succession, we may well feel surprise that the central fluidity of the planet should have been called in to account for volcanic phenomena. To suppose the entire globe to be in a state of igneous fusion, with the exception of a solid shell, not more than from thirty to one hundred miles thick, and to imagine that the central heat of this fluid spheroid exceeds by more than two hundred times that of liquid lava, is to introduce a force altogether disproportionate to the effects which it is required to explain.

The ordinary repose of the surface implies, on the contrary, an inertness in the internal mass which is truly wonderful. When we consider the combustible nature of the elements of the earth, so far as they are known to us,—the facility with which their compounds may be decomposed, and made to enter into new combinations,—the quantity of heat which they evolve during these processes; when we recollect the expansive power of steam, and that water itself is composed of two gases which, by their union, produce intense heat; when we call to mind the number of explosive and detonating compounds which have been already discovered, we may be allowed to share the astonishment of Pliny, that a single day should pass without a general conflagration:—"Excedit profectò omnia miracula, ullum diem fuisse quo non cuncta conflagrarent."*

Fig. 60.



Centre of Earth.

* Hist. Mundi, lib. ii. c. 107.

The signs of internal heat observable on the surface of the earth do not necessarily indicate the permanent existence of subterranean heated masses, whether fluid or solid, by any means so vast as our continents and seas; yet how insignificant would these appear if distributed through an external shell of the globe one or two hundred miles in depth! The principal facts in proof of the accumulation of heat below the surface may be summed up in a few words. Several volcanos are constantly in eruption, as Stromboli and Nicaragua; others are known to have been active for periods of 60 or even 150 years, as those of Sangay in Quito, Popocatepetl in Mexico, and the volcano of the Isle of Bourbon. Many craters emit hot vapours in the intervals between eruptions, and solfataras evolve incessantly the same gases as volcanos. Steam of high temperature has continued for more than twenty centuries to issue from the "stufas," as the Italians call them,—thermal springs abound not only in regions of earthquakes, but are found in almost all countries, however distant from active vents; and, lastly, the temperature in the mines of various parts of the world is found to increase in proportion as we descend.

It is probably to this unceasing discharge of subterranean heat that we owe the general tranquillity of the globe; and the occasional convulsions which occur may arise from the temporary stoppage of the channels by which heat is transmitted to the surface; for the passage of caloric from below upwards may be compared to the descent of water from the continents to the sea; and as a partial interruption of the drainage of a country causes a flood, so any obstruction to the discharge of volcanic heat may give rise to an earthquake or eruption.

The annexed diagram may convey some idea of the proportion which our continents and the ocean bear to the radius of the earth.* If all the land were about as high as the Himalaya mountains, and the ocean every where as deep as the Pacific, the whole of both might be contained within a space expressed by the thickness of the line *a b*; and masses of nearly equal volume might be placed in the space marked by the line *c d*, in the interior. Seas of lava, therefore, of the size of the Mediterranean, or even of the Atlantic, would be as nothing if distributed through such an outer shell of the globe as is represented by the shaded portion of the figure *a b c d*. If throughout that space we imagine electro-chemical causes to be continually in operation, even of very feeble power, they might give rise to heat which, if accumulated at certain points, might melt or render red-hot entire mountains, or sustain the temperature of stufas and hot springs for ages.

Causes of earthquakes—wave like motion.—I shall now proceed to examine the manner in which the heat of the interior may give rise to

* Reduced, by permission, from a figure in plate 40, of Mr. De la Beche's Geological Sections and Views.

earthquakes; and shall then pass on to the probable causes of eruptions. One of the most common phenomena attending subterranean movements, is the undulatory motion of the ground. And this, says Michell, will seem less extraordinary, if we call to mind the extreme elasticity of the earth, and the compressibility of even the most solid materials. Large districts, he suggests, may rest on fluid lava; and, when this is disturbed, its motions may be propagated through the incumbent rocks. He also adds the following ingenious speculation:—"As a small quantity of vapour almost instantly generated at some considerable depth below the surface of the earth will produce a vibratory motion, so a very large quantity (whether it be generated almost instantly, or in any small portion of time) will produce a wave-like motion. The manner in which this wave-like motion will be propagated may, in some measure, be represented by the following experiment:—Suppose a large cloth, or carpet (spread upon a floor), to be raised at one edge, and then suddenly brought down again to the floor; the air under it, being by this means propelled, will pass along, till it escapes at the opposite side, raising the cloth in a wave all the way as it goes. In like manner, a large quantity of vapour may be conceived to raise the earth in a wave, as it passes along between the strata, which it may easily separate in a horizontal direction, there being little or no cohesion between one stratum and another. The part of the earth that is first raised, being bent from its natural form, will endeavour to restore itself by its elasticity; and the parts next to it being to have their weight supported by the vapour, which will insinuate itself under them, will be raised in their turn, till it either finds some vent, or is again condensed by the cold into water, and by that means prevented from proceeding any farther."*

To this hypothesis of Michell it has been objected, with some reason, that the wave-like movements of the surface of the land during earthquakes, though violent, are on a very minute scale; as appears from the account of tall trees touching the ground with their tops, and then resuming their erect position, the sea-sickness experienced by spectators, and other phenomena, clearly indicating that the radius of each superficial curvature is very small. On the other hand, the sudden fracture, it is said, of solid strata, might produce a vibratory jar; which, being propagated in undulations through a mass of rock several thousand feet thick, would give rise to superficial waves, even though the subjacent crust of the globe were entirely solid, and not reposing either on fluid or gaseous matter.†

The facility with which all the particles of a solid mass can be made to vibrate, may be illustrated, says Gay Lussac, by many familiar exam-

* On the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. sect. 58. 1760.

† Quarterly Review, No. lxxxvi. p. 463.

ples. If we apply the ear to one end of a long wooden beam, and listen attentively when the other end is struck by a pin's head, we hear the shock distinctly; which shows that every fibre throughout the whole length has been made to vibrate. The rattling of carriages on the pavement shakes the largest edifices; and in the quarries underneath some quarters in Paris, it is found that the movement is communicated through a considerable thickness of rock.*

The rending and upheaving of continental masses are operations which are not difficult to explain, when we are once convinced that heat, of sufficient power not only to melt, but to reduce to a gaseous form a great variety of substances, is accumulated in certain parts of the interior. We see that elastic fluids are capable of projecting solid masses to immense heights in the air; and the volcano of Cotopaxi has been known to throw out, to the distance of eight or nine miles, a mass of rock about one hundred cubic yards in volume. When we observe these aëriform fluids rushing out from particular vents for months, or even years, continuously, what power may we not expect them to exert in other places where they happen to be confined under an enormous weight of rock?

Liquid gases.—The experiments of Faraday and others have shown, within the last twelve years, that many of the gases, including all those which are most copiously disengaged from volcanic vents, as the carbonic, sulphurous, and muriatic acids, may be condensed into liquids by pressure. At temperatures of from 30° to 50° F., the pressure required for this purpose varies from fifteen to fifty atmospheres; and this amount of pressure we may regard as very insignificant in the operations of nature. A column of Vesuvian lava that would reach from the lip of the crater to the level of the sea, must be equal to about three hundred atmospheres; so that, at depths which may be termed moderate in the interior of the crust of the earth, the gases may be condensed into liquids, even at very high temperatures. The method employed to reduce some of these gases to a liquid state is, to confine the materials, from the mutual action of which they are evolved, in tubes hermetically sealed, so that the accumulated pressure of the vapour, as it rises and expands, may force some part of it to assume the liquid state. A similar process may, and indeed must, frequently take place in subterranean caverns and fissures, or even in the pores and cells of many rocks; by which means, a much greater store of expansive power may be *packed* into a small space than could happen if these vapours had not the property of becoming liquid. For, although the gas occupies much less room in a liquid state, yet it exerts exactly the same pressure upon the sides of the containing cavity as if it remained in the form of vapour.

If a tube, whether of glass or other materials, filled with condensed

* Ann. de Ch. et de Ph., tom. xxii. p. 428.

gas, have its temperature slightly raised, it will often burst; for a slight increment of heat causes the elasticity of the gas to increase in a very high ratio. We have only to suppose certain rocks permeated by these liquid gases (as porous strata are sometimes filled with water), to have their temperature raised some hundred degrees, and we obtain a power capable of lifting superincumbent masses of almost any conceivable thickness: while, if the depth at which the gas is confined be great, there is no reason to suppose that any other appearances would be witnessed by the inhabitants of the surface than vibratory movements and rents, from which no vapour might escape. In making their way through fissures a very few miles only in length, or in forcing a passage through soft yielding strata, the vapours may be cooled and absorbed by water. For water has a strong affinity to several of the gases; and will absorb large quantities, with a very slight increase of volume. In this manner, the heat or the volume of springs may be augmented, and their mineral properties made to vary.

Permanent elevation and subsidence.—It is easy to conceive that the shattered rocks may assume an arched form during a convulsion, so that the country above may remain permanently upheaved. In other cases gas may drive before it masses of liquid lava, which may thus be injected into newly opened fissures. The gas having then obtained more room, by the forcing up of the incumbent rocks, may remain at rest; while the lava congealing in the rents, may afford a solid foundation for the newly raised district.

Experiments have recently been made in America, by Colonel Totten, to ascertain the ratio according to which some of the stones commonly used in architecture expand with given increments of heat.* It was found impossible, in a country where the annual variation of temperature was more than 90° F., to make a coping of stones, five feet in length, in which the joints should fit so tightly as not to admit water between the stone and the cement; the annual contraction and expansion of the stones causing, at the junctions, small crevices, the width of which varied with the nature of the rock. It was ascertained that fine-grained granite expanded with 1° F., at the rate of ·000004825; white crystalline marble ·000005668; and red sandstone ·000009532, or about twice as much as granite.

Now, according to this law of expansion, a mass of sandstone, a mile in thickness, which should have its temperature raised 200° F., would lift a superimposed layer of rock to the height of ten feet above its former level. But, suppose a part of the earth's crust, one hundred miles in thickness and equally expansible, to have its temperature raised 600° or

* Silliman's American Journ., vol. xxii. p. 136. The application of these results to the theory of earthquakes, was first suggested to me by Mr. Babbage.

800°, this might produce an elevation of between two and three thousand feet. The cooling of the same mass might afterwards cause the overlying rocks to sink down again and resume their original position. By such agency we might explain the gradual rise of Scandinavia or the subsidence of Greenland, if this last phenomenon should also be established as a fact on further inquiry.

It is also possible that as the clay in Wedgwood's pyrometer contracts, by giving off its water, and then, by incipient vitrification; so, large masses of argillaceous strata in the earth's interior may shrink, when subjected to heat and chemical changes, and allow the incumbent rocks to subside gradually. It may frequently happen that fissures of great extent may be formed in rocks simply by the unequal expansion of a continuous mass, heated in one part, while in another it remains at a comparatively low temperature. The sudden subsidence of land may also be occasioned by subterranean caverns giving way, when gases are condensed, or when they escape through newly-formed crevices. The subtraction, moreover, of matter from certain parts of the interior, by the flowing of lava, and of mineral springs, must, in the course of ages, cause vacuities below, so that the undermined surface may at length fall in.

Cause of volcanic eruptions.—The most probable causes of a volcanic outburst at the surface have been in a great degree anticipated in the preceding speculations on the liquefaction of rocks and the generation of gases. When a minute hole is bored in a tube filled with gas condensed into a liquid, the whole becomes instantly aëriform, or, as some writers have expressed it, "flashes into vapour," and often bursts the tube. Such an experiment may represent the mode in which gaseous matter may rush through a rent in the rocks, and continue to escape for days or weeks through a small orifice, with an explosive power sufficient to reduce every substance which opposes its passage into small fragments, or even dust. Lava may be propelled upwards at the same time, and ejected in the form of scoriæ. In some places, where the fluid lava lies in a space intervening between a fissure, communicating with the surface, and a cavern in which a considerable body of vapour has been formed, there will be an efflux of lava, followed by the escape of gas. Eruptions often commence and close with the discharge of vapour: and, when this is the case, the next outburst may be expected to take place by the same vent, for the concluding evolution of elastic fluids will keep open the duct, and leave it unobstructed.

The breaking out of lava from the side or base of a lofty cone, rather than from the summit, may be attributed to the hydrostatic pressure to which the flanks of the mountain are exposed, when the column of lava has risen to a great height. If, before it has reached the top, there should happen to be a stoppage of the main duct, the upward pressure of the ascending column of gas and lava may be sufficient to burst a lateral opening.

Geysers of Iceland.—As aqueous vapour constitutes the most abundant of the aëriform products of volcanos in eruption, it may be well to consider attentively a case in which steam is exclusively the moving power —that of the Geysers of Iceland. These intermittent hot springs occur in a district situated in the south-western division of Iceland, where nearly one hundred of them are said to break out within a circle of two miles. They rise through a thick current of lava, which may perhaps have flowed from Mount Hecla, the summit of that volcano being seen from the spot at the distance of more than thirty miles. In this district, the rushing of water is sometimes heard in chasms beneath the surface; for here, as on Etna, rivers flow in subterranean channels through the porous and cavernous lavas. It has more than once happened, after earthquakes, that some of the boiling fountains have increased or diminished in violence and volume, or entirely ceased, or that new ones have made their appearance—changes which may be explained by the opening of new rents and the closing of pre-existing fissures. It has often been reported that the powers of the Geysers are, upon the whole, on the decline; but the description given by Mr. Barrow, Jun. of the eruptions in 1834, agrees very closely with that of Sir J. Banks, written more than sixty years before.*

Fig. 61.

View of the Crater of the great Geyser in Iceland.†

* See Barrow's Visit to Iceland, ch. vi. 1834.

† Reduced from a sketch given by W. J. Hooker, M. D., in his Tour in Iceland, vol. i. p. 149.

Few of the Geysers play longer than five or six minutes at a time, and the intervals between their eruptions are for the most part very irregular. The great Geyser rises out of a spacious basin at the summit of a circular mound composed of siliceous incrustations deposited from the spray of its waters. The diameter of this basin, in one direction, is fifty-six feet, and forty-six in another.

In the centre is a pipe seventy-eight feet in perpendicular depth, and from eight to ten feet in diameter, but gradually widening, as it rises into the basin. The inside of the basin is whitish, consisting of a siliceous crust, and perfectly smooth, as are likewise two small channels on the sides of the mound, down which the water escapes when the bowl is filled to the margin. The circular basin is sometimes empty, as represented in the above sketch; but is usually filled with beautifully transparent water in a state of ebullition. During the rise of the boiling water in the pipe, especially when the ebullition is most violent, and when the water is thrown up in jets, subterranean noises are heard, like the distant firing of cannon, and the earth is slightly shaken. The sound then increases, and the motion becomes more violent, till at length a column of water is thrown up, with loud explosions, to the height of one or two hundred feet. After playing for a time like an artificial fountain, and giving off great clouds of vapour, the pipe or tube is emptied; and a column of steam rushing up with amazing force and a thundering noise, terminates the eruption.

If stones are thrown into the crater, they are instantly ejected; and such is the explosive force, that very hard rocks are sometimes shivered by it into small pieces. Henderson found that by throwing a great quantity of large stones into the pipe of Strockr, one of the Geysers, he could bring on an eruption in a few minutes.* The fragments of stone, as well as the boiling water, were thrown in that case to a much greater height than usual. After the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour; but the Geyser, as if exhausted by this effort, did not send out a fresh eruption when its usual interval of rest had elapsed.

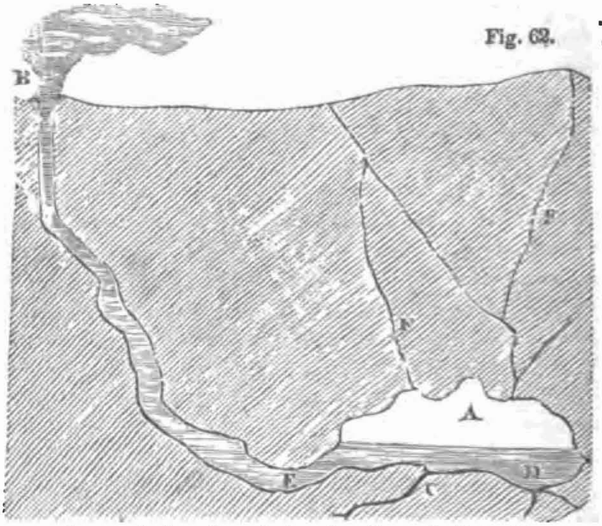
Among the different theories proposed to account for these phenomena, I shall first mention one suggested by Sir J. Herschel. An imitation of these jets, he says, may be produced on a small scale, by heating red hot the stem of a tobacco pipe, filling the bowl with water, and so inclining the pipe as to let the water run through the stem. Its escape, instead of taking place in a continued stream, is then performed by a succession of violent explosions, at first of steam alone, then of water mixed with steam; and, as the pipe cools, almost wholly of water. At every such paroxysmal escape of the water a portion is driven back, accompanied with steam,

* Journal of a Residence in Iceland, p. 74.

into the bowl. The intervals between the explosions depend on the heat, length, and inclination of the pipe; their continuance, on its thickness and conducting power.* The application of this experiment to the Geysers merely requires that a subterranean stream, flowing through the pores and crevices of lava, should suddenly reach a fissure, in which the rock is red hot, or nearly so. Steam would immediately be formed, which, rushing up the fissure, might force up water along with it to the surface, while, at the same time, part of the steam might drive back the water of the supply for a certain distance towards its source. And when, after the space of some minutes, the steam was all condensed, the water would return, and a repetition of the phenomena take place.

There is, however, another mode of explaining the action of the Geyser, perhaps more probable than that above described. Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D by the fissures F F, while, at the same time, steam, at an extremely high temperature, such as is commonly given out from the rents of lava currents during congelation, emanates from the fissures C.

Fig. 62.



Supposed reservoir and pipe of a Geyser in Iceland.†

A portion of the steam is at first condensed into water, while the temperature of the water is raised by the latent heat thus evolved, till, at last, the lower part of the cavity is filled with boiling water and the upper with steam under high pressure. The expansive force of the steam becomes, at length, so great, that the water is forced up the fissure or pipe E B, and runs over the rim of the basin. When the pressure is thus

* MS. read to Geol. Soc. of London, Feb. 29, 1832.
† From Sir George Mackenzie's Iceland.

diminished, the steam in the upper part of the cavity A expands, until all the water D is driven into the pipe: and when this happens, the steam, being the lighter of the two fluids, rushes up through the water with great velocity. If the pipe be choked up artificially, even for a few minutes, a great increase of heat must take place; for it is prevented from escaping in a latent form in steam; so that the water is made to boil more violently, and this brings on an eruption.

If we suppose that large subterranean cavities exist at the depth of some miles below the surface of the earth, in which melted lava accumulates, and that water penetrates into these, the steam thus generated may press upon lava and force it up the duct of a volcano, in the same manner as a column of water is driven up the pipe of a Geyser.

Agency of water in volcanos.—No theory seems at first more improbable than that which represents water as affording an inexhaustible supply of fuel to the volcanic fires; yet, if subterraneous heat be derived from chemical action, as before hinted, and if electric currents in the crust of the earth may exert a slow decomposing power, the hypothesis is far from visionary.

It is a fact that must never be overlooked, when we are speculating on the probable causes of volcanos, that, while a great number are entirely submarine, the remainder are for the most part in islands or maritime tracts. There are a few exceptions, but some of these, as Dr. Daubeny observes, are near inland salt lakes, as in Central Tartary; while others form part of a train of volcanos, the extremities of which are near the sea. Thus Jorullo, in Mexico, though itself not less than forty leagues from the nearest ocean, appears to be connected with the volcano of Tuxtla on the one hand, and that of Colima on the other; the first bordering on the Atlantic, the latter on the Pacific Ocean. This communication is rendered more probable by the parallelism that exists between these and several intermediate volcanic hills.*

Sir H. Davy supposes that, when the sea is distant, as in the case of some of the South American volcanos, they may still be supplied with water from subterranean lakes; since, according to Humboldt, large quantities of fish are often thrown out during eruptions.†

It has been already stated, that the gases exhaled from volcanos, together with steam, are such as would result from the decomposition of salt water, and the fumes which escape from the Vesuvian lava have been observed to deposit common salt.‡ The emission of free muriatic acid gas in great quantities favours the theory of the decomposion of the salt contained in sea water; but M. Boussingault did not meet with this gas

* See Daubeny's remarks—"Volcanos," p. 368.

† Phil. Trans., 1828, p. 250.

‡ Davy, Phil. Trans., 1828, p. 244.

in his late examination of the elastic fluids evolved from the volcanos of equatorial America. He informs us, that the same are given out by all the different vents, namely, aqueous vapour, in very large quantity, carbonic acid gas, sulphurous acid gas, and sometimes fumes of sulphur. The same naturalist found by analysis, that all the thermal waters of the Cordilleras were charged with sulphurated hydrogen gas.*

M. Gay Lussac, while he avows his opinion that the decomposition of water contributes largely to volcanic action, calls attention, nevertheless, to the fact, that hydrogen has not been detected in a separate form among the gaseous products of volcanos; nor can it, he says, be present; for, in that case, it would be inflamed in the air by the red-hot stones thrown out during an eruption. Dr. Davy, also, in his account of Graham Island, says, "I watched when the lightning was most vivid, and the eruption of the greatest degree of violence, to see if there was any inflammation occasioned by this natural electric spark—any indication of the presence of inflammable gas; but in vain."†

May not the hydrogen, Gay Lussac inquires, be combined with chlorine, and produce muriatic acid? for this gas has been observed to be evolved from Vesuvius—and the chlorine may have been derived from sea salt; which was, in fact, extracted by simple washing from the Vesuvian lava of 1822, in the proportion of nine per cent.‡ But it was answered, that Sir H. Davy's experiments had shown, that hydrogen is not combustible when mixed with muriatic acid gas; so that if muriatic gas was evolved in large quantities, the hydrogen might be present without inflammation.§

M. Gay Lussac, in the memoir just alluded to, expresses doubt as to the presence of sulphurous acid; but the abundant disengagement of this gas during eruptions is now ascertained: and thus all difficulty in regard to the absence of hydrogen in an inflammable state is removed. For, as Dr. Daubeny supposes, the hydrogen of decomposed water may unite with sulphur to form sulphuretted hydrogen gas, and this gas will then be mingled with the sulphurous acid as it rises to the crater. It is shown by experiment, that these gases mutually decompose each other when mixed where steam is present; part of the hydrogen of the one immediately uniting with the oxygen of the other, to form water, while the excess of sulphurous acid alone escapes into the atmosphere. Sulphur is at the same time precipitated.

This explanation is sufficient; but it may be asked, whether the flame of hydrogen would be visible during an eruption; as that gas, when inflamed in a pure state, burns with a very faint blue flame, which even

* Ann. de Chim. et de Phys., tom. lii. p. 181. † Phil. Trans., 1832, p. 240.

‡ Ann. de Chim. et de Phys. tom. xxii.

§ Quart. Journ. of Science, 1823, p. 132, note by editor.

in the night could hardly be perceptible by the side of red-hot and incandescent cinders. Its immediate conversion into water when inflamed in the atmosphere, might also account for its not appearing in a separate form.

When treating of springs and overflowing wells, I have stated that porous rocks are percolated by fresh water to great depths, and that sea-water probably penetrates in the same manner through the rocks which form the bed of the ocean. But, besides this universal circulation in regions not far from the surface, it must be supposed that, wherever earthquakes prevail, much larger bodies of water will be forced up by the pressure of the ocean into fissures at greater depths, or swallowed up in chasms; in the same manner as, on the land, towns, houses, cattle, and trees are sometimes engulfed. It will be remembered, that these chasms often close again after houses have fallen into them; and, for the same reason, when water has penetrated to a mass of melted lava, the steam into which it is converted may often rush out at a different aperture from that by which the water entered. The frequent explosions caused by the generation of steam in the neighbourhood of the sea or of deep lakes, may shatter the solid crust of the earth, and allow the free escape of gases and lava which, but for this cause, might never have reached the surface, and might only have given rise to earthquakes.

Dr. Daubeny has suggested that water containing atmospheric air may descend from the surface of the earth to the volcanic foci, and that the same process of combustion by which water is decomposed may deprive such subterranean air of its oxygen. In this manner we might explain the great quantities of nitrogen evolved from volcanic vents, and thermal waters, and the fact that air disengaged from the earth in volcanic regions is either wholly or in part deprived of its oxygen.

Sir H. Davy, in his memoir on the "Phenomena of Volcanos," remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air; and he imagined that subterranean cavities which threw out large volumes of steam during the eruption, might afterwards, in the quiet state of the volcano, become filled with atmospheric air.* The presence of ammoniacal salts in volcanic emanations, and of ammonia in lava, favours greatly, says Dr. Daubeny, the notion of air as well as water being deoxidated in the interior of the earth.†

Such phenomena admit of a ready explanation on the principles of the chemical theory of volcanos, considered in the last chapter; but are left unexplained by the hypothesis of the gradual contraction of an external crust upon a fluid nucleus.

* Phil. Trans. 1828.

† Ammonia is composed of hydrogen and nitrogen: or the elements of air without its oxygen. See Daubeny, Encyc. Metrop., Part 40.

Importance of attending to the unseen volcanic phenomena.—In concluding these remarks on the causes of volcanos and earthquakes, I may observe, that speculations and conjectures on this obscure subject should be encouraged; because a great step is gained, if geologists are rendered more conscious of the changes in the earth's crust now going on *out of sight*, and under circumstances widely different from any which can ever come within the sphere of human observation. In estimating the effects of existing causes, we are too apt to confine our views to operations such as we actually see in progress upon the habitable surface, regardless of those which must be going on at various depths below. But when we examine the geological structure of the earth, we behold the results of former processes both subterranean and superficial; and recognise at once the exact agreement of many of the superficial class with the effects of known causes. To what agency, then, ought we to refer the phenomena which still remain unexplained? Surely not to imaginary forces, which may by possibility have prevailed in the infancy of the planet; but rather to the unseen portion of that machinery which is still at work. Let it be supposed that a person has made such progress in a foreign language—German, for example—that, in perusing the works of living authors, he understands the meaning of about two-thirds of what he reads. If, on taking up a book written two or three centuries ago, he finds that he is able to interpret about as much of that also, he might naturally conclude that the language had remained the same, or nearly the same, during the intervening time. Would he have any doubt respecting this identity, from being unable to comprehend *all* that is written in the older volume? or would he not, on the contrary, think it unreasonable, while he remains ignorant of a great part of the living language, to expect to interpret every thing in the ancient book?

The balance of dry land, how preserved.—In the present state of our knowledge, we cannot pretend to estimate the average number of earthquakes which may happen in the course of a single year. As the area of the ocean is nearly three times that of the land, it is probable that about three submarine earthquakes may occur for one exclusively continental: and when we consider the great frequency of slight movements in certain districts, we can hardly suppose that a day ever passes without one or more shocks being experienced in some part of the globe. We have also seen that in Sweden and other countries, changes in the relative level of sea and land may take place without commotion, and these perhaps produce the most important geographical and geological changes; for the position of land may be altered to a greater amount by an elevation or depression of one inch over a vast area, than by the sinking of a more limited tract, such as the forest of Aripao, to the depth of many fathoms at once.*

* See pp. 390, 391.

It must be evident from the historical details above given, that the force of subterranean movement, whether intermittent or continuous, whether with or without disturbance, does not operate at random, but is developed in certain regions only; and although the alterations produced during the time required for the occurrence of a few volcanic eruptions may be inconsiderable, we can hardly doubt that during the ages necessary for the formation of large volcanic cones, composed of thousands of lava currents, shoals might be converted into lofty mountains, and low lands into deep seas.

In a former chapter, I have stated that aqueous and igneous agents may be regarded as antagonist forces; the aqueous labouring incessantly to reduce the inequalities of the earth's surface to a level, while the igneous are equally active in renewing the unevenness of the surface.* By some geologists it has been thought that the levelling power of running water was opposed rather to the *elevating* force of earthquakes than to their action generally. This opinion is, however, untenable; for the sinking down of the bed of the ocean is one of the means by which the gradual submersion of land is prevented. The depth of the sea cannot be increased at any one point without a universal fall of the waters, nor can any partial deposition of sediment occur without the displacement of a quantity of water of equal volume, which will raise the sea, though in an imperceptible degree, even to the antipodes. The preservation, therefore, of the dry land may sometimes be effected by the subsidence of part of the earth's crust (that part, namely, which is covered by the ocean), and in like manner, an upheaving movement must tend often to destroy land; for if it render the bed of the sea more shallow, it will displace a certain quantity of water, and thus tend to submerge low tracts.

Astronomers having proved that there has been no change in the diameter of the earth during the last two thousand years, we may assume it as probable, that the dimensions of the planet remain uniform.† If, then, we inquire in what manner the force of earthquakes must be regulated, in order to restore perpetually the inequalities of the surface which the leveling power of water tends to efface, it will be found that the amount of depression must exceed that of elevation. It would be otherwise if the action of volcanos and mineral springs were suspended; for then the forcing outwards of the earth's envelope ought to be no more than equal to its sinking in.

To understand this proposition more clearly, it must be borne in mind, that the deposits of rivers and currents probably add as much to the height of lands which are rising, as they take from those which have risen. Suppose a large river to bring down sediment to a part of the ocean two thousand feet deep, and that the depth of this part is gradually reduced by the accumulation of sediment till only a shoal remains, covered by water

* Book ii. chap. i. † Ante, p. 145.

at high tides; if now an upheaving force should uplift this shoal to the height of 2000 feet, the result would be a mountain 2000 feet high. But had the movement raised the same part of the bottom of the sea before the sediment of the river had filled it up, then, instead of changing a shoal into a mountain 2000 feet high, it would only have converted a deep sea into a shoal.

It appears, then, that the operations of the earthquake are often such as to cause the levelling power of water to counteract itself; and although the idea may appear paradoxical, we may be sure, wherever we find hills and mountains composed of stratified deposits, that such inequalities of the surface would have had no existence if water, at some former period, had not been labouring to reduce the earth's surface to one level.

But, besides the transfer of matter by running water from the continents to the ocean, there is a constant transportation from below upwards, by mineral springs and volcanic vents. As mountain masses are, in the course of ages, created by the pouring forth of successive streams of lava, so stratified rocks, of great extent, originate from the deposition of carbonate of lime, and other mineral ingredients, with which springs are impregnated. The surface of the land, and portions of the bottom of the sea, being thus raised, the external accessions due to these operations would cause the dimensions of the planet to enlarge continually, if the amount of depression of the earth's crust were no more than equal to the elevation. In order, therefore, that the mean diameter of the earth should remain uniform, and the unevenness of the surface be preserved, it is necessary that the amount of subsidence should be in excess. And such a predominance of depression is far from improbable, on mechanical principles, since every upheaving movement must be expected either to produce caverns in the mass below, or to cause some diminution of its density. Vacuities must, also, arise from the subtraction of the matter poured out from volcanos and mineral springs; and the foundations having been thus weakened, the earth's crust, shaken and rent by reiterated convulsions, must, in the course of time, fall in.

If we embrace these views, important geological consequences will follow; since, if there be, upon the whole, more subsidence than elevation, the average depth to which former surfaces have sunk beneath their original level must exceed the height which ancient marine strata have attained above the sea. If, for example, marine strata, about the age of our chalk and green-sand, have been lifted up in Europe to an extreme height of more than eleven thousand feet, and a mean elevation of some hundreds, we may conclude that certain parts of the surface, which existed when those strata were deposited, have sunk to an extreme depth of *more than* eleven thousand feet below their original level, and to a mean depth of *more than* a few hundreds.

In regard to faults, also, we must infer, according to the hypothesis now composed, that a greater number have arisen from the sinking down than from the elevation of rocks.

Mr. Conybeare, and some other writers, have contended, that the upheaving force of earthquakes was more energetic during remote geological epochs, and that it has since been gradually on the decline;* while M. Elie de Beaumont, on the contrary, maintains, that the most tremendous of known convulsions belong to times comparatively modern.† But in order to compare the relative amount of change produced, at different periods, by any given cause, we must obtain some standard for the measurement of time at both the periods compared.

I have shown that, during the last two thousand years, considerable tracts of land have been upheaved above, or depressed below their former level.‡ Now, they who contend that a greater or less amount of change was formerly accomplished in an equal number of years, must first explain the mode in which they measure the time referred to; for they cannot, in geology, avail themselves of the annual revolutions of our planet in its orbit. If they assume that the power of volcanos to emit lava, and of running water to transport sediment from one part of the globe to the other, has remained uniform from the earliest periods, they may then attempt to compare the effects of subterranean movements in ancient and modern times by reference to one common standard; and to show that, during the time required for the production of a certain number of lava currents, or of so many cubic yards of sediment, the elevation and depression of the earth's crust were once much greater than they are now. Or, if they premise that the progressive rate of change of species in the animal and vegetable kingdoms had been always uniform, they may then endeavour to prove the diminished energy of earthquakes, by showing that, in relation to the periods connected with the changes of organic species, earthquakes had become comparatively feeble.

But those who contend for the reduced activity of natural agents, have not attempted to support this line of argument; nor does our scanty acquaintance, both with the animate and inanimate world, warrant such generalizations. That it would be most premature, in the present state of natural history, to reason on the comparative rate of fluctuation in the species of organic beings in ancient and modern times, or at any two geological periods, will be more fully demonstrated, when I come, in the next book, to consider the intimate connexion between geology and the study of the present condition of the animal and vegetable kingdoms.

* Phil. Mag., No. 48. Dec. 1830, p. 402.
† Ann. des Sci. Nat., 1829.—Phil. Mag., No. 58. Oct. 1831.
‡ See Chapters vi. vii. viii. and ix.

To conclude: it seems to be rendered probable, by the views above explained, that the constant repair of the land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of causes acting in the interior of the earth; which, although so often the source of death and terror to the inhabitants of the globe—visiting, in succession, every zone, and filling the earth with monuments of ruin and disorder—are, nevertheless, the agents of a conservative principle above all others essential to the stability of the system.

BOOK III.

CHAPTER I.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

Division of the subject—Examination of the question, Whether species have a real existence in nature?—Importance of this question in geology—Sketch of Lamarck's arguments in favour of the transmutation of species, and its conjectures respecting the origin of existing animals and plants (p. 483.)—His theory of the transformation of the orang outang into the human species.

THE last book was occupied with the consideration of the changes brought about on the earth's surface, within the period of human observation, by inorganic agents; such, for example, as rivers, marine currents, volcanos, and earthquakes. But there is another class of phenomena relating to the organic world, which have an equal claim on our attention, if we desire to obtain possession of all the preparatory knowledge respecting the existing course of nature, which may be available in the interpretation of geological monuments. It appeared, from our preliminary sketch of the progress of the science, that the most lively interest was excited among its earlier cultivators, by the discovery of the remains of animals and plants in the interior of mountains frequently remote from the sea. Much controversy arose respecting the nature of these remains, the causes which may have brought them into so singular a position, and the want of a specific agreement between them and known animals and plants. To qualify ourselves to form just views on these curious questions, we must first study the present condition of the animate creation on the globe.

This branch of our inquiry naturally divides itself into two parts; first, we may examine the vicissitudes to which species are subject; secondly, the processes by which certain individuals of these species occasionally become fossil. The first of these divisions will lead us, among other topics, to inquire, first, whether species have a real and permanent existence in nature? or whether they are capable, as some naturalists pretend, of being indefinitely modified in the course of a long series of generations? Secondly, whether, if species have a real existence, the individuals composing them have been derived originally from many similar stocks, or each from one only, the descendants of which have spread themselves gradually from a particular point over the habitable lands and waters? Thirdly, how far the duration of each species of animal and plant is limited by its dependence on certain fluctuating and temporary conditions in the state of the animate and inanimate world? Fourthly, whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place?

Whether species have a real existence in nature.—Before we can advance a step in our proposed inquiry, we must be able to define precisely the meaning which we attach to the term species. This is even more necessary in geology than in the ordinary studies of the naturalist; for they who deny that such a thing as a species exists, concede nevertheless that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the geographer, in constructing his maps from century to century, may proceed as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration were brought about by the precession of the equinoxes; so, it is said, in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world; and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly M. Geoffroy St. Hilaire has declared his opinion, that there has been an uninterrupted succession in the animal kingdom, effected by means of generation, from the earliest ages of the world up to the present day; and that the ancient animals whose remains have been preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. This notion is not very generally received, but we are not warranted in assuming the contrary, without fully explaining the data and reasoning by which it may be refuted.

I shall begin by stating as concisely as possible all the facts and ingenious arguments by which the theory has been supported; and for this purpose I cannot do better than offer the reader a rapid sketch of Lamarck's statement of the proofs which he regards as confirmatory of the doctrine, and which he has derived partly from the works of his predecessors and in part from original investigations.

His proofs and inferences will be best considered in the order in which they appear to have influenced his mind, and I shall then point out some of the results to which he was led while boldly following out his principles to their legitimate consequences.

Lamarck's arguments in favour of the transmutation of species.—The name of species, observes Lamarck, has been usually applied to "every collection of similar individuals produced by other individuals like themselves."* This definition, he admits, is correct; because every living individual bears a very close resemblance to those from which it springs. But this is not all which is usually implied by the term species; for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species.

In order to shake this opinion, Lamarck enters upon the following line of argument:—The more we advance in the knowledge of the different organized bodies which cover the surface of the globe, the more our embarrassment increases, to determine what ought to be regarded as a species, and still more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species; and sometimes we are induced to pronounce individuals but slightly differing, and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that every thing passes by insensible shades into something else: that even the more remarkable differences are evanescent, and that nature has, for the most part, left us nothing at our disposal for establishing distinctions, save trifling, and, in some respects, puerile particularities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may presume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and

* Phil. Zool., tom. i. p. 54.

even entire orders—nay, whole classes, which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar; and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made himself master of the intermediate links, that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock; and these newly acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races*.

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate, and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organization, in such a manner that every thing in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate, a great difference of situation and exposure causes individuals to vary; but if these individuals continue to live and to be reproduced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a word, at the end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species.*

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing, and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a particular species.† The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birth-place, and

* Phil. Zool., tom. i. p. 62. † Ibid.

cultivated in gardens, undergo changes which render them no longer recognisable as the same plants. Many which were naturally hairy become smooth, or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperites; others, again, from the ligneous state which their stem possessed in hot climates, where they were indigenous, pass to the herbaceous; and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

"Is not the cultivated wheat" (*Triticum sativum*), asks Lamarck, "a vegetable brought by man into the state in which we now see it? Let any one tell me in what country a similar plant grows wild, unless where it has escaped from cultivated fields? Where do we find in nature our cabbages, lettuces, and other culinary vegetables, in the state in which they appear in our gardens? Is it not the same in regard to a great quantity of animals which domesticity has changed or considerably modified?"* Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild greese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances be also altered.

The numerous races of dogs which we have produced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great that they would be readily admitted as specific between wild animals; "yet all these have sprung originally from a single race, at first approaching very near to a wolf, if, indeed, the wolf be not the true type which at some period or other was domesticated by man."

Although important changes in the nature of the places which they inhabit modify the organization of animals as well as vegetables, yet the former, says Lamarck, require more time to complete a considerable degree of transmutation; and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or

* Phil. Zool., tom. i. p. 227.

plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local particulars. These circumstances are as varied as are the characters of the species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same.*

Every considerable alteration in the local circumstances in which each race of animals exists causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater development follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions.†

I must here interrupt the author's argument, by observing, that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse; or, on the contrary, be matured and augmented by active exertion; just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable—that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

[It was necessary to point out to the reader this important chasm in the chain of evidence, because he might otherwise imagine that I had merely omitted the illustrations for the sake of brevity, but the plain truth is, that there were no examples to be found; and when Lamarck talks "of the efforts of internal sentiment," "the influence of subtle fluids," and "acts of organization," as causes whereby animals and plants may acquire *new organs*, he substitutes names for things; and, with a disregard to the strict rules of induction, resorts to fictions, as ideal as the "plastic virtue," and other phantoms, of the geologists of the middle ages.]

It is evident that, if some well-authenticated facts could have been

* Phil. Zool., tom. i. p. 232.

† Ibid., p. 234.

adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, time alone might then be supposed sufficient to bring about any amount of metamorphosis. The gratuitous assumption, therefore, of a point so vital to the theory of transmutation, was unpardonable on the part of its advocate.

But to proceed with the system: it being assumed as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete, and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however staggering and absurd it may seem, is logically deduced from the assumed premises. It is not the organs, or, in other words, the nature and form of the parts of the body of an animal, which have given rise to its habits, and its particular faculties; but, on the contrary, its habits, its manner of living, and those of its progenitors, have in the course of time determined the form of its body, the number and condition of its organs, in short, the faculties which it enjoys. Thus otters, beavers, water-fowl, turtles, and frogs, were not made web-footed in order that they might swim; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base acquired a habit of extension, until, in the course of time, the broad membranes which now connect their extremities were formed.

In like manner, the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity; a habit which, in the course of many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The camelopard was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage; but, being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its fore legs became longer than the hinder, and its neck so elongated that it could raise its head to the height of twenty feet above the ground.

Another line of argument is then entered upon, in further corroboration of the instability of species. In order, it is said, that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another; but such sexual unions do take place, both among plants and animals; and although the offspring of such irregular connexions are usually sterile, yet such is not always the case. Hybrids have sometimes proved prolific, where the disparity between the species was not too great; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species.*

But if the soundness of all these arguments and inferences be admitted, we are next to inquire, what were the original types of form, organization, and instinct, from which the diversities of character, as now exhibited by animals and plants, have been derived? We know that individuals which are mere varieties of the same species would, if their pedigree could be traced back far enough, terminate in a single stock; so, according to the train of reasoning before described, the species of a genus, and even the genera of a great family, must have had a common point of departure. What, then, was the single stem from which so many varieties of form have ramified? Were there many of these, or are we to refer the origin of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or, at least, with very few interruptions, from beings of more simple to those of a more compound structure; and, in proportion as the complexity of their organization increases, the number and dignity of their faculties increase also. Among plants, a similar approximation to a graduated scale of being is apparent. Secondly, it appears, from geological observations, that plants and animals of more simple organization existed on the globe before the appearance of those of more compound structure, and the latter were successively formed at more modern periods; each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings; and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, so as to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his Telliamed, and by several modern writers; so

* Phil. Zool., p. 64.

that the tables were completely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker; and that there was a tendency to progressive deterioration in sublunary things when left to themselves—

————— omnia fatis
In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of philosophy imbued with this doctrine, that, to check this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed, and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life; until, in the course of ages, sensation was superadded to mere vitality: sight, hearing, and the other senses were afterwards acquired; then instinct and the mental faculties; until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive that when all the higher order of plants and animals were thus supposed to be comparatively modern, and to have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances? Why are there such multitudes of infusoria and polyps, or of confervæ and other cryptogamic plants? Why, moreover, has the process of development acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity; but a delegated power—a mere instrument—a piece of mechanism acting by necessity—an order of things constituted by the Supreme Being, and subject to laws which are the expressions of his will. This Nature is *obliged* to proceed gradually in all her operations; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds, and out of them elaborate the more compound, adding to them, successively, different systems of organs, and multiplying more and more their number and energy.

This Nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generation*. She is always beginning anew, day by day, the work of creation, by forming monads, or "rough draughts" (ébauches), which are the only living things she gives birth to *directly*.

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms.* These are gradually developed into the higher and more perfect classes by the slow but unceasing agency of two influential principles: first, *the tendency to progressive advancement* in organization, accompanied by greater dignity in intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For, as species spread themselves gradually over the globe, they are exposed from time to time to variations in climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development, by supplying them with nutriment, or destroying their foes. The nature, also, of each locality, is in itself fluctuating; so that, even if the relation of other animals and plants were invariable, the habits and organization of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But, in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan; and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the Orang-Outang into the human species.—Such is the machinery of the Lamarckian system; but the reader will hardly, perhaps, be able to form a perfect conception of so

* Animaux sans Vert. tom. i. p. 56. Introduction.

complicated a piece of mechanism, unless it is exhibited in motion, so that we may see in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. I have only space for exhibiting a small part of the entire process by which a complete metamorphosis is achieved, and shall, therefore, omit the mode by which, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape; passing on at once to the last grand step in the progressive scheme, by which the orang-outang, having been already evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances (concerning the exact nature of which tradition is unfortunately silent), the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged, for a long series of generations, to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals; and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed, insensibly, a conformation fitted to support them in an erect attitude, till at last these animals could no longer go on all-fours without much inconvenience.

The Angola orang (*Simia troglodytes*, Linn.) is the most perfect of animals; much more so than the Indian orang (*Simia Satyrus*), which has been called the orang-outang, although *both* are *very inferior* to many in corporeal powers and intelligence. These animals frequently hold themselves upright; but their organization has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all-fours, showing clearly that this was the original position of the animal. Even in man, whose organization, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing, and can be supported only for a limited time, and by aid of the contraction of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the upright position be a state of repose: but, as the human head does not articulate in the centre of gravity, as the chest, belly, and other parts press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling. Children which have large heads and prominent bellies can hardly walk at the end even of two years;

and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest them in organization and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods, and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded; while, in the mean time, the dominant race spread itself in every direction, and lived in large companies, where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect; and, in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external circumstances*, which causes such wide chasms in the regular series of animated being.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, though most of them were gregarious, acquired no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs—whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice; but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue, and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech.*

In effecting this mighty change, "the exigencies of the individuals were the sole agents; they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment." Hence, in this peculiar race, the origin of the admirable faculty of speech; hence, also, the diversity of languages, since the distance of places where the individuals composing the race established themselves soon favoured the corruption of conventional signs.†

In conclusion, it may be proper to observe that the above sketch of the Lamarckian theory is no exaggerated picture, and those passages which have probably excited the greatest surprise in the mind of the reader are literal translations from the original.

CHAPTER II.

TRANSMUTATION OF SPECIES—*continued.*

Recapitulation of the arguments in favour of the theory of transmutation of species —Their insufficiency—Causes of difficulty in discriminating species—Some varieties possibly more distinct than certain individuals of distinct species (p. 497.)—Variability in a species consistent with a belief that the limits of deviation are fixed —No facts of transmutation authenticated—Varieties of the Dog—the Dog and Wolf distinct species—Mummies of various animals from Egypt identical in character with living individuals (p. 501.)—Seeds and plants from the Egyptian tombs —Modifications produced in plants by agriculture and gardening.

The theory of the transmutation of species, considered in the last chapter, has met with some degree of favour from many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world by the regular action of secondary causes, we have seen that in truth many perplexing difficul-

* Lamarck's Phil. Zool., tom. i. p. 356.

† Ibid. p. 357.

ties present themselves to one who attempts to establish the nature and reality of the specific character. And if once there appears ground of reasonable doubt, in regard to the constancy of species, the amount of transformation which they are capable of undergoing may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.

Before entering upon the reasons which may be adduced for rejecting Lamarck's hypothesis, I shall recapitulate, in a few words, the phenomena, and the whole train of thought, by which I conceive it to have been suggested, and which have gained for this and analogous theories, both in ancient and modern times, a considerable number of votaries.

In the first place, the various groups into which plants and animals may be thrown seem almost invariably, to a beginner, to be so natural, that he is usually convinced at first, as was Linnæus to the last, "that genera are as much founded in nature as the species which compose them."* When, by examining the numerous intermediate gradations, the student finds all lines of demarcation to be in most instances obliterated, even where they at first appeared most distinct, he grows more and more sceptical as to the real existence of genera, and finally regards them as mere arbitrary and artificial signs, invented, like those which serve to distinguish the heavenly constellations, for the convenience of classification, and having as little pretensions to reality.

Doubts are then engendered in his mind as to whether species may not also be equally unreal. The student is probably first struck with the phenomenon, that some individuals are made to deviate widely from the ordinary type by the force of peculiar circumstances, and with the still more extraordinary fact, that the newly acquired peculiarities are faithfully transmitted to the offspring. How far, he asks, may such variations extend in the course of indefinite periods of time, and during great vicissitudes in the physical condition of the globe? His growing incertitude is at first checked by the reflection, that nature has forbidden the intermixture of the descendants of distinct original stocks, or has, at least, entailed sterility on their offspring, thereby preventing their being confounded together; and pointing out that a multitude of distinct types must have been created in the beginning, and must have remained pure and uncorrupted to this day.

Relying on this general law, he endeavours to solve each difficult problem by direct experiment, until he is again astounded by the phenomenon of a prolific hybrid, and still more by an example of a hybrid perpetuating itself throughout several generations in the vegetable world. He then feels himself reduced to the dilemma of choosing between two

* Genus omne est naturale, in primordio tale creatum, &c. Phil. Bot. § 159. See also Ibid. § 162.

alternatives; either to reject the test, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If he prefer the latter, he is compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids: for, although he may not be enabled immediately to procure, in all such instances, a fruitful offspring; yet experiments show, that after repeated failures, the union of two recognised species may at last, under very favourable circumstances, give birth to a fertile progeny. Such circumstances, therefore, the naturalist may conceive to have occurred again and again, in the course of a great lapse of ages.

His first opinions are now fairly unsettled, and every stay at which he has caught has given way one after another; he is in danger of falling into any new and visionary doctrine which may be presented to him; for he now regards every part of the animate creation as void of stability, and in a state of continual flux. In this mood he encounters the Geologist, who relates to him how there have been endless vicissitudes in the shape and structure of organic beings in former ages—how the approach to the present system of things has been gradual—that there has been a progressive development of organization subservient to the purposes of life, from the most simple to the most complex state—that the appearance of man is the last phenomenon in a long succession of events; and finally, that a series of physical revolutions can be traced in the inorganic world, coeval and coextensive with those of organic nature.

These views seem immediately to confirm all his preconceived doubts as to the stability of the specific character, and he begins to think there may exist an inseparable connexion between a series of changes in the inanimate world, and the capability of the species to be indefinitely modified by the influence of external circumstances. Henceforth his speculations know no definite bounds; he gives the rein to conjecture, and fancies that the outward form, internal structure, instinctive faculties, nay, that reason itself may have been gradually developed from some of the simplest states of existence—that all animals, that man himself, and the irrational beings, may have had one common origin; that all may be parts of one continuous and progressive scheme of development, from the most imperfect to the more complex; in fine, he renounces his belief in the high genealogy of his species, and looks forward, as if in compensation, to the future perfectibility of man in his physical, intellectual, and moral attributes.

Let us now proceed to consider what is defective in evidence, and what fallacious in reasoning, in the grounds of these strange conclusions. Blumenbach judiciously observes, that "no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*." The multitude, in fact, and complexity of the proofs to be weighed, is so great, that we can only hope to obtain presumptive evidence, and we must, therefore, be the more careful to derive our general views as much as possible from those observations where the chances of deception are least. We must be on our guard not to tread in the footsteps of the naturalists of the middle ages, who believed the doctrine of spontaneous generation to be applicable to all those parts of the animal and vegetable kingdoms which they least understood, in direct contradiction to the analogy of all the parts best known to them; and who, when at length they found that insects and cryptogamous plants were also propagated from eggs or seeds, still persisted in retaining their old prejudices respecting the infusory animalcules and other minute beings, the generation of which had not then been demonstrated by the microscope to be governed by the same laws.

Lamarck has, indeed, attempted to raise an argument in favour of his system, out of the very confusion which has arisen in the study of some orders of animals and plants, in consequence of the slight shades of difference which separate the new species discovered within the last half century. That the embarrassment of those who attempt to classify and distinguish the new acquisitions, poured in such multitudes into our museums, should increase with the augmentation of their number, is quite natural; since to obviate this it is not enough that our powers of discrimination should keep pace with the increase of the objects, but we ought to possess greater opportunities of studying each animal and plant in all stages of its growth, and to know profoundly their history, their habits, and physiological characters, throughout several generations; for, in proportion as the series of known animals grows more complete, none can doubt that there is a nearer approximation to a graduated scale of being; and thus the most closely allied species will be found to possess a greater number of characters in common.

Causes of the difficulty of discriminating species.—But, in point of fact, our new acquisitions consist, more and more as we advance, of specimens brought from foreign and often very distant and barbarous countries. A large proportion have never even been seen alive by scientific inquirers. Instead of having specimens of the young, the adult, and the aged individuals of each sex, and possessing means of investigating the anatomical structure, the peculiar habits, and instincts of each, what is usually the state of our information? A single specimen, perhaps, of a dried plant, or a stuffed bird or quadruped; a shell, without the soft parts of the animal; an insect in one stage of its numerous transformations;—these are the scanty and imperfect data which the naturalist possesses. Such information may enable us to separate species which stand at a considerable distance from each other; but we have no right to expect any thing but difficulty and ambiguity, if we attempt, from such imperfect opportunities, to obtain distinctive marks for defining the characters of species which are closely related.

If Lamarck could introduce so much certainty and precision into the classification of several thousand species of recent and fossil shells, notwithstanding the extreme remoteness of the organization of these animals from the type of those vertebrated species which are best known, and in the absence of so many of the living inhabitants of shells, we are led to form an exalted conception of the degree of exactness to which specific distinctions are capable of being carried, rather than to call in question their reality.

When our data are so defective, the most acute naturalist must expect to be sometimes at fault, and, like the novice, to overlook essential points of difference, passing unconsciously from one species to another, until, like one who is borne along in a current, he is astonished, on looking back, at observing that he has reached a point so remote from that whence he set out.

It is by no means improbable, that, when the series of species of certain genera is very full, they may be found to differ less widely from each other than do the mere varieties or races of certain species. If such a fact could be established, it would, undoubtedly, diminish the chance of our obtaining certainty in our results; but it would by no means overthrow our confidence in the reality of species.

Some mere varieties possibly more distinct than certain individuals of distinct species.—It is almost necessary, indeed, to suppose that varieties will differ in some cases more decidedly than some species, if we admit that there is a graduated scale of being, and assume that the following laws prevail in the economy of the animate creation:—first, that the organization of individuals is capable of being modified to a limited extent by the force of external causes; secondly, that these modifications are, to a certain extent, transmissible to their offspring; thirdly, that there are fixed limits, beyond which the descendants from common parents can never deviate from a certain type; fourthly, that each species springs from one original stock, and can never be permanently confounded by intermixing with the progeny of any other stock; fifthly, that each species shall endure for a considerable period of time. Now, let us assume, for the present, these rules hypothetically, and see what consequences may naturally be expected to result from them.

We must suppose that when the Author of Nature creates an animal or plant, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself, and survive under all the varying circumstances to which it must be inevitably exposed. Now, the range of variation of circumstances will differ essentially in almost every case. Let us take, for example, any one of the most influential conditions of existence, such as temperature. In some extensive districts near the equator, the thermometer might never vary, throughout several thousand centuries, for more than 20° Fahrenheit; so that if a plant or animal be provided with an organization fitting it to endure such a range, it may continue on the globe for that immense period, although every individual might be liable at once to be cut off by the least possible excess of heat or cold beyond the determinate degree. But if a species be placed in one of the temperate zones, and have a constitution conferred on it capable of supporting a similar range of temperature only, it will inevitably perish before a single year has passed away.

Humboldt has shown that, at Cumana, within the tropics, there is a difference of only four degrees (Fahr.) between the temperature of the warmest and coldest months; whereas at Quebec and Pekin, in the temperate zones, the annual variation amounts to about 60°.

The same remark might be applied to any other condition, as food, for example: it may be foreseen that the supply will be regular throughout indefinite periods in one part of the world, and in another very precarious and fluctuating both in kind and quantity. Different qualifications may be required for enabling species to live for a considerable time under circumstances so changeable. If, then, temperature and food be among those external causes which, according to certain laws of animal and vegetable physiology, modify the organization, form, or faculties, of individuals, we instantly perceive that the degrees of variability from a common standard must differ widely in the two cases above supposed; since there is a necessity of accommodating a species in one case to a much greater latitude of circumstances than in the other.

If it be a law, for instance, that scanty sustenance should check those individuals in their growth which are enabled to accommodate themselves to privations of this kind, and that a parent, prevented in this manner from attaining the size proper to its species, should produce a dwarfish offspring, a stunted race will arise, as is remarkably exemplified in some varieties of the horse and dog. The difference of stature in some races of dogs, when compared to others, is as one to five in linear dimensions, making a difference of a hundred-fold in volume.* Now, there is good reason to believe that species in general are by no means susceptible of existing under a diversity of circumstances, which may give rise to such a disparity in size, and, consequently, there will be a multitude of distinct species, of which no two adult individuals can ever depart so widely from a certain standard of dimensions as the mere varieties of certain other species—the dog, for instance. Now, we have only to suppose that what is true of size, may also hold in regard to colour and many other attributes; and it will at once follow, that the degree of possible discord-

* Cuvier, Disc. Prélim., p. 128, sixth edition.

ance between varieties of the same species may, in certain cases, exceed the utmost disparity which can arise between two individuals of many distinct species.

The same remarks may hold true in regard to instincts; for, if it be foreseen that one species will have to encounter a great variety of foes, it may be necessary to arm it with great cunning and circumspection, or with courage or other qualities capable of developing themselves on certain occasions; such, for example, as those migratory instincts which are so remarkably exhibited at particular periods, after they have remained dormant for many generations. The history and habits of one variety of such a species may often differ more considerably from some other than those of many distinct species which have no such latitude of accommodation to circumstances.

Extent of known variability in species.—Lamarck has somewhat misstated the idea commonly entertained of a species; for it is not true that naturalists in general assume that the organization of an animal or plant remains absolutely constant, and that it can never vary in any of its parts.* All must be aware that circumstances influence the habits, and that the habits may alter the state of the parts and organs; but the difference of opinion relates to the extent to which these modifications of the habits and organs of a particular species may be carried.

Now, let us first inquire what positive facts can be adduced in the history of known species, to establish a great and permanent amount of change in the form, structure, or instinct of individuals descending from some common stock. The best authenticated examples of the extent to which species can be made to vary may be looked for in the history of domesticated animals and cultivated plants. It usually happens, that those species, both of the animal and vegetable kingdom, which have the greatest pliability of organization, those which are most capable of accommodating themselves to a great variety of new circumstances, are most serviceable to man. These only can be carried by him into different climates, and can have their properties or instincts variously diversified by differences of nourishment and habits. If the resources of a species be so limited, and its habits and faculties be of such a confined and local character, that it can only flourish in a few particular spots, it can rarely be of great utility.

We may consider, therefore, that, in the domestication of animals and the cultivation of plants, mankind have first selected those species which have the most flexible frames and constitutions, and have then been engaged for ages in conducting a series of experiments, with much patience and at great cost, to ascertain what may be the greatest possible deviation from a common type which can be elicited in these extreme cases.

* Phil. Zool., tom. i. p. 266.

Varieties of the dog—no transmutation.—The modifications produced in the different races of dogs exhibit the influence of man in the most striking point of view. These animals have been transported into every climate, and placed in every variety of circumstances; they have been made, as a modern naturalist observes, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius has had a wonderful influence, not only on their forms, but on their manners and intelligence.* Different races have undergone remarkable changes in the quantity and colour of their clothing; the dogs of Guinea are almost naked, while those of the arctic circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads.

But, if we look for some of those essential changes which would be required to lend even the semblance of a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration of others, we find nothing of the kind. For, in all these varieties of the dog, says Cuvier, the relation of the bones with each other remains essentially the same; the form of the teeth never changes in any perceptible degree, except that, in some individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other.† The greatest departure from a common type—and it constitutes the maximum of variation as yet known in the animal kingdom—is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones; a variety analogous to one presented by six-fingered families of the human race.‡

Lamarck has thrown out as a conjecture, that the wolf may have been the original of the dog; but he has adduced no data to bear out such an hypothesis. "The wolf," observes Dr. Prichard, "and the dog differ, not only with respect to their habits and instincts, which in the brute creation are very uniform within the limits of one species, but some differences have also been pointed out in their internal organization, particularly in the structure of a part of the intestinal canal.§

Domestic animals in South America have reverted to their original character.—It is well known that the horse, the ox, the boar, and other domestic animals, which have been introduced into South America, and have run wild in many parts, have entirely lost all marks of domesticity, and have reverted to the original characters of their species. But dogs have also become wild in Cuba, Hayti, and in all the Caribbean islands.

* Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 63. Sept. 1830.

† Disc. Prél., p. 129, sixth edition. ‡ Ibid.

§ Prichard, Phys. Hist. of Mankind, vol. i. p. 96, who cites Professor Güldenstädt.

In the course of the seventeenth century, they hunted in packs from twelve to fifty, or more, in number, and fearlessly attacked herds of wild boars and other animals. It is natural, therefore, to inquire to what form they reverted? Now, they are said by many travellers to have resembled very nearly the shepherd's dog; but it is certain that they were never turned into wolves. They were extremely savage, and their ravages appear to have been as much dreaded as those of wolves; but when any of their whelps were caught, and brought from the woods to the towns, they grew up in the most perfect submission to man.

Mummies of animals in Egyptian tombs identical with species still living.—As the advocates of the theory of transmutation trust much to the slow and insensible changes which time may work, they are accustomed to lament the absence of accurate descriptions, and figures of particular animals and plants, handed down from the earliest periods of history, such as might have afforded data for comparing the condition of species, at two periods considerably remote. But, fortunately, we are in some measure independent of such evidence; for, by a singular accident, the priests of Egypt have bequeathed to us, in their cemeteries, that information which the museums and works of the Greek philosophers have failed to transmit.

For the careful investigation of these documents, we are greatly indebted to the skill and diligence of those naturalists who accompanied the French armies during their brief occupation of Egypt: that conquest of four years, from which we may date the improvement of the modern Egyptians in the arts and sciences, and the rapid progress which has been made of late in our knowledge of the arts and sciences of their remote predecessors. Instead of wasting their whole time, as so many preceding travellers had done, in exclusively collecting human mummies, M. Geoffroy and his associates examined diligently, and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog, the cat, the ape, the ichneumon, the crocodile, and the ibis.

To those who have never been accustomed to connect the facts of Natural History with philosophical speculations, who have never raised their conceptions of the end and import of such studies beyond the mere admiration of isolated and beautiful objects, or the exertion of skill in detecting specific differences, it will seem incredible that amidst the din of arms, and the stirring excitement of political movements, so much enthusiasm could have been felt in regard to these precious remains.

In the official report, drawn up by the Professors of the Museum at Paris, on the value of these objects, there are some eloquent passages, which may appear extravagant, unless we reflect how fully these naturalists could appreciate the bearing of the facts thus brought to light on the past history of the globe.

"It seems," say they, "as if the superstition of the ancient Egyptians had been inspired by Nature, with a view of transmitting to after ages a monument of her history. That extraordinary and whimsical people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognisable, many an animal, which at Thebes or Memphis, two or three thousand years ago, had its own priests and altars."*

Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles, but, what was perhaps of still higher importance in deciding the great question under discussion, there were the mummies of domestic animals, among which those above mentioned, the bull, the dog, and the cat, were frequent. Now, such was the conformity of the whole of these species to those now living, that there was no more difference, says Cuvier, between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every climate, and forced to accommodate their habits to the greatest variety of circumstances. The cat, for example, has been carried over the whole earth, and, within the last three centuries, has been naturalized in every part of the new world—from the cold regions of Canada to the tropical plains of Guiana; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians.

Of the ox, undoubtedly, there are many very distinct races: but the bull Apis, which was led in solemn processions by the Egyptian priests, did not differ from some of those now living. The black cattle that have run wild in America, where there were many peculiarities in the climate not to be found, perhaps, in any part of the old world, and where scarcely a single plant on which they fed was of precisely the same species, instead of altering their form and habits, have actually reverted to the exact likeness of the aboriginal wild cattle of Europe.

In answer to the arguments drawn from the Egyptian mummies, Lamarck said that they were identical with their living descendants in the same country, because the climate and physical geography of the banks of the Nile have remained unaltered for the last thirty centuries. But why, it may be asked, have other individuals of these species retained the same

* Ann. du Muséum d'Hist. Nat., tom. i. p. 234. 1802. The reporters were MM. Cuvier, Lacépède, and Lamarck.

characters in so many different quarters of the globe, where the climate and many other conditions are so varied?

Seeds and plants from the Egyptian tombs.—The evidence derived from the Egyptian monuments was not confined to the animal kingdom; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form, but even their colour; so effectual has proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to all the other plants.

Native country of the common wheat.—And here I may observe, that there is an obvious answer to Lamarck's objection, that the botanist cannot point out a country where the common wheat grows wild, unless in places where it may have been derived from neighbouring cultivation.* All naturalists are well aware that the geographical distribution of a great number of species is extremely limited; that it was to be expected that every useful plant should first be cultivated successfully in the country where it was indigenous; and that, probably, every station which it partially occupied, when growing wild, would be selected by the agriculturist as best suited to it when artificially increased. Palestine has been conjectured, by a late writer on the Cerealia, to have been the original habitation of wheat and barley; a supposition which appears confirmed by Hebrew and Egyptian traditions, and by tracing the migrations of the worship of Ceres, as indicative of the migrations of the plant.†

If we are to infer that some one of the wild grasses has been transformed into the common wheat, and that some animal of the genus *canis*, still unreclaimed, has been metamorphosed into the dog, merely because we cannot find the domestic dog or the cultivated wheat, in a state of nature, we may be next called upon to make similar admissions in regard to the camel; for it seems very doubtful whether any race of this species of quadruped is now wild.

Changes in plants produced by cultivation.—But if agriculture, it will be said, does not supply examples of extraordinary changes of form and organization, the horticulturist can, at least, appeal to facts which may confound the preceding train of reasoning. The crab has been transformed into the apple; the sloe into the plum: flowers have changed their colour, and become double; and these new characters can be perpetuated by seed: a bitter plant, with wavy sea-green leaves, has been taken from the sea-side, where it grew like wild charlock—has been transplanted

* Phil. Zool., tom. i. p. 227.

† L'Origine et la Patrie des Céréales, &c., Ann. des Sci. Nat., tom. ix. p. 61.

into the garden, lost its saltness, and has been metamorphosed into two distinct vegetables, as unlike each other as is each to the parent plant—the red cabbage and the cauliflower. These, and a multitude of analogous facts, are undoubtedly among the wonders of nature, and attest more strongly, perhaps, the extent to which species may be modified, than any examples derived from the animal kingdom. But in these cases we find that we soon reach certain limits, beyond which we are unable to cause the individuals descending from the same stock to vary; while, on the other hand, it is easy to show that these extraordinary varieties could seldom arise, and could never be perpetuated in a wild state for many generations, under any imaginable combination of accidents. They may be regarded as extreme cases, brought about by human interference, and not as phenomena which indicate a capability of indefinite modification in the natural world.

The propagation of a plant by buds or grafts, and by cuttings, is obviously a mode which nature does not employ; and this multiplication, as well as that produced by roots and layers, seems merely to operate as an extension of the life of an individual, and not as a reproduction of the species such as happens by seed. All plants increased by grafts or layers retain precisely the peculiar qualities of the individual to which they owe their origin, and, like an individual, they have only a determinate existence; in some cases longer, and in others shorter.* It seems now admitted by horticulturists, that none of our garden varieties of fruit are entitled to be considered strictly permanent, but that they wear out after a time;† and we are thus compelled to resort again to seeds: in which case there is so decided a tendency in the seedlings to revert to the original type, that our utmost skill is sometimes baffled in attempting to recover the desired variety.

Varieties of the cabbage.—The different races of cabbages afford, as was admitted, an astonishing example of deviation from a common type; but we can scarcely conceive them to have originated, much less to have lasted for several generations, without the intervention of man. It is only by strong manures that these varieties have been obtained, and in poorer soils they instantly degenerate. If, therefore, we suppose in a state of nature the seed of the wild Brassica oleracea to have been wafted from the sea-side to some spot enriched by the dung of animals, and to have there become a cauliflower, it would soon diffuse its seed to some comparatively sterile soils around, and the offspring would relapse to the likeness of the parent stock.

But if we go so far as to imagine the soil, in the spot first occupied, to be constantly manured by herds of wild animals, so as to continue as

* Smith's Introduction to Botany, p. 138. Edit. 1807.

† See Mr. Knight's Observations, Hort. Trans., vol. ii. p. 160.

rich as that of a garden, still the variety could not be maintained; because we know that each of these races is prone to fecundate others, and gardeners are compelled to exert the utmost diligence to prevent cross-breeds. The intermixture of the pollen of varieties growing in the poorer soil around would soon destroy the peculiar characters of the race which occupied the highly manured tract; for, if these accidents so continually happen, in spite of our care, among the culinary varieties, it is easy to see how soon this cause might obliterate every marked singularity in a wild state.

Besides, it is well known that, although the pampered races which we rear in our gardens for use or ornament may often be perpetuated by seed, yet they rarely produce seed in such abundance, or so prolific in quality, as wild individuals; so that if the care of man were withdrawn, the most fertile variety would always, in the end, prevail over the more sterile.

Similar remarks may be applied to the double flowers, which present such strange anomalies to the botanist. The ovarium, in such cases, is frequently abortive; and the seeds, when prolific, are generally much fewer than where the flowers are single.

Changes caused by soil.—Some curious experiments, recently made on the production of blue instead of red flowers in the Hydrangea hortensis, illustrate the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Varieties of the primrose.—Linnæus was of opinion that the primrose, oxlip, cowslip, and polyanthus, were only varieties of the same species. The majority of modern botanists, on the contrary, consider them to be distinct, although some conceived that the oxlip might be a cross between the cowslip and the primrose. Mr. Herbert has lately recorded the following experiment:—"I raised from the natural seed of one umbel of a highly manured red cowslip a primrose, a cowslip, oxlips of the usual and other colours, a black polyanthus, a hose-in-hose cowslip, and a natural primrose bearing its flower on a polyanthus stalk. From the seed of that very hose-in-hose cowslip, I have since raised a hose-in-hose primrose. I therefore consider all these to be only local varieties, depending upon soil and situation."* Professor Henslow, of Cambridge, has since confirmed this experiment of Mr. Herbert; so that we have an example, not only of the remarkable varieties which the florist can obtain from a common stock, but of the distinctness of analogous races found in a wild state.†

On what particular ingredient, or quality in the earth, these changes

* Hort. Trans., vol. iv. p. 19.

† Loudon's Mag. of Nat. Hist., Sept. 1830, vol. iii. p 406.

depend, has not yet been ascertained.* But gardeners are well aware that particular plants, when placed under the influence of certain circumstances, are changed in various ways, according to the species; and as often as the experiments are repeated, similar results are obtained. The nature of these results, however, depends upon the species, and they are, therefore, part of the specific character; they exhibit the same phenomena again and again, and indicate certain fixed and invariable relations between the physiological peculiarities of the plant, and the influence of certain external agents. They afford no ground for questioning the instability of species, but rather the contrary: they present us with a class of phenomena which, when they are more thoroughly understood, may afford some of the best tests for identifying species, and proving that the attributes originally conferred endure so long as any issue of the original stock remains upon the earth.

CHAPTER III.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE—*continued.*

Variability of a species compared to that of an individual—Species susceptible of modification may be altered greatly in a short time, and in a few generations; after which they remain stationary—The animals now subject to man had originally an aptitude to domesticity—Acquired peculiarities which become hereditary have a close connexion with the habits or instincts of the species in a wild state (p. 508.)—Some qualities in certain animals have been conferred with a view of their relation to man—Wild elephant domesticated in a few years, but its faculties incapable of further development (p. 513.).

Variability of a species compared to that of an individual.—I ENDEAVOURED, in the last chapter, to show, that a belief in the reality of species is not inconsistent with the idea of a considerable degree of variability in the specific character. This opinion, indeed, is little more than an extension of the idea which we must entertain of the identity of an individual, throughout the changes which it is capable of undergoing.

If a quadruped, inhabiting a cold northern latitude, and covered with a warm coat of hair or wool, be transported to a southern climate, it will often, in the course of a few years, shed a considerable portion of its coat, which it gradually recovers on being again restored to its native country.

* Hort. Trans., vol. iii. p. 173.

Even there the same changes are, perhaps, superinduced to a certain extent by the return of winter and summer. We know that the Alpine hare, (*Lepus variabilis*, Pal.,) and the ermine, or stoat, (*Mustela erminea*, Linn.,) become white during winter, and again obtain their full colour during the warmer season; that the plumage of the ptarmigan undergoes a like metamorphosis in colour and quantity, and that the change is equally temporary. We are aware that, if we reclaim some wild animal, and modify its habits and instincts by domestication, it may, if it escapes, become in a few years nearly as wild and untractable as ever; and if the same individual be again retaken, it may be reduced to its former tame state. A plant is placed in a prepared soil, in order that the petals of its flowers may multiply, and their colour be heightened or changed; if we then withhold our care, the flowers of this same individual become again single. In these, and innumerable other instances, we must suppose that the individual was produced with a certain number of qualities; and, in the case of animals, with a variety of instincts, some of which may or may not be developed, according to circumstances, or which, after having been called forth, may again become latent when the exciting causes are removed.

Now, the formation of races seems the necessary consequence of such a capability in individuals to vary, if it be a general law that the offspring should very closely resemble the parent. But, before we can infer that there are no limits to the deviation from an original type which may be brought about in the course of an indefinite number of generations, we ought to have some proof that, in each successive generation, individuals may go on acquiring an equal amount of new peculiarities, under the influence of equal changes of circumstances. The balance of evidence, however, inclines most decidedly on the opposite side; for in all cases we find that the quantity of divergence diminishes from the first in a very rapid ratio.

Species susceptible of modification may be greatly altered in a few generations.—It cannot be objected, that it is out of our power to go on varying the circumstances in the same manner as might happen in the natural course of events during some great geological cycle. For in the first place, where a capacity is given to individuals to adapt themselves to new circumstances, it does not generally require a very long period for its development; if, indeed, such were the case, it is not easy to see how the modification would answer the ends proposed, for all the individuals would die before new qualities, habits, or instincts were conferred.

When we have succeeded in naturalizing some tropical plant in a temperate climate, nothing prevents us from attempting gradually to extend its distribution to higher latitudes, or to greater elevations above the level of the sea, allowing equal quantities of time, or an equal number of generations, for habituating the species to successive increments of cold.

But every husbandman and gardener is aware that such experiments will fail; and we are more likely to succeed in making some plants, in the course of the first two generations, support a considerable degree of difference of temperature than a very small difference afterwards, though we persevere for many centuries.

It is the same if we take any other cause instead of temperature; such as the quality of the food, or the kind of dangers to which an animal is exposed, or the soil in which a plant lives. The alteration in habits, form, or organization, is often rapid during a short period; but when the circumstances are made to vary further, though in ever so slight a degree, all modification ceases, and the individual perishes. Thus some herbivorous quadrupeds may be made to feed partially on fish or flesh; but even these can never be taught to live on some herbs which they reject, and which would even poison them, although the same may be very nutritious to other species of the same natural order. So, when man uses force or stratagem against wild animals, the persecuted race soon becomes more cautious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations: but let the skill and address of man increase, however gradually, no further variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, however indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

Animals now subject to man had originally an aptitude to domesticity.—It has been well observed by M. F. Cuvier and M. Dureau de la Malle, that, unless some animals had manifested in a wild state an aptitude to second the efforts of man, their domestication would never have been attempted. If they had all resembled the wolf, the fox, and the hyæna, the patience of the experimentalist would have been exhausted by innumerable failures before he at last succeeded in obtaining some imperfect results; so, if the first advantages derived from the cultivation of plants had been elicited by as tedious and costly a process as that by which we now make some slight additional improvement in certain races, we should have remained to this day in ignorance of the greater number of their useful qualities.

Acquired instincts of some animals become hereditary.—It is undoubtedly true, that many new habits and qualities have not only been acquired in recent times by certain races of dogs, but have been transmitted to their offspring. But in these cases it will be observed, that the new peculiarities have an intimate relation to the habits of the animal in a wild state, and therefore do not attest any tendency to departure to an indefinite extent from the orignal type of the species. A race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico, affords a beautiful illustration of a new hereditary instinct. The mode of attack, observes M. Roulin, which they employ, consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the deer, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank; whereas other hunting dogs, though of superior strength and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar precautions, they are often killed by the deer on the spot, the vertebræ of their neck being dislocated by the violence of the shock.*

A new instinct has also become hereditary in a mongrel race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and, whatever may be his strength, is destroyed in a moment.

Some of our countrymen, engaged of late in conducting one of the principal mining associations in Mexico, that of Real del Monte, carried out with them some English greyhounds of the best breed to hunt the hares which abound in that country. The great platform which is the scene of sport is at an elevation of about nine thousand feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant, in order to spring with unerring aim. The faculty of the Retriever, however, may justly be regarded as more inex-

* M. Roulin, Ann. des Sci. Nat, tom. xvi. p 16. 1829.

plicable and less easily referrible to the instinctive passions of the species. M. Majendie, says a French writer in a recently published memoir, having learnt that there was a race of dogs in England which stopped and brought back game of their own accord, procured a pair, and, having obtained a whelp from them, kept it constantly under his eyes, until he had an opportunity of assuring himself that, without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

Attributes of animals in their relation to man.—Such attainments, as well as the habits and dispositions which the shepherd's dog and many others inherit, seem to be of a nature and extent which we can hardly explain by supposing them to be modifications of instincts necessary for the preservation of the species in a wild state. When such remarkable habits appear in races of this species, we may reasonably conjecture that they were given with no other view than for the use of man and the preservation of the dog, which thus obtains protection.

As a general rule, I fully agree with M. F. Cuvier, that, in studying the habits of animals, we must attempt, as far as possible, to refer their domestic qualities to modifications of instincts which are implanted in them in a state of nature; and that writer has successfully pointed out, in an admirable essay on the domestication of the mammalia, the true origin of many dispositions which are vulgarly attributed to the influence of education alone.* But we should go too far if we did not admit that some of the qualities of particular animals and plants may have been given solely with a view to the connexion which it was foreseen would exist between them and man—especially when we see that connexion to be in many cases so intimate, that the greater number, and sometimes all the individuals of the species which exist on the earth, are in subjection to the human race.

We can perceive in a multitude of animals, especially in some of the parasitic tribes, that certain instincts and organs are conferred for the purpose of defence or attack against some other species. Now, if we are reluctant to suppose the existence of similar relations between man and the instincts of many of the inferior animals, we adopt an hypothesis no less violent, though in the opposite extreme to that which has led some to imagine the whole animate and inanimate creation to have been made solely for the support, gratification, and instruction of mankind.

Many species, most hostile to our persons or property, multiply, in spite of our efforts to repress them; others, on the contrary, are intentionally augmented many hundred-fold in number by our exertions. In such instances, we must imagine the relative resources of man and of

* Mém. du Mus. d'Hist. Nat.—Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

species, friendly or inimical to him, to have been prospectively calculated and adjusted. To withhold assent to this supposition, would be to refuse what we must grant in respect to the economy of Nature in every other part of the organic creation; for the various species of contemporary plants and animals have obviously their relative forces nicely balanced, and their respective tastes, passions, and instincts so contrived, that they are all in perfect harmony with each other. In no other manner could it happen that each species, surrounded, as it is, by countless dangers, should be enabled to maintain its ground for periods of considerable duration.

The docility of the individuals of some of our domestic species, extending, as it does, to attainments foreign to their natural habits and faculties, may, perhaps, have been conferred with a view to their association with man. But, lest species should be thereby made to vary indefinitely, we find that such habits are never transmissible by generation.

A pig has been trained to hunt and point game with great activity and steadiness;* and other learned individuals, of the same species, have been taught to spell; but such fortuitous acquirements never become hereditary, for they have no relation whatever to the exigencies of the animal in a wild state, and cannot, therefore, be developments of any instinctive propensities.

Influence of domestication.—An animal in domesticity, says M. F. Cuvier, is not essentially in a different situation, in regard to the feeling of restraint, from one left to itself. It lives in society without constraint, because, without doubt, it was a social animal; and it conforms itself to the will of man, because it had a chief, to which, in a wild state, it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals, when left to themselves, form herds more or less numerous; and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which, by its superiority, has become the chief of the herd. Our domestic species had, originally, this sociability of disposition; and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope, to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up; and, when individuals of gregarious species have been accustomed to one master, it

* In the New Forest, near Ringwood, Hants, by Mr. Toomer, keeper of Broomy Lodge. I have conversed with witnesses of the fact.

is he alone whom they acknowledge as their chief—he only whom they obey. "The elephant allows himself to be directed only by the carnac whom he has adopted; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others; and every body knows how dangerous it is to be in the midst of a herd of cows, in pasturages that are little frequented, when they have not at their head the keeper who takes care of them."

"Every thing, therefore, tends to convince us, that formerly men were only, with regard to the domestic animals, what those who are particularly charged with the care of them still are—namely, members of the society which these animals form among themselves; and that they are only distinguished, in the general mass by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognises man as a member, and as the chief of its herd, is a domestic animal. It might even be said, that, from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it."*

But the ingenious author whose observations I have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person, is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed; but, when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, and is subjected to the whole human race. It seems fair to presume that the capability in the instinct of the horse to be thus modified, was given to enable the species to render greater services to man; and, perhaps, the facility with which many other acquired characters become hereditary in various races of the horse, may be explicable only on a like supposition. The amble, for example, a pace to which the domestic races in Spanish America are exclusively trained, has, in the course of several generations, become hereditary, and is assumed by all the young colts before they are broken in.†

It seems, also, reasonable to conclude, that the power bestowed on the horse, the dog, the ox, the sheep, the cat, and many species of domestic fowls, of supporting almost every climate, was given expressly to enable them to follow man throughout all parts of the globe, in order that we might obtain their services, and they our protection. If it be objected that the elephant, which, by the union of strength, intelligence,

* Mém. du Mus. d'Hist. Nat.

† Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 58.

and docility, can render the greatest services to mankind, is incapable of living in any but the warmest latitudes, we may observe, that the quantity of vegetable food required by this quadruped would render its maintenance in the temperate zone too costly, and in the arctic impossible.

Among the changes superinduced by man, none appear, at first sight, more remarkable than the perfect tameness of certain domestic races. It is well known that, at however early an age we obtain possession of the young of many unreclaimed races, they will retain, throughout life, a considerable timidity and apprehensiveness of danger; whereas, after one or two generations, the descendants of the same stock will habitually place the most implicit confidence in man. There is good reason, however, to suspect that such changes are not without analogy in a state of nature; or, to speak more correctly, in situations where man has not interfered.

Thus, Dr. Richardson informs us, in his able history of the habits of North American animals, that, "in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species;* but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and scale the rocks with a speed and agility that baffles pursuit."*

It is probable, therefore, that as man, in diffusing himself over the globe, has tamed many wild races, so, also, he has made many tame races wild. Had some of the larger carnivorous beasts, capable of scaling the rocks, made their way into the North American mountains before our hunters, a similar alteration in the instincts of the sheep would doubtless have been brought about.

Wild elephants domesticated in a few years.—No animal affords a more striking illustration of the principal points which I have been endeavouring to establish, than the elephant; for, in the first place, the wonderful sagacity with which he accommodates himself to the society of man, and the new habits which he contracts, are not the result of time, nor of modifications produced in the course of many generations. These animals will breed in captivity, as is now ascertained, in opposition to the vulgar opinion of many modern naturalists, and in conformity to that of the ancients Ælian and Columella:† yet it has always been the custom, as the least expensive mode of obtaining them, to capture wild individuals in the forests, usually when full grown; and, in a few years after they are taken—sometimes, it is said, in the space of a few months—their education is completed.

* Fauna Boreali-Americana, p. 273.

† Mr. Corse on the Habits, &c. of the Elephant, Phil. Trans. 1799.

Had the whole species been domesticated from an early period in the history of man, like the camel, their superior intelligence would, doubtless, have been attributed to their long and familiar intercourse with the lord of the creation; but we know that a few years is sufficient to bring about this wonderful change of habits; and, although the same individual may continue to receive tuition for a century afterwards, yet it makes no further progress in the general development of its faculties. Were it otherwise, indeed, the animal would soon deserve more than the poet's epithet of "half-reasoning."

From the authority of our countrymen employed in the late Burmese war, it appears, in corroboration of older accounts, that, when elephants are required to execute extraordinary tasks, they may be made to understand that they will receive unusual rewards. Some favourite dainty is shown to them, in the hope of acquiring which the work is done; and so perfectly does the nature of the contract appear to be understood, that the breach of it, on the part of the master, is often attended with danger. In this case, a power has been given to the species to adapt their social instincts to new circumstances with surprising rapidity; but the extent of this change is defined by strict and arbitrary limits. There is no indication of a tendency to continued divergence from certain attributes with which the elephant was originally endued—no ground whatever for anticipating that, in thousands of centuries, any material alteration could ever be effected. All that we can infer from analogy is, that some more useful and peculiar races might probably be formed, if the experiment were fairly tried; and that some individual characteristic, now only casual and temporary, might be perpetuated by generation.

In all cases, therefore, where the domestic qualities exist in animals, they seem to require no lengthened process for their development; and they appear to have been wholly denied to some classes, which, from their strength and social disposition, might have rendered great services to man; as, for example, the greater part of the quadrumana. The orang-outang, indeed, which, for its resemblance in form to man, and apparently for no other good reason, has been assumed by Lamarck to be the most perfect of the inferior animals, has been tamed by the savages of Borneo, and made to climb lofty trees, and to bring down the fruit. But he is said to yield to his masters an unwilling obedience, and to be held in subjection only by severe discipline. We know nothing of the faculties of this animal which can suggest the idea that it rivals the elephant in intelligence; much less any thing which can countenance the dreams of those who have fancied that it might have been transmuted into "the dominant race." One of the baboons of Sumatra (*Simia carpolegus*) appears to be more docile, and is frequently trained by the inhabitants to ascend trees, for the purpose of gathering cocoa-nuts; a service in which the animal is very expert. He selects, says Sir Stamford Raffles, the ripe nuts, with great judgment, and pulls no more than he is ordered.* The capuchin and cacajao monkeys are, according to Humboldt, taught to ascend trees in the same manner, and to throw down fruit on the banks of the lower Orinoco.†

It is for the Lamarckians to explain how it happens that those same savages of Borneo have not themselves acquired, by dint of longing, for many generations, for the power of climbing trees, the elongated arms of the orang, or even the prehensile tails of some American monkeys. Instead of being reduced to the necessity of subjugating stubborn and untractable brutes, we should naturally have anticipated "that their wants would have excited them to efforts, and that continued efforts would have given rise to new organs;" or, rather to the re-acquisition of organs which, in a manner irreconcileable with the principle of the *progressive* system, have grown obsolete in tribes of men which have such constant need of them.

Recapitulation.—It follows, then, from the different facts which have been considered in this chapter, that a short period of time is generally sufficient to effect nearly the whole change which an alteration of external circumstances can bring about in the habits of a species, and that such capacity of accommodation to new circumstances is enjoyed, in very different degrees, by different species.

Certain qualities appear to be bestowed exclusively with a view to the relations which are destined to exist between different species and, among others, between certain species and man; but these latter are always so nearly connected with the original habits and propensities of each species in a wild state, that they imply no indefinite capacity of varying from the original type. The acquired habits derived from human tuition are rarely transmitted to the offspring; and when this happens, it is almost universally the case with those merely which have some obvious connexion with the attributes of the species when in a state of independence.

* Linn. Trans., vol. xiii. p. 244.

† Pers. Narr. of Travels to the Equinoctial Regions of the New Continent, in the years 1799—1804.

CHAPTER IV.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE—*continued.*

Phenomena of hybrids—Hunter's opinions—Mules not strictly intermediate between parent species—Hybrid plants—Experiments of Kölreuter and Wiegmann—Vegetable hybrids prolific throughout several generations—Why rare in a wild state (p. 519.)—De Candolle on hybrid plants—The phenomena of hybrids confirm the distinctness of species—Theory of the gradation in the intelligence of animals as indicated by the facial angle (p. 524.)—Tiedemann on the brain of the fœtus in mammalia assuming successively the form of the brain of fish, reptile, and bird—Bearing of this discovery on the theory of progressive development and transmutation (p. 527.)—Recapitulation.

Phenomena of hybrids.—We have yet to consider another class of phenomena, those relating to the production of hybrids, which have been regarded in a very different light with reference to their bearing on the question of the permanent distinctness of species; some naturalists considering them as affording the strongest of all proofs in favour of the reality of species; others, on the contrary, appealing to them as countenancing the opposite doctrine, that all the varieties of organization and instinct now exhibited in the animal and vegetable kingdoms may have been propagated from a small number of original types.

In regard to the mammifers and birds, it is found that no sexual union will take place between races which are remote from each other in their habits and organization; and it is only in species that are very nearly allied that such unions produce offspring. It may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the hybrid progeny is sterile; and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation. The principal number of observations and experiments relate to the mixed offspring of the horse and ass; and in this case it is well established that the he-mule can generate, and the she-mule produce. Such cases occur in Spain and Italy, and much more frequently in the West Indies and New Holland; but these mules have never bred in cold climates, seldom in warm regions, and still more rarely in temperate countries.

The hybrid offspring of the she-ass and the stallion, the γιννος of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare. In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude, but in the figure of the body; whereas in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. The same naturalist infers, from various experiments respecting cross-breeds between the he-goat and ewe, the dog and she-wolf, the goldfinch and canary-bird, that the male transmits his sex to the greatest number, and that the preponderance of males over females exceeds that which prevails where the parents are of the same species.

Hunter's opinion.—The celebrated John Hunter has observed, that the true distinction of species must ultimately be gathered from their incapacity of propagating with each other, and producing offspring capable of again continuing itself. He was unwilling, however, to admit that the horse and the ass were of the same species, because some rare instances had been adduced of the breeding of mules, although he maintained that the wolf, the dog, and the jackal were all of one species; because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule in each case, would breed again with the dog. In these cases, however, it may be observed, that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated; a fact of which I believe no examples are yet recorded, either in regard to mixtures of the horse and ass, or any other of the mammalia.

Should the fact be hereafter ascertained, that two mules can propagate their kind, we must still inquire whether the offspring may not be regarded in the light of a monstrous birth, proceeding from some accidental cause, or, rather, to speak more philosophically, from some general law not yet understood, but which may not be permitted permanently to interfere with those laws of generation by which species may, in general, be prevented from becoming blended. If, for example, we discovered that the progeny of a mule race degenerated greatly, in the first generation, in force, sagacity, or any attribute necessary for its preservation in a state of nature, we might infer that, like a monster, it is a mere temporary and fortuitous variety. Nor does it seem probable that the greater number of such monsters could ever occur unless obtained by art; for, in Hunter's experiments, stratagem or force was, in most instances, employed to bring about the irregular connexion.*

Mules not strictly intermediate between the parent species.—It seems rarely to happen that the mule offspring is truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments, one of the hybrid pups resembled the wolf much more than the rest of the litter; and we are informed by Weigmann, that, in a litter lately obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

There is undoubtedly a very close analogy between these phenomena and those presented by the intermixture of distinct races of the same species, both in the inferior animals and in man. Dr. Prichard, in his

* Phil. Trans. 1787. Additional Remarks, Phil. Trans., 1789.

"Physical History of Mankind," cites examples where the peculiarities of the parents have been transmitted very unequally to the offspring; as where children, entirely white, or perfectly black, have sprung from the union of the European and the negro. Sometimes the colour or other peculiarities of one parent, after having failed to show themselves in the immediate progeny, reappear in a subsequent generation; as where a white child is born of two black parents, the grandfather having been a white.*

The same author judiciously observes that, if different species mixed their breed, and hybrid races were often propagated, the animal world would soon present a scene of confusion; its tribes would be every where blended together, and we should perhaps find more hybrid creatures than genuine and uncorrupted races.†

Hybrid plants—Kölreuter's experiments.—The history of the vegetable kingdom has been thought to afford more decisive evidence in favour of the theory of the formation of new and permanent species from hybrid stocks. The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata*, which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a female plant of *N. rustica* was impregnated with the pollen of a male plant of *N. paniculata*. The seed ripened, and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata*, and obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata*.

The plan of impregnation adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma.

Wiegmann's experiments.—The same experiment has since been repeated with success by Wiegmann, who found that he could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times.

The blending of the characters of the parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being intermediate, as in the offspring of the two species of verbascum. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached

* Prichard, vol. i. p. 217. † Ibid. p. 97.

most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks, that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species, *but they never exhibit characters foreign to both.* A recross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

In general, the success attending the production and perpetuity of hybrids among plants depends, as in the animal kingdom, on the degree of proximity between the species intermarried. If their organization be very remote, impregnation never takes place; if somewhat less distant, seeds are formed, but always imperfect and sterile. The next degree of relationship yields hybrid seedlings, but these are barren; and it is only when the parent species are very nearly allied that the hybrid race may be perpetuated for several generations. Even in this case, the best authenticated examples seem confined to the crossing of hybrids with individuals of pure breed. In none of the experiments most accurately detailed does it appear that both the parents were mules.

Wiegmann diversified as much as possible his mode of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed; and, instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined; so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

Vegetable hybrids, why rare in a wild state.—The same observer saw a good exemplification of the manner in which hybrids may be formed in a state of nature. Some wallflowers and pinks had been growing in a garden, in a dry sunny situation; and their stigmas had been ripened so as to be moist, and to absorb pollen with avidity, although their anthers were not yet developed. These stigmas became impregnated by pollen blown from some other adjacent plants of the same species; but, had they been of different species, and not too remote in their organization, mule races must have resulted.

When, indeed, we consider how busily some insects have been shown to be engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting the red and yellow powder by which the stamens of flowers are covered, loading it on their hind legs, and carrying it to their hive for the purpose of feeding their young! In thus providing for their own progeny, these insects assist materially the process of fructification.* Few persons need be reminded that the stamens in certain plants grow on different blossoms from the pistils; and, unless the summit of the pistil be touched with the fertilizing dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees, chiefly, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther-dust of others, seems almost to realize the converse of the miracle believed by the credulous herdsmen of the Lusitanian mares—

> Ore omnes versæ in Zephyrum, stant rupibus altis,
> Exceptantque leves auras: et sæpe sine ullis
> Conjugiis, vento gravidæ, mirabile dictu.†

But, in the first place, it appears that there is a natural aversion in plants, as well as in animals, to irregular sexual unions; and in most of the successful experiments in the animal and vegetable world, some violence has been used in order to procure impregnation. The stigma imbibes, slowly and reluctantly, the granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

If we consider the vegetable kingdom generally, it must be recollected that even of the seeds which are well ripened, a great part are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations, even if they were ever produced

* See Barton on the Geography of Plants, p. 67. † Georg. lib. iii. 273.

beyond one generation in a wild state. In the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness, in which hybrids are acknowledged to be deficient.

Centaurea hybrida, a plant which never bears seed, and is supposed to be produced by the frequent intermixture of two well-known species of Centaurea, grows wild upon a hill near Turin. *Ranunculus lacerus*, also sterile, has been produced accidentally at Grenoble, and near Paris. by the union of two Ranunculi; but this occurred in gardens.*

Mr. Herbert's experiments.—Mr. Herbert, in one of his ingenious papers on mule plants, endeavours to account for their non-occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur have already been made many centuries ago, and have formed the various species of botanists; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species.† But we have no data, as yet, to warrant the conclusion, that a single permanent hybrid race has ever been formed, even in gardens, by the intermarriage of two allied species brought from distant habitations. Until some fact of this kind is fairly established, and a new species, capable of perpetuating itself in a state of perfect independence of man, can be pointed out, it seems reasonable to call in question entirely this hypothetical source of new species. That varieties do sometimes spring up from cross breeds, in a natural way, can hardly be doubted; but they probably die out even more rapidly than races propagated by grafts or layers.

Opinion of De Candolle.—De Candolle, whose opinion on a philosophical question of this kind deserves the greatest attention, has observed, in his Essay on Botanical Geography, that the *varieties* of plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various arguments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, "I can perfectly comprehend, without altogether sharing the opinion, that, where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but

* Hon. and Rev. W. Herbert, Hort. Trans., vol. iv. p. 41. † Ibid.

I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organized beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute *species*."*

Reality of species confirmed by the phenomena of hybrids.—The most decisive arguments, perhaps, amongst many others, against the probability of the derivation of permanent species from cross-breeds, are to be drawn from the fact alluded to by De Candolle, of species having a close affinity to each other occurring in distinct botanical provinces, or countries inhabited by groups of distinct species of indigenous plants: for in this case naturalists who are not prepared to go the whole length of the transmutationists, are under the necessity of admitting that, in some cases, species which approach very near to each other in their characters, were so created from their origin; an admission fatal to the idea of its being a general law of nature, that a few original types only should be formed, and that all intermediate races should spring from the intermixture of those stocks.

This notion, indeed, is wholly at variance with all that we know of hybrid generation: for the phenomena entitle us to affirm, that had the types been at first somewhat distant, *no cross-breeds would ever have been produced*, much less those prolific races which we now recognise as distinct species.

In regard, moreover, to the permanent propagation of hybrid races among animals, insuperable difficulties present themselves, when we endeavour to conceive the blending together of the different instincts and propensities of two species, so as to insure the preservation of the intermediate race. The common mule, when obtained by human art, may be protected by the power of man; but, in a wild state, it would not have precisely the same wants either as the horse or the ass; and if, in consequence of some difference of this kind, it strayed from the herd, it would soon be hunted down by beasts of prey, and destroyed.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In the case of the common hive-bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct instincts.† So also we find that, amongst a most numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the

* Essai Elémentaire, &c., 3me partie.

† Intr. to Entom., vol. ii., p. 504. Ed. 1817.

animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of two of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

We might also ask, if a few generetic types alone have been *created* among insects, and the intermediate species have proceeded from hybridity, where are those original types, combining, as they ought to do, the elements of all the instincts which have made their appearance in the numerous derivative races? So also in regard to animals of all classes, and of plants; if species in general are of hybrid origin, where are the stocks which combine in themselves the habits, properties, and organs, of which all the intervening species ought to afford us mere modifications?

Recapitulation of the arguments from hybrids.—I shall now conclude this subject by summing up, in a few words, the results to which I have been led by the consideration of the phenomena of hybrids. It appears, that the aversion of individuals of distinct species to the sexual union is common to animals and plants; and that it is only when the species approach near to each other in their organization and habits, that any offspring are produced from their connexion. Mules are of extremely rare occurrence in a state of nature, and no examples are yet known of their having procreated in a wild state. But it has been proved, that hybrids are not universally sterile, provided the parent stocks have a near affinity to each other, although the continuation of the mixed race, for several generations, appears hitherto to have been obtained only by crossing the hybrids with individuals of pure species; an experiment which by no means bears out the hypothesis that a true hybrid race could ever be permanently established.

Hence we may infer, that aversion to sexual intercourse is, in general, a good test of the distinctness of original stocks, or of *species*; and the procreation of hybrids is a proof of the very near affinity of species. Perhaps, hereafter, the number of generations for which hybrids may be continued, before the race dies out (for it seems usually to degenerate rapidly), may afford the zoologist and botanist an experimental test of the difference in the degree of affinity of allied species.

I may also remark, that if it could have been shown that a single permanent species had ever been produced by hybridity (of which there is no satisfactory proof), it might certainly have lent some countenance to the notions of the ancients respecting the gradual deterioration of created things, but none whatever to Lamarck's theory of their progressive perfectibility; for observations have hitherto shown that there is a tendency in mule animals and plants to degenerate in organization.

It was before remarked, that the theory of progressive development arose from an attempt to ingraft the doctrines of the transmutationists upon one of the most popular generalizations in geology. But modern geological researches have almost destroyed every appearance of that gradation in the successive groups of animate beings, which was supposed to indicate the slow progress of the organic world from the more simple to the more compound structure. In the more modern formations, we find clear indications that the highest orders of the terrestrial mammalia were fully represented during several successive epochs; but in the monuments which we have hitherto examined of more remote eras, in which there are as yet discovered few fluviatile, and perhaps no lacustrine formations, and, therefore, scarcely any means of obtaining an insight into the zoology of the continents then existing, we have only as yet found one example of a mammiferous quadruped. The recent origin of man, and the absence of all signs of any rational being holding an analogous relation to former states of the animate world, affords one, and the only reasonable argument, in support of the hypothesis of a progressive scheme; but none whatever in favour of the fancied evolution of one species out of another.

Theory of the gradation in intellect as shown by the facial angle.—When the celebrated anatomist, Camper, first attempted to estimate the degrees of sagacity of different animals, and of the races of man, by the measurement of the facial angle, some speculators were bold enough to affirm, that certain simiæ differed as little from the more savage races of men, as those do from the human race in general; and that a scale might be traced from "apes with foreheads villanous low" to the African variety of the human species, and from that to the European. The facial angle was measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower jaw-bone, and observing the angle which it made with the horizontal line; and it was affirmed, that there was a regular series of such angles from birds to the mammalia.

The gradation from the dog to the monkey was said to be perfect, and from that again to man. One of the ape tribe has a facial angle of 42°; and another, which approximated nearest to man in figure an angle of 50° To this succeeds (longo sed proximus intervallo) the head of the African negro, which as well as that of the Kalmuc, forms an angle of 70°; while that of the European contains 80°. The Roman painters preferred the angle of 95°; and the character of beauty and sublimity, so striking in some works of Grecian sculpture, as in the head of the Apollo, and in the Medusa of Sisocles, is given by an angle which amounts to 100°.*

A great number of valuable facts and curious analogies in comparative anatomy were brought to light during the investigations which were made

* Prichard's Phys. Hist of Mankind, vol. i. p. 159.

by Camper, John Hunter, and others, to illustrate this scale of organization; and their facts and generalizations must not be confounded with the fanciful systems which White and others deduced from them.*

That there is some connexion between an elevated and capacious forehead, in certain races of men, and a large development of the intellectual faculties, seems highly probable; and that a low facial angle is frequently accompanied with inferiority of mental powers, is certain; but the attempt to trace a graduated scale of intelligence through the different species of animals accompanying the modifications of the form of the skull, is a mere visionary speculation. It has been found necessary to exaggerate the sagacity of the ape tribe at the expense of the dog; and strange contradictions have arisen in the conclusions deduced from the structure of the elephant; some anatomists being disposed to deny the quadruped the intelligence which he really possesses, because they found that the volume of his brain was small in comparison to that of the other mammalia; while others were inclined to magnify extravagantly the superiority of his intellect, because the vertical height of his skull is so great when compared to its horizontal length.

Different races of men are all of one species.—It would be irrelevant to our subject if we were to enter into a further discussion on these topics; because, even if a graduated scale of organization and intelligence could have been established, it would prove nothing in favour of a tendency, in each species, to attain a higher state of perfection. I may refer the reader to the writings of Blumenbach, Prichard, Lawrence, and others, for convincing proofs that the varieties of form, colour, and organization of different races of men, are perfectly consistent with the generally received opinion, that all the individuals of the species have originated from a single pair; and, while they exhibit in man as many diversities of a physiological nature as appear in any other species, they confirm also the opinion of the slight deviation from a common standard of which species are capable.

The power of existing and multiplying in every latitude, and in every variety of situation and climate, which has enabled the great human family to extend itself over the habitable globe, is partly, says Lawrence, the result of physical constitution, and partly of the mental prerogative of man. If he did not possess the most enduring and inflexible corporeal frame, his arts would not enable him to be the inhabitant of all climates, and to brave the extremes of heat and cold, and the other destructive influences of local situation.† Yet, notwithstanding this flexibility of bodily frame, we find no signs of indefinite departure from a common

* Ch. White on the Regular Gradation in Man, &c., 1799.

† Lawrence, Lectures on Phys. Zool. and Nat. Hist. of Man, p. 192. Ed. 1823.

standard, and the intermarriages of individuals of the most remote varieties are not less fruitful than between those of the same tribe.

Tiedemann on the brain of the fœtus in vertebrated animals.—There is yet another department of anatomical discovery to which I must allude, because it has appeared, to some persons, to afford a distant analogy, at least, to that progressive development by which some of the inferior species may have been gradually perfected into those of more complex organization. Tiedemann found, and his discoveries have been most fully confirmed and elucidated by M. Serres, that the brain of the fœtus, in the highest class of vertebrated animals, assumes, in succession, forms analogous to those which belong to fishes, reptiles, and birds, before it acquires the additions and modifications which are peculiar to the mammiferous tribe. So that, in the passage from the embryo to the perfect mammifer, there is a typical representation, as it were, of all those transformations which the primitive species are supposed to have undergone, during a long series of generations, between the present period and the remotest geological era.

If you examine the brain of the mammalia, says M. Serres, at an early stage of uterine life, you perceive the cerebral hemispheres consolidated, as in fish, in two vesicles, isolated one from the other; at a later period, you see them affect the configuration of the cerebral hemispheres of reptiles; still later again, they present you with the forms of those of birds; finally, they acquire, at the era of birth, and sometimes later, the permanent forms which the adult mammalia present.

The cerebral hemispheres, then, arrive at the state which we observe in the higher animals only by a series of successive metamorphoses. If we reduce the whole of these evolutions to four periods, we shall see, that in the first are born the cerebral lobes of fishes; and this takes place homogeneously in all classes. The second period will give us the organization of reptiles; the third, the brain of birds; and the fourth, the complex hemispheres of mammalia.

If we could develope the different parts of the brain of the inferior classes, we should make, in succession, a reptile out of a fish, a bird out of a reptile, and a mammiferous quadruped out of a bird. If, on the contrary, we could starve this organ in the mammalia, we might reduce it successively to the condition of the brain of the three inferior classes.

Nature often presents us with this last phenomenon in monsters, but never exhibits the first. Among the various deformities which organized beings may experience, they never pass the limits of their own classes to put on the forms of the class above them. Never does a fish elevate itself so as to assume the form of the brain of a reptile; nor does the latter ever attain that of birds; nor the bird that of the mammifer. It may happen that a monster may have two heads; but the conformation of the brain always remains circumscribed narrowly within the limits of its class.*

Bearing of these discoveries on the theory of progressive development.—It will be observed, that these curious phenomena disclose, in a highly interesting manner, the unity of plan that runs through the organization of the whole series of vertebrated animals; but they lend no support whatever to the notion of a gradual transmutation of one species into another; least of all of the passage, in the course of many generations, from an animal of a more simple to one of a more complex structure. On the contrary, were it not for the sterility imposed on monsters, as well as on hybrids in general, the argument to be derived from Tiedemann's discovery, like that deducible from experiments respecting hybridity, would be in favour of the successive *degeneracy*, rather than the perfectibility, in the course of ages, of certain classes of organic beings.

Recapitulation.—For the reasons, therefore, detailed in this and the two preceding chapters, we may draw the following inferences in regard to the reality of *species* in nature:—

1st. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species.

2dly. When the change of situation which they can endure is great, it is usually attended by some modifications of the form, colour, size, structure, or other particulars; but the mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the permanent specific character.

3dly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually; indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance

* E. R. A. Serres, Anatomie Comparée du Cerveau, illustrated by numerous plates, tome i., 1824.

of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature; and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

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.

Albite. See "Felspar."

Alembic. An apparatus for distilling.

Algæ. An order of 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. II., pp. 122, 123. 298.

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 aluminous 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 statutes 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 anologue 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.

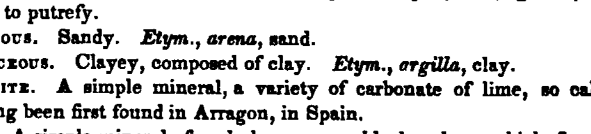
Anthracite. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, ανθραξ, *anthrax*, coal,

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.* i.]



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. Name applied by Pliny to a particular mineral, from the Greek αυγη, *auge*, lustre.

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. II. p. 453. *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. II. p. 456); 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. II., p. 454.

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., Vol. II.

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. II. p. 456. 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. 139., Vol. II. p. 343, 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.

Coombe. 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. II. p. 454.

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. II. p. 453.

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, seaweeds, 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. II. p. 318.

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*.

Dikes. 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. II. p. 224.

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.

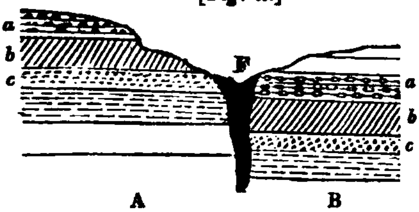
Experimentum Crucis. A decisive experiment, so called because, like a cross or direction post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture whereby the nature of the thing is extorted, as it were, by violence.

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.

[*Fig.* ii.]



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.

Foraminifera. A name given by D'Orbigny to a family of microscopic shells, several of which are figured in Plate XIII., Vol. II. p. 377, of this work. Their different chambers are united by a small perforation or *foramen*. Recent observation has shown that some at least are not cephalopoda, as D'Orbigny supposed.

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, *gaster*, 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 greensand. See Table I., F, Vol. II. p. 454.

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. II. p. 454. 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. II. p. 434.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREYWACKE. *Grauwacke*, a German name, generally adopted by geologists for the lowest members of the secondary strata. Table I., O, Vol. II. p. 456; see also Vol. II. pp. 450, 451. The rock is very often of a gray colour; hence the name, *grau*, being German for gray, 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 freshwater deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of freshwater plants of the genus *chara*. See Vol. II. pp. 158, 159. *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. II., Ch. xxvii.

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.

IGNEOUS ROCKS. All rocks, such as lava, trap, and granite, known or supposed to have been melted by volcanic heat.

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. II. p. 454) 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. II. p. 454. 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. II. p. 455.

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. Flinty slate; a kind of quartz or flint, allied to hornstone, but of a grayish 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. II. p. 455.

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. *Etym.*, 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 Melastomaceæ, 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. II., Ch. xxvii.

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. II. p. 224.

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. II. p. 348. *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. II. p. 456.

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 plaintains.

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. II. p. 455.

NAPHTHA. 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 and argillaceous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish gray. 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 magnesian limestone. See Table I., K, Vol. II. p. 455.

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 formation immediately below the Carboniferous Group, and sometimes classed with it. See Table I., N, Vol. II. p. 456.

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, Table I., H, Vol. II. p. 454, characterized by peculiar fossils, because limestone of this kind occurs in this group in England, France, &c. *Etym.*, ωον, *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 ORTHOCERE. 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, *palaios*, 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. II. p. 33. 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.

Pitchstone. 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. II. p. 453), 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, a lizard.

Pliocene. See explanation of this term, Vol. II. p. 223.

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. II., Ch. xxvi.

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. II. p. 454), 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, chiefly felspathic, 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. II. p. 454.

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. II. p. 455.

Reticulate. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

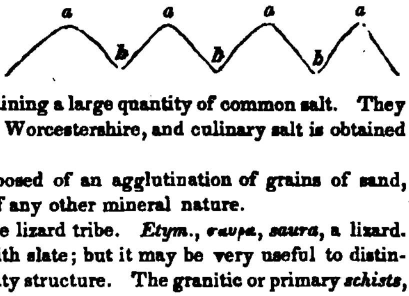
Rock Salt. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire; and it is then called *rock*-salt.

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.

[*Fig. iii.*]



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. II. p. 432; and Table I., Vol. II. p. 454.

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 iron-stone, 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 statified, 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. II. p. 471.

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. II. p. 478.

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. II. p. 479, 480.

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 transtiburtinus.

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 backbone, 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 VOL. I.