PRINCIPLES

OF

GEOLOGY.

VOL. III.

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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.

FOREIGN SECRETARY TO THE GEOLOGICAL SOCIETY OF LONDON.

" Verè scire est per causas scire." Bacon.

IN FOUR VOLUMES.

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Plate VI.

1. Montagnuola 2. Torre del filosofo. 3. Highest Cone. 4. Lepra. 5. Finocchio. 6. Capra. 7. Cone of 1811. 8. Cima del asino. 9. Musara.

View of the Val del Bove Etna.


MAP
of Part of
SICILY
Capo Milazzo
Milazzo
Capo Calva
Patti
St. Lucia
VAL DI DEMONE
Mojo
Randazzo
Mt. Etna
Traino
Caltabiano
R. Simeto
R. Salso
Aderno
Castrogiovanni
R. Dittaino
Paterno
Trezza
Cyclopian I.s
Misterbianco
CATANIA
Plain of Catania
R. Simeto
Piazza
R. Gurna Luga
Palagonia
Militello
Villasmundo
C. St. Croce
Lentini
Augusta
Caltagirone
Grammichele
Melilli
Vizzini
Sortino
Pentalica
SYRACUSE
VAL DI NOTO
Terranova
Floridia
Chiaramonte
R. Dirillo
Vittoria
Noto
Ragusa
Modica
R. Ragusa
Spaccaforno
Pachino
C. Passero
Pt. delle Correnti
1
Volcanic
2
Newer Pliocene
3
Newer Pliocene Alternating with Volcanic
14 30'
15
38
36'
37

PRINCIPLES OF GEOLOGY.

BOOK III.

CHAPTER VII.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES — *continued.*

Geographical distribution and migrations of fish — of testacea — of zoophytes — Distribution of insects — Migratory instincts of some species — Certain types characterize particular countries — Their means of dissemination — Geographical distribution and diffusion of man — Speculations as to the birth-place of the human species — Progress of human population — Drifting of canoes to vast distances — On the involuntary influence of man in extending the range of many other species.

Geographical Distribution and Migrations of Fish.— ALTHOUGH we are less acquainted with the habitations of marine animals than with the grouping of the terrestrial species before described, yet it is well ascertained that their distribution is governed by the same general laws. The testimony borne by MM. Péron and Lesueur to this important fact is remarkably strong. These eminent naturalists, after collecting and describing many thousand species of marine animals which they brought to Europe from the south-

ern hemisphere, insist most emphatically on their distinctness from those north of the equator; and this remark they extend to animals of all classes, from those of a more simple to those of a more complex organization—from the sponges and medusæ to the cetacea. "Among all those which we have been able to examine," say they, "with our own eyes, or with regard to which it has appeared to us possible to pronounce with certainty, there is not a single animal of the southern regions which is not distinguished by essential characters from the analogous species in the northern seas."*

The fish of the Arabian gulf are said to differ entirely from those of the Mediterranean, notwithstanding the proximity of these seas. The flying-fish are found (some stragglers excepted) only between the tropics; in receding from the Line, they never approach a higher latitude than the fortieth parallel. Those inhabiting the Atlantic are said to be different species from those of the eastern ocean.† The electric gymnotus belongs exclusively to America; the trembler, or *Silurus electricus*, to the rivers of Africa; but the torpedo, or cramp-fish, is said to be dispersed over all tropical, and many temperate seas.‡

All are aware, that there are certain fish of passage which have their periodical migrations, like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The

* Sur les Habitations des Animaux Marins.—Ann. du Mus., tom. xv., cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 51.

† Malte-Brun, vol. i. p. 507.

‡ Ibid.

herring and the haddock, after frequenting certain shores, in vast shoals, for a series of years, desert them again, and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it. *

Gmelin says, that the anseres subsist, in their migrations, on the spawn of fish; and that oftentimes, when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired.† When there are many disconnected freshwater lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source; but it has been suggested, that the minute eggs of these animals may sometimes be entangled in the feathers of water-fowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water-beetles, also, as the dyticidæ, are amphibious, and in the evening quit their lakes and pools, and, flying in the air, transport the minute ova of fishes to distant waters. In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains.

* Phil. Trans., 1747, p. 395. † Amœn. Acad., Essay 75.

Geographical Distribution and Migrations of Testacea.

The testacea, of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist, because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine molluscs is extensive.

Causes which limit the extension of many species.—Some forms, as those of the nautili, volutæ, and cyprææ, attain their fullest development in warm latitudes; and most of their species are exclusively confined to them. Péron and Lesueur remark, that the Haliotis gigantea of Van Diemen's Land, and the Phasianella, diminish in size as they follow the coasts of New Holland to King George's Sound, and entirely disappear beyond them.* Almost all the species of South American shells differ from those of the Indian Archipelago in the same latitudes; and on the shores of many of the isles of the South Pacific, peculiar species have been obtained. But we are as yet by no means able to sketch out the submarine provinces of shells, as the botanist has done those of the terrestrial, and even of the subaqueous plants. There can be little doubt, however, that the boundaries in this case, both of latitude and longitude, will be found in general well defined. The continuous lines of continents, stretching from north to south, prevent a particular species from belting the globe, and following the

* Ann. du Mus. d'Hist. Nat., tom. xv.

direction of the isothermal lines. The inhabitants of the West Indian seas, for example, cannot enter the Pacific, without passing round through the inclement climate of Cape Horn. Currents also flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses.

Great range of some species.—Some few species, however, have an immense range, as the *Bulla aperta*, for example, which is found in almost all zones. The habitation of the *Bulla striata* extends from the shores of Egypt to the coasts of England and France, and it recurs again in the seas of Senegal, Brazil, and the West Indies. The *Turbo petræus* inhabits the seas of England, Guadaloupe, and the Cape of Good Hope *, and many instances of a similar kind might be enumerated.

The *Ianthina fragilis* has wandered into almost every sea, both tropical and temperate. This "common oceanic snail" derives its buoyancy from an admirably-contrived float, which has enabled it not only to disperse itself so universally, but to become an active agent in disseminating other species, which attach themselves, or their ova, to its shell.†

It is evident that, among the testacea, as in plants

* Fér. Art. Geogr. Phys. Dict. Class. d'Hist. Nat.

† Mr. Broderip possesses specimens of *Ianthina fragilis*, bearing more than one species of barnacle (*Pentelasmis*,) presented to him by Captain King and Lieutenant Graves. One of these specimens, taken alive by Captain King far at sea, and a little north of the equator, is so loaded with those cirrhipeds, and with numerous ova, that all the upper part of its shell is invisible.

and the higher order of animals, there are species which have a power of enduring a wide range of temperature, whereas others cannot resist a considerable change of climate. Among the freshwater molluscs, and those which breathe air, Férussac mentions a few instances of species of almost universal diffusion.

The Helix putris (*Succinea putris* Lam.), so common in Europe, where it reaches from Norway to Italy, is also found in Egypt, in the United States, in Newfoundland, Jamaica, Tranquebar, and, it is even said, in the Marianne Isles. As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different water-fowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. *Helix aspersa*, one of the commonest of our larger land-shells, is found in South America, at the foot of Chimborazo, as also in Cayenne. Some conchologists have conjectured that it was accidentally imported in some ship; for it is an eatable species, and these animals are capable of retaining life during long voyages, without air or nourishment.*

Confined range of others.—Mr. Lowe, in a memoir published in the Cambridge Transactions in 1831, enumerates seventy-one species of land mollusca, collected by him in the islands of Madeira and Porto Santo, sixty

* Four individuals of a large species of Bulimus, from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his late expedition to the Straits of Magellan. They had been packed up in a box, and enveloped in cotton; two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months; but, on being exposed by Mr. Broderip to the warmth of a fire in London, and provided with tepid water and leaves, they revived, and lived for several months in Mr. Loddiges' palm-house.

of which belonged to the genus Helix alone, including as sub-genera Bulimus and Achatina, and excluding Vitrina and Clausilia;—forty-four of these are new. It is remarkable, that very few of the above-mentioned species are common to the neighbouring archipelago of the Canaries; but it is a still more striking fact, that, of the sixty species of the three genera above mentioned, thirty-one are natives of Porto Santo; whereas, in Madeira, which contains ten times the superficies, were found but twenty-nine. Of these, only four were common to the two islands, which are only separated by a distance of twelve leagues; and two even of these four (namely, *Helix rhodostoma* and *H. ventrosa*,) are species of general diffusion, common to Madeira, the Canaries, and the South of Europe.*

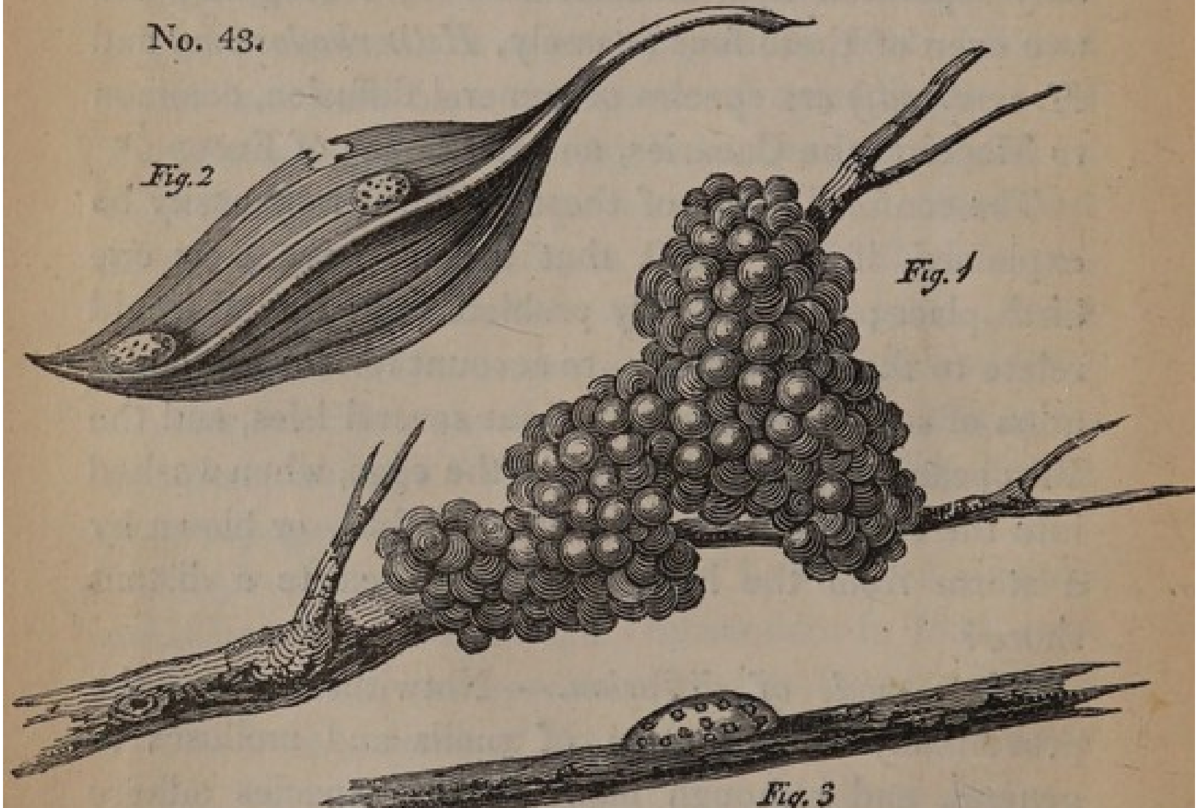
The confined range of these molluscs may easily be explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions—to account for the dissemination of some species throughout several isles, and the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

Their mode of diffusion.—Notwithstanding the proverbially slow motion of snails and molluscs in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth; and this buoyant substance floats far and wide as readily as

* Camb. Phil. Trans., vol. iv., 1831.

sea-weed. The young of other viviparous tribes are often borne along, entangled in sea-weed. Sometimes they are so light, that, like grains of sand, they can be easily moved by currents. Balani and serpulæ are sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice. In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away during floods, from tributaries to the main streams, and from thence to all parts of the same basins. Particular

No. 43.



Eggs of fresh-water Molluscs.

Fig. 1. Eggs of Ampullaria ovata (a fluviatile species), fixed to a small sprig which had fallen into the water.

Fig. 2. Eggs of Planorbis albus, attached to a dead leaf lying under water.

Fig. 3. Eggs of the common Limneus (L. vulgaris), adhering to a dead stick under water.

species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles.

An illustration of the mode of attachment of these eggs will be seen in the annexed cut. (No. 43.)

The habit of some testacea to adhere to floating wood is proved by their fixing themselves to the bottoms of ships. By this mode of conveyance *Mytilus polymorphus* has been brought from northern Europe to the Commercial Docks in the Thames, where the species is now domiciled.

A lobster (*Astacus marinus*) was lately taken alive covered with living mussels (*Mytilus edulis*)*, and a large female crab (*Cancer pagurus*), covered with oysters, and bearing also Anomia ephippium, and actiniæ, was taken in April, 1832, off the English coast. The oysters, seven in number, include individuals of six years' growth, and the two largest are four inches long and three inches and a half broad. Both the crab and the oysters were seen alive by Mr. Robert Brown.†

From this example we learn the manner in which oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on

* The specimen is preserved in the Museum of the Zool. Soc. of London.

† This specimen is in the collection of my friend Mr. Broderip, who observes, that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists have stated that the species moults annually, without limiting the moulting period to the early stages of growth of the animal.

the death of the crab. In this instance the oysters survived the crab many days, and were only killed at last by long exposure to the air.

Geographical Distribution and Migrations of Zoophytes.

Zoophytes are very imperfectly known, but there can be little doubt that each maritime region possesses species peculiar to itself. The madrepores, or lamelliferous polyparia, are found in their fullest development only in the tropical seas of Polynesia and the East and West Indies, and this family is represented only by a few species in our seas. Those even of the Mediterranean are inferior in size, and, for the most part, different from such as inhabit the tropics. Péron and Lesueur, after studying the Holothuriæ, Medusæ, and other congeners of delicate and changeable forms, came to the conclusion that each kind has its place of residence determined by the temperature necessary to support its existence. Thus, for example, they found the abode of Pyrosoma Atlantica to be confined to one particular region of the Atlantic ocean. *

Let us now inquire how the transportation of polyps from one part of the globe to another is effected. Many of them, as in the families Flustra and Sertularia, attach themselves to sea-weed, and are occasionally drifted along with it. Many fix themselves to the shells of gasteropods, and are thus borne along by them to short distances. Some polyps, like the sea-pens, swim freely about in the sea. But the most frequent mode of transportation probably consists in the buoyancy of their eggs, or certain small vesicles,

* Voy. aux Terres Australes, tome i. p. 492.

which are detached, and are capable of becoming the foundation of a new colony. These gems, as they have been called, may be swept along by a wave that breaks upon a coral reef, and may then be borne by a current to a distance.

That some zoophytes adhere to floating bodies is proved by their being found attached to the bottoms of ships, as in the case of testacea before alluded to.

Geographical Distribution and Migrations of Insects.

Before I conclude this sketch of the manner in which the habitable parts of the earth are shared out among particular assemblages of organic beings, I must offer a few remarks on insects, which by their numbers, and the variety of their powers and instincts, exert a prodigious influence in the economy of animate nature. As a large portion of these minute creatures are strictly dependent for their subsistence on certain species of vegetables, the entomological provinces must coincide in a considerable degree with the botanical.

All the insects, says Latreille, brought from the eastern parts of Asia, and China, whatever be their latitude and temperature, are distinct from those of Europe and of Africa. The insects of the United States, although often they approach very close to our own, are nevertheless specifically distinguishable by some characters. In South America, the equinoctial lands of New Granada and Peru on the one side, and of Guiana on the other, contain for the most part distinct groups; the Andes forming the division, and interposing a narrow line of severe cold between climates otherwise very similar.*

* Géographie Générale des Insectes et des Arachnides. Mém. du Mus. d'Hist. Nat., tome iii.

Migratory instincts. — The insects of the United States, even those of the northern provinces as far as Canada, differ specifically from the European, while those of Greenland appear to be in a great measure identical with our own. Some insects are very local, while a few, on the contrary, are common to remote countries, between which the torrid zone and the ocean intervene. Thus our painted lady butterfly (*Vanessa cardui*) re-appears in New Holland and Japan with scarcely a varying streak.* The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, and America; and its wide range is the more interesting, because it seems explained by its migratory instinct, seconded, no doubt, by a capacity enjoyed by few species, of enduring a great diversity of temperature.

A vast swarm of this species, forming a column from ten to fifteen feet broad, was, a few years since, observed in the Canton de Vaud; they traversed the country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers, that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin. The fact is the more worthy of notice, be-

* Kirby and Spence, vol. iv. p. 487.

cause the caterpillars of this butterfly are not gregarious, but solitary from the moment that they are hatched; and this instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Not only peculiar species but certain types distinguish particular countries; and there are groups, observes Kirby, which represent each other in distant regions, whether in their form, their functions, or in both. Thus the honey and wax of Europe, Asia, and Africa, are in each case prepared by bees congenerous with our common hive-bee (*Apis* Latr.); while, in America, this genus is nowhere indigenous, but is replaced by Melipona and Trigona; and in New Holland by a still different, but undescribed type.*

Their means of dissemination.—As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as I before stated, when speaking of floating seeds, may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air.†

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from

* Kirby and Spence, vol. iv. p. 497.

† Description of the Equatorial Regions — Malte-Brun, vol. v. p. 379.

the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they alighted at Selbourne, spreading at the same time in great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella septem-punctata*), which feed upon them.*

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the libellulæ, coccinellæ, carabi, cicadæ, &c. are not usually social insects, but seem to congregate, like swallows, merely for the purpose of emigration.† Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious, and to venture sometimes even to cross the ocean.

The armies of locusts which darken the air in Africa and traverse the globe from Turkey to our southern counties in England, are well known to all. When the western gales sweep over the Pampas, they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused, I may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint.‡ Captain W. H. Smyth

* Kirby and Spence, vol. ii. p. 9. 1817. † Id. p. 12.

‡ I am indebted to Lieutenant Graves, R.N., for this information.

was obliged to repaint his vessel, the Adventure, in the Mediterranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

To the southward of the river Plate, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's late expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned, for many can repose without sinking on the unruffled surface of the deep. The slender long-legged tipulæ have been seen standing on the surface of the sea, when driven out far from our coast, and took wing immediately on being approached.* Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt water; and the periodical appearance of some conspicuous butterflies amongst us, after being unseen for five or fifty years, has been ascribed, not without probability, to the agency of the winds.

Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c., so that when the waters subside, the entomologist may generally reap a plentiful harvest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in num-

* I state this fact on the authority of my friend, Mr. John Curtis.

berless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable, like seeds, of resisting the digestive powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

Geographical Distribution and Diffusion of Man.

I have reserved for the last some observations on the range and diffusion of the human species over the earth, and the influence of man in spreading other animals and plants, especially the terrestrial.

Many naturalists have amused themselves in speculating on the probable birth-place of mankind, the point from which, if we assume the whole human race to have descended from a single pair, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birth-place was situated within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

Progress of human population.—" The hunter state," it has been argued, " which Montesquieu placed the first, was probably only the second stage to which mankind arrived, since so many arts must have been invented to catch a salmon or a deer, that society could no longer have been in its infancy when they came into use." * When regions where the spontaneous fruits of

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate zone; but a considerable time would probably elapse before this event took place; and it is possible, as a writer before cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practised at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity.*

A distinguished modern writer, who coincides for the most part in the views above mentioned, has introduced one of the persons in his second dialogue as objecting to the theory of the human race having gradually advanced from a savage to a civilized state, on the ground that "the first man must have inevitably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force." † He then contends against the difficulty here started by various arguments, all of which were, perhaps, superfluous; for if a philosopher is pleased to indulge in conjectures on this subject, why should he not assign, as the original seat of man, some one of those large islands within the tropics, which are as free from wild beasts as Van Diemen's Land or Australia? Here man may have remained for a period, peculiar to a single isle, just as some of the large anthropomor-

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

† Sir H. Davy, Consolations in Travel, p. 74.

phous species are now limited to one island within the tropics. In such a situation, the new-born race might have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country, until the whole is covered with scattered settlements. It has been calculated that eight hundred acres of hunting-ground only produce as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost invariably been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally by seals and turtles, and was covered with a forest of trees and shrubs, all of species peculiar to it, with one or

two exceptions, and which seem to have been expressly created for this remote and insulated spot.*

Drifting of canoes to vast distances.—But very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to inquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Cook, Forster, and others, have remarked that parties of savages in their canoes must often have lost their way, and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Captain Cook found on the island of Wateoo three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is 550 miles. In 1696, two canoes, containing thirty persons, who had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of eight hundred miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Farroilep to the island of Guaham, one of the Marians, a distance of two hundred miles.†

Kotzebue, when investigating the Coral Isles of Radack, at the eastern extremity of the Caroline Isles, became acquainted with a person of the name of Kadu, who was a native of Ulea, an isle fifteen hundred miles distant, from which he had been drifted with a party. Kadu and three of his countrymen one day

* See Vol. II. p. 410.

† Malte-Brun's Geography, vol. iii. p. 419.

left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course; they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. "Kadu," says Kotzebue, "who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening." When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur, in a state of insensibility *; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.

Captain Beechey, in his late voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked, to the number of 150 souls, in three double canoes, from Anaa, or Chain Island, situate about three hundred miles to the eastward of Otaheite. They were overtaken by the monsoon, which dispersed the canoes, and, after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of, but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of six

* Kotzebue's Voyage, 1815—1818. Quarterly Review, vol. xxvi. p. 361.

hundred miles, they were found and carried to their home in the Blossom.*

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America: so that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then, to wonder, that during the ages required for some tribes of the human race to attain that advanced stage of civilization which empowers the navigator to cross the ocean in all directions with security, the whole earth should have become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we might expect their descendants, though they should never become more enlightened than the South Sea Islanders or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase, in a limited district, beyond the means of subsistence, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Involuntary Influence of Man in diffusing Animals and Plants.

Many of the general remarks which have been made respecting the influence of man in spreading or in

* Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

checking the diffusion of plants apply equally to his relations with the animal kingdom. On a future occasion, I shall be led to speak of the instrumentality of our species in naturalizing useful animals and plants in new regions, when explaining my views of the effects which the spreading and increase of certain species exert in the extirpation of others. At present I shall confine myself to a few remarks on the involuntary aid which man lends to the dissemination of species.

In the mammiferous class our influence is chiefly displayed in increasing the number of quadrupeds which are serviceable to us, and in exterminating or reducing the number of those which are noxious.

Sometimes, however, we unintentionally promote the multiplication of inimical species, as when we introduced the rat, which was not indigenous in the New World, into all parts of America. They have been conveyed over in ships, and now infest a great multitude of islands and parts of that continent. In like manner the Norway rat has been imported into England, where it plunders our property in ships and houses.

Among birds, the house sparrow may be cited as a species known to have extended its range with the tillage of the soil. During the last century it has spread gradually over Asiatic Russia towards the north and east, always following the progress of cultivation. It made its first appearance on the Irtisch in Tobolsk, soon after the Russians had ploughed the land. It came in 1735 up the Obi to Beresow, and four years after to Naryn, about fifteen degrees of longitude farther east. In 1710 it had been seen in the higher parts of the course of the Lena, in the government of Irkutzk. In all these places it is now common, but is

not yet found in the uncultivated regions of Kamtschatka.*

The great viper (*Fer de lance*), a species no less venomous than the rattle-snake, which now ravages Martinique and St. Lucia, was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects, which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to an *universal* geographical distribution.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. Notwithstanding the coldness of our climate, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North American species. "The commercial relations," says Malte-Brun†, "between France and India, have transported from the latter country the aphis which destroys the apple-tree, and two sorts of Neuroptera, the *lucifuga* and *flavicola*, mostly confined to Provence and the neighbourhood of Bordeaux, where they devour the timber in the houses and naval arsenals."

Among molluscs we may mention the *Teredo navalis*, which is a native of equatorial seas, but which, by

* Gloger, Abänd. de Vögel, p. 103.; Pallas, Zoog. Rosso-Asiat. tom. ii. p. 197.

† Syst. of Geog., vol. viii. p. 169.

adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalized in England, and other countries enjoying an extensive commerce. *Bulimus undatus*, a land species of considerable size, native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool, and is now naturalized in the woods near that town.*

In all these and innumerable other instances we may regard the involuntary agency of man as strictly analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

* On the authority of Mr. Broderip.

CHAPTER VIII.

THEORIES RESPECTING THE ORIGINAL INTRODUCTION OF SPECIES.

Proposal of an hypothesis on this subject — Supposed centres or foci of creation — Why the distinct provinces of animals and plants have not become more blended together — Brocchi's speculations on the loss of species — Stations of plants and animals — Complication of causes on which they depend — Stations of plants, how affected by animals — Equilibrium in the number of species, how preserved — Peculiar efficacy of insects in this task — Rapidity with which certain insects multiply or decrease in numbers — Effect of omnivorous animals in preserving the equilibrium of species — Reciprocal influence of aquatic and terrestrial species on each other.

Theory of Linnæus.—It would be superfluous to examine the various attempts which were made to explain the phenomena of the distribution of species alluded to in the preceding chapters, in the infancy of the sciences of botany, zoology, and physical geography. The theories or rather conjectures then indulged now stand refuted by a simple statement of facts; and if Linnæus were living, he would be the first to renounce the notions which he promulgated. For he imagined the habitable world to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primæval ocean. In this fertile spot he supposed the originals of all the species of plants which exist on this globe to have been congregated, together with the first ancestors of all animals and of the human race. "In quâ commodè habitaverint animalia omnia, et

vegetabilia lætè germinaverint." In order to accommodate the various habitudes of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were to be found all temperatures and every climate, from that of the torrid to that of the frozen zone.*

That there never was a universal ocean since the planet was inhabited, or, rather, since the oldest groups of strata yet known to contain organic remains were formed, is proved by the presence of terrestrial plants in all the older formations; and if this conclusion was not established, yet no geologist could deny that, since the first small portion of the earth was laid dry, there have been many entire changes in the species of plants and animals inhabiting the land.

A theory proposed. — But without dwelling on the above and other refuted theories, let us inquire whether some hypothesis cannot be substituted as simple as that of Linnæus, to which the phenomena now ascertained in regard to the distribution both of aquatic and terrestrial species may be referred. The following may, perhaps, be reconcileable with known facts: — Each species may have had its origin in a single pair, or individual, where an individual was sufficient, and species may have been created in succession at such times and in such places as to enable them to multiply

* De terra habitabili incremento; also Prichard, Phys. Hist. of Mankind, vol. i. p. 17., where the hypotheses of different naturalists are enumerated.

and endure for an appointed period, and occupy an appointed space on the globe.

In order to explain this theory, let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.

Now it is easy to conceive that the result of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe. It would be necessary for naturalists, before they imported species into particular localities, to study attentively the climate and other physical conditions of each spot. It would be no less requisite to introduce the different species in succession, so that each plant and animal might have time and opportunity to multiply before the species destined to prey upon it was admitted. Many herbs and shrubs, for example, must spread far and wide before the sheep, the deer, and the goat could be allowed to enter, lest they should devour and annihilate the original stocks of many plants, and then perish themselves for want of food. The above-mentioned herbivorous animals in their turn must be permitted to make considerable progress before the entrance of the first pair of wolves or lions. Insects must be allowed to swarm before the swallow could be permitted to skim through the air, and feast on thousands at one repast.

It is evident that, however equally in this case our original stocks were distributed over the whole surface of land and water, there would nevertheless arise

distinct botanical and zoological provinces, for there are a great many natural barriers which oppose common obstacles to the advance of a variety of species. Thus, for example, almost all the animals and plants naturalized by us towards the extremity of South America, would be unable to spread beyond a certain limit, towards the east, west, and south, because they would be stopped by the ocean, and a few of them only would succeed in reaching the cooler latitudes of the northern hemisphere, because they would be incapable of bearing the heat of the tropics, through which they must pass. In the course of ages, undoubtedly, exceptions would arise, and some species might become common to the temperate and polar regions, or both sides of the equator; for I have before shown that the powers of diffusion conferred on some classes are very great. But we might confidently predict that these exceptions would never become so numerous as to invalidate the general rule.

Some of the plants and animals transplanted by us to the coast of Chili or Peru would never be able to cross the Andes, so as to reach the Eastern plains; nor, for a similar reason, would those first established in the Pampas, or the valleys of the Amazon and the Orinoco, ever arrive at the shores of the Pacific.

In the ocean an analogous state of things would prevail; for there, also, climate would exert a great influence in limiting the range of species, and the land would stop the migrations of aquatic tribes as effectually as the sea arrests the dispersion of the terrestrial. As certain birds, insects, and the seeds of plants, can never cross the direction of prevailing winds, so currents form natural barriers to the dissemination of many oceanic races. A line of shoals may be as im-

passable to pelagian species, as are the Alps and the Andes to plants and animals peculiar to plains; while deep abysses may prove insuperable obstacles to the migrations of the inhabitants of shallow waters.

Supposed centres, or foci, of creation. — It is worthy of observation, that one effect of the introduction of single pairs of each species must be the confined range of certain groups in spots, which, like small islands, or solitary inland lakes, have few means of interchanging their inhabitants with adjoining regions. Now this congregating, in a small space, of many peculiar species, would give an appearance of *centres*, or *foci*, of creation, as they have been termed, as if there were favourite points where the creative energy has been in greater action than in others, and where the numbers of peculiar organic beings have consequently become more considerable.

I do not mean to call in question the soundness of the inferences of some botanists, as to the former existence of certain limited spots whence species of plants have been propagated, radiating, as it were, in all directions from a common centre. On the contrary I conceive these phenomena to be the necessary consequences of the plan of nature before suggested, operating during the successive mutations of the surface, some of which the geologist can prove to have taken place subsequently to the period when many species now existing were created. In order to exemplify how this arrangement of plants may have been produced, let us imagine that, about three centuries before the discovery of St. Helena (itself of submarine volcanic origin), a multitude of new isles had been thrown up in the surrounding sea, and that these had each become clothed with plants emigrating from St.

Helena, in the same manner as the wild plants of Campania have diffused themselves over Monte Nuovo. Whenever the first botanist investigated the new archipelago, he would, in all probability, find a different assemblage of plants in each of the isles of recent formation; but, in St. Helena itself, he would meet with individuals of every species belonging to all parts of the archipelago, and some, in addition, peculiar to itself, viz., those which had not been able to obtain a passage into any one of the surrounding new-formed lands. In this case, it might be truly said that the original isle was the primitive focus, or centre, of a certain type of vegetation, whereas, in the surrounding isles, there would be a smaller number of species, yet all belonging to the same group.

But this peculiar distribution of plants would not warrant the conclusion that, in the space occupied by St. Helena, there had been a greater exertion of creative power than in the spaces of equal area occupied by the new adjacent lands, because, within the period in which St. Helena had acquired its peculiar vegetation, each of the spots supposed to be subsequently converted into land may have been the birth-places of a great number of *marine* animals and plants, which may have had time to scatter themselves far and wide over the southern Atlantic.

Why distinct provinces not more blended.— Perhaps it may be objected to some parts of the foregoing train of reasoning, that during the lapse of past ages, especially during many partial revolutions of the globe of comparatively modern date, different zoological and botanical provinces ought to have become more confounded and blended together — that the distribution of species approaches too nearly to what might have

been expected, if animals and plants had been introduced into the globe when its physical geography had already assumed the features which it now wears; whereas we know that, in certain districts, considerable geographical changes have taken place since species identical with those now in being were created.

Brocchi's speculations on loss of species. — These, and many kindred topics, cannot be fully discussed until we have considered, not merely the general laws which may regulate the first introduction of species, but those which may limit their *duration* on the earth. Brocchi, whose untimely death in Egypt is deplored by all who have the progress of geology at heart, has remarked, when hazarding some interesting conjectures respecting "the loss of species," that a modern naturalist had no small assurance, who declared "that individuals alone were capable of destruction, and that species were so perpetuated that nature could not annihilate them, so long as the planet lasted, or at least that nothing less than the shock of a comet, or some similar disaster, could put an end to their existence."* The Italian geologist, on the contrary, had satisfied himself, that many species of testacea, which formerly inhabited the Mediterranean, had become extinct, although a great number of others, which had been the contemporaries of those lost races, still survived He came to the opinion, that about half the species which peopled the waters when the Subapennine strata were deposited, had gone out of existence; and in this inference he does not appear to have been far wrong.

But, instead of seeking a solution of this problem,

* Necker, Phytozool. Philosoph., p. 21. Brocchi, Conch. Foss. Subap., tome i. p. 229.

like some other geologists of his time, in a violent and general catastrophe, Brocchi endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiarities of constitution conferred upon them at their birth; and as the longevity of the one depends on a certain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species, which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, "until that fatal term arrives, when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated, — and so all dies with it."

Now we might coincide in opinion with the Italian naturalist, as to the gradual extinction of species one after another, by the operation of regular and constant causes, without admitting an inherent principle of deterioration in their physiological attributes. We might concede, "that many species are on the decline, and that the day is not far distant when they will cease to exist;" yet deem it consistent with what we know of the nature of organic beings, to believe that the last individuals of each species retain their prolific powers in their full intensity.

Brocchi has himself speculated on the share which a change of climate may have had in rendering the Mediterranean unfit for the habitation of certain testacea, which still continued to thrive in the Indian

Ocean, and of others which were now only represented by analogous forms within the tropics. He must also have been aware that other extrinsic causes, such as the progress of human population, or the increase of some one of the inferior animals, might gradually lead to the extirpation of a particular species, although its fecundity might remain to the last unimpaired. If, therefore, amid the vicissitudes of the animate and inanimate world, there are known causes capable of bringing about the decline and extirpation of species, it became him thoroughly to investigate the full extent to which these might operate, before he speculated on any cause of so purely hypothetical a kind, as "the diminution of the prolific virtue."

If it could have been shown that some wild plant had insensibly dwindled away and died out, as sometimes happens to cultivated varieties propagated by cuttings, even though climate, soil, and every other circumstance should continue identically the same — if any animal had perished while the physical condition of the earth, and the number and force of its foes, with every other extrinsic cause, remained unaltered, then might we have some ground for suspecting that the infirmities of age creep on as naturally on species as upon individuals. But in the absence of such observations, let us turn to another class of facts, and examine attentively the circumstances which determine the *stations* of particular animals and plants, and perhaps we shall discover, in the vicissitudes to which these stations are exposed, a cause fully adequate to explain the phenomena under consideration.

Stations of plants and animals. — Stations comprehend all the circumstances, whether relating to the animate or inanimate world, which determine whether

a given plant or animal can exist in a given locality; so that if it be shown that stations can become essentially modified by the influence of known causes, it will follow that species, as well as individuals, are mortal.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than three thousand species of plants, ten thousand insects, and a great variety in each of the other classes, yet there will not be more than a hundred, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed tract: it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of their powers of diffusion, of invading adjacent territories.

The principal causes which enable a certain assemblage of plants thus to maintain their ground against all others depend, as is well known, on the relations between the physiological nature of each species, and the climate, exposure, soil, and other physical conditions of the locality. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass, — others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so

fatal to the generality of species, affords the most proper station. The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendancy over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and, as in the case of heaths, live in societies. In like manner the Bog moss (*Sphagnum palustre*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but each plant, for reasons not fully explained by the physiologist, has the property of rendering the soil where it has grown less fitted for the support of other individuals of its own species, or even other species of the same family. Yet the same spot, so far from being impoverished, is improved, for plants of *another* family. Animals also interfere most actively to preserve an equilibrium in the vegetable kingdom.

Equilibrium in the number of species, how preserved. — "All the plants of a given country," says De Candolle, in his usual spirited style, "are at war one with another. The first which establish themselves by chance in a particular spot, tend, by the mere occupancy of space, to exclude other species — the greater choke the smaller, the longest livers replace those which last for a shorter period, the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill."

In this continual strife, it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, a herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure, because its leaves are unpalatable to cattle, which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the sunny fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may, nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with seeds which perpetuate the species throughout the surrounding tract.

In the above example we see one plant shielding another from the attacks of animals; but instances are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom.

Scarcely any beast, observes a Swedish naturalist*,

* Amœn. Acad., vol. vi. p. 17. § 12.

will touch the nettle, but fifty different kinds of insects are fed by it. Some of these seize upon the root, others upon the stem; some eat the leaves, others devour the seeds and flowers: but for this multitude of enemies, the nettle would annihilate a great number of plants. Linnæus tells us, in his Tour in Scania, that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet and water-hemlock, plants which are injurious to cattle.*

Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. "Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the Phalæna graminis (*Bombyx gram.*), with her numerous progeny, find a well-spread table: they multiply in immense numbers, and the farmer for some years laments the failure of his crop; but, the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the otner plants, which were before choked by it, spring up, and the ground becomes variegated with a multitude of different species of flowers. Had not nature given a commission to this minister for that purpose, the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up."†

In the above passage allusion is made to the ravages committed in 1740 and the two following years in many provinces in Sweden, by a most destructive insect.

* Amœn. Acad., vol. vii. p. 409.

† Ibid., vol. vi. p. 17. § 11. and 12.

The same moth is said never to touch the fox-tail grass*, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance. A discovery of Rolander, cited in the treatise of Wilcke above mentioned, affords a good illustration of the checks and counter-checks which nature has appointed to preserve the balance of power amongst species. "The Phalæna strobilella has the fir cone assigned to it to deposit its eggs upon: the young caterpillars coming out of the shell consume the cone and superfluous seed; but lest the destruction should be too general, the Ichneumon strobilellæ lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched destroys it." †

Agency of insects.—Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly appointed to prey on them.‡ Few, perhaps, are in the habit of duly appreciating the extent to which insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals.

The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing, without the intervention

* Kirby and Spence, vol. i. p. 178.

† Amœn. Acad., vol. vi. § 14.

‡ Kirby and Spence, vol. iv. p. 218.

of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which nature has been so prodigal. A scanty number of minute individuals, only to be detected by careful research, are ready in a few days, weeks, or months, to give birth to myriads, which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been executed than the gigantic power becomes dormant—each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either by the elements, or by the augmentation of some of its numerous foes which may prey upon it in these stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their

strength, and then, like Milton's spirits, which thronged the spacious hall, "reduce to smallest forms their shapes immense"—

> ———— So thick the aëry crowd
> Swarm'd and were straiten'd; till, the signal given,
> Behold a wonder! they but now who seem'd
> In bigness to surpass earth's giant sons,
> Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable, matter; and, upon considering a catalogue of eight thousand British insects and arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some appointed to consume living, others dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give birth to twenty thousand young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there was ground, says Kirby, for the assertion of Linnæus, that three flies of M. vomitoria could devour a dead horse as quickly as a lion *; and another Swedish naturalist remarks, that so great are the powers of propagation of a single species, even of the smallest insects, that each can commit, when required, more ravages than the elephant. †

* Kirby and Spence, vol. i. p. 250.

† Wilcke, Amœn. Acad., chap. ii.

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations.* Mr. Curtis † observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides; some are particular, others more general, feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than in others. In 1793 they were the chief, and in 1798 the sole, cause of the failure of the hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them, while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller moths afford a good illustration of the temporary increase of a species. The oak-trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix viridana*), which has been observed the year following not to abound.‡ The Gamma moth (*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations, but legions of their

* Kirby and Spence, vol. i. p. 174.

† Trans. Linn. Soc., vol. vi.

‡ Lib. Ent. Know., Insect Trans., p. 203. See Haworth, Lep.

caterpillars have at times created alarm in France, as in 1735. Reaumur observes that the female moth lays about four hundred eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if all fertile, would produce 800,000.* A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the two thousand other British species, would soon destroy more than half of our vegetation.†

In the latter part of the last century an ant, most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Granada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and roads were filled with them; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by torrents of rain, which accompanied a dreadful hurricane.‡

Devastations caused by locusts.—We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures, which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the

* Reaumur, ii. 237.

† Lib. Ent. Know., Insect Trans., p. 212.

‡ Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

famine they occasioned. St. Augustin mentions a plague of this kind in Africa which destroyed no less than 800,000 men in the kingdom of Masinissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591 an infinite army of locusts migrated from Africa into Italy, and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

In the Venetian territory, also, in 1478, more than thirty thousand persons are said to have perished in a famine occasioned by this scourge; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland,—in Arabia and India, and other countries,—their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in southern Africa, they were driven into the sea by a north-west wind, they formed, says Barrow, along the shore, for fifty miles, a bank three or four feet high.* But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in the temperate zone, affect the proportional numbers of almost all classes of animals and plants, and are probably fatal to the existence of many which would otherwise thrive there, while, on the contrary, they must be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this does not always happen; partly because many species feed in common on the same kinds of food, and partly because many kinds of food are often consumed indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of these insects may only cause a slight and almost imperceptible augmentation of each of these species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where our English buzzards devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, by which means the balance may be restored.

Agency of omnivorous animals. — The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus, when the racoon of the West Indies can neither procure fowls, fish, snails, nor insects, it will attack the sugar-canes, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots.

Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous, and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians, Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species. — The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated causes which determine the existence of animals and plants in certain regions. A large portion of the amphibious quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect

state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connection between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the sea-shore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years the otters at the distance of several hundred miles inland will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate a greater number of illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances, — on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed

on certain plants, being often restricted to a small number, and sometimes to one only; other members of the animal kingdom feed on plant-eating species, and thus become dependent on the conditions of the *stations* not only of their prey, but of the plants consumed by them.

Having duly reflected on the nature and extent of these mutual relations in the different parts of the organic and inorganic worlds, we may next proceed to examine the results which may be anticipated from the fluctuations now continually in progress in the state of the earth's surface, and in the geographical distribution of its living productions.

CHAPTER IX.

THE CIRCUMSTANCES WHICH CONSTITUTE THE STATIONS OF ANIMALS ARE CHANGEABLE.

Extension of the range of one species alters the condition of many others — The first appearance of a new species in a region causes the chief disturbance — Changes known to have resulted from the advance of human population — Whether man increases the productive powers of the earth — Indigenous quadrupeds and birds of Great Britain known to have been extirpated — Extinction of the Dodo — Rapid propagation of the domestic quadrupeds over the American continent — Power of exterminating species no prerogative of man — Concluding remarks.

We have seen that the stations of animals and plants depend not merely on the influence of external agents in the inanimate world, and the relations of that influence to the structure and habits of each species, but also on the state of the contemporary living beings which inhabit the same part of the globe. In other words, the possibility of the existence of a certain species in a given locality, or of its thriving more or less therein, is determined not merely by temperature, humidity, soil, elevation, and other circumstances of the like kind, but also by the existence or non-existence, the abundance or scarcity, of a particular assemblage of other plants and animals in the same region.

If it be shown that both these classes of circumstances, whether relating to the animate or inanimate creation, are perpetually changing, it will follow that species are subject to incessant vicissitudes; and if the result of these mutations, in the course of ages, be so

great as materially to affect the general condition of *stations*, it will follow that the successive destruction of species must now be part of the regular and constant order of nature.

Extension of the range of one species alters the condition of others.—It will be desirable, first, to consider the effects which every extension of the numbers or geographical range of one species must produce on the condition of others inhabiting the same regions. When the necessary consequences of such extensions have been fully explained, the reader will be prepared to appreciate the important influence which slight modifications in the physical geography of the globe may exert on the condition of organic beings.

In the first place it is clear that, when any region is stocked with as great a variety of animals and plants as the productive powers of that region will enable it to support, the addition of any new species, or the *permanent* numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way: but whilst the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the

fact that, when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

The darnel, hemlock, and rank fumitory,

pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we inclose a park, and stock it with as many deer as the herbage will support, we cannot add sheep without lessening the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey; and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, this may deprive a large number of phytophagous animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey;—certain species, perhaps, which had the weakest footing in the island may thus be annihilated.

We have seen how many distinct geographical provinces there are of aquatic and terrestrial species, and how great are the powers of migration conferred on different classes, whereby the inhabitants of one region may be enabled from time to time to invade another, and do actually so migrate and diffuse themselves over new countries. Now, although our knowledge of the history of the animate creation dates from so recent a period, that we can scarcely trace the advance

or decline of any animal or plant, except in those cases where the influence of man has intervened, yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the Polar bear into Iceland.— Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that, when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms — each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm; nor did our islanders muster more promptly for the defence of their lives and property against a common enemy than the modern Icelanders against these formidable brutes. It often happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been heightened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape.*

Let us cast our thoughts back to the period when the first Polar bears reached Iceland, before it was colonized by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice, like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had surrounded for four centuries. By the aid of such means

* Journal of a Residence in Iceland, p. 276.

of transportation a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region; and the changes caused indirectly would ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation, its nests being seldom if ever found on the shores of the main

land, or even of a large island. The Icelanders are so well aware of this, that they have expended a great deal of labour in forming artificial islands, by separating from the main land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Hooker*, it happened that, in the small island of Vidoc, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alar m ,as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.

The first appearance of a new species causes the chief disturbance.—It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitively settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two centuries a frost of unusual intensity, or a volcanic eruption of great violence accompanied by floods from the melt-

* Tour in Iceland, vol. i. p. 64. second edition.

ing of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others,—these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comer, such as the bear before mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, may pass away without any great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at preceding periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by famine, in consequence of the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

Changes caused by Man.

We are best acquainted with the mutations brought about by the progress of human population, and the growth of plants and animals favoured by man. To

these, therefore, we should, in the first instance, turn our attention. If we conclude, from the concurrent testimony of history and of the evidence yielded by geological data, that man is, comparatively speaking, of very modern origin, we must at once perceive how great a revolution in the state of the animate world the increase of the human race, considered merely as consumers of a certain quantity of organic matter, must necessarily cause.

Whether man increases the productive powers of the earth.—It may, perhaps, be said, that man has, in some degree, compensated for the appropriation to himself of so much food, by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt whether, upon the whole, we fertilize or impoverish the lands which we occupy. This assertion may seem startling to many, because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass is converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface—that we have not empowered it to support a larger quantity of organic life. In such cases, however, a tract, before of no utility to man, may be reclaimed, and become of high agricultural importance, though it may, nevertheless, yield a scantier vegetation. If a lake be drained, and turned into a meadow, the space will provide sustenance to man, and many terrestrial ani-

mals serviceable to him, but not, perhaps, so much food as it previously yielded to the aquatic races.

If the pestiferous Pontine Marshes were drained, and covered with corn, like the plains of the Po, they might, perhaps, feed a smaller number of animals than they do now; for these morasses are filled with herds of buffaloes and swine, and they swarm with birds, reptiles, and insects.

The felling of dense and lofty forests, which covered, even within the records of history, a considerable space on the globe, now tenanted by civilized man, must generally have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilizing effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti,

and wild swine. They describe the torment which the planter and the naturalist suffer from the musquitoes, and the devastation of the ants and blattæ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, lizards, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, observe these naturalists, these evils will gradually diminish; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will, by degrees, triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity.*

The number of human beings now peopling the earth is supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds, and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

Indigenous quadrupeds and birds extirpated in Great Britain.—Let us make some inquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of our indigenous British animals. Dr. Fleming has prosecuted this inquiry with his usual zeal and ability; and in a memoir† on the subject has enumerated the best authenticated examples of the decrease or extirpation of certain

* Travels in Brazil, vol. i. p. 260.

† Ed. Phil. Journ., No. xxii. p. 287. Oct. 1824.

species during a period when our population has made the most rapid advances. I shall offer a brief outline of his results.

The stag, as well as the fallow deer and the roe, were formerly so abundant in our island, that, according to Lesley, from five hundred to a thousand were sometimes slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the pole-cat, were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district which at former periods they inhabited.

Besides these, which have been driven out from some haunts, and every where reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, and the wild boar; of the wild oxen, a few remains are still preserved in the parks of some of our nobility. The beaver, which was eagerly sought after for its fur, had become scarce at the close of the ninth century; and, by the twelfth century, was only to be met with, according to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England at a much earlier period. The bear, which, in Wales, was regarded as a beast of the chase equal to the hare or

the boar*, only perished, as a native of Scotland, in the year 1057.†

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British isles; whereas the large capercailzies, or wood grouse, formerly natives of the pine-forests of Ireland and Scotland, have been destroyed within the last fifty years. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants.‡

The bustard (*Otis tarda*), observes Graves, in his British Ornithology§, "was formerly seen in the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now a circumstance of rare occurrence to meet with a single individual." Bewick also remarks, "that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east—in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire." In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from Wiltshire and Dorsetshire.‖

These changes, it may be observed, are derived from very imperfect memorials, and relate only to the larger and more conspicuous animals inhabiting a small

* Ray, Syn. Quad., p. 214.

† Fleming, Ed. Phil. Journ., No. xxii. p. 295.

‡ Fleming, ibid., p. 292.

§ Vol. iii., London, 1821.

‖ Land Birds, vol. i. p. 316. ed. 1821.

spot on the globe; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of several thousand years, the whole human species must have effected.

Extinction of the Dodo.—The kangaroo and the emu are retreating rapidly before the progress of colonization in Australia; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last two centuries, of a remarkable species, is that of the dodo—a bird first seen by the Dutch, when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size, and singular form; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.

Many naturalists gave figures of the dodo after the commencement of the seventeenth century; and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head, in an imperfect state, but M. Cuvier doubts the identity of this species with that of which the painting is preserved in London.*

* Some have complained that inscriptions on tomb-stones convey no general information, except that individuals were born and died—accidents which must happen alike to all men. But the death of a *species* is so remarkable an event in natural history, that

In spite of the most active search, during the last century, no information respecting the dodo was obtained, and some authors have gone so far as to pretend that it never existed; but, amongst a great mass of satisfactory evidence in favour of the recent existence of this species, we may mention that an assemblage of fossil bones were recently discovered, under a bed of lava, in the Isle of France, and sent to the Paris Museum by M. Desjardins. They almost all belonged to a large living species of land-tortoise, called *Testudo Indica*, but amongst them were the head, sternum, and humerus of the dodo. M. Cuvier showed me these valuable remains in Paris, and assured me that they left no doubt in his mind that the huge bird was one of the gallinaceous tribe.*

Rapid propagation of domestic quadrupeds over the American continent.—Next to the direct agency of man, his indirect influence in multiplying the numbers of large herbivorous quadrupeds of domesticated races may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three cen-

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it deserves commemoration; and it is with no small interest that we learn, from the archives of the University of Oxford, the exact day and year when the remains of the last specimen of the dodo, which had been permitted to rot in the Ashmolean museum, were cast away. The relics, we are told, were "a Musæo subducta, annuente Vice-cancellario aliisque curatoribus, ad ea lustranda convocatis, die Januarii, 8vo., A. D. 1755."—Zool. Journ., No. 12. p. 559. 1828.

* Sur quelques Ossemens, &c.—Ann. des Sci., tome xxi. p. 103. Sept. 1830.

turies, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which over-ran the plains of South America sprung from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels*, on the authority of Azzara, that it is believed there exist, in the Pampas of Buenos Ayres, twelve million cows and three million horses, without comprising, in this enumeration, the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as fourteen thousand a year. In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that 1,200,000 oxen, 180,000 horses, and 90,000 mules, wandered at large.† In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses are immensely numerous.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of

* Pers. Nar., vol. iv.

† Quarterly Review, vol. xxi. p. 335.

four thousand head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to eight thousand. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was 35,444; and in the same year there were exported 64,350 from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into that country, had not been able to engage in any thing else than war.*

All our readers are aware that these animals are now established throughout the American continent, from Canada to Paraguay.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked, defended themselves with their mouths. If a horse happened to stray into the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead.†

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery, in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled; and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat, which last, as before stated, has been imported unintentionally in ships. The

* Quarterly Review, vol. xxi. p. 335.

† Ulloa's Voyage. Wood's Zoog., vol. i. p. 9.

dogs introduced by man, which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Ulloa in his voyage, and Buffon on the authority of old writers, relate a fact which illustrates very clearly the principle before explained by us, of the check which the increase of one animal necessarily offers to that of another. The Spaniards had introduced goats into the island of Juan Fernandez, where they became so prolific as to furnish the pirates who infested those seas with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased.*

Increase of rein-deer imported into Iceland.—As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, I may mention, that in the year 1773 thirteen rein-deer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty years, that it was not uncommon to meet with herds consisting of from forty to one hundred in various districts.

In Lapland, observes a modern writer, the rein-deer is a loser by his connexion with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than forty thousand square miles, without a single

* Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the rein-deer, being almost unmolested by man, will have no enemy whatever, unless it has brought with it its own tormenting gad-fly.*

Besides the quadrupeds before enumerated, our domestic fowls have also succeeded in the West Indies and America, where they have the common fowl, the goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations they became familiarized to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries.

The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe. That it should have remained for us to witness such mighty revolutions is a proof, even if there was no other evidence, that the entrance of man into the planet is, comparatively speaking, of extremely modern date, and that the effects of his agency are only beginning to be felt.

* Travels in Iceland in 1810, p. 342.

Population which the globe is capable of supporting.—A modern writer has estimated, that there are in America upwards of four million square miles of useful soil, each capable of supporting two hundred persons; and nearly six million, each mile capable of supporting 490 persons.* If this conjecture be true, it will follow, as that author observes, that if the natural resources of America were fully developed, it would afford sustenance to five times as great a number of inhabitants as the entire mass of human beings existing at present upon the globe. The new continent, he thinks, though less than half the size of the old, contains an equal quantity of useful soil, and much more than an equal amount of productive power. Be this as it may, we may safely conclude that the amount of human population now existing constitutes but a small proportion of that which the globe is capable of supporting, or which it is destined to sustain at no distant period, by the rapid progress of society, especially in America, Australia, and certain parts of the old continent.

Power of exterminating species no prerogative of man.—But if we reflect that many millions of square miles of the most fertile land, occupied originally by a boundless variety of animal and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly-civilized nations spread themselves over unoccupied lands.

* Maclaren, art. America. Encyc. Britannica.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc committed, nor to fancy, with the Scotch poet, that "we violate the social union of nature;" or complain, with the melancholy Jaques, that we

> Are mere usurpers, tyrants, and what 's worse,
> To fright the animals and to kill them up
> In their assign'd and native dwelling-place.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called "the rust" in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the "lords of the creation." The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks. — Although we have as yet considered one class only of the causes (the organic) whereby species may become exterminated, yet it cannot but appear evident that the continued action of these alone, throughout myriads of future ages, must work an entire change in the state of the organic creation, not merely on the continents and islands, where the power of man is chiefly exerted, but in the great ocean, where his control is almost unknown.

The mind is prepared by the contemplation of such future revolutions to look for the signs of others, of an analogous nature, in the monuments of the past. Instead of being astonished at the proofs there manifested of endless mutations in the animate world, they will appear to one, who has thought profoundly on the fluctuations now in progress, to afford evidence in favour of the uniformity of the system, unless, indeed, we are precluded from speaking of *uniformity* when we characterize a principle of endless variation.

CHAPTER X.

INFLUENCE OF INORGANIC CAUSES IN CHANGING THE HABITATIONS OF SPECIES.

Powers of diffusion indispensable, that each species may maintain its ground — How changes in the physical geography affect the distribution of species — Rate of the change of species due to this cause cannot be uniform — Each change in the physical geography of large regions must occasion the extinction of species — Effects of a general alteration of climate on the migration of species — Gradual refrigeration would cause species in the northern and southern hemispheres to become distinct — elevation of temperature the reverse — Effects on the condition of species which must result from inorganic changes why inconsistent with the theory of transmutation.

Powers of diffusion indispensable that each species may maintain its ground. —HAVING shown in the last chapter how considerably the numerical increase or the extension of the geographical range of any one species must derange the numbers and distribution of others, let us now direct our attention to the influence which the inorganic causes described in the second book are continually exerting on the habitations of species.

So great is the instability of the earth's surface, that if nature were not continually engaged in the task of sowing seeds and colonizing animals, the depopulation of a certain portion of the habitable sea and land would in a few years be considerable. Whenever a river transports sediment into a lake or sea, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain

useless, but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river banishes many subaqueous species from their native abodes; but the new-formed plain is not permitted to lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coast, and precipitates forests or rich pasture land into the waves; but this space is not lost to the animate creation, for shells and sea-weed soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic isle been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure, while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks, pines, and chestnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every advance of the sand-flood, every conversion of salt-water into fresh when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary—these and countless other causes displace in the course of a few centuries certain

plants and animals from stations which they previously occupied. If, therefore, the Author of nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth—if he had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the dark abysses of the ocean, or the moving sands of the Sahara.

The powers then of migration and diffusion conferred on animals and plants are indispensable to enable them to maintain their ground, and would be necessary even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other, since the strongest of those barriers which I before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

How changes in physical geography affect the distribution of species.—The numbers and distribution of particular species are affected in two ways, by changes in the physical geography of the earth. First, these changes promote or retard the migrations of species; secondly, they alter the physical conditions of the localities which species inhabit. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas previously disjoined, and would, at the same time, close a free communication

which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land which formed the isthmus into sea. This space previously occupied by terrestrial plants and animals would be immediately delivered over to the aquatic, a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of species of two distinct provinces.

Rate of change of species cannot be uniform.—This observation leads me to point out one of the most interesting conclusions to which we are led by the contemplation of the vicissitudes of the inanimate world in relation to those of the animate. It is clear that, if the agency of inorganic causes be uniform, as I have supposed, they must operate very irregularly on the state of organic beings, so that the rate according to which these will change in particular regions will not be equal in equal periods of time.

I am not about to advocate the doctrine of general catastrophes recurring at certain intervals, as in the ancient oriental cosmogonies, nor do I doubt that, if very considerable periods of equal duration could be taken into our consideration and compared one with another, the rate of change in the living, as well as in the inorganic world, would be nearly uniform; but if we regard each of the causes separately, which we know to be at present the most instrumental in remodelling the state of the surface, we shall find that we must expect each to be in action for thousands of years,

without producing any extensive alterations in the habitable surface, and then to give rise, during a very brief period, to important revolutions.

Illustration derived from subsidences by earthquakes.—I shall illustrate this principle by a few of the most remarkable examples which present themselves. In the course of the last century, as we have seen, a considerable number of instances are recorded of the solid surface, whether covered by water or not, having been permanently sunk or upraised by the power of earthquakes. Most of these convulsions are only accompanied by temporary fluctuations in the state of limited districts, and a continued repetition of these events for thousands of years might not produce any decisive change in the state of many of those great zoological or botanical provinces of which I have sketched the boundaries.

When, for example, large parts of the ocean and even of inland seas are a thousand fathoms or upwards in depth, it is a matter of no moment to the animate creation that vast tracts should be heaved up many fathoms at certain intervals, or should subside to the same amount. Neither can any material revolution be produced in South America either in the terrestrial or the marine plants or animals by a series of shocks on the coast of Chili, each of which, like that of Penco, in 1750, should uplift the coast about twenty-five feet. Nor if the ground sinks fifty feet at a time, as in the harbour of Port Royal, in Jamaica, in 1692, will such alterations of level work any general fluctuations in the state of organic beings inhabiting the West India islands, or the Caribbean Sea.

It is only when these subterranean powers, by shifting gradually the points where their principal force is

developed, happen to strike upon some particular region where a slight change of level immediately affects the distribution of land and water, or the state of the climate, or the barriers between distinct groups of species over extensive areas, that the rate of fluctuation becomes accelerated, and may, in the course of a few years or centuries, work mightier changes than had been experienced in myriads of antecedent years.

Thus, for example, a repetition of subsidences causing the narrow isthmus of Panamá to sink down a few hundred feet, would, in a few centuries, bring about a great revolution in the state of the animate creation in the western hemisphere. Thousands of aquatic species would pass for the first time from the Caribbean Sea into the Pacific; and thousands of others, before peculiar to the Pacific Ocean, would make their way into the Caribbean Sea, the Gulf of Mexico, and the Atlantic. A considerable modification would probably be occasioned by the same event in the direction or volume of the Gulf stream, and thereby the temperature of the sea and the contiguous lands might be altered as far as the influence of that current extends. A change of climate might thus be produced in the ocean from Florida to Spitzbergen, and in many countries of North America, Europe, and Greenland. Not merely the heat, but the quantity of rain which falls would be altered in certain districts, so that many species would be excluded from tracts where they before flourished; others would be reduced in number; and some would thrive more and multiply. The seeds also and the fruits of plants would no longer be drifted in precisely the same directions, nor the eggs of aquatic animals; neither would species be any longer impeded in their migrations towards particular stations before shut out from them by their inability to cross the mighty current.

Let us take another example from a part of the globe which is at present liable to suffer by earthquakes, namely, the low sandy tract which intervenes between the sea of Azof and the Caspian. If there should occur a sinking down to a trifling amount, and such ravines should be formed as might be produced by a few earthquakes, not more considerable than have fallen within our limited observation during the last 140 years, the waters of the sea of Azof would pour rapidly into the Caspian, which, according to the levellings of the Russian travellers, Engelhardt and Parrot *, is about 350 feet below the level of the Black Sea. The sea of Azof would immediately borrow from the Euxine, the Euxine from the Mediterranean, and the Mediterranean from the Atlantic, so that an inexhaustible current would pour down into the low tracts of Asia bordering the Caspian, by which all the sandy salt steppes adjacent to that sea would be inundated. An area of at least eighteen thousand square leagues, now below the level of the Mediterranean, would be converted from land into sea.

The diluvial waters would reach the salt lake of Aral, nor stop until their eastern shores were bounded by the high land which in the steppe of the Kirghis connects the Altay with the Himalaya mountains. Saratof, Orenburg, and the low regions of the Oxus and Jaxartes, would be submerged. A few years, perhaps a few months, might suffice for the accomplishment of this great revolution in the geography of the interior of Asia; and it is impossible for those who believe in the

* Reise in den Kaukasus.—I have stated about 300 feet, Vol. II. p. 51.; but the exact amount ascertained, both by levellings and barometrical observations, was fifty-four toises and a half, or 348·39 English feet.

permanence of the energy with which existing causes now act, not to anticipate analogous events again and again in the course of future ages.

Illustration derived from the elevation of land.—Let us next imagine a few cases of the elevation of land of small extent at certain critical points, as, for example, in the shallowest parts of the Straits of Gibraltar, where the soundings from the African to the European side give only 220 fathoms. In proportion as this submarine barrier of rock was upheaved, to effect which would merely require the shocks of partial and confined earthquakes, the volume of water which pours in from the Atlantic into the Mediterranean would be lessened. But the loss of the inland sea by evaporation would remain the same, so that being no longer able to draw on the ocean for a supply sufficient to restore its equilibrium, it must sink, and leave dry a certain portion of land around its borders. The current which now flows constantly out of the Black Sea into the Mediterranean would then rush in more rapidly, and the level of the Mediterranean would be thereby prevented from falling so low; but the level of the Black Sea would, for the same reason, sink: so that when, by a continued series of elevatory movements, the Straits of Gibraltar had become completely closed up, we might expect large and level sandy steppes to surround both the Euxine and Mediterranean, like those occurring at present on the skirts of the Caspian, and the Lake of Aral. The geographical range of hundreds of aquatic species would be thereby circumscribed, and that of hundreds of terrestrial plants and animals extended.

A line of submarine volcanos crossing the channel of some strait, and gradually choking it up with ashes and lava, might produce a new barrier as effectually as a series of earthquakes; especially if thermal springs,

charged with carbonate of lime, silica, and other mineral ingredients, should promote the rapid multiplication of corals and shells, and cement them together with solid matter precipitated during the intervals between eruptions. Suppose in this manner a stoppage to be caused of the Bahama Channel between the bank of that name and the coast of Florida. This insignificant revolution, confined to a mere spot in the bottom of the ocean, would, by diverting the main current of the Gulf stream, give rise more effectually than the opening of the Straits of Panamá, before supposed, to extensive changes in the climate and distribution of animals and plants inhabiting the northern hemisphere.

Illustration from the formation of new islands.—A repetition of elevatory movements of earthquakes might continue over an area as extensive as Europe, for thousands of ages, at the bottom of the ocean, in certain regions, and produce no visible effects; whereas, if they should operate in some shallow parts of the Pacific, amid the coral archipelagos, they would soon give birth to a new continent. Hundreds of volcanic islands may be thrown up, and become covered with vegetation, without causing more than local fluctuations in the animate world; but if a chain like the Aleutian archipelago, or the Kurile isles, run for a distance of many hundred miles, so as to form an almost uninterrupted communication between two continents, or two distant islands, the migrations of plants, birds, insects, and even of some quadrupeds, may cause, in a short time, an extraordinary series of revolutions tending to augment the range of some animals and plants, and to limit that of others. A new archipelago might be formed in the Mediterranean, the Bay of Biscay, and a thousand other localities, and might

produce less important events than one rock which should rise up between Australia and Java, so placed that winds and currents might cause an interchange of the plants, insects, and birds of the latter country.

From the wearing through of an isthmus.—If we turn from the igneous to the aqueous agents, we find the same tendency to an irregular rate of change, naturally connected with the strictest uniformity in the energy of those causes. When the sea, for example, gradually encroaches upon both sides of a narrow isthmus, as that of Sleswick, separating the North Sea from the Baltic, where, as before stated, the cliffs on both the opposite coasts are wasting away*, no material alteration results for thousands of years, save only that there is a progressive conversion of a small strip of land into water. A few feet only, or a few yards, are annually removed; but when, at last, the partition shall be broken down, and the tides of the ocean shall enter by a direct passage into the inland sea, instead of going by a circuitous route through the Cattegat, a body of salt water will sweep up as far as the Gulfs of Bothnia and Finland, the waters of which are now brackish, or almost fresh; and this revolution will be attended by the local annihilation of many species.

Similar consequences must have resulted, on a small scale, when the sea opened its way through the isthmus of Staveren in the thirteenth century, forming an union between an inland lake and the ocean, and opening, in the course of one century, a shallow strait, more than half as wide as the narrowest part of that which divides England from France.

* Vol. II. p. 8.

Changes in physical geography which must occasion extinction of species.—It will almost seem superfluous, after I have thus traced the important modifications in the condition of living beings which flow from changes of trifling extent, to argue that entire revolutions might be brought about, if the climate and physical geography of the whole globe were greatly altered. It has been stated, that species are in general local, some being confined to extremely small spots, and depending for their existence on a combination of causes, which, if they are to be met with elsewhere, occur only in some very remote region. Hence it must happen that, when the nature of these localities is changed, the species will perish; for it will rarely happen that the cause which alters the character of the district will afford new facilities to the species to establish itself elsewhere.

African desert.—If we attribute the origin of a great part of the desert of Africa to the gradual progress of moving sands, driven eastward by the westerly winds, we may safely infer, that a variety of species must have been annihilated by this cause alone. The sand-flood has been inundating, from time immemorial, the rich lands on the west of the Nile, and we have only to multiply this effect a sufficient number of times, in order to understand how, in the lapse of ages, a whole group of terrestrial animals and plants may become extinct.

This desert, without including Bornou and Darfour, extends, according to the calculation of Humboldt, over 194,000 square leagues, an area nearly three times as great as that of France. In a small portion of so vast a space, we may infer from analogy that there were many peculiar species of plants and animals

which must have been banished by the sand, and their habitations invaded by the camel, and by birds and insects formed for the arid sands.

There is evidently nothing in the nature of the catastrophe to favour the escape of the former inhabitants to some adjoining province; nothing to weaken, in the bordering lands, that powerful barrier against emigration — pre-occupancy. Nor, even if the exclusion of a certain group of species from a given tract were compensated by an extension of their range over a new country, would that circumstance tend to the conservation of species in general; for the extirpation would merely then be transferred to the region so invaded. If it be imagined, for example, that the aboriginal quadrupeds, birds, and other animals of Africa, emigrated in consequence of the advance of drift-sand, and colonized Arabia, the indigenous Arabian species must have given way before them, and have been reduced in number or destroyed.

Let us next suppose that, in some central and more elevated parts of the great African desert, the upheaving power of earthquakes should be exerted throughout an immense series of ages, accompanied, at certain intervals, by volcanic eruptions, such as gave rise at once, in 1755, to a mountain 1600 feet high, on the Mexican plateau. When the continued repetition of these events had caused a mountain-chain, it is obvious that a complete transformation in the state of the climate would be brought about throughout a vast area.

We may imagine the summits of the new chain to rise so high as to be covered, like Mount Atlas, for several thousand feet, with snow, during a great part of the year. The melting of these snows, during the

greatest heat, would cause the rivers to swell in the season when the greatest drought now prevails; the waters, moreover, derived from this source, would always be of lower temperature than the surrounding atmosphere, and would thus contribute to cool the climate. During the numerous earthquakes and volcanic eruptions supposed to accompany the gradual formation of the chain, there would be many floods caused by the bursting of temporary lakes, and by the melting of snows by lava. These inundations might deposit alluvial matter far and wide over the original sands, as the country assumed various shapes, and was modified again and again by the moving power from below, and the aqueous erosion of the surface above. At length the Sahara might be fertilized, irrigated by rivers and streamlets intersecting it in every direction, and covered by jungle and morasses, so that the animals and plants which now people Northern Africa would disappear, and the region would gradually become fitted for the reception of a population of species perfectly dissimilar in their forms, habits, and organization.

There are always some peculiar and characteristic features in the physical geography of each large division of the globe; and on these peculiarities the state of animal and vegetable life is dependent. If, therefore, we admit incessant fluctuations in the physical geography, we must, at the same time, concede the successive extinction of terrestrial and aquatic species to be part of the economy of our system. When some great class of *stations* is in excess in certain latitudes, as, for example, in wide savannahs, arid sands, lofty mountains, or inland seas, we find a corresponding development of species adapted for such

circumstances. In North America, where there is a chain of vast inland lakes of fresh water, we find an extraordinary abundance and variety of aquatic birds, fresh-water fish, testacea, and small amphibious reptiles, fitted for such a climate. The greater part of these would perish if the lakes were destroyed,—an event that might be brought about by some of the least of those important revolutions contemplated in geology. It might happen, that no fresh-water lakes of corresponding magnitude might then exist on the globe; or that, if they occurred elsewhere, they might be situated in New Holland, Southern Africa, Eastern Asia, or some region so distant as to be quite inaccessible to the North American species; or they might be situated within the tropics, in a climate uninhabitable by species fitted for a temperate zone; or, finally, we may presume that they would be pre-occupied by *indigenous* tribes.

To pursue this train of reasoning farther is unnecessary; the reader has only to reflect on what has been said of the habitations and stations of organic beings in general, and to consider them in relation to those effects which were contemplated in the second book, as resulting from the igneous and aqueous causes now in action, and he will immediately perceive that, amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish, one after the other, like the individuals which compose them. There is no possibility of escaping from this conclusion, without resorting to some hypothesis as violent as that of Lamarck, who imagined, as we have before seen, that species are each of them endowed with indefinite powers of modifying their organization, in

conformity to the endless changes of circumstances to which they are exposed.

Effects of a general Alteration in Climate on the Distribution of Species.

Some of the effects which must attend every general alteration of *climate* are sufficiently peculiar to claim a separate consideration before concluding the present chapter.

I have before stated that, during seasons of extraordinary severity, many northern birds, and, in some countries, many quadrupeds, migrate southwards. If these cold seasons were to become frequent, in consequence of a gradual and general refrigeration of the atmosphere, such migrations would be more and more regular, until, at length, many animals, now confined to the arctic regions, would become the tenants of the temperate zone; while the inhabitants of the latter would approach nearer to the equator. At the same time, many species previously established on high mountains would begin to descend, in every latitude, towards the middle regions; and those which were confined to the flanks of mountains would make their way into the plains. Analogous changes would also take place in the vegetable kingdom.

If, on the contrary, the heat of the atmosphere be on the increase, the plants and animals of low grounds would ascend to higher levels, the equatorial species would migrate into the temperate zone, and those of the temperate into the arctic circle.

But although some species might thus be preserved, every great change of climate must be fatal to many which can find no place of retreat when their original

habitations become unfit for them. For if the general temperature be on the rise, then is there no cooler region whither the polar species can take refuge; if it be on the decline, then the animals and plants previously established between the tropics have no resource. Suppose the general heat of the atmosphere to increase, so that even the arctic region became too warm for the musk-ox and rein-deer, it is clear that they must perish; so, if the torrid zone should lose so much of its heat by the progressive refrigeration of the earth's surface, as to be an unfit habitation for apes, boas, bamboos, and palms, these tribes of animals and plants, or, at least, most of the species now belonging to them, would become extinct, for there would be no warmer latitudes for their reception.

It will follow, therefore, that as often as the climates of the globe are passing from the extreme of heat to that of cold,—from the summer to the winter of the great year before alluded to*,—the migratory movement will be directed constantly from the poles towards the equator; and for this reason the species inhabiting parallel latitudes, in the northern and southern hemispheres, must become widely different. For I assume, on grounds before explained†, that the original stock of each species is introduced into one spot of the earth only, and, consequently, no species can be at once indigenous in the arctic and antarctic circles.

But when, on the contrary, a series of changes in the physical geography of the globe, or any other supposed cause, occasions an elevation of the general temperature,—when there is a passage from the winter

* Book I. chap. vii. † Chap. viii.

to one of the vernal or summer seasons of the great cycle of climates, — then the order of the migratory movement is inverted. The different species of animals and plants direct their course from the equator towards the poles; and the northern and southern hemispheres may become peopled, to a great degree, by identical species. Such is not the actual state of the inhabited earth, as I have already shown in my sketch of the geographical distribution of its living productions; and this fact adds an additional proof to the geological evidence, derived from independent sources, that the general temperature has been cooling down during the epochs which immediately preceded our own.

I do not mean to speculate on the entire transposition of a group of animals and plants from tropical to polar latitudes, or the reverse, as a probable, or even possible, event; for although we believe the mean annual temperature of one zone to be transferrible to another, we know that the same climate cannot be so transferred. Whatever be the general temperature of the earth's surface, comparative equability of heat will characterize the tropical regions, while great periodical variations will belong to the temperate, and still more to the polar, latitudes. These, and many other peculiarities connected with heat and light, depend on fixed astronomical causes, such as the motion of the earth and its position in relation to the sun, and not on those fluctuations of its surface, which may influence the general temperature.

Among many obstacles to such extensive transference of habitations we must not forget the immense lapse of time required, according to the hypothesis before suggested*, to bring about a considerable change

* See Book I. chap. vi. vii. and viii.

in climate. During a period so vast, the other causes of extirpation, before enumerated, would exert so powerful an influence as to prevent all, save a very few hardy species, from passing from equatorial to polar regions, or from the tropics to the pole.

But the power of accommodation to new circumstances is great in certain species, and might enable many to pass from one zone to another, if the mean annual heat of the atmosphere and the ocean were greatly altered. To the marine tribes, especially, such a passage would be possible, for they are less impeded in their migrations, by barriers of land, than are the terrestrial by the ocean. Add to this, that the temperature of the ocean is much more uniform than that of the atmosphere investing the land, so that we may easily suppose that most of the testacea, fish, and other classes, might pass from the equatorial into the temperate regions, if the mean temperature of those regions were transposed, although a second expatriation of these species of tropical origin into the arctic and antarctic circles would probably be impossible.

On the principles above explained, if we found that at some former period, as when, for example, our carboniferous strata were deposited, the same tree-ferns and other plants inhabited the regions now occupied by Europe and Van Diemen's Land, we should suspect that the species in question had, at some antecedent period, inhabited lands within the tropics, and that an increase of the mean annual heat had caused them to emigrate into both the temperate zones. There are no geological data, however, as yet obtained, to warrant the opinion that such identity of species existed in the two hemispheres in the era in question.

Let us now consider more particularly the effect of

vicissitudes of climate in causing one species to give way before the increasing numbers of some other.

When temperature forms the barrier which arrests the progress of an animal or plant in a particular direction, the individuals are fewer and less vigorous as they approach the extreme confines of the geographical range of the species. But these stragglers are ready to multiply rapidly on the slightest increase or diminution of heat that may be favourable to them, just as particular insects increase during a hot summer, and certain plants and animals gain ground after a series of congenial seasons.

In almost every district, especially if it be mountainous, there are a variety of species the limits of whose habitations are conterminous, some being unable to proceed farther without encountering too much heat, others too much cold. Individuals, which are thus on the borders of the regions proper to their respective species, are like the outposts of hostile armies, ready to profit by every slight change of circumstances in their favour, and to advance upon the ground occupied by their neighbours and opponents.

The proximity of distinct climates, produced by the inequalities of the earth's surface, brings species possessing very different constitutions into such immediate contact, that their naturalizations are very speedy whenever opportunities of advancing present themselves. Many insects and plants, for example, are common to low plains within the arctic circle, and to lofty mountains in Scotland and other parts of Europe. If the climate, therefore, of the polar regions were transferred to our own latitudes, the species in question would immediately descend from these elevated stations to over-run the low grounds. Invasions of this

kind, attended by the expulsion of the pre-occupants, are almost instantaneous, because the change of temperature not only places the one species in a more favourable position, but renders the others sickly and almost incapable of defence.

These changes inconsistent with the theory of transmutation.—Lamarck, when speculating on the transmutation of species, supposed every modification in organization and instinct to be brought about slowly and insensibly in an indefinite lapse of ages. But he does not appear to have sufficiently considered how much every alteration in the physical condition of the habitable surface changes the relations of a great number of co-existing species, and that some of these would be ready instantly to avail themselves of the slightest change in their favour, and to multiply to the injury of others. Even if we thought it possible that the palm or the elephant, which now flourish in equatorial regions, could ever learn to bear the variable seasons of our temperate zone, or the rigours of an arctic winter, we might, with no less confidence, affirm, that they must perish before they had time to become habituated to such new circumstances. That they would be displaced by other species as often as the climate varied, may be inferred from the data before explained respecting the local extermination of species produced by the multiplication of others.

Suppose the climate of the highest part of the woody zone of Etna to be transferred to the sea-shore at the base of the mountain, no botanist would anticipate that the olive, lemon-tree, and prickly pear (*Cactus opuntia*), would be able to contend with the oak and chestnut, which would begin forthwith to descend to a lower level, or that these last would be able to stand their ground

against the pine, which would also, in the space of a few years, begin to occupy a lower position. We might form some kind of estimate of the time which might be required for the migrations of these plants; whereas we have no data for concluding that any number of thousands of years would be sufficient for one step in the pretended metamorphosis of one species into another, possessing distinct attributes and qualities.

This argument is applicable not merely to *climate*, but to any other cause of mutation. However slowly a lake may be converted into a marsh, or a marsh into a meadow, it is evident that before the lacustrine plants can acquire the power of living in marshes, or the marsh-plants of living in a less humid soil, other species, already existing in the region, and fitted for these several stations, will intrude and keep possession of the ground. So if a tract of salt water becomes fresh by passing through every intermediate degree of brackishness, still the marine molluscs will never be permitted to be gradually metamorphosed into fluviatile species; because long before any such transformation can take place by slow and insensible degrees, other tribes, already formed to delight in brackish or fresh water, will avail themselves of the change in the fluid, and will, each in their turn, monopolize the space.

It is idle therefore to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature, which must always intervene and prevent the actual accomplishment of such conversions. A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which it previously inhabited, and where it has to contend with a more vigorous species, is presented by the

extirpation of savage tribes of men by the advancing colony of some civilized nation. In this case the contest is merely between two different *races*, — two varieties, moreover, of a species which exceeds all others in its aptitude to accommodate its habits to the most extraordinary variations of circumstances. Yet few future events are more certain than the speedy extermination of the Indians of North America and the savages of New Holland in the course of a few centuries, when these tribes will be remembered only in poetry and tradition.

CHAPTER XI.

EXTINCTION AND CREATION OF SPECIES.

Theory of the successive extinction of species consistent with their limited geographical distribution — Opinions of botanists respecting the centres from which plants have been diffused — Whether there are grounds for inferring that the loss, from time to time, of certain animals and plants, is compensated by the introduction of new species? — Whether any evidence of such new creations could be expected within the historical era? — The question whether the existing species have been created in succession must be decided by geological monuments.

Successive Extinction of Species consistent with their limited Geographical Distribution.

In the preceding chapters I have pointed out the strict dependence of each species of animal and plant on certain physical conditions in the state of the earth's surface, and on the number and attributes of other organic beings inhabiting the same region. I have also endeavoured to show that all these conditions are in a state of continual fluctuation, the igneous and aqueous agents remodelling, from time to time, the physical geography of the globe, and the migrations of species causing new relations to spring up successively between different organic beings. I have deduced as a corollary, that the species existing at any particular period must, in the course of ages, become extinct one after the other. "They must die out," to borrow an emphatical expression from Buffon, "because Time fights against them."

If the views which I have taken are just, there will

be no difficulty in explaining why the habitations of so many species are now restrained within exceedingly narrow limits. Every local revolution, such as those contemplated in the preceding chapter, tends to circumscribe the range of some species, while it enlarges that of others; and if we are led to infer that new species originate in one spot only, each must require time to diffuse itself over a wide area. It will follow, therefore, from the adoption of our hypothesis, that the recent origin of some species, and the high antiquity of others, are equally consistent with the general fact of their limited distribution, some being local, because they have not existed long enough to admit of their wide dissemination; others, because circumstances in the animate or inanimate world have occurred to restrict the range which they may once have obtained.

As considerable modifications in the relative levels of land and sea have taken place in certain regions since the existing species were in being, we can feel no surprise that the zoologist and botanist have hitherto found it difficult to refer the geographical distribution of species to any clear and determinate principles, since they have usually speculated on the phenomena, upon the assumption that the physical geography of the globe had undergone no material alteration since the introduction of the species now living. So long as this assumption was made, the facts relating to the geography of plants and animals appeared capricious in the extreme, and by many the subject was pronounced to be so full of mystery and anomalies, that the establishment of a satisfactory theory was hopeless.

Centres from which plants have been diffused.—Some botanists conceived, in accordance with the hypothesis

of Willdenow, that mountains were the centres of creation from which the plants now inhabiting large continents have radiated, to which De Candolle and others, with much reason, objected, that mountains, on the contrary, are often the barriers between two provinces of distinct vegetation. The geologist who is acquainted with the extensive modifications which the surface of the earth has undergone in very recent geological epochs, may be able, perhaps, to reconcile both these theories in their application to different regions.

A lofty range of mountains, which is so ancient as to date from a period when the species of animals and plants differed from those now living, will naturally form a barrier between contiguous provinces; but a chain which has been raised, in great part, within the epoch of existing species, and around which new lands have arisen from the sea within that period, will be a centre of peculiar vegetation.

"In France," observes De Candolle*, "the Alps and Cevennes prevent a great number of the plants of the south from spreading themselves to the northward; but it has been remarked that some species have made their way through the gorges of these chains, and are found on their northern sides, principally in those places where they are lower and more interrupted." Now the chains here alluded to have probably been of considerable height ever since the era when the existing vegetation began to appear, and were it not for the deep fissures which divide them, they might have caused much more abrupt terminations to the extension of distinct assemblages of species.

Parts of the Italian peninsula, on the other hand,

* Essai Elémentaire, &c., p. 46.

have gained a considerable portion of their present height since a majority of the marine species now inhabiting the Mediterranean, and probably, also, since the terrestrial plants of the same region, were in being. Large tracts of land have been added, both on the Adriatic and Mediterranean side, to what originally constituted a much narrower range of mountains, if not a chain of islands running nearly north and south, like Corsica and Sardinia. It may therefore be presumed that the Apennines have been a centre whence species have diffused themselves over the contiguous *lower* and *newer* regions. In this and all analogous situations, the doctrine of Willdenow, that species have radiated from the mountains as from centres, may be well founded.

Introduction of new Species.

If the reader should infer, from the facts laid before him in the preceding chapters, that the successive extinction of animals and plants may be part of the constant and regular course of nature, he will naturally inquire whether there are any means provided for the repair of these losses? Is it part of the economy of our system that the habitable globe should, to a certain extent, become depopulated both in the ocean and on the land; or that the variety of species should diminish until some new era arrives when a new and extraordinary effort of creative energy is to be displayed? Or is it possible that new species can be called into being from time to time, and yet that so astonishing a phenomenon can escape the observation of naturalists?

Humboldt has characterized these subjects as among the mysteries which natural science cannot reach; and he observes that the investigation of the origin of

beings does not belong to zoological or botanical geography. To geology, however, these topics do strictly appertain; and this science is chiefly interested in inquiries into the state of the animate creation as it now exists, with a view of pointing out its relations to antecedent periods when its condition was different.

Before offering any hypothesis towards the solution of so difficult a problem, let us consider what kind of evidence we ought to expect, in the present state of science, of the first appearance of new animals or plants, if we could imagine the successive creation of species to constitute, like their gradual extinction, a regular part of the economy of nature.

In the first place, it is obviously more easy to prove that a species, once numerously represented in a given district, has ceased to be, than that some other which did not pre-exist has made its appearance — assuming always, for reasons before stated, that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once.

So imperfect has the science of natural history remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old continent, long inhabited by the most civilized nations. Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult, even in contemplation, to

anticipate the time when we shall be entitled to make any other hypothesis in regard to all the marine tribes, and to by far the greater number of the terrestrial;—such as birds, which possess such unlimited powers of migration; insects which, besides their numbers, are also so capable of being diffused to vast distances; and cryptogamous plants, to which, as to many other classes, both of the animal and vegetable kingdom, similar observations are applicable.

What kind of evidence of new creations could be expected?—What kind of proofs, therefore, could we reasonably expect to find of the origin at a particular period of a new species?

Perhaps it may be said in reply that, within the last two or three centuries, some forest tree or new quadruped might have been observed to appear suddenly in those parts of England or France which had been most thoroughly investigated;—that naturalists might have been able to show that no such being inhabited any other region of the globe, and that there was no tradition of any thing similar having before been observed in the district where it had made its appearance.

Now, although this objection may seem plausible, yet its force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such conspicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our observation. There are perhaps more than a million species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe. The terrestrial plants may amount, says De Candolle, to somewhere between

110,000 and 120,000 *; but the data on which this conjecture is founded are considered by many botanists to be vague and unsatisfactory. Sprengel only enumerated, in 1827, about 31,000 known phænogamous, and 6000 cryptogamous plants; but that naturalist omitted many, perhaps 7000 phænogamous, and 1000 cryptogamous species. Mr. Lindley is of opinion that it would be rash, in the present state of science, to speculate on the existence of more than 80,000 phænogamous, and 10,000 cryptogamous plants. †

It was supposed by Linnæus that there were four or five species of insects in the world for each phænogamous plant: but if we may judge from the relative proportion of the two classes in Great Britain, the number of insects must be still greater; for the total number of British insects, " according to the last census," is about 12,500 ‡, whereas there are only 1500 phænogamous plants indigenous to our island. As the insects are much more numerous in hot countries than in our temperate latitudes, it seems difficult to avoid the conclusion that there are more than half a million species in the world.

The number of known mammifers, according to Temminck, exceeds 800, and Baron Cuvier estimated

* Géog. des Plantes. Dict. des Sci.

† " If we take," says Mr. L., in a letter to the author on this subject, " 37,000 as the number of published phænogamous species, and then add, for the undiscovered species in Asia and New Holland 15,000, in Africa 10,000, and in America 18,000, we have 80,000 species; and if 7000 be the number of published cryptogamous plants, and we allow 3000 for the undiscovered species (making 10,000), there would then be, on the whole, 90,000 species."

‡ See Catalogue of Brit. Insects, by John Curtis, Esq.

the amount of known fishes at 6000. Nearly 6000 species of birds have likewise been ascertained.* We have still to add the reptiles, and all the invertebrated animals, exclusive of insects. It remains, in a great degree, mere matter of conjecture what proportion the aquatic tribes may bear to the denizens of the land; but the habitable surface beneath the waters can hardly be estimated at less than double that of the continents and islands, even admitting that a very considerable area is destitute of life, in consequence of great depth, cold, darkness, and other circumstances. In the late polar expedition it was found that, in some regions, as in Baffin's Bay, there were marine animals inhabiting the bottom at great depths, where the temperature of the water was below the freezing point. That there is life at much greater profundities in warmer regions, may be confidently inferred. I have before stated that marine plants not only exist, but acquire vivid colours at depths where, to our senses, there would be darkness deep as night.

The ocean teems with life—the class of *polyps* alone are conjectured by Lamarck to be as strong in individuals as insects. Every tropical reef is described as covered with corals and sponges, and swarming with crustacea, echini, and testacea; while almost every tide-washed rock in the world is carpeted with fuci and supports some corallines, actiniæ, and mollusca. There are innumerable forms in the seas of the warmer zones, which have scarcely begun to attract the attention of the naturalist; and there are parasitic animals without number, three or four of which are sometimes appropriated to one genus, as to the *Balæna*, for example.

* See Quarterly Review, No. xciv. p. 337.

Even though we concede, therefore, that the geographical range of marine species is more extensive in general than that of the terrestrial (the temperature of the sea being more uniform, and the land impeding less the migrations of the oceanic than the ocean those of the terrestrial species), yet it seems probable that the aquatic tribes far exceed in number the inhabitants of the land.

Without insisting on this point, it may be safe to assume, that, exclusive of microscopic beings, there are between one and two millions of species now inhabiting the terraqueous globe; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, much more than a million of years might be required to bring about a complete revolution in organic life.

I am not hazarding at present any hypothesis as to the probable rate of change, but none will deny that, when the *annual* birth and the *annual* death of one species on the globe is proposed as a mere speculation, this at least is to imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water about equal in dimensions to Europe, and might contain a twentieth part of the million of species which may be assumed to exist in the animal kingdom. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century. But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we must exclude them from our consideration; and if they constitute half of

the entire number, then one species only might be lost in forty years among the terrestrial tribes. Now the mammalia, whether terrestrial or aquatic, bear so small a proportion to other classes of animals, forming less, perhaps, than one thousandth part of the whole, that, if the longevity of species in the different orders were equal, a vast period must elapse before it would come to the turn of this conspicuous class to lose one of their number. If one species only of the whole animal kingdom died out in forty years, no more than one mammifer might disappear in 40,000 years, in a region of the dimensions of Europe.

It is easy, therefore, to see, that, in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world.

The observations of naturalists, upon living species, may, in the course of future centuries, accumulate positive data, from which an insight into the laws which govern this part of our terrestrial system may be derived; but, in the present deficiency of historical records, we have traced up the subject to that point where geological monuments alone are capable of leading us on to the discovery of ulterior truths. To these, therefore, we must now appeal, carefully examining the strata of recent formation wherein the remains of *living* species, both animal and vegetable, are known to occur. We must study these strata in strict reference to their chronological order as deduced from their superposition, and other relations. From

these sources we may learn which of the species, now our contemporaries, have survived the greatest revolutions of the earth's surface; which of them have co-existed with the greatest number of animals and plants now extinct, and which have made their appearance only when the animate world had nearly attained its present condition.

From such data we may be enabled to infer, whether species have been called into existence in succession, or all at one period; whether singly, or by groups simultaneously; whether the antiquity of man be as high as that of any of the inferior beings which now share the planet with him, or whether the human species is one of the most recent of the whole.

To some of these questions we can even now return a satisfactory answer; and with regard to the rest, we have some data to guide conjecture, and to enable us to speculate with advantage: but it would be premature to anticipate such discussions until I have laid before the reader an ample body of materials amassed by the industry of modern geologists.

CHAPTER XII.

EFFECTS PRODUCED BY THE POWERS OF VITALITY ON THE STATE OF THE EARTH'S SURFACE.

Modifications in physical geography caused by organic beings — Why the vegetable soil does not augment in thickness — The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water, untenable — Conservative influence of vegetation — Rain diminished by the felling of forests — Distribution of American forests dependent on direction of predominant winds — Influence of man in modifying the physical geography of the globe.

THE second branch of our inquiry, respecting changes of the organic world, relates to the processes by which the remains of animals and plants become fossil, or, to speak still more generally, to all the effects produced by the powers of vitality on the surface and shell of the earth. Before entering on the principal division of this subject, the imbedding and preservation of animal and vegetable remains, I shall offer a few remarks on the superficial modifications caused directly by the agency of organic beings, as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

In considering alterations of this kind, brought about in the physical geography of particular tracts, we are too apt to think exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings,

we are familiar. Here the direct power of animals and plants to cause any important variations is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and, instead of contemplating the dry land, consider that larger portion which is assigned to the aquatic tribes, we discover the great influence of the living creation, in imparting varieties of conformation to the solid exterior which the sole agency of inanimate causes would not produce.

Thus, when timber is floated into the sea, it is often drifted to vast distances, and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs; it is probable that almost all the matter of which they are composed is supplied by mineral springs, which often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions hundreds of leagues in extent. The matter thus constantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest and secrete the carbonate of lime on the summits of submarine mountains, and form reefs many hundred feet in thickness, and hundreds of miles in length, where, but for them, none might ever have existed.

Why the vegetable soil does not augment in thickness. — If no such voluminous masses are formed on the

land, it is not from the want of solid matter in the structure of terrestrial animals and plants, but merely because, as I have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place — where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there in the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials might constitute, perhaps, a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea.

The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported. For the decomposition of the strata themselves, especially of their alkaline ingredients and of the organic remains which they so frequently include, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest parts of animals and plants which die and are exposed to putrefy in the air, where they are soon resolved into the elements of which they are composed; and while a portion of these parts is volatilized, the rest is taken up by rain water, and sinks into the earth, or flows

towards the sea; so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen; so that water and the atmosphere contain all of them, either in their own composition or in solution.* The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks before mentioned, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean, and to circulate round the globe.

It is well known that, when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil, he observes, consists partly of loose earthy materials easily removed, in the form of sand and gravel, partly of finer particles suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. The soil, although continually diminished from this cause, "remains the same in quantity, or at least nearly the

* See some good remarks on the Formation of Soils, Bakewell's Geology, chap. xviii.

same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks."*

That the repair of the *earthy* portion of the soil can only proceed, as Playfair suggests, from the decomposition of rocks, may be admitted; but the *vegetable* matter may be supplied, and is actually furnished, in a great degree, by absorption from the atmosphere; so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the fine vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

If we supposed the quantity of food consumed by terrestrial animals, and the elements imbibed by the roots and leaves of plants, to be derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single particle by the action of organic beings. This conclusion is not far from the truth; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down, every century, into the sea, and, together with forests of drift-timber, are imbedded in subaqueous

* Illust. of Hutt. Theory, § 103.

deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

On the other hand, fresh supplies are derived by the atmosphere, and by running water, as before stated, from the disintegration of rocks and their organic contents, and from the interior of the earth, from whence all the elements before mentioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found, by Dr. Daubeny, to be contained very generally in the waters of mineral springs.

Vegetation not an antagonist power counterbalancing the action of running water.—If we suppose that the copious supply from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we concede the utmost that is consistent with probability. But when more is required by a theorist,—when we are told that a counterpoise is derived from the same source to that enormous disintegration of solid rock and its transportation to lower levels, which is the annual result of the action of rivers and marine currents,—we must entirely withhold our assent. Such an opinion has been recently advanced by an eminent geologist, or I should have deemed it unnecessary to dwell on propositions which appear to me so clear and obvious.

The descriptions which I gave of the degradation

yearly going on through the eastern shores of England, and of the enormous weight of solid matter hourly rolled down by the Ganges or the Mississippi, has been represented as an extreme case, calculated to give a partial view of the changes now in progress, especially as I omitted, it is said, to point out the silent but universal action of a great antagonist power, whereby the destructive operations before alluded to are neutralized, and even, in a great degree, counterbalanced.

"Are there," says Professor Sedgwick, "no *antagonist* powers in nature to oppose these mighty ravages—no conservative principle to meet this vast destructive agency? The forces of degradation very often, of themselves, produce their own limitation. The mountain-torrent may tear up the solid rock, and bear its fragments to the plain below; but there its power is at an end, and the rolled fragments are left behind to a new action of material elements. And what is true of a single rock is true of a mountain-chain; and vast regions on the surface of the earth, now only the monuments of spoliation and waste, may hereafter rest secure under the defence of a thick vegetable covering, and become a new scene of life and animation.

"It well deserves remark, that the destructive powers of nature act only upon lines, while some of the grand principles of conservation act upon the whole surface of the land. By the processes of vegetable life, an incalculable mass of solid matter is absorbed, year after year, from the elastic and non-elastic fluids circulating round the earth, and is then thrown down upon its surface. In this *single* operation there is a *vast counterpoise to all* the agents of destruction.

And the deltas of the Ganges and the Mississippi are not solely formed at the expense of the solid materials of our globe; but in part, and I believe also in a considerable part, by one of the great conservative operations by which the elements are made to return into themselves."*

This is splendid eloquence, full of the energy and spirit that breathes through the whole address:—

> Monte decurrens velut amnis, imbres
> Quem super notas aluere ripas,
> Fervet, immensusque ruit —

but we must pause for a moment, lest we be hurried away by its tide. Let us endeavour calmly to consider whither it would carry us.

If by the elements returning *into themselves* be meant their return to higher levels, it is certainly possible that a fraction of the organic matter which is intermixed with the mud and sand deposited in alternate strata in the delta of the Ganges may have been derived by the leaves and roots of plants from such aqueous vapour, carbonic acid, and other gases, as had ascended into the atmosphere from *lower* regions, and which were not, therefore, derived from the waste of rocks and their organic contents, or from the putrescence of vegetables previously nourished from these sources. This fraction, and this alone, may then be deducted from the mass of solid matter annually transported into the Bay of Bengal; and what remains, whether organic or inorganic, will be the measure of the degradation which thousands of torrents in the Himalaya mountains, and many rivers of other parts of

* Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

India, bring down in a single year. Even in this case it will be found that the sum of the force of vegetation can merely be considered as having been in a slight degree *conservative*, retarding the waste of land, and not acting as an antagonist power.

But the untenable nature of the doctrine now controverted may be set in a clearer light by examining the present state of the earth's surface, on which it is declared that "an incalculable mass of solid matter is thrown down year after year," in such a manner as to form a counterpoise to the agents of decay. Is it not a fact, that the vegetable mould is seldom more than a few feet in thickness, and that it often does not exceed a few inches? Do we find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs? On the contrary, are not these higher and older regions more frequently denuded, so as to expose the bare rock to the action of the sun and air?

Do we find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of matter due to their agency are most conspicuous on the surface of the land? On the contrary, is it not there, where the vegetation is most active, that, for reasons to be explained in the next chapter, even those superficial peat mosses are unknown which cover a large area in some parts of our temperate zone? If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually

into the sea, along particular river-courses and lines of coast, the effects would have become, ere now, most striking; and would have constituted one of the most leading features in the structure and composition of our continents. All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist, the only case, perhaps, which affords the shadow of a support to the theory under consideration, has not, in every instance, a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. The turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within, and a violent inundation sometimes ensues when that skin bursts, as has often happened in Ireland, and many parts of the Continent. Examples will be mentioned in a subsequent chapter, where the Stygian torrent has hollowed out ravines, and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat. Here, therefore, the force of vegetation accelerates the rate of decay of land, and the solid matter swept down to lower levels during such floods counterbalances, to a certain degree, the accessions of vegetable mould which may accrue to the land by the growth of peat.

I may explain more clearly the kind of force which I imagine vegetation to exert, by comparing it to the

action of frost, which augments the height of some few Alpine summits, by causing a mass of perpetual snow to lodge thereon; or fills up some valleys with glaciers; but although by this process of congelation the rain-water that has risen by evaporation from the sea is retained for a while in a solid form upon the land, and although some elevated spots may be protected from waste by a constant covering of ice, yet, by the sudden melting of snow and ice, the degradation of rocks is often accelerated. Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase; the one melts, the other putrefies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life; and these, by their combined energy, might restore to continents a portion of that solid matter which is swept down into the sea from mountains and wasting cliffs.

I have before stated* that, in the known operation of the *igneous* causes, a real antagonist power is found, which may counterbalance the levelling action of running water; and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the ejection of matter by volcanos, may not be fully adequate to restore the superficial inequalities which rivers and oceanic currents annually tend to lessen. If a counterpoise be derived from this source, the quantity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the

* Vol. i. p. 245.; Vol. ii. p. 317.

surface of the earth more nearly to a state of equilibrium than that which it has now attained; and, on the other hand, the force of the aqueous agents themselves might thus continue for ever unimpaired. This permanence of the intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned; provided only that indefinite periods of time are contemplated.

As to the *intensity* of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient convulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But, notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time, is in its infancy; and there can be no doubt that great partial mutations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Conservative influence of vegetation.—If, then, vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative,—how far it may retard the levelling power of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river,

and may prevent hills of loose sand from being blown away by the wind; for the roots bind together the separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually, instead of flowing off in a mass and with great velocity. The old Italian hydrographers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausentinium of the Romans) was denuded, and, immediately, the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil.*

This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rainwater and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain,

* Treatise on Rivers and Torrents, p. 5. Garston's translation.

and undermining the cliffs on each side of every valley, the height of the intervening rising grounds may remain stationary.

In this manner a cone of loose scoriæ, sand, and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any further dilapidation; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer, from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated, since their formation; but the atmospheric action alone, in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a tour in Spain, in 1830, I was surprized to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage, while the roots of the pines, holm oaks, and some other trees, were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Orista and Vich, and near San Lorenzo. But, being overtaken by a violent thunderstorm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained; and I was taught that, in speculating on the greater effects which the direct action of rain may once have

produced on the surface of certain parts of England, we need not revert to periods when the heat of the climate was *tropical*.

In the torrid zone the degradation of land is generally more rapid, but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall; the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction, so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains; which, when they have thus been broken in their fall, are quickly absorbed by the ground beneath, or, when thrown into the drainage, depressions give rise to furious torrents.*

Influence of Man in modifying the physical Geography of the Globe.

Before concluding this chapter, I must offer a few observations on the influence of man in modifying the physical geography of the globe; for we must class his agency among the powers of organic nature.

Felling of forests.—The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica.† For in tropical coun-

* De la Beche, Geol. Man., p. 184. first ed.

† Phil. Trans., vol. ii. p. 294.

tries, where the quantity of aqueous vapour in the atmosphere is great, but where, on the other hand, the direct rays of the sun are most powerful, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a new source of humidity, and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves, moreover, of all plants are alembics, and some of those in the torrid zone have the remarkable property of distilling water, thus contributing to prevent the earth from becoming parched up.

Distribution of the American forests.— There can be no doubt, then, that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation re-acts upon the climate; but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject, "that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean," seems far more rational. In all countries, he says, "having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees, because, after the surface is saturated with water, the

rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours." *

"In all regions," he continues, "where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry; and hence parched deserts will generally be found on the west side of countries within the tropics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is precipitated in part upon the mountains of Brazil, which are but low, and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, is at length arrested by the Andes, where it falls down in showers on their summits. The aërial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in India, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side;

* Maclaren, art. America, Encyc. Britannica.

while on the other the weather remains clear and dry. The rains in this case change regularly from the west side to the east, and vice versâ, *with the monsoons*. But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture brought by the prevailing winds from the Pacific Ocean: rains are copious on their summits, and in Chili on their *western* declivities; but none falls on the plains to the *eastward*, except occasionally when the wind blows from the Atlantic." *

I have been more particular in explaining these views, because they appear to place in a true light the dependence of vegetation on climate, notwithstanding the reciprocal action which each exerts on the other, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

It has often been affirmed, that formerly, when France and England were covered with wood, Europe was much colder than at present; that the winters in Italy were longer, and that the Seine, and many other rivers, froze more regularly every winter than now. M. Arago, in a recent essay on this subject†, has endeavoured to show, by a comparative table of observations on the congelation of the Rhine, Danube, Rhone, Po, Seine, and other rivers, at different periods, that there is no reason to believe the cold in general to have been more intense in ancient times. He admits, however, that the climate of Tuscany has been so far modified, by the removal of wood, as that the winters are less cold; but the summers also, he contends, are less hot

* Maclaren, art. America, Encyc. Britannica, where the position of the American forests, in accordance with this theory, is laid down in a map.

† Annuaire par le Bureau des Long. 1834.

than of old; and the summers, he says, were formerly hotter in France than in our own times. His evidence is derived chiefly from documents showing that wine was made three centuries ago in the Vivarais and several other provinces, at an earlier season, at greater elevations, and in higher latitudes than are now found suitable to the vine.

In the United States of North America it is unquestionable that the rapid *clearing* of the country has rendered the winters less severe and the summers less hot; in other words, the extreme temperature of January and July have been observed from year to year to approach nearer to each other. Whether in this case, or in France, the *mean* temperature has been raised, seems by no means as yet decided; but there is no doubt that the climate has become, as Buffon would have said, "less excessive."

The modifications of the surface, resulting from human agency, are only on a considerable scale when we have obtained so much knowledge of the working of the laws of nature as to be able to use them as instruments to effect our purposes. We must command nature by obeying her laws, according to the saying of the philosopher; and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to reconvey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. But they have, nevertheless, been able to vary the

distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread by annual inundations over the plains.

I have explained how the form of the delta of the Po has been altered by this system of embankment, and how much more rapid, in consequence of these banks, have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit, however, to these modifications, since the danger of floods augments with the increasing height of the river-beds, while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country.

In the Ganges, says Major R. H. Colebrooke, no sooner is a slight covering of soil observed on a new sand-bank than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year, and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, the natives take possession, and bring over their families, cattle, and effects. They choose the highest spots, for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for, although the foundation is sandy, the uppermost soil, being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and

endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject.*

If Bengal were inhabited by a nation more advanced in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods ; but no human power could ever prevent the Ganges or the Mississippi from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point ; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted whether any system could be devised so conducive to *national* wealth as the simple plan pursued by the peasants of Hindostan, who, wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist the Gangetic islands and their migratory colonies may present an epitome of the globe as tenanted by man. For during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which sub-

* Asiatic Trans., vol. vii.

terranean causes have upheaved from the deep. Whether the human species will outlast the whole or a great part of the continents and islands now seen above the waters is a subject far beyond the reach of our conjectures; but thus much may be inferred from geological data, — that if such should be its lot, it will be no more than has already fallen to pre-existing species, some of which have, ere now, outlived the form and distribution of land and sea which prevailed at the era of their birth.*

I have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents. If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries. But, in the mean time, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town must have projected as a narrow promontory, becoming exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which man can exert over the igneous agents is less even than that which he may obtain over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of

* See book iv. chap. ix.

volcanic eruptions ; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect is occasionally to divert the course of a lava-stream, and to prevent the burning matter, for a season at least, from overwhelming a city, or other fruit of human industry.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult, if not impossible, to find any thing analogous in the agency of inferior beings. For we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider all the powers of other animate agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species; a topic on which I have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of the vegetation, and such may often have been the result of the entrance of new species into the earth.

The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

I do not, however, pretend to decide how far the power of man, to modify the surface, may differ in kind or degree from that of other living beings, but the problem is certainly more complex than many who have speculated on such topics have imagined. If new land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the tract would become covered with vegetation. The change next in importance would seem to be when animals enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that *a single species*, in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct removing power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. He conveys upwards a certain quantity of materials from the bowels of the earth in mining operations; but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards

thrown into the sea, whereby, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the abrading force of rain, and destroy the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical causes, whether aqueous or igneous, in the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanos in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean, wherein it might approach most nearly to the profundities from which it rose in the volcanic vent, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption.*

* Vol. I. p. 365.

CHAPTER XIII.

INCLOSING OF FOSSILS IN PEAT, BLOWN SAND, AND VOLCANIC EJECTIONS.

Division of the subject — Imbedding of organic remains in deposits on emerged land — Growth of peat — Peat abundant in cold and humid climates — Site of ancient forests in Europe now occupied by peat — Sources of bog iron-ore — Preservation of animal substances in peat — Miring of quadrupeds — Bursting of the Solway moss — Imbedding of organic bodies and human remains in blown sand — Moving sands of African deserts — De Luc on their recent origin — Buried temple of Ipsambul — Dried carcasses in the sands — Towns overwhelmed by sand-floods in England and France — Imbedding of organic and other remains in volcanic formations on the land.

Division of the subject. — The next subject of inquiry is the mode in which the remains of animals and plants become fossil, or are buried in the earth by natural causes. M. Constant Prevost has observed, that the effects of geological causes are divisible into two great classes; those produced on the surface during the submersion of land beneath the waters, and those which take place after its emersion. Agreeably to this classification, I shall consider, first, in what manner animal and vegetable remains become included and preserved in deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of seas or lakes; secondly, the manner in which organic remains become imbedded in subaqueous deposits.

Under the first division, I shall treat of the following

topics:—1st, the growth of peat, and the preservation of vegetable and animal remains therein;—2dly, the burying of organic remains in blown sand;—3dly, of the same in the ejections and alluviums of volcanos; —4thly, in alluviums generally, and in the ruins of landslips;—5thly, in the mud and stalagmite of caves and fissures.

Growth of Peat and Preservation of Vegetable and Animal Remains therein.

The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrefying. It may consist of any of the numerous plants which are capable of growing in such *stations;* but a species of moss (*Sphagnum palustre*) constitutes a considerable part of the peat found in marshes of the north of Europe; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying.* Reeds, rushes, and other aquatic plants may usually be traced in peat, and their organization is often so entire, that there is no difficulty in discriminating the distinct species.

Analysis of peat.—In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire, and the residuum consists of earths usually of the same kind as the substratum of clay, marl, gravel, or rock on which they are found, together with oxide of iron. "The peat of the chalk counties of England," observes

* For a catalogue of the plants which contribute to the generation of peat, see Dr. Rennie on Peat, pp. 171—178. Dr. Macculloch's Western Isles, vol. i. p. 129.

the same writer, "contains much gypsum; but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter."* From the researches of Dr. Macculloch, it appears that peat is intermediate between simple vegetable matter and lignite, the conversion of peat to lignite being gradual, and being brought about by the prolonged action of water. †

Peat abundant in cold and humid climates.—Peat is sometimes formed on a declivity in mountainous regions, where there is much moisture, but in such situations it rarely if ever exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick, and upwards; but in such cases it generally owes one half of its volume to the water which it contains. It has seldom, if ever, been discovered within the tropics; and it rarely occurs in the valleys, even in the south of France and Spain. It abounds more and more, in proportion as we advance farther from the equator, and becomes not only more frequent but more inflammable in northern latitudes.‡

Extent of surface covered by peat.—There is a vast extent of surface in Europe covered with peat, which, in Ireland, is said to extend over a tenth of the whole island. One of the mosses on the Shannon is described by Dr. Boate to be fifty miles long, by two or three broad; and the great marsh of Montoire, near the mouth of the Loire, is mentioned, by Blavier, as being more than fifty leagues in circumference. It is a curious and well-ascertained fact, that many of these

* Irish Bog Reports, p. 209.

† System of Geology, vol. ii. p. 353

‡ Rev. Dr. Rennie on Peat, p. 260.

mosses of the north of Europe occupy the place of forests of pine and oak, which have, many of them, disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects, or by putrefaction; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes originating in this source. Thus, in Mar forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immured in peat, formed partly out of their perishing leaves and branches, and in part from the growth of other plants. We also learn, that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat-moss near Lochbroom, in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat.* Dr. Walker mentions a similar change, when, in the year 1756, the whole wood of Drumlanrig was overset by the wind. Such events explain the occurrence, both in Britain and on the Continent, of mosses where the trees are all broken within two or three feet of the original surface, and where their trunks all lie in the same direction.†

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed

* Dr. Rennie's Essays, p. 65. † Ibid., p. 30.

to the sub-soil, that no doubt can be entertained of their having generally grown on the spot. They consist, for the most part, of the fir, the oak, and the birch; where the sub-soil is clay, the remains of oak are the most abundant; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has, moreover, been observed, that in Scotland, as also in many parts of the Continent, the largest trees are found in those peat-mosses which lie in the least elevated regions, and that the trees are proportionably smaller in those which lie at higher levels; from which fact De Luc and Walker have both inferred, that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves also, and fruits of each species, are continually found immersed in the moss, along with the parent trees; as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Recent origin of some peat-mosses. — In Hatfield moss, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found ninety feet long, and sold for masts and keels of ships; oaks have also been discovered there above one hundred feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions,

No. 275., which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of Kincardine, and several others, Roman roads have been found covered to the depth of eight feet by peat. All the coins, axes, arms, and other utensils found in British and French mosses, are also Roman; so that a considerable portion of the European peat-bogs are evidently not more ancient than the age of Julius Cæsar. Nor can any vestiges of the ancient forests described by that general, along the line of the great Roman way in Britain, be discovered, except in the ruined trunks of trees in peat.

De Luc ascertained, that the very site of the aboriginal forests of Hircinia, Semana, Ardennes, and several others, are now occupied by mosses and fens; and a great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. Several of the British forests, however, which are now mosses, were cut at different periods, by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut and burnt, in the reign of Edward I.; as were many of those in Ireland, by Henry II., to prevent the natives from harbouring in them, and harassing his troops.

It is curious to reflect, that considerable tracts have, by these accidents, been permanently sterilized, and that during a period when civilization has been making great progress, large areas in Europe have, by human agency, been rendered less capable of administering to the wants of man. Rennie observes, with

truth, that in those regions alone which the Roman eagle never reached—in the remote circles of the German empire, in Poland and Prussia, and still more in Norway, Sweden, and the vast empire of Russia—can we see what Europe was before it yielded to the power of Rome.* Desolation now reigns where stately forests of pine and oak once flourished, such as might now have supplied all the navies of Europe with timber.

Sources of bog iron-ore.—At the bottom of peat-mosses there is sometimes found a cake, or "pan," as it is termed, of oxide of iron, and the frequency of bog iron-ore is familar to the mineralogist. The oak which is so often found dyed black in peat owes its colour to the same metal. From what source the iron is derived is by no means obvious, since we cannot in all cases suppose that it has been precipitated from the waters of mineral springs. According to Fourcroy there is iron in all compact wood, and it is the cause of one-twelfth part of the weight of oak. The heaths (*Ericæ*) which flourish in a sandy, ferruginous soil, are said to contain more iron than any other vegetable.

It has been suggested that iron, being soluble in acids, may be diffused through the whole mass of vegetables, when they decay in a bog, and may, by its superior specific gravity, sink to the bottom, and be there precipitated, so as to form bog iron-ore; or where there is a subsoil of sand or gravel, it may cement them into ironstone or ferruginous conglomerate. †

Preservation of animal substances in peat.—One interesting circumstance attending the history of peat-

* Essays, &c., p. 74. † Ibid., p. 347.

mosses is the high state of preservation of animal substances buried in them for periods of many years. In June, 1747, the body of a woman was found six feet deep, in a peat-moor in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages; yet her nails, hair, and skin, are described as having shown hardly any marks of decay. In a turbary on the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was fresh and unimpaired.* In the Philosophical Transactions, we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; "the colour of their skin was fair and natural, their flesh soft as that of persons newly dead."†

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous, and tasteless substance; but which, when exposed to

* Dr. Rennie, Essays, &c., p. 521., where several other instances are referred to.

† Phil. Trans., vol. xxxviii., 1734.

heat, emitted an odour precisely similar to broiled bacon.*

Cause of the antiseptic property of peat.—We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way.†

The tannin occasionally present in peat is the produce, says Dr. Macculloch, of tormentilla, and some other plants, but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocire by the action of water merely; an explanation which appears clearly applicable to some of the cases above enumerated.‡

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud, underlying a turfy surface, upon which they have rashly ventured, or, at other times, a bog "bursts," in the manner described in a preceding chapter, and animals may be involved in the peaty alluvium.

* Dr. Rennie, Essays, &c., p. 521.

† Ibid., p. 531.

‡ Syst. of Geol., vol. ii. pp. 340—346.

In the extensive bogs of Newfoundland cattle are sometimes found buried with their heads only and neck above ground, and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on the "quaking moss" are often mired, or "laired," as it is termed; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible. *

Solway moss.—The description given of the Solway moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semifluid. The adventurous passenger, therefore, who sometimes in dry seasons traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

"At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional, but it is now authenticated; a man and horse, in complete armour, having been found by peat-diggers, in the place where it was always supposed the

* Phil. Trans., vol. xv. p. 949.

affair had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished." *

This same moss, on the 16th of December, 1772, having been filled with water during heavy rains, rose to an unusual height, and then burst. A stream of black, half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about twenty-five feet, and the height of the moss, on the lowest parts of the country which it invaded, was at least fifteen feet.

Bursting of a peat-moss in Ireland.—A recent inundation in Sligo (January, 1831,) affords another example of this phenomenon. After a sudden thaw of snow the bog between Bloomfield and Geevah gave way, and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream, and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

Bones of herbivorous quadrupeds in peat.—The antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed, for

* Observations on Picturesque Beauty, &c., 1772.

portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also occur; and in Ireland and the Isle of Man skeletons of a gigantic elk. M. Morren has discovered, in the turbaries of Flanders, the bones of otters and beavers *; but no remains have been met with belonging to those extinct qnadrupeds of which the living congeners inhabit warmer latitudes, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, though these are so common in superficial deposits of silt, mud, sand, or stalactite, in various localities throughout Great Britain. Their absence seems to imply that they had ceased to live before the atmosphere of this part of the world acquired that cold and humid character which favours the growth of peat.

Remains of ships, &c., in peat-mosses.—From the facts before mentioned, that mosses occasionally burst, and descend in a fluid state to lower levels, it will readily be seen that lakes and arms of the sea may occasionally become the receptacles of drift-peat. O this, accordingly, there are numerous examples, and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses; and Gerard, in his History of the Valley of the Somme, mentions that in the lowest tier of that moss was found a boat loaded with bricks, proving that these mosses were at one period navigable lakes and arms of the sea, as were also many mosses on the coast of

* Bulletin de la Soc. Géol. de France, tom. ii. p. 26.

Picardy, Zealand, and Friesland, from which soda and salt are procured. * The canoes, stone hatchets, and stone arrow-heads, found in peat in different parts of Great Britain, lead to similar conclusions.

Imbedding of Human and other Remains and Works of Art in Blown Sand.

The drifting of sand may next be considered among the causes capable of preserving organic remains and works of art on the emerged land.

African sands.—The sands of the African deserts have deen driven by the west winds over all the lands capable of tillage on the western banks of the Nile, except such as are sheltered by mountains.† And thus the ruins of ancient cities have been buried between the Temple of Jupiter Ammon and Nubia. M. G. A. de Luc attempted to infer the recent origin of our continents, from the fact that these moving sands have only arrived in modern times at the fertile plains of the Nile. The same scourge, he said, would have afflicted Egypt for ages anterior to the times of history, had the continents risen above the level of the sea several hundred centuries before our era. ‡ But the author proceeded in this, as in all his other chronological computations, on a multitude of gratuitous assumptions. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period; for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand flood might have been long posterior to the laying dry of the greater

* Dr. Rennie, Essays on Peat-Moss, p. 205.

† M. G. A. de Luc, Mercure de France, Sept. 1809. ‡ Ibid.

portion of that continent. That the different parts of Europe were not all elevated at one time is now generally admitted. De Luc should also have pointed out the depth of drift sand in various parts of the great Lybian deserts, and have shown whether any valleys of large dimensions had been filled up—how long these may have arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history.

No mode of interment can be conceived more favourable to the conservation of monuments for indefinite periods than that now so common in the region immediately westward of the Nile. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust.*

At some future period, perhaps, when the pyramids shall have perished, the action of the sea, or an earthquake, may lay open to the day some of these buried temples. Or we may suppose the desert to remain undisturbed, and changes in the surrounding sea and land to modify the climate and the direction of the prevailing winds, so that these may then waft away the Lybian sands as gradually as they once brought them to those regions. Thus, many a town and temple of higher antiquity than Thebes or Memphis

* Stratton, Ed. Phil. Journ., No. V. p. 62.

might re-appear in their original integrity, and a part of the gloom which overhangs the history of earlier nations might be dispelled.

Whole caravans are said to have been overwhelmed by the Lybian sands; and Burckhardt informs us that "after passing the Akaba, near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sand." — "We did not see," says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, "the least appearance of vegetation; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently-expired animals I could not perceive the slightest offensive smell; and in those long dead, the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places, for, in a short time, a slight mound is formed round them, and they become stationary."*

Towns overwhelmed by sand-floods.—The burying of several towns and villages in England and France by blown sand is on record; thus, for example, near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that nothing was seen but the spire of the church.†

In Suffolk, in the year 1688, part of Downham was

* Travels in North Africa in the years 1818, 1819, and 1820, p. 83.

† Mém. de l'Acad. des Sci. de Paris, 1772.—Malte-Brun's Geog., vol. i. p. 425.

overwhelmed by sands which had broken loose about one hundred years before, from a warren five miles to the south-west. This sand had, in the course of a century, travelled five miles, and covered more than a thousand acres of land.* A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells, in which some terrestrial shells are inclosed entire. By the shifting of these sands the ruins of ancient buildings have been discovered; and in some cases where wells have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some localities, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand. †

Imbedding of Organic and other Remains in Volcanic Formations on the Land.

I have in some degree anticipated the subject of this section in a former volume, when speaking of the buried cities around Naples, and those on the flanks of Etna.‡ From the facts referred to, it appeared that the preservation of human remains and works of art is frequently due to the descent of floods caused by the copious rains which accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity, and in 1822 surprised and

* Phil. Trans., vol. ii. p. 722.

† Boase on Submersion of Part of the Mount's Bay, &c., Trans. Roy. Geol. Soc. of Cornwall, vol. ii. p. 140.

‡ Vol. II. pp. 98—117.

suffocated, as was stated, seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those formed after the eruption of Vesuvius in 1822 are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava current. After consolidation, the lava affords secure protection to the lighter and more removeable mass below, in which the organic relics may be enveloped. The Herculanean tuffs containing the rolls of Papyrus, of which the characters are still legible, have, as was before remarked, been for ages covered by lava.

Another mode whereby lava may tend to the conservation of imbedded remains, at least of works of human art, is by overflowing them when not intensely heated, in which case they sometimes suffer little or no injury.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down a great number of statues and other articles in the vaults of Catania; and at the depth of thirty-five feet in the same current, on the site of Mompiliere, one of the buried towns, the bell of a church and some statues were found uninjured.*

* Vol. II. p. 118.

There are several buried cities in central India, which might probably yield a richer harvest to the antiquary than Pompeii and Herculaneum.* The city of Oujein (or Oojain) was, about fifty years before the Christian era, the seat of empire, of art, and of learning; but in the time of the Rajah Vicramaditya, it was overwhelmed, together, as tradition reports, with more than eighty other large towns in the provinces of Malwa and Bagur, "by a shower of earth." The city which now bears the name is situated a mile to the southward of the ancient town. On digging on the spot where the latter is supposed to have stood, to the depth of fifteen or eighteen feet, there are frequently discovered, says Mr. Hunter, entire brick walls, pillars of stone, and pieces of wood of an extraordinary hardness, besides utensils of various kinds, and ancient coins. Many coins are also found in the channels cut by the periodical rains, or in the beds of torrents into which they have been washed. "During our stay at Oujein, a large quantity of wheat was found by a man digging for bricks. It was, as might have been expected, almost entirely consumed, and in a state resembling charcoal. In a ravine cut by the rains, from which several stone pillars had been dug, I saw a space from twelve to fifteen feet long and seven or eight high, composed of earthern vessels, broken and closely compacted together. It was conjectured, with great appearance of probability, to have been a potter's kiln. Between this place and the new town is a hollow, in which, tradition says, the river Sipparah formerly ran. It changed its course at the time the city was buried, and now runs to the westward."†

* Vol. II. p. 95.

† Narrative of Journey from Agra to Oujein, Asiatic Researches, vol. vi. p. 36.

The soil which covers Oujein is described as "being of an ash-grey colour, with minute specks of black sand."*

That the "shower of earth" which is reported to have "fallen from heaven" was produced by a volcanic eruption, we can hardly doubt, although no information has been obtained respecting the site of the vent; and the nearest volcano of which we read is that which was in eruption during the Cutch earthquake in 1819, at the distance of about thirty miles from Bhooj, the capital of Cutch, and at least three hundred geographical miles from Oujein.

Captain F. Dangerfield, who accompanied Sir John Malcolm in his late expedition into Central India, states that the river Nerbuddah, in Malwa, has its channel excavated through *columnar basalt*, above which are beds of *marl* impregnated with salt. The upper of these marls is of a light colour, and from thirty to forty feet thick, and rests horizontally on the lower bed, which is of a reddish colour. Both appear from the description to be tuffs composed of the materials of volcanic ejections, and forming a covering from sixty to seventy feet deep overlying the basalt, which seems to resemble some of the currents of prismatic lava in Auvergne and the Vivarais. Near the middle of this tufaceous mass, and therefore at the depth of thirty feet or more from the surface, just where the two beds of tuff meet, Captain Dangerfield was shown, near the city of Mhysir, buried bricks and large earthen vessels, said to have belonged to the ancient city of Mhysir, destroyed by the catastrophe of Oujein.†

* Asiatic Journal, vol. ix. p. 35.

† Sir J. Malcolm's Cent. Ind.—Geol. of Malwa, by Captain F. Dangerfield, App. No. ii. pp. 324, 325.

CHAPTER XIV.

BURYING OF FOSSILS IN ALLUVIAL DEPOSITS AND IN CAVES.

Imbedding of organic bodies in alluvium — Alluvium defined — Effects of sudden inundations — Terrestrial animals most abundantly preserved in alluvium where earthquakes prevail — Marine alluvium — Effects of landslips — Preservation of organic remains in fissures and caves — Form and dimensions of caverns — their probable origin — Closed basins and engulphed rivers of the Morea — Katavothra — Formation of breccias with red cement — Human remains imbedded in Morea — Intermixture in caves of south of France and other countries of human remains and bones of extinct quadrupeds no proof of former co-existence of man with those lost species.

Alluvium. — The next subject for our consideration, according to the division before proposed, is the imbedding of organic bodies in alluvium, by which I mean such transported matter as has been thrown down, whether by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas,—I say *permanently submerged*, in order to distinguish between *alluviums* and regular subaqueous deposits. The latter are accumulated in lakes or great submarine receptacles, the former in the channels of rivers and currents, where the materials may be regarded as still *in transitu*, or on their way to a place of rest. There may be cases where it is impossible to draw a line of demarcation between these two classes of formations, but these exceptions are rare, and the division is, upon the whole, convenient and natural.

The alluvium of the bed of a river does not often contain any animal or vegetable remains, for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand, mud, and rubbish, are suddenly swept by a flood, and then let fall upon the land, such an alluvium may envelop trees or the remains of animals, which, in this manner, are often permanently preserved. In the mud and sand produced by the floods in Scotland, in 1829, the dead and mutilated bodies of hares, rabbits, moles, mice, partridges, and even the bodies of men, were found partially buried.* But in these and similar cases one flood usually effaces the memorials left by another, and there is rarely a sufficient depth of undisturbed transported matter, in any one spot, to preserve the organic remains for ages from destruction.

Where earthquakes prevail, and the levels of a country are changed from time to time, the remains of animals may more easily be inhumed and protected from disintegration. Portions of plains, loaded with alluvial accumulations by transient floods, may be gradually upraised; and, if any organic remains have been imbedded in the transported materials, they may, after such elevation, be placed beyond the reach of the erosive power of streams. In districts where the drainage is repeatedly deranged by subterranean movements, every fissure, every hollow caused by the sinking in of land, becomes a depository of organic and inorganic substances, hurried along by transient floods.

* Sir T. D. Lauder, Bart., on the great Floods in Morayshire, Aug. 1829, p.177.

Marine alluvium. — The term "marine alluvium" is, perhaps, admissible, if confined to banks of shingle thrown up like the Chesil bank in Dorsetshire, or to materials cast up by a wave of the sea upon the land, or those which a submarine current has left in its track. The kind last mentioned must necessarily, when the bed of the ocean is laid dry, resemble terrestrial alluviums, with this difference, that if any fragments of organic bodies have escaped destruction they will belong principally to marine species.

In May, 1787, a dreadful inundation of the sea was caused, at Coringa, Ingeram, and other places, on the coast of Coromandel, in the East Indies, by a hurricane blowing from the N. E., which raised the waters so that they rolled inland to the distance of about twenty miles from the shore, swept away many villages, drowned more than 10,000 people, and left the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. An old tradition of the natives of a similar flood, said to have happened about a century before, was, till this event, regarded as fabulous by the European settlers.* The same coast of Coromandel was, so late as May, 1832, the scene of another catastrophe of the same kind; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa.

Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant on them, and by the sounds heard in the ground, and the odours emitted. Such were the circumstances

* Dodsley's Ann. Regist., 1788.

which accompanied the swell of the sea in Jamaica, in 1780, when a great wave desolated the western coast, and, bursting upon Savanna la Mar, swept away the whole town in an instant, so that not a vestige of man, beast, or habitation, was seen upon the surface.*

Works of art in alluvial deposits.—We are informed, by M. Boblaye, that in the Morea, the formation termed céramique, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes an important stratum which might, in the absence of zoological characters, serve to mark our epoch in a most indestructible manner.†

Landslips.—The landslip, by suddenly precipitating large masses of rock and soil into a valley, overwhelms a multitude of animals, and sometimes buries permanently whole villages, with their inhabitants and large herds of cattle. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice ‡; and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of St. André, the ruins occupying an extent of about nine square miles. §

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than eight hundred, a great number of the

* Edwards, Hist. of West Indies, vol. i. p. 235. ed. 1801.

† Ann. des Sci. Nat., tome xxii. p. 117. Feb. 1831.

‡ Malte-Brun's Geog., vol. i. p. 435.

§ Bakewell, Travels in the Tarentaise, vol. i. p. 201.

bodies, as well as several villages and scattered houses, being buried deep under mud and rock. In the same country, several hundred cottages, with eighteen of their inhabitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets. In the year 1618, a portion of Mount Conto fell, in the county of Chiavenna in Switzerland, and buried the town of Pleurs with all its inhabitants, to the number of 2430.

It is unnecessary to multiply examples of similar local catastrophes, which, however numerous they may have been in mountainous parts of Europe, within the historical period, have been, nevertheless, of rare occurrence when compared to events of the same kind which have taken place in regions convulsed by earthquakes. It is then that enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river-courses, and often so unexpectedly that they overwhelm, even in the daytime, every living thing upon the plains.

Preservation of Organic Remains in Fissures and Caves.

In the history of earthquakes it was shown that many hundreds of new fissures and chasms had opened in certain regions during the last 150 years, some of which are described as being of unfathomable depth. We also perceive that mountain masses have been violently fractured and dislocated, during their rise above the level of the sea ; and thus we may account for the existence of many cavities in the interior of the earth by the simple agency of earthquakes ; but there are some caverns, especially in limestone rocks, which,

although usually, if not always, connected with rents, are nevertheless of such forms and dimensions, alternately expanding into spacious chambers, and then contracting again into narrow passages, that it is difficult to conceive that they can owe their origin to the mere fracturing and displacement of solid masses.

In the limestone of Kentucky, in the basin of Green river, one of the tributaries of the Ohio, a line of underground cavities has been traced in one direction for a distance of ten miles, without any termination; and one of the chambers, of which there are many, all connected by narrow tunnels, is no less than ten acres in area, and 150 feet in its greatest height. Besides the principal series of "antres vast," there are a great many lateral embranchments not yet explored.*

The cavernous structure here alluded to is not altogether confined to calcareous rocks; for it has lately been observed in micaceous and argillaceous schist, in the Grecian island of Thermia (Cythnos of the ancients), one of the Cyclades. Here also spacious halls, with rounded and irregular walls, are connected together by narrow passages or tunnels, and there are many lateral branches which have no outlet. A current of water has evidently at some period flowed through the whole, and left a muddy deposit of bluish clay upon the floor; but the erosive action of the stream cannot be supposed to have given rise to the excavations in the first instance. M. Virlet suggests that fissures were first caused by earthquakes, and that these fissures became the chimneys or vents for the disengagement of gas, generated below by

* Mem. by Nahum Ward, Trans. of Antiq. Soc. of Massachusetts. Holmes's Un. States, p. 438.

volcanic heat. Gases, he observes, such as the muriatic, sulphuric, fluoric, and others, might, if raised to a high temperature, alter and decompose the rocks which they traverse. There are signs of the former action of such vapours in rents of the micaceous schist of Thermia, and thermal springs now issue from the grottos of that island. We may suppose that afterwards the elements of the decomposed rocks were gradually removed in a state of solution by mineral waters, a theory which, according to M. Virlet, is confirmed by the effect of heated gases which escape from rents in the isthmus of Corinth, and which have greatly altered and corroded the hard siliceous and jaspidious rocks.*

When we reflect on the quantity of carbonate of lime annually poured out by mineral waters †, we are prepared to admit that large cavities must, in the course of ages, be formed at considerable depths below the surface in calcareous rocks. These rocks, it will be remembered, are at once more soluble, more permeable, and more fragile, than any others, at least all the compact varieties are very easily broken by the movements of earthquakes, which would only produce flexures in argillaceous strata. Fissures once formed in limestone are not liable, as in many other formations, to become closed up by impervious clayey matter, and hence a stream of acidulous water might for ages obtain a free and unobstructed passage. ‡

Morea. — After these observations on the possible origin of some subterraneous hollows, I shall next consider in what manner they may be filled up with mud,

* Bull. de la Soc. Géol. de France, tom. ii. p. 329.

† See vol. i. p. 316.

‡ See some remarks by M. Boblaye, Ann. des Mines, 3me série, tom. iv.

pebbles, and other substances. When a mass of cavernous rock is raised above the level of the sea, it will usually be intersected by ravines and valleys, and it must then happen that here and there a torrent or river will break into some cavern. Accordingly, engulphed streams occur in almost every region of cavernous limestone, as in the north of England, for example; but in no district are they more conspicuous than in the Morea, where the phenomena attending them have been lately studied and described in great detail by M. Boblaye and his fellow-labourers of the French expedition to Greece. From his account* it appears, that numerous caverns are there found in a compact limestone, of the age of the English chalk, immediately below which are arenaceous strata referred to the period of our green-sand. In the more elevated districts of that peninsula there are many deep land-locked valleys, or basins, closed round on all sides by mountains of fissured and cavernous limestone. The year is divided almost as distinctly as between the tropics into a rainy season, which lasts upwards of four months, and a season of drought, of nearly eight months' duration. When the torrents are swollen by the rains, they rush from surrounding heights into the inclosed basins; but, instead of giving rise to lakes, as would be the case in most other countries, they are received into gulphs or chasms, called by the Greeks "Katavothra," and which correspond to what are termed "swallow-holes" in the north of England. The water of these torrents is charged with pebbles and red ochreous earth, resembling precisely the well-known cement of the

* See Ann. des Mines, 3me série, tom. iv. 1833.

osseous breccias of the Mediterranean. It dissolves in acids with effervescence, and leaves a residue of hydrated oxide of iron, granular iron, impalpable grains of silex, and small crystals of quartz. Soil of the same description abounds every where on the surface of the decomposing limestone in Greece, that rock containing in it much siliceous and ferruginous matter.

Many of the Katavothra being insufficient to give passage to all the water in the rainy season, a temporary lake is formed round the mouth of the chasm, which then becomes still farther obstructed by pebbles, sand, and red mud, thrown down from the turbid waters. The lake being thus raised, its waters generally escape through other openings, at higher levels, around the borders of the plain, constituting the bottom of the closed basin.

In some places, as at Kavaros and Tripolitza, where the principal discharge is by a gulph in the middle of the plain, nothing can be seen over the opening in summer, when the lake dries up, but a deposit of red mud, cracked in all directions. But the Katavothron is more commonly situated at the foot of the surrounding escarpment of limestone, and in that case there is sometimes room enough to allow a person to enter, in summer, and even to penetrate far into the interior. Within is seen a suite of chambers, communicating with each other by narrow passages; and M. Virlet relates, that in one instance he observed, near the entrance, human bones imbedded in recent red mud, mingled with the remains of plants and animals of species now inhabiting the Morea. It is not wonderful, he says, that the bones of man should be met with in such receptacles, for so murderous have been

the late wars in Greece, that skeletons are often seen lying exposed on the surface of the country.*

In summer, when no water is flowing into the Katavothron, its mouth, half closed up with red mud, is masked by a vigorous vegetation, which is cherished by the moisture of the place. It is then the favourite hiding-place and den of foxes and jackals, so that the same cavity serves at one season of the year for the habitation of carnivorous beasts, and at another as the channel of an engulphed river. Near the mouth of one chasm, M. Boblaye and his companions saw the carcass of a horse, in part devoured, the size of which seemed to have prevented the jackals from dragging it in: the marks of their teeth were observed on the bones, and it was evident that the floods of the ensuing winter would wash in whatsoever might remain of the skeleton.

It has been stated that the waters of all these torrents of the Morea are turbid where they are engulphed; but when they come out again, often at the distance of many leagues, they are perfectly clear and limpid, being only charged occasionally with a slight quantity of calcareous sand. The points of efflux are usually near the sea-shores of the Morea, but sometimes they are submarine; and when this is the case, the sands are seen to boil up for a considerable space, and the surface of the sea, in calm weather, swells in large convex waves. It is curious to reflect, that when this discharge fails in seasons of drought, the sea may break into subterraneous caverns, and carry in marine sand and shells, to be mingled with ossiferous mud, and the remains of terrestrial animals.

* Bull. de la Soc. Géol. de France, tom. iii. p. 223.

In general, however, the efflux of water at these inferior openings is surprisingly uniform. It seems, therefore, that the large caverns in the interior must serve as reservoirs, and that the water only escapes gradually from them, in consequence of the smallness of the rents and passages by which they communicate with the surface.

The phenomena above described are not confined to the Morea, but occur in Greece generally, and in those parts of Italy, Spain, Asia Minor, and Syria, where the formations of the Morea extend. When speaking of the numerous fissures in the limestone of Greece, M. Boblaye reminds us of the famous earthquake of 469 B. C., when, as we learn from Cicero, Plutarch, Strabo, and Pliny, Sparta was laid in ruins, part of the summit of Mount Taygetus torn off, and numerous gulphs and fissures caused in the rocks of Laconia.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient water-mills were transferred.*

When the courses of engulphed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subterranean floods, and their carcasses buried under heaps

* I learnt this from some inhabitants of Sortino in 1829, and visited the points alluded to.

of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be drifted along, and mixed up with mud, sand, and fragments of rock, so as to form osseous breccias.

But it is not merely in spots where streams are engulphed that the bones of animals may be collected in rents and caverns, for open fissures often serve as natural pit-falls in which herbivorous animals perish. This may happen the more readily when they are chased by beasts of prey, especially when they are carelessly browsing on the shrubs which so often overgrow and conceal the edges of fissures.*

Above the village of Selside, near Ingleborough in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. "The chasm," says Professor Sedgwick, "is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now prevented by a strong lofty wall, but there can be no doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet." †

When any of these natural pit-falls happen to communicate with lines of subterranean caverns, the bones,

* Buckland, Reliquiæ Diluvianæ, p. 25.

† Memoir on the Structure of the Lake Mountains of the North of England, &c., read before the Geological Society, Jan. 5. 1831.

earth, and breccia, may sink by their own weight, or be washed into the vaults below.

We have seen that the ravines which opened in Calabria, in 1783, were very numerous, varying in their ordinary depth from fifty to two hundred feet*; and that animals were sometimes engulphed during the shocks. If a torrent chance to be in the line of any of these chasms, it might pour in a quantity of alluvial matter under which the animal remains might lie inhumed for ages. Where houses with their inhabitants have been swallowed up in fissures, there appears to have been usually a sliding in of all the loose matter which lay upon the surface, so that, in such rents, we might look for the ruins of buildings, and the skeletons of men and animals, buried in alluvium at the depth often of several hundred feet.

At the north extremity of the rock of Gibraltar are perpendicular fissures, on the ledges of which a number of hawks nestle and rear their young in the breeding season. They throw down from their nests the bones of small birds, mice, and other animals on which they feed, and these are gradually united into a breccia of angular fragments of the decomposing limestone with a cement of red earth.

At the pass of Escrinet in France, on the northern escarpment of the Coiron hills, near Aubenas, I have seen a breccia in the act of forming. Small pieces of disintegrating limestone are transported, during heavy rains, by a streamlet, to the foot of the declivity, where land shells are very abundant. The shells and pieces of stone soon become cemented together by stalagmite into a compact mass, and the talus thus

* Vol. II. p. 211.

formed is in one place fifty feet deep, and five hundred yards wide. So firmly is the lowest portion consolidated, that it is quarried for millstones.

I have lately had an opportunity of examining the most celebrated caves of Franconia, and among others that of Rabenstein, newly discovered. Their general form, and the nature and arrangement of their contents appeared to me to agree perfectly with the notion of their having once served as the channels of subterraneous rivers. This mode of accounting for the introduction of transported matter into the Franconian and other caves, filled up as they often are even to their roofs with osseous breccia, was long ago proposed by M. C. Prevost*, and seems at length to be very generally adopted. But I do not doubt that bears inhabited some of the German caves, or that the cavern of Kirkdale, in Yorkshire, was once the den of hyænas. The abundance of bony dung, associated with hyænas bones, has been pointed out by Dr. Buckland, and with reason, as confirmatory of this opinion.

Alternations of stalagmite and alluvium.—The same author observed in every cave examined by him in Germany that deposits of mud and sand, with or without rolled pebbles and angular fragments of rock, were covered over with a *single* crust of stalagmite.† In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. But Dr. Schmerling has discovered in a cavern at Chockier, about two leagues from Liège, three distinct beds of stalagmite, and between each of them a mass of breccia,

* Mém. de la Soc. d'Hist. Nat. de Paris, tom. iv.

† Reliquiæ Diluvianæ, p. 108.

and mud mixed with quartz pebbles, and in the three deposits the bones of extinct quadrupeds. *

This exception does not invalidate the generality of the phenomenon pointed out by Dr. Buckland, one cause of which may perhaps be this, that if several floods pass at different intervals of time through a subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may have been previously formed. Another cause may be, that a particular line of caverns will rarely be so situated, in relation to the lowest levels of a country, as to become, at two distinct epochs, the receptacle of engulphed rivers ; and if this should happen, some of the caves, or at least the tunnels of communication, may at the first period be entirely choked up with transported matter, so as not to allow the subsequent passage of water in the same direction.

As the same chasms may remain open throughout periods of indefinite duration, the species inhabiting a country may in the mean time be greatly changed, and thus the remains of animals belonging to very different epochs may become mingled together in a common tomb. For this reason it is often difficult to separate the monuments of the human epoch from those relating to periods long antecedent, and it was not without great care and skill that Dr. Buckland was enabled to guard against such anachronisms in his investigation of several of the English caves. He mentions that human skeletons were found in the cave of Wokey Hole, near Wells, in the Mendips, dispersed through reddish mud and clay, and some of them united by stalagmite into

* Journ. de Géol., tom. i. p. 286. July, 1830.

a firm osseous breccia. "The spot on which they lie is within reach of the highest floods of the adjacent river, and the mud in which they are buried is evidently fluviatile."*

In speaking of the cave of Paviland, on the coast of Glamorganshire, the same author states that the entire mass through which bones were dispersed appeared to have been disturbed by ancient diggings, so that the remains of extinct animals had become mixed with recent bones and shells. In the same cave was a human skeleton, and the remains of recent testacea of eatable species, which may have been carried in by man.

In several caverns on the banks of the Meuse, near Liège, Dr. Schmerling has found human bones in the same mud and breccia with those of the elephant, rhinoceros, bear, and other quadrupeds of extinct species. He has observed none of the dung of any of these animals; and from this circumstance, and the appearance of the mud and pebbles, he concludes that these caverns were never inhabited by wild beasts, but washed in by a current of water. As the human skulls and bones were in fragments, and no entire skeleton had been found, he does not believe that these caves were places of sepulture, but that the human remains were washed in at the same time as the bones of extinct quadrupeds.

Caverns in the South of France. — Similar associations in the south of France, of human bones and works of art with remains of extinct quadrupeds, have induced some geologists to maintain that man was an inhabitant of that part of Europe before the rhinoceros, hyæna, tiger, and other fossil species

* Reliquiæ Diluvianæ, p. 165.

disappeared. I may first mention the cavern of Bize, in the department of Aude, where M. Marcel de Serres met with a small number of human bones mixed with those of extinct animals and with land-shells They occur in a calcareous stony mass, bound together by a cement of stalagmite. On examining the same caverns, M. Tournal found not only in these calcareous beds, but also in a black mud which overlies a red osseous mud, several human teeth, together with broken angular fragments of a rude kind of pottery, and also recent marine and terrestrial shells. The teeth preserve their enamel; but the fangs are so much altered as to adhere strongly when applied to the tongue. Of the terrestrial shells thus associated with the bones and pottery, the most common are Cyclostoma elegans, Bulimus decollatus, Helix nemoralis, and H. nitida. Among the marine are found Pecten jacobæus, Mytilus edulis, and Natica mille-punctata, all of them eatable kinds, and which may have been brought there for food. Bones were found in the same mass belonging to three new species of deer, an extinct bear (*Ursus arctoïdeus*), and the wild bull (*Bos urus*), formerly a native of Germany. *

In the same part of France, M. de Christol has found in caverns in a tertiary limestone at Pondres and Souvignargues, two leagues north of Lunel-viel, in the department of Herault, human bones and pottery confusedly mixed with remains of the rhinoceros, bear, hyæna, and other terrestrial mammifers. They were imbedded in alluvial mud, of the solidity of calcareous tufa, and containing some flint pebbles and fragments of the limestone of the country. Beneath

* M. Marcel de Serres, Géognosie des Terrains Tertiaires, p. 64. Introduction.

this mixed accumulation, which sometimes attained a thickness of thirteen feet, is the original floor of the cavern, about a foot thick, covered with bones and the dung of animals (*album græcum*), in a sandy and tufaceous cement.

The human bones in these caverns of Pondres and Souvignargues were found, upon a careful analysis, to have parted with their animal matter to as great a degree as those of the hyæna which accompany them, and are equally brittle, and adhere as strongly to the tongue.

In order to compare the degree of alteration of these bones with those known to be of high antiquity, M. Marcel de Serres, and M. Ballard, chemist of Montpellier, procured some from a Gaulish sarcophagus in the plain of Lunel, supposed to have been buried for fourteen or fifteen centuries at least. In these the cellular tissue was empty, but they were more solid than fresh bones. They did not adhere to the tongue in the same manner as those of the caverns of Bize and Pondres, yet they had lost at least three fourths of their original animal matter.

The superior solidity of the Gaulish bones to those in a fresh skeleton is a fact in perfect accordance with the observations made by Mr. Mantell on bones taken from a Saxon tumulus near Lewes.

M. Teissier has also described a cavern near Mialet, in the department of Gard, where the remains of the bear and other animals were mingled confusedly with human bones, coarse pottery, teeth pierced for amulets, pointed fragments of bone, bracelets of bronze, and a Roman urn. Part of this deposit reached to the roof of the cavity, and adhered firmly to it. The author suggests that the exterior portion of the grotto

may at one period have been a den of bears, and that afterwards the aboriginal inhabitants of the country took possession of it either for a dwelling or a burial place, and left there the coarse pottery, amulets, and pointed pieces of bone. At a third period the Romans may have used the cavern as a place of sepulture or concealment, and to them may have belonged the urn and bracelets of metal. If we then suppose the course of the neighbouring river to be impeded by some temporary cause, a flood would be occasioned, which, rushing into the open grotto, may have washed all the remains into the interior caves and tunnels, heaping the whole confusedly together.*

In the controversy which has arisen on this subject MM. Marcel de Serres, De Christol, Tournal, and others, have contended, that the phenomena of this and other caverns in the south of France prove that the fossil rhinoceros, hyæna, bear, and several other lost species, were once contemporaneous inhabitants of the country, together with man, while M. Desnoyers has supported the opposite opinion. The flint hatchets and arrow heads, he says, and the pointed bones and coarse pottery of many French and English caves, agree precisely in character with those found in the tumuli, and under the dolmens (rude altars of unhewn stone) of the primitive inhabitants of Gaul, Britain, and Germany. The human bones, therefore, in the caves which are associated with such fabricated objects, must belong not to antediluvian periods, but to a people in the same stage of civilization as those who constructed the tumuli and altars.

In the Gaulish monuments, we find, together with the objects of industry above mentioned, the bones of

* Bull. de la Soc. Géol. de France, tom. ii. pp. 56—63.

wild and domestic animals of species now inhabiting Europe, particularly of deer, sheep, wild boars, dogs, horses, and oxen. This fact has been ascertained in Quercy, and other provinces, and it is supposed by antiquaries, that the animals in question were placed beneath the Celtic altars in memory of sacrifices offered to the Gaulish divinity Hesus, and in the tombs to commemorate funeral repasts, and also from a superstition prevalent among savage nations, which induces them to lay up provisions for the manes of the dead in a future life. But in none of these ancient monuments have any bones been found of the elephant, rhinoceros, hyæna, tiger, and other quadrupeds, such as are found in caves, as might certainly have been expected, had these species continued to flourish at the time that this part of Gaul was inhabited by man.*

We are also reminded by M. Desnoyers of a passage in Florus, in which it is related that Cæsar ordered the caves into which the Aquitanian Gauls had retreated to be closed up.† It is also on record, that, so late as the eighth century, the Aquitanians defended themselves in caverns against King Pepin. As many of these caverns, therefore, may have served in succession as temples and habitations, as places of sepulture, concealment, or defence, it is easy to conceive that human bones, and those of animals, in osseous breccias of much older date, may have been swept away together, by inundations, and then buried in one promiscuous heap.

It is not on the evidence of such intermixtures that we ought readily to admit either the high antiquity of the human race, or the recent date of certain lost species of quadrupeds.

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 252.

† Hist. Rom. Epit. lib. iii. c. 10.

CHAPTER XV.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

Division of the subject — Phenomena relating to terrestrial animals and plants — Increased specific gravity of wood sunk to great depths in the sea — Experiments of Scoresby — Drift timber carried by the Mackenzie into Slave Lake and Polar sea — Floating trees in the Mississippi — in the Gulf stream — on the coast of Iceland, Spitzbergen, and Labrador — Imbedding of the remains of insects — of reptiles — Bones of birds why rare — Imbedding of terrestrial quadrupeds — Effects of a flood in the Solway Firth — Wild horses drowned in savannahs of South America — Skeletons in recent shell marl — Imbedding of mammiferous remains in marine strata.

Division of the subject. — HAVING treated of the imbedding of organic remains in deposits formed upon the land, I shall next consider the including of the same in deposits formed under water.

It will be convenient to divide this branch of our subject into three parts; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations; secondly, the modes whereby animals and plants inhabiting *fresh-water* may be so entombed; thirdly, how *marine* species may become preserved in new strata.

The phenomena above enumerated demand a fuller share of attention than those previously examined, since the deposits which originate upon dry land are insignificant in thickness, superficial extent, and durability, when contrasted with those of subaqueous origin. At the same time, the study of the latter is

beset with greater difficulties; for we are here concerned with the results of processes much farther removed from the sphere of ordinary observation. There is, indeed, no circumstance which so seriously impedes the acquisition of just views in our science as an habitual disregard of the important fact, that the reproductive effects of the principal agents of change are confined to another element, — to that larger portion of the habitable globe, from which, by our very organization, we are almost entirely excluded.*

Imbedding of Terrestrial Plants.

When a tree falls into a river from the undermining of the banks, or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies differently in different woods; but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

Wood sunk to a great depth in the sea.—If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions †, that on one occasion a whale, on being harpooned, ran out all the lines in the boat, which it then dragged under water, to the depth of several thousand feet, the men having just time to escape to a piece of ice. When the fish returned to the surface "to blow," it was struck a

* Book i. chap. v. † Vol. ii. p. 191.

second time, and soon afterwards killed. The moment it expired it began to sink,—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then hauled up with great labour, for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. "When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore as if they had lain at the bottom of the sea since the flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and, though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless; even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible." *

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c., to the depth of four thousand and sometimes six thousand feet, they became impregnated with sea-water, and when drawn up again, after immersion, for an hour, would no longer float. The effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every

* Account of the Arctic Regions, vol. ii. p. 193.

solid inch having increased one-twentieth in size and twenty-one twenty-fifths in weight. *

Drift-wood of the Mackenzie river.—When timber is drifted down by a river, it is often arrested by lakes, and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming: sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which vies in dimensions with some of the great fresh-water seas of Canada, the quantity of drift-timber brought down annually is enormous. "As the trees," says Dr. Richardson, "retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked, and, accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost; and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish-brown substance resembling peat, but which still retains more or less of the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the depth of four or five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little in-

* Account of the Arctic Regions, vol. ii. p. 202.

filtration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the older alluvial banks presented, or the *regular curve* that the strata assumed from unequal subsidence.

"It was in the rivers only that we could observe sections of these deposits, but the same operation goes on on a much more magnificent scale in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable debris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave River. Vast quantities of drift-timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake."*

The banks of the Mackenzie display almost every where horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding the vast forests intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood grows at present, except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie

* Dr. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

is owing, as Dr. Richardson informs me, to the direction and to the length of the course of this river, which runs from south to north, so that the sources of the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the former are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and, finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-wood of the Mississippi.—I have already observed* that the navigation of the Mississippi is much impeded by trunks of trees half sunk in the river. On reaching the Gulf of Mexico many of them subside and are imbedded in the new strata which form the delta, but many of them float on and enter the Gulf stream. "Tropical plants (says M. Constant Prevost) are taken up by this great current, and carried in a northerly direction, till they reach the shores of Iceland and Spitzbergen uninjured. A great portion of them are doubtless arrested on their passage, and probably always in the same inlets, or the same spots on the bottom of the ocean; in fact, wherever an eddy or calm determines their distribution, which, in this single example, extends over a space comprehended between the equator and the eightieth degree of latitude—an immense space, six times more considerable than that occupied by all Europe, and thirty times larger than France. The drifting of various sub-

* Vol. I. p. 272.

stances, though regular, is not continual; it takes place by intermittance after great inundations of rivers, and in the intervals the waters may only carry sand or mud, or each of these alternately, to the same localities."*

Drift-timber on coasts of Iceland, Spitzbergen, &c.—The ancient forests of Iceland, observes Malte-Brun, have been improvidently exhausted; but, although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees, are thrown upon the northern coast of the island, especially upon North Cape and Cape Langaness, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Crantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent.†

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch trees, pines, Siberian cedars, firs, and Fernambucco and Campeachy woods. These trunks appear to have been swept away by the great rivers of Asia and America. Some of them are brought from the Gulf of Mexico, by the Bahama stream, while others are hurried forward by the current which, to the north of Siberia, constantly sets in from

* Mém. de la Soc. d'Hist. Nat. de Paris, vol. iv. p. 84.

† Malte-Brun, Geog., vol. v. part i. p. 112.—Crantz, Hist. of Greenland, tome i. pp. 50—54.

east to west. Some of these trees have deen deprived of their bark by friction, but are in such a state of preservation as to form excellent building timber.* Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea, into latitudes too cold for the growth of such timber, but the trunks are usually barked.

Lighter parts of plants carried out to sea by hurricanes.—The leaves and lighter parts of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the atmosphere which sometimes accompany earthquakes and volcanic eruptions.†

Concluding remarks.—It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers, yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of unfathomable abysses, and there accumulate without intermixture of other substances.

It may be asked whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently preserved, so as to be hereafter recognizable, supposing the strata now in progress to be at some future period upraised? To this inquiry it may be answered, that there are no reasons for expecting that more than a

* Olafsen, Voyage to Iceland, tome i. Malte-Brun's Geog., vol. v. part i. p. 112.

† De la Beche, Geol. Manual, p. 477.

small number of the plants now flourishing in the globe will become fossilized, since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains. Those naturalists, therefore, who infer that the ancient flora of the globe was, at certain periods, less varied than now, merely because they have as yet discovered only a few hundred fossil species of a particular epoch, while they can enumerate more than fifty thousand living ones, are reasoning on a false basis, and their standard of comparison is not the same in the two cases.

Imbedding of the Remains of Insects.

I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy. Amongst these, Mr. Curtis recognized Elater lineatus and Atopa cervina, species still living in Scotland. These, as well as other remains which accompanied them, appear to belong to terrestrial, not aquatic species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon: but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are rare. In the blue clay of very modern origin of Lewes Levels, Mr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera Planorbis, Limnea, &c., adhering to them. *

* Trans. Geol. Soc., vol. iii. part i. p. 201. second series.

When speaking of the migrations of insects, I pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or decomposed.

Remains of Reptiles.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java in the year 1699, we may imagine that extraordinary floods of mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck carried into the sea by the late inundations in Morayshire *; and it is evident that whenever a sea-cliff is undermined, or land is swept by other violent causes into the sea, land reptiles may be carried in.

Remains of Birds.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. In consequence of the hollow tubular structure of their bones and the quantity of their

* Sir T. D. Lauder's Account, second edition, p. 312.

feathers, they are extremely light in proportion to their volume, so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals. To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

Sir T. D. Lauder records that some aquatic birds were dashed to pieces by the impetuous waters of the Deveron, in Aberdeenshire, as they rushed through a narrow pass among the rocks during the floods of 1829.* In this manner torrents charged with mud may occasionally deposit the remains of birds in lacustrine strata.

Imbedding of terrestrial Quadrupeds.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains where herds of herbivorous quadrupeds congregate together. These animals are often surprised, and being unable to stem the current, are hurried along until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth, or at latest the fourteenth day. The pressure of a thin covering of mud

* Account of the Great Floods, &c., second ed., p. 330.

would not be sufficient to retain them at the bottom, for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and in sea-water they would be still more buoyant.

Where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random over the bottom of a lake, estuary, or sea, so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third—all included, perhaps, in a matrix of fine materials, where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are instantly devoured by sharks, alligators, and other carnivorous beasts, which may have power to digest even the bones. But during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water, lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of carcasses becoming permanently imbedded is considerable.

Flood in the Solway Firth, 1794.—One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of

Scotland, on the 24th of January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway, so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank, called "the beds of Esk," where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of nine black cattle, three horses, 1840 sheep, forty-five dogs, 180 hares, besides a great number of smaller animals, and, mingled with the rest, the corpes of two men and one woman.*

Floods in Scotland, 1829.—In those more recent floods in Scotland, in August, 1829, whereby a fertile district, on the east coast, became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire:—"For several miles along the beach crowds were employed in endeavouring to save the wood and other wreck with which the heavy rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits. Thousands of living frogs, also,

* Treatise on Practical Store Farming, p. 25.

swept from the fields, no one can say how far off, were observed leaping among the wreck." *

Savannahs of South America.—We are informed by Humboldt, that during the periodical swellings of the large rivers in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, thousands are said to perish when the river Apure is swollen, before they have time to reach the rising grounds of the Llanos. The mares, during the season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. "Such is the pliability," observes the celebrated traveller, "of the organization of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring." †

Floods of the Ganges.—We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen.‡

* Sir T. D. Lauder's Floods in Morayshire, 1829, p. 312., second ed.; and see above, vol. i. p. 252.

† Humboldt's Pers. Nar., vol. iv. pp. 394—396.

‡ Malte-Brun, Geog., vol. iii. p. 22.

In Java, 1699.—I have already referred to the effects of a flood which attended an earthquake in Java in 1699, when the turbid waters of the Batavian river destroyed all the fish except the carp; and when drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud.*

On the western side of the same island, in the territory of Goulongong, in the Regencies, a more recent volcanic eruption (1821) was attended by a flood, during which the river Tjetandoy bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than one hundred men and women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed.†

In Virginia, 1771.—I might enumerate a great number of local deluges that have swept through the fertile lands bordering on large rivers, especially in tropical countries, but I should surpass the limits assigned to this work. I may observe, however, that the destruction of the islands, in rivers, is often attended with great loss of lives. Thus, when the principal river in Virginia rose, in 1771, to the height of twenty-five feet above its ordinary level, it swept entirely away Elk Island, on which were seven hundred head of quadrupeds,—horses, oxen, sheep, and hogs,—and nearly one hundred houses.‡

* See Vol. II. p. 248.

† This account I had from Mr. Baumhauer, Director-General of Finances in Java.

‡ Scots Mag., vol. xxxiii.

The reader will gather, from what was before said respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in fresh-water formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Skeletons of animals in recent shell-marl, Scotland.— In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in Scotland. The remains of several hundred skeletons have been procured within the last century, from five or six small lakes in Forfarshire, where shell-marl has been worked. Those of the stag (*Cervus elaphus*) are most numerous, and if the others be arranged in the order of their relative abundance, they will follow nearly thus: — the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare, but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

In the greater part of these lake deposits there are no signs of floods, and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed, by swim-

ming, from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape may have plunged deeper into the marly bottom. Some individuals, I suspect, of different species, have fallen in when crossing the frozen surface in winter; for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs, which are numerous, and which, retaining always an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other part of the lake it is strong enough to bear the heaviest weights.

Mammiferous remains in marine strata.—As the bones of mammalia are often so abundantly preserved in peat, and in such lakes as have just been described, the encroachments of a sea upon a coast may sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in subaqueous formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although I believe it to be of comparatively small importance amongst the numerous agents whereby terrestrial organic remains are included in submarine strata.

CHAPTER XVI.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

Drifting of human bodies to the sea by river inundations — Destruction of bridges and houses — Loss of lives by shipwreck — How human corpses may be preserved in recent deposits — Number of wrecked vessels — Examples of fossil skeletons of men — of fossil canoes, ships, and works of art — of the chemical changes which metallic articles have undergone after long submergence — Imbedding of cities and forests in subaqueous strata by subsidence of land — Earthquake of Cutch in 1819 — Submarine forests — Example on the coast of Hampshire — Origin of a submarine forest — Berkley's arguments for the recent date of the creation of man — Concluding remarks.

I SHALL now proceed to inquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in the course of a few thousand years; but, of the smaller number that perish in the waters, a considerable proportion must frequently be entombed, under such circumstances, that parts of them may endure throughout entire geological epochs.

The bodies of men, together with those of the inferior animals, are occasionally washed down during river inundations into seas and lakes.* Belzoni witnessed a flood on the Nile in September, 1818, where, although the river only rose three feet and a half above its ordi-

* See pp. 179, 180.

nary level, several villages, with some hundreds of men, women, and children, were swept away.* It was before mentioned that a rise of six feet of water in the Ganges, in 1763, was attended with a much greater loss of lives.†

In the year 1771, when the inundations in the north of England appear to have equalled the recent floods in Morayshire, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep, were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically. As the population increases, and buildings and bridges are multiplied, we must expect the loss of lives and property to augment.‡

Fossilization of human bodies in the bed of the sea.— If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwreck, we shall find that, in the course of a single year, a great number of human remains are consigned to the subaqueous regions. I shall hereafter advert to a calculation by which it ap-

* Narrative of Discovery in Egypt, &c., London, 1820.

† Vol. I. p. 357.

‡ Scots Mag., vol. xxxiii., 1771.

pears that more than five hundred *British* vessels alone, averaging each a burden of about one hundred and twenty tons, are wrecked, and sink to the bottom, *annually*. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them; but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of a river is advancing, they may be preserved for an incalculable series of ages.

Often at the distance of a few hundred feet from a coral reef, where wrecks are not unfrequent, there are no soundings at the depth of many hundred fathoms. Canoes, merchant vessels, and ships of war, may have sunk and have been enveloped, in such situations, in calcareous sand and breccia, detached by the breakers from the summit of a submarine mountain. Should a volcanic eruption happen to cover such remains with ashes and sand, and a current of lava be afterwards poured over them, the ships and human skeletons might remain uninjured beneath the superincumbent mass, like the houses and works of art in the subterranean cities of Campania. Already may human remains have been thus preserved beneath formations more than a thousand feet in thickness; for, in some volcanic archipelagos, a period of thirty or forty centuries might well be supposed sufficient for such an accumulation.

It was stated that, at the distance of about forty miles from the base of the delta of the Ganges, there is a circular space about fifteen miles in diameter where soundings of a thousand feet sometimes fail to reach the bottom.* As during the flood season the quantity of mud and sand poured by the great rivers into the Bay of Bengal is so great that the sea only recovers its transparency at the distance of sixty miles from the coast, this depression must be gradually shoaling, especially as during the monsoons the sea, loaded with mud and sand, is beaten back in that direction towards the delta. Now, if a ship or human body sink down to the bottom in such a spot, it is by no means improbable that it may become buried under a depth of three or four thousand feet of sediment in the same number of years.

Even on that part of the floor of the ocean to which no accession of drift matter is carried (a part which probably constitutes, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom, and is overturned, in which case the ballast, consisting of sand, shingle, and rock, or the cargo, frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel as they decay, and

* Vol. I. p. 353.

beneath these and the metallic substances the bones of man may be preserved.

Number of wrecked vessels.—When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven fifty-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments ; in each were an infinite variety of instruments of the arts of war and peace, many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water.

But the reader must not imagine that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists from the year 1793 to the commence-

ment of 1829 it has appeared that the number of *British vessels* alone lost during that period amounted, on an average, to no less than one and a half *daily**, an extent of loss which would hardly have been anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at one time, in the navigation of England and Scotland, amounts to about twenty thousand, having one with another a mean burden of 120 tons.† Out of 551 ships of the royal navy lost to the country during the period above mentioned, only 160 were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident ‡, a striking proof that the dangers of our naval warfare, however great, may be far exceeded by the storm, the hurricane, the shoal, and all the other perils of the deep.

Durable nature of many of their contents.— Millions of silver dollars and other coins have been sometimes submerged in a single ship, and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants in some of the ancient secondary rocks. In almost every large ship, more-

* I am indebted to Captain W. H. Smyth, R.N., for this information; and my friend Mr. J. L. Prevost, F.G.S., has found, by inspecting Lloyd's lists for the years 1829, 1830, and 1831, that no less than 1953 vessels were lost in those three years, their average tonnage being above 150 tons. This increased loss arises, I presume, from increasing activity in commerce.

† Cæsar Moreau's Tables of the Navigation of Great Britain.

‡ I give these results on the authority of Captain W. H. Smyth, R.N.

over, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved — engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was, therefore, a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

> ——— as rich with praise
> As is the ooze and bottom of the deep
> With sunken wreck and sumless treasuries;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will be seen at any one time on the surface of the continents.

If our species be of as recent a date as is generally supposed, it will be vain to seek for the remains of man and the works of his hands imbedded in submarine strata, except in those regions where violent earthquakes are frequent, and the alterations of relative level so great, that the bed of the sea may have been converted into land within the historical era. We need not despair, however, of the discovery of such monuments when those regions which have been peopled by man from the earliest ages, and which are at the same time the principal theatres of volcanic action, shall be examined by the joint skill of the antiquary and geologist.

Power of human remains to resist decay. — There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior

animals; and I have already cited the remark of Cuvier, that "in ancient fields of battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave."* In the delta of the Ganges bones of men have been found in digging a well at the depth of ninety feet†; but as that river frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Fossil skeletons of men.— Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement resembling travertin, by which also the different grains are bound together. The lens shows that some of the fragments of coral composing this stone still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the Bulimus Guadaloupensis of Férussac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to Mr. König, the rock in which the former is inclosed is harder

* Vol. I. p. 231. † Von Hoff, vol. i. p. 379.

under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Similar formations are in progress in the whole of the West-Indian archipelago, and they have greatly extended the plain of Cayes in St. Domingo, where fragments of vases and other human works have been found at a depth of twenty feet. In digging wells also near Catania, in Sicily, tools have been discovered in a rock somewhat similar.

Buried ships, canoes, and works of art.—When a vessel is stranded in shallow water, it usually becomes the nucleus of a sand-bank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. About fifty years ago, a vessel from Purbeck, laden with three hundred tons of stone, struck on a shoal off the entrance of Poole harbour and foundered; the crew were saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that Point.* The cause is obvious; the tidal current deposits the sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it just as the African sand-winds, before described, raise a small hillock over the carcasses of every dead camel exposed on the surface of the desert.

* This account I received from the Honourable Chas. Harris.

I before alluded * to an ancient Dutch vessel, discovered in the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged. The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vesel and two anchors in a very perfect state were dug up far from the sea.†

At the mouth of a river in Nova Scotia, a schooner of thirty-two tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about ten feet in perpendicular height, rushed into the estuary and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand, that the taffrel or upper rail of the deck was alone visible.‡ We are informed by Leigh, that on draining Martin Meer, a lake eighteen miles in circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this Meer a whetstone and an axe of mixed metal were dug up. § In Ayr-

* Vol. I. p. 412. † Von Hoff, vol. i. p. 368.

‡ Silliman's Geol. Lectures, p. 78., who cites Penn.

§ Leigh's Lancashire, p. 17., A.D. 1700.

shire also, three canoes were found in Loch Doon some few years ago; and during the year 1831 four others, each hewn out of separate oak trees. They were twenty-three feet in length, two and a half in depth, and nearly four feet in breath at the stern. In the mud which filled one of them was found a war-club of oak and a stone battle-axe. A canoe of oak was also found in 1820, in peat overlying the shell-marl of the Loch of Kinnordy in Forfarshire.*

Manner in which ships may be preserved in a deep sea.—It is extremely possible that the submerged wood-work of ships which have sunk where the sea is two or three miles deep has undergone greater chemical changes in an equal space of time, than in the cases above mentioned; for the experiments of Scoresby show that wood may at certain depths be impregnated in a single hour with salt-water, so that its specific gravity is entirely altered. It may often happen that hot springs charged with carbonate of lime, silex, and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion also of wood into lignite is probably more rapid under enormous pressure. But the change of the timber into lignite or coal would not prevent the original form of a ship from being distinguished, for as we find in strata of the carboniferous era the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal; while in the indurated mud, sandstone, or lime-

* Geol. Trans., second ser., vol. ii. p. 87.

stone, filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Submerged metallic substances.—Many of the metallic substances which fall into the waters probably lose, in the course of ages, the forms artificially imparted to them; but under certain circumstances these may be preserved for indefinite periods. The cannon inclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long as the calcareous matrix; but even if the metallic matter had been removed, and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen, sweeping for anchors in the Gull stream (a part of the sea near the Downs), drew up a very curious old swivel gun, near eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of an exceeding strong texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there was no such incrustation, the greater part of it being clean, and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, "just as they are often found in a fossil

state." These were all so strongly attached, that it required as much force to separate them from the matrix "as to break a fragment off any hard rock."*

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian, and went to pieces. About thirty-three years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses, "consisting of iron, ropes, and balls," covered over with ochreous sand, concreted and hardened into a kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, "just as impressions of extraneous fossil bodies are found in various kinds of strata."†

After a storm, in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's, in Scotland, a gun-barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of the Spanish Armada. It is now in the museum of the Antiquarian Society of Scotland, and is incrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common cardium, mya, &c.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coasts, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes, in the Philosophical Transactions‡, a bronze helmet, of the antique Grecian

* Phil. Trans., 1779. † Ibid., vol. lxix., 1779.

‡ 1826, part ii. p. 55.

form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially incrusted with shells, and a deposit of carbonate of lime. The surface generally, both under the incrustation, and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

The mineralizing process, says Dr. Davy, which has produced these new combinations, has, in general, penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath; in some places considerably corroded, in others very slightly. It proves, on analysis, to be copper, alloyed with 18·5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility.

"It is a curious question," he adds, "how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralizing process depends on a small motion and separation of the particles of the original compound? This motion may have been due to the operation of electro-chemical powers which may have separated the different metals of the alloy.

Effects of the Subsidence of Land, in imbedding Cities and Forests in subaqueous Strata.

We have hitherto considered the transportation of plants and animals from the land by *aqueous* agents,

and their inhumation in lacustrine or submarine deposits, and we may now inquire what tendency the subsidence of tracts of land by *earthquakes* may have to produce analogous effects. Several examples of the sinking down of buildings, and portions of towns near the shore, to various depths beneath the level of the sea during subterranean movements, were before enumerated in treating of the changes brought about by *inorganic* causes. The events alluded to were comprised within a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable changes in the physical geography of the globe. If, during the earthquake of Jamaica, in 1692, some of the houses in Port Royal subsided, together with the ground they stood upon, to the depth of twenty-four, thirty-six, and forty-eight feet under water, we are not to suppose that this was the only spot throughout the whole range of the coasts of that island, or the bed of the surrounding sea, which suffered similar depressions. If the quay at Lisbon sunk at once to the depth of several hundred feet in 1755, we must not imagine that this was the only point on the shores of the peninsula where similar phenomena might have been witnessed.

If, during the short period since South America has been colonized by Europeans, we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception*, we cannot for a moment suspect that these cities, so distant from each other, have been selected as the

* See Vol. II. pp. 176. 243. 246.

peculiar points where the desolating power of the earthquake has expended its chief fury. "It would be a knowing arrow that could choose out the brave men from the cowards," retorted the young Spartan, when asked if his comrades who had fallen on the field of battle were braver than he and his fellow-prisoners; we might, in the same manner, remark that a geologist must attribute no small discrimination and malignity to the subterranean force, if he should suppose it to spare habitually a line of coast many thousand miles in length, with the exception of those few spots where populous towns have been erected. On considering how small is the area occupied by the sea-ports of this disturbed region,—points where alone each slight change of the relative level of the sea and land can be recognized, and reflecting on the proofs in our possession, of the local revolutions that have happened on the site of each port, within the last century and a half,—our conceptions must be greatly exalted respecting the magnitude of the alterations which the country between the Andes and the sea may have undergone, even in the course of the last six thousand years.

Cutch earthquake.—The manner in which a large extent of surface may be submerged, so that the terrestrial plants and animals may be imbedded in subaqueous strata, cannot be better illustrated than by the earthquake of Cutch, in 1819, before alluded to.* It is stated, that, for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon formed by subsidence, on the site of the village of

* Vol. II. p. 183.

Sindree and its environs; but after the flood of 1826 they were seen no longer. Every geologist will at once perceive, that forests sunk by such subterranean movements may become imbedded in subaqueous deposits, both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Submarine forests.—But, although a certain class of geological phenomena may be referred to the repetition of such catastrophes, we must hesitate before we call in to our aid the action of earthquakes, to explain what have been termed submarine forests, observed at various points around the shores of Great Britain. I have already hinted, that the explanation of some of these may be sought in the encroachments of the sea, in estuaries, and the varying level of the tides, at distant periods, on the same parts of our coast.* After examining, in 1829, the so-called submarine forest of Happisborough, in Norfolk, I found that it was nothing more than a tertiary lignite; which becomes exposed in the bed of the sea as soon as the waves sweep away the superincumbent strata of blueish clay. So great has been the advance of the sea upon our eastern shores, within the last eight centuries, that whenever we find a mass of submerged timber near the sea-side, or at the foot of the existing cliffs, which we cannot suppose to be a mere accumulation of drift vegetable matter, we should endeavour to find a solution of the problem, by reference to any cause rather than an earthquake. For we can

* Vol. I. p. 399.

scarcely doubt that the present outline of our coast, the shape of its estuaries, and the formation of its cliffs, are of very modern date, probably within the historical era, whereas we have no reason whatever to imagine that this part of Europe has been agitated by subterranean convulsions, capable of altering the relative level of land and sea, at so recent a period.

In Scotland.—It has been observed, by Dr. Fleming, that the roots of the trees, in several submarine forests in Scotland, are in lacustrine silt. The stumps of the trees evidently occupy the position in which they formerly grew, and are sometimes from eight to ten feet below high-water mark. The horizontality of the strata, and other circumstances, preclude the supposition of a slide; and the countries in question have been, from time immemorial, free from violent earthquakes, which might have produced subsidences. He has, therefore, attributed the depression, with much probability, to the drainage of peaty soil, on the removal of a seaward barrier. Suppose a lake, separated from the sea by a chain of sand hills, to become a marsh, and a stratum of vegetable matter to be formed on the surface, of sufficient density to support trees. Let the outlet of the marsh be elevated a few feet only above the rise of the tide. All the strata below the level of the outlet would be kept constantly wet, or in a semifluid state; but if the tides rise in the estuary, and the sea encroaches, portions of the gained lands are swept away, and the extremities of the alluvial and peaty strata, whereon the forest grew, are exposed to the sea, and at every ebb tide left dry to a depth equal to the increased fall of the tide. Much water, formerly prevented from escaping, now oozes out from the moist beds,—the strata collapse,

and the surface of the morass, instead of remaining at its original height, sinks below the level of the sea.*

Submarine forest on coast of Hants, how formed.—Mr. Charles Harris discovered lately evident traces of a fir wood, beneath the mean level of the sea, at Bournmouth, in Hampshire, the formation having been laid open during a low spring tide. It is composed of peat and wood, and is situated between the beach and a bar of sand about two hundred yards off, and extends fifty yards along the shore. It also lies in the direct line of the Bournmouth Valley, from the termination of which it is separated by two hundred yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch trees, and a great abundance of the Myrica gale. Seventy-six rings of annual growth were counted in a transverse section of one of the buried fir trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, pieces of alder and birch are found in the peat; and it is a curious fact, that a part of many of the trees has been converted into iron pyrites. The peat rests on pebbly strata, precisely similar to the sand and pebbles occurring on the adjoining heaths.

As the sea is encroaching on this shore, we may suppose that at some former period the Bourne Valley extended farther, and that its extremity consisted, as at present, of boggy ground, partly clothed with fir trees. The bog rested on that bed of pebbles which we now see below the peat; and the sea, in

* See Memoirs by the Rev. Dr. Fleming, Trans. R. S. Edin., vol. ix. p. 419., and Quarterly Journ. of Sci., No. 13., new series.

its progressive encroachments, eventually laid bare, at low water, the sandy foundations; upon which a stream of fresh water rushing through the sand at the fall of the tides, carried out loose sand with it. The superstratum of vegetable matter being matted and bound together by the roots of trees, remained; but being undermined, sank down below the level of the sea, and then the waves washed sand and shingle over it. In support of this hypothesis, it may be observed, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dry-shod; and the water is seen, at the point where it issues, to carry out sand, and even pebbles.

Buildings how preserved under water. — Some of the buildings which have at different times subsided beneath the level of the sea have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and at the site of the Temple of Serapis, in the environs of Puzzuoli, probably in the twelfth century. The entrance of a river charged with sediment in the vicinity may still more frequently occasion the rapid envelopment of buildings in regularly stratified formations. But if no foreign matter be introduced, the buildings when once removed to a depth where the action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and

I am informed by an eye-witness that eighty-eight years after the convulsion of 1692, the houses of Port Royal were still visible at the bottom of the sea.*

Berkley's arguments for the recent date of the creation of man.—I cannot conclude this chapter without recalling to the reader's mind a memorable passage written by Berkley a century ago, in which he inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. "To any one," says he, "who considers that on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there in all probability some thousands of years; it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglias, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during

* Admiral Sir Charles Hamilton frequently saw the submerged houses of Port Royal in the year 1780, in that part of the harbour which lies between the town and the usual anchorage of men-of-war. Bryan Edwards also says, in his History of the West Indies, (vol. i. p. 235., oct. ed., 3 vols. 1801,) that in 1793 the *ruins* were visible in clear weather from the boats which sailed over them.

which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times."*

That many signs of the agency of man would have lasted at least as long as "the shells of the primeval world," had our race been so ancient, we may feel as fully persuaded as Berkley; and we may anticipate with confidence that many edifices and implements of human workmanship, and the skeletons of men, and casts of the human form, will continue to exist when a great part of the present mountains, continents, and seas, have disappeared. Assuming the future duration of the planet to be indefinitely protracted, we can foresee no limit to the perpetuation of some of the memorials of man, which are continually entombed in the bowels of the earth or in the bed of the ocean, unless we carry forward our views to a period sufficient to allow the various causes of change, both igneous and aqueous, to remodel more than once the entire crust of the earth. *One* complete revolution will be inadequate to efface every monument of our existence; for many works of art might enter again and again into

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

the formation of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organized remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, " that none of the works of a mortal being can be eternal."* They are in the first place wrested from the hands of man, and lost as far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish, for every year some portion of the earth's crust is shattered by earthquakes or melted by volcanic fire, or ground to dust by the moving waters on the surface. " The river of Lethe," as Bacon eloquently remarks, " runneth as well above ground as below." †

* Davy, Consolations in Travel, p. 276.

† Essay on the Vicissitude of Things.

CHAPTER XVII.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

Inhumation of fresh-water plants and animals — Shell marl — Fossilized seed-vessels and stems of Chara — Recent deposits in the American lakes — Fresh-water species drifted into seas and estuaries — Lewes levels — Alternations of marine and fresh-water strata, how caused — Imbedding of marine plants and animals — Cetacea stranded on our shores — Liability of littoral and estuary testacea to be swept into the deep sea — Effects of a storm in the Firth of Forth — Burrowing shells secured from the ordinary action of waves and currents — Living testacea found at considerable depths — Extent of some recent shelly deposits.

Having treated of the imbedding of terrestrial plants and animals, and of human remains, in deposits now forming beneath the waters, I come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

Fresh-water plants and animals. — The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh-water are for the most part preserved in the beds of lakes or estuaries, but they are oftentimes swept down by rivers into the sea, and there intermingled with the exuviæ of marine races. The phenomena attending their inhumation in lacustrine deposits are sometimes revealed to our observation by the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell marl for agricultural uses.

In these recent formations, as seen in Forfarshire,

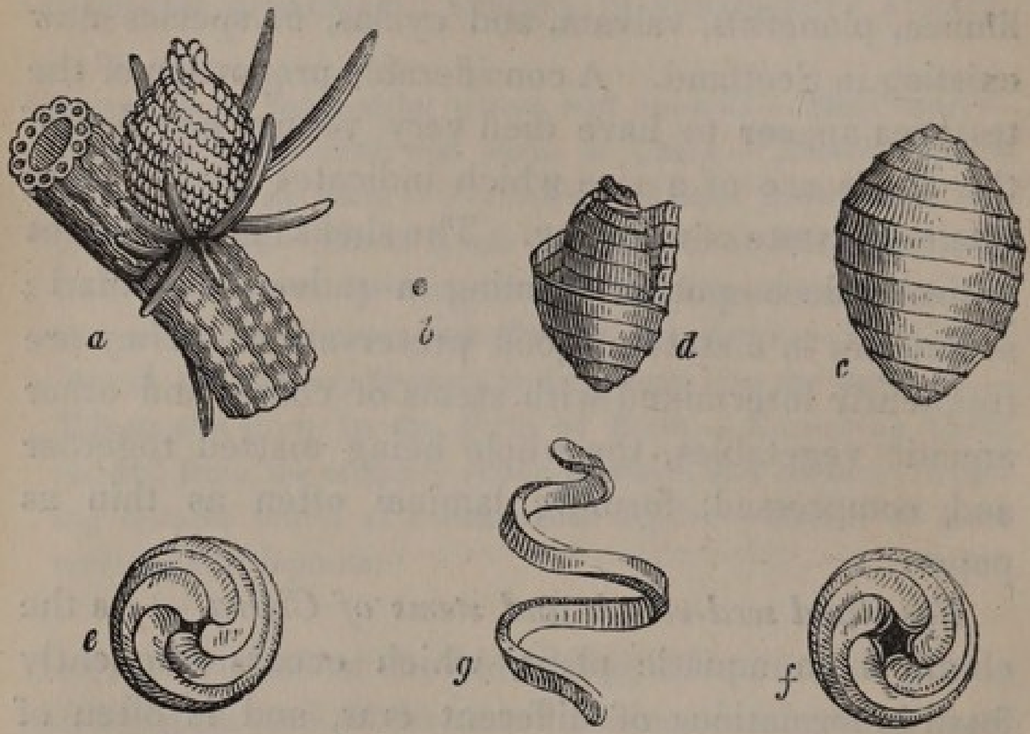
two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera limnea, planorbis, valvata, and cyclas, of species now existing in Scotland. A considerable proportion of the testacea appear to have died very young, and few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes in a state of good preservation. They are frequently intermixed with stems of charæ and other aquatic vegetables, the whole being matted together and compressed, forming laminæ often as thin as paper.

Fossilized seed-vessels and stems of Chara.—As the chara is an aquatic plant, which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterizing entire groups of strata, I shall describe the manner in which I have found the recent species in a petrified state. They occur in a marl-lake in Forfarshire, inclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

The seed-vessel of these plants is remarkably tough and hard, and consists of a membranous nut covered by an integument (fig. *d*, diagram No. 44.), both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of a quadrangular form (fig. *g*). In *Chara hispida*, which abounds in the lakes of Forfarshire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and

eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

No. 44.



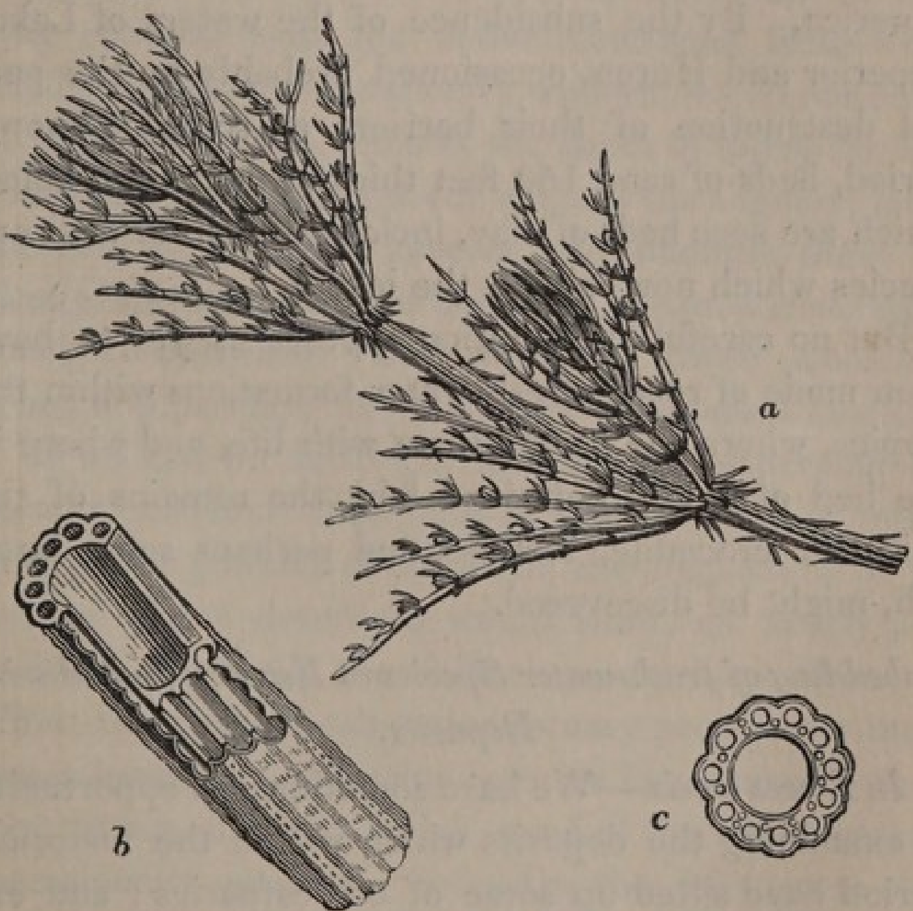
Seed-vessel of Chara hispida.

a. Part of the stem with the seed-vessel attached. Magnified.
b. Natural size of the seed-vessel.
c. Integument of the Gyrogonite, or petrified seed-vessel of Chara hispida, found in the Scotch marl-lakes. Magnified.
d. Section showing the nut within the integument.
e. Lower end of the integument to which the stem was attached.
f. Upper end of the integument to which the stigmata were attached.
g. One of the spiral valves of *c*.

The stems of charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida*, the plant when living contains so much carbonate of lime in its vegetable organization, independently of calcareous incrustation, that it effervesces strongly with acids when dried. The stems of *Chara hispida* are longitudinally striated, with a tendency to

be spiral. These striæ, as appears to be the case with all charæ, turn always like the worm of a screw from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (diagram No. 45. figs. *b*, *c*), as is seen in some extinct as well as recent species. In the stems of several species, however, there is only a single tube.*

No. 45.



Stem and branches of Chara hispida.

a. Stem and branches of the natural size.
b. Section of the stem magnified.
c. Showing the central tube surrounded by two rings of smaller tubes.

* Geol. Trans., vol. ii., second series, p. 73. On Fresh-wate Marl, &c. By C. Lyell.

The valves of a small animal called cypris (*C. ornata, Lam.*) occur completely fossilized like the stems of charæ, in the Scotch travertin above mentioned. This cypris inhabits the lakes and ponds of England, where it is not uncommon. Species of the same genus also occur abundantly in ancient fresh-water formations.

Recent deposits in North American lakes.—The recent strata of lacustrine origin above alluded to are of very small extent, but analogous deposits on the grandest scale are forming in the great lakes of North America. By the subsidence of the waters of Lakes Superior and Huron, occasioned probably by the partial destruction of their barriers at some unknown period, beds of sand 150 feet thick are exposed, below which are seen beds of clay, inclosing shells of the very species which now inhabit the lake.*

But no careful examination appears as yet to have been made of recent fresh-water formations within the tropics, where the waters teem with life, and where in the bed of a newly-drained lake the remains of the alligator, crocodile, tortoise, and perhaps some large fish, might be discovered.

Imbedding of fresh-water Species in Estuary and Marine Deposits.

In Lewes levels.—We have sometimes an opportunity of examining the deposits which within the historical period have silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouze between Newhaven and Lewes is

* Dr. Bigsby, Journal of Science, &c. No. xxxvii. pp. 262, 263.

one of several estuaries from which the sea has retired within the last seven or eight centuries ; and here, as appears from the researches of Mr. Mantell, strata thirty feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about five feet thick, inclosing many trunks of trees. Next below is a stratum of blue clay containing fresh-water shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned fresh-water shells, several marine species well known on our coast. In the lowest beds, often at the depth of thirty-six feet, these marine testacea occur without the slightest intermixture of fluviatile species, and amongst them the skull of the narwal, or sea-unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk.*

If we had no historical information respecting the former existence of an inlet of the sea in this valley, and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine testacea identical with those now living, and into which some of the larger cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of fresh-water and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued

* Mantell, Geol. of Sussex, p. 285. ; also Catalogue of Org. Rem., Geol. Trans., vol. iii. part i. p. 201. Second series.

until the river-water prevailed, so that it was no longer habitable by marine testacea, but fitted only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed where some trees grew, or perhaps were drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being only flooded by the river at distant intervals, became a verdant meadow.

In delta of Ganges.—It was before stated*, that on the sea-coast, in the delta of the Ganges, there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge. Now, as the base of the delta is two hundred miles in length, it must happen that, as often as the great volume of river-water is thrown into the sea by a new mouth, the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the exception of those parts where the principal discharge takes place, the salt-water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident, then, that repeated alternations of beds containing fresh-water shells, with others filled with corals and marine exuviæ, may here be formed, and each series may be of great thickness, as the sea on which the Gangetic delta gains is of considerable depth, and intervals of centuries elapse between each alteration in the course of the principal stream.

In delta of Indus.—Analogous phenomena must sometimes be occasioned by such alternate elevation and depression of the land as was shown to be taking place in the delta of the Indus.† But the subterranean

* Vol. I. p. 352. † Vol. II. p. 183.

movements affect but a small number of the deltas formed at one period on the globe; whereas, the silting up of some of the arms of great rivers and the opening of others, and the consequent variation of the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small, but the abundance of individuals extremely great, a circumstance very characteristic of fresh-water formations in general as compared to marine; for in the latter, as is seen on sea-beaches, coral reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

Imbedding of the Remains of Marine Plants and Animals.

Marine plants.—The large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans were before alluded to.* These, when they subside, may often produce considerable beds of vegetable matter. In Holland, submarine peat is derived from fuci, and on parts of our own coast from *Zostera marina*. In places where algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Cetacea.—It is not uncommon for the larger cetacea, which can only float in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high

* Vol. II. p. 142.

water, they are stranded. Thus a narwal (*Monodon monoceros*) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn and tried to pull it out, when the animal began to stir itself.* An individual of the common whale (*Balæna mysticetus*), which measured seventy feet, came ashore near Peterhead, in 1682. Many individuals of the genus Balænoptera have met the same fate. It will be sufficient to refer to those cast on shore near Burnt Island, and at Alloa, recorded by Sibbald and Neill. The other individual mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a Razor-back. Of the genus Catodon (*Cachalot*) Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of one hundred in number, were found stranded at Kairston, in Orkney. The dead bodies of the larger cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith.

To some accident of this kind, we may refer the position of the skeleton of a whale seventy-three feet long, which was found at Airthrey, on the Forth, near Alloa, imbedded in clay twenty feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman sta-

* Fleming's Brit. Animals, p. 37.; in which work may be seen many other cases enumerated.

tion and causeways at a small distance from the spot, it is concluded that the whale must have been stranded there at a period prior to the Christian era.*

Other fossil remains of this class have also been found in estuaries, known to have been silted up in recent times, one example of which has been already mentioned near Lewes, in Sussex.

Marine Testacea.—The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep. For as a river is perpetually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud, against which it turns its force. These banks may consist in great measure of shells peculiar to shallow, and sometimes brackish water, which may have been accumulating for centuries, until at length they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable even than fresh-water species, to be intermixed with the exuviæ of pelagic tribes.

After the storm of February 4. 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high-water mark. I collected many of these oysters, as also the common eatable whelks (*buccina*), thrown up with them, and observed that, although still living, their shells were

* Quart. Journ. of Lit. Sci., &c. No. 15. p. 172. Oct. 1819.

worn by the long attrition of sand which had passed over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they were cast ashore.

From these facts we learn that the union of the two parts of a bivalve shell does not prove that it has not been transported to a distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells.—It sometimes appears extraordinary, when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs, and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve testacea, and many also of the turbinated univalves, burrow in sand or mud. The solen and the cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the pholas can drill a cavity through mud of considerable hardness. The species of these and many other tribes can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these testacea may remain below secure and uninjured.

Shells become fossil at considerable depths. — I have already stated that, at the depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smyth found a

gravelly bottom, with fragments of broken shells carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for, even in our own colder latitudes, the depths at which living marine animals abound is very considerable. Captain Vidal ascertained, by soundings lately made off Tory island, on the north-west coast of Ireland, that crustacea, star-fish, and testacea, occurred at various depths between fifty and one hundred fathoms; and he drew up dentalia from the mud of Galway bay in 230 and 240 *fathoms* water.

The same hydrographer discovered on the Rockall bank large quantities of shells at depths varying from 45 to 190 fathoms. These shells were for the most part pulverized, and evidently recent, as they retained their bright colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in eighty and ninety fathoms water. At the eastern extremity also of Rockall bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe islands, usually at the depth of from forty

to one hundred fathoms. In one part of this tract (long. 6° 30′, lat. 61° 50′) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some vertebræ being attached. This "bone bed," as it was called by our surveyors, is three miles and a half in length, and forty-five fathoms under water, and contains a few shells intermingled with the bones.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel; whereas, in the bed of the Adriatic, Donati found them frequently enclosed in stone of recent origin. This is precisely the difference in character which we might have expected to exist between the British marine formations now in progress, and those of the Adriatic. For calcareous and other mineral springs abound in the Mediterranean and lands adjoining, while they are almost entirely wanting in our own country.

During his survey of the west coast of Africa, Captain Belcher found, by frequent soundings between the twenty-third and twentieth degrees of north latitude, that the bottom of the sea, at the depth of from twenty to about fifty fathoms, consists of sand with a great intermixture of shells, often entire, but sometimes finely comminuted. Between the eleventh and ninth degress of north latitude, on the same coast, at soundings varying from twenty to about eighty fathoms, he brought up abundance of corals and shells mixed with sand. These also were in some parts entire, and in others worn and broken.

In all these cases, it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line

of cliffs, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

But, although some deposits may thus extend continuously for a thousand miles or more near certain coasts, the greater part of the bed of the ocean, remote from continents and islands, may very probably receive, at the same time, no new accessions of drift matter, all sediment being intercepted by intervening hollows. Erroneous theories in geology may be formed not only from overlooking the great extent of simultaneous deposits now in progress, but also, from the assumption that such formations may be universal or coextensive with the bed of the ocean.*

* See book iv. chap. 3. where this subject is discussed more fully.

CHAPTER XVIII.

FORMATION OF CORAL REEFS.

Reefs are composed partly of shells — Conversion of a reef into an island — Extent and thickness of coral formations — The Maldiva isles — Rate of growth of coral — Its geological importance — Circular and oval forms of coral islands — Lagoons — Causes of their peculiar configuration — Why the windward side higher than the leeward — Stratification — Extent of some reefs — That the subsidence by earthquakes in the Pacific exceeds the elevation — Henderson's Island — Coral and shell limestones now in progress — The hypothesis that the quantity of calcareous matter has been and is still on the increase, considered.

The powers of the organic creation in modifying the form and structure of those parts of the earth's crust which may be said to be undergoing repair, or where new rock-formations are continually in progress, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean to the effects produced on a smaller scale upon the land, by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates while the lower portion is entering into a mineral mass, where the traces of organization remain, after that life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away serve as the foundation on which living animals are continuing to rear a similar structure.

In part composed of shells.— The calcareous masses

usually termed coral reefs are by no means exclusively composed of zoophytes; a great variety of shells, and, among them, some of the largest and heaviest of known species, contributing to augment the mass. In the south Pacific, great beds of oysters, mussels, *pinnæ marinæ*, and other shells, cover in profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and broken fragments of crustaceous animals. Large shoals of fish are also discernible through the clear blue water, and their teeth and hard palates are probably preserved, although a great portion of their soft cartilaginous bones decay.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the genera Meandrina, Caryophyllia, and Astrea, but especially the latter.

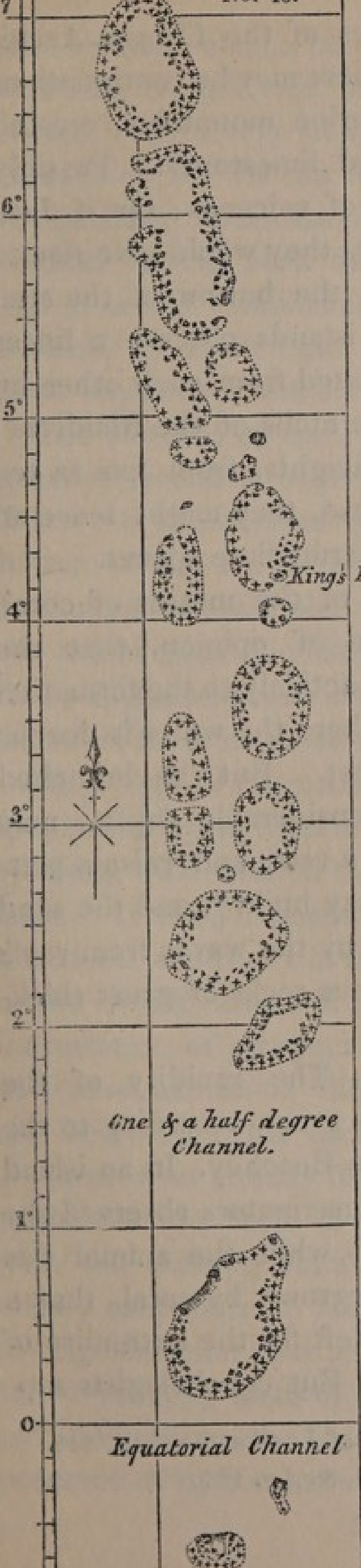
How converted into islands. — The reefs, which just raise themselves above the level of the sea, are usually of a circular or oval form, and surrounded by a deep and often unfathomable ocean. In the centre of each, there is usually a comparatively shallow lagoon, where there is still water, and where the smaller and more delicate kind of zoophytes find a tranquil abode, while the more strong species live on the exterior margin of the isle, where a great surf usually breaks. When the reef, says M. Chamisso, a naturalist who accompanied Kotzebue, is of such a height that it remains almost dry at low water, the corals leave off building. A continuous mass of solid stone is seen composed of the shells of molluscs and echini, with their broken-off prickles and fragments of coral, united by a cement of calcareous sand, produced by the pulverization of shells. Fragments of coral lime-

stone are thrown up by the waves, until the ridge becomes so high, that it is covered only during some seasons of the year by the high tides. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places. The force of the waves is thereby enabled to separate and lift blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef. " After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting place after their long wanderings: with these come some small animals, such as lizards and insects, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take refuge in the bushes: and, at a much later period, when the work has been long since completed, man appears, and builds his hut on the fruitful soil.*

Extent and thickness. — The Pacific ocean throughout a space comprehended between the thirtieth parallel of latitude on each side of the equator, is extremely productive of coral. The Arabian gulf is rapidly filling with the same, and it is said to abound in the Persian gulf. Between the coast of Malabar and that of Madagascar, there is also a great sea of coral. Flinders describes an unbroken reef, 350 miles in length, on the east coast of New Holland; and, between that country and New Guinea, Captain P. King found the coral formations to extend throughout a distance

* Kotzebue's Voyages, 1815–18, vol. iii. pp. 331—333.

No. 46.



of seven hundred miles, interrupted by no intervals exceeding thirty miles in length.

Maldiva isles.—The chain of coral reefs and islets called the Maldivas, situated in the Indian ocean, to the south-west of Malabar, form a chain 480 geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, the larger groups being from forty to fifty miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, informs me, that outside of each circle or atoll, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to twenty fathoms deep. In the channels between the atolls, no soundings have been obtained at the depth of 150 fathoms.

Laccadive islands.—The Laccadive islands run in the same line with the Maldivas,

on the north, as do the isles of the Chagos Archipelago, on the south; so that these may be continuations of the same chain of submarine mountains, crested in a similar manner by coral limestones. Possibly they may all be the summits of volcanos; for if Java and Sumatra were submerged, they would give rise to a somewhat similar shape in the bottom of the sea; since the volcanos of those islands observe a linear direction, and are often separated from each other by intervals, corresponding to the atolls of the Maldivas; and as they rise to various heights, from five to ten thousand feet above their base, they might leave an unfathomable ocean in the intermediate spaces.

In regard to the thickness of the masses of coral, MM. Quoy and Gaimard are of opinion, that the species which contribute most actively to the formation of solid masses do not grow where the water is deeper than twenty-five or thirty feet. But the branched madrepores, which live at considerable depth, may form the first foundation of a reef, and raise a platform on which other species may build *, and the sand and broken fragments washed by the waves from reefs may, in time, produce calcareous rocks of great thickness.

Rate of growth of Coral. — The rapidity of the growth of coral is by no means great, according to the report of the natives to Captain Beechey. In an island west of Gambier's group, our navigators observed the *Chama gigas* (Tridacna, Lam.), while the animal was yet living, so completely overgrown by coral, that a space only of two inches was left for the extremity of the shell to open and shut. † But conchologists sup-

* Journ. of Roy. Geograph. Soc. of London, 1831, p. 218.

† Beechey's Voyage to the Pacific, &c., p. 157.

pose that the chama may require thirty years or more to attain its full size, so that the fact is quite consistent with a very slow rate of increase in the calcareous reefs. In the late expedition to the Pacific, no positive information could be obtained of any channel having been filled up within a given period; and it seems established, that several reefs had remained, for more than half a century, at about the same depth from the surface.

The increase of coral limestone, however, may vary greatly, according to the sites of mineral springs; for these, we know, often issue in great numbers at the bottom of the sea in volcanic regions; as in the Mediterranean, for example, where they sometimes cause the sea at great depths to be fresher than at the surface; a phenomenon also declared by the South Sea islanders to be common in the Pacific.

Its geological importance.— But, when we admit the increase of coral limestone to be slow, we are merely speaking with relation to the periods of human observation. It often happens that parisitic testacea live and die on the shells of the larger slow-moving gasteropods in the South Seas, and become entirely inclosed in an incrustation of compact limestone; while the animal, to whose habitation they are attached, crawls about, and bears upon his back these shells, which may be considered as already fossilized. It is, therefore, probable, that the reefs increase as fast as is compatible with the thriving state of the organic beings which chiefly contribute to their formation; and, if the rate of augmentation thus implied be called, in conformity to our ordinary ideas of time, gradual and slow, it does not diminish, in the least degree, the geological importance of such calcareous masses.

Suppose the ordinary growth of coral limestone to to amount to six inches in a century, it will then require three thousand years to produce a reef fifteen feet thick: but have we any ground for presuming, that, at the end of that period, or of ten times thirty centuries, there will be a failure in the supply of lime, or that the polyps and molluscs will cease to act, or that the hour of the dissolution of our planet will first arrive, as the earlier geologists were fain to anticipate?

Instead of contemplating the brief annals of human events, let us turn to some natural chronometers; to the volcanic isles of the Pacific, for example, which shoot up ten or fifteen thousand feet above the level of the ocean. These islands bear evident marks of having been produced by successive volcanic eruptions; and coral reefs are sometimes found on the volcanic soil, reaching for some distance from the sea-shore into the interior. When we consider the time required for the accumulation of such mountain masses of igneous matter, according to the analogy of known volcanic agency, all idea of extenuating the comparative magnitude of coral limestones, on the ground of the slowness of the operations of lithogenous polyps, must instantly vanish.

Form of Coral Islands.—The information collected during the late expedition to the Pacific, throws much additional light on the peculiarities of form and structure of coral islands. Of thirty-two of these, examined by Captain Beechey, the largest was thirty miles in diameter, and the smallest less than a mile. They were of various shapes, all formed of living coral, except one, which, although of coral formation, was raised about eighty feet above the level of the

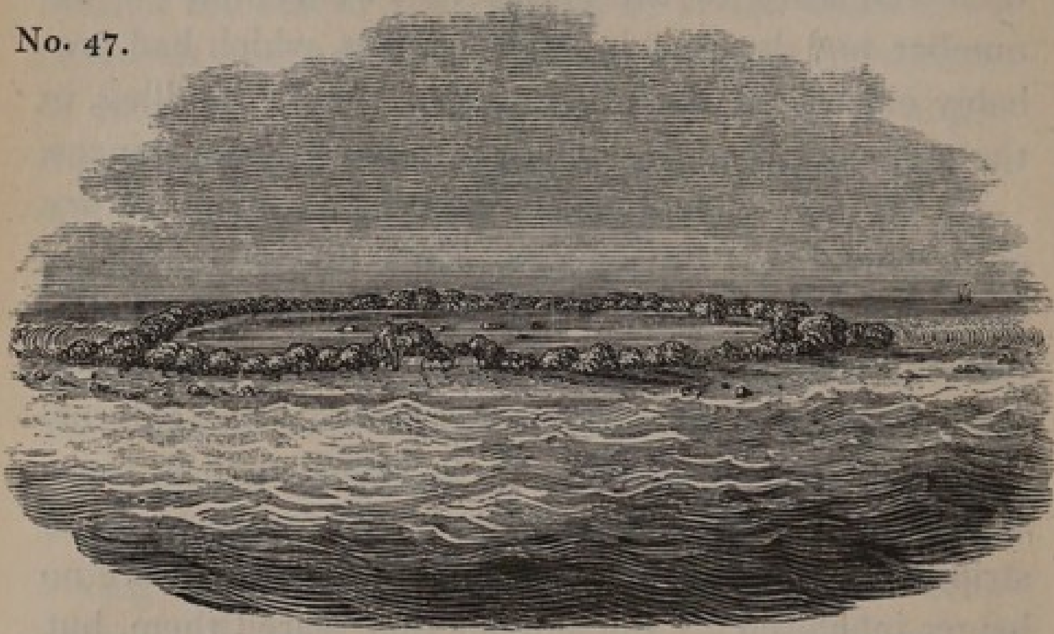
sea, and encompassed by a reef of living coral. All were increasing their dimensions by the active operations of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. Twenty-nine of the number had lagoons in their centres, which had probably existed in the others, until they were filled, in the course of time, by zoophytic and other substances.

In the above-mentioned islands, the strips of dry coral encircling the lagoons, when divested of loose sandy materials heaped upon them, are rarely elevated more than two feet above the level of the sea; and, were it not for the abrupt descent of the external margin which causes the sea to break upon it, these strips would be wholly inundated. Those parts of the strip which are beyond the reach of the waves are no longer inhabited by the animals that reared them, but have their cells filled with a hard calcareous substance, and present a brown rugged appearance. The parts which are still immersed, or which are only dry at low water, are intersected by small channels, and are so full of hollows, that the tide, as it recedes, leaves small lakes of water upon them. The width of the plain, or strip of dead coral, in the islands which fell under Captain Beechey's observation, in no instance exceeded half a mile from the usual wash of the sea to the edge of the lagoon, and, in general, was only about three or four hundred yards.* Beyond these limits the sides of the island descend rapidly, apparently by a succession of inclined ledges, each terminating in a precipice. The depth of the lagoons is various; in some, entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

* Captain Beechey, part i. p. 188.

Whitsunday Island.—In the annexed cut (No. 47.), one of these circular islands is represented just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within a lagoon of tranquil water.

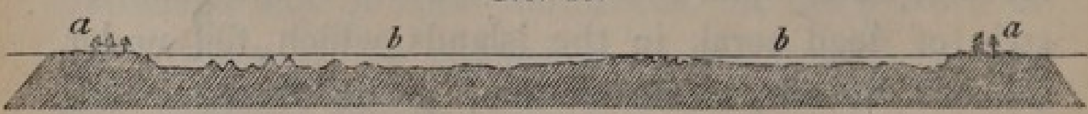
No. 47.



*View of Whitsunday Island.**

Sections of Coral Isles. — The accompanying section will enable the reader to comprehend the usual form of such islands. (No. 48.)

No. 48.



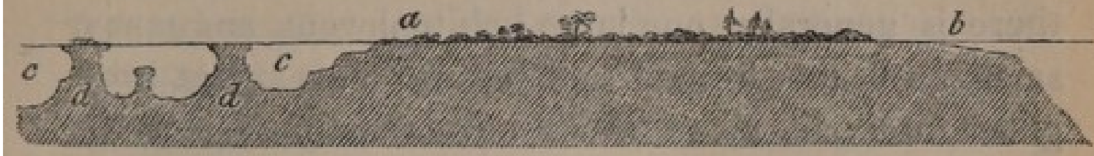
Section of a Coral Island.

a a. Habitable part of the island, consisting of a strip of coral, inclosing the lagoon. *b b.* The lagoon.

The subjoined cut (No. 49.) exhibits a small part of the section of a coral island on a larger scale.

* This plate and the section which follows are copied, by permission of Captain Beechey, from the illustrations of his valuable work before alluded to.

No. 49.



Section of part of a Coral Island.

a b. Habitable part of the island.
b e. Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
c c. Part of the lagoon.
d d. Knolls of coral in the lagoon, with overhanging masses of coral, resembling the capitals of columns.

Origin of their peculiar configuration.—The circular or oval forms of the numerous coral isles of the Pacific, with the lagoons in their centre, naturally suggest the idea that they are nothing more than the crests of submarine volcanos, having the rims and bottoms of their craters overgrown by coral. This opinion is strengthened by the conical form of the submarine mountain, and the steep angle at which it plunges on all sides into the surrounding ocean. It is also well known that the Pacific is a great theatre of volcanic action, and every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones.

It has also been observed that although, within the circular coral reefs, there is usually nothing discernible but a lagoon, the bottom of which is covered with coral, yet within some of these basins, as in Gambier's group, rocks composed of porous lava, and other volcanic substances, rise up, resembling the two Kameni's and other eminences of ingeous origin, which have been thrown up within the times of history, in the midst of the Gulf of Santorin.*

* See Vol. II. p. 153.

It has been mentioned that, in volcanic archipelagos, there is generally one large habitual vent, and many smaller volcanos formed at different points and at irregular intervals, all of which have usually a linear arrangement. Now, in several of the groups of Eastern Oceanica there appears to be a similar disposition, the great islands, such as Otaheite, Owhyhee, and Terra del Spirito Santo, being habitual vents, and the lines of small circular coral isles which are dependent on them being very probably trains of minor volcanos, which may have been in eruption singly and at irregular intervals.

The absence of circular groups in the West Indian seas, and the tropical parts of the Atlantic, where corals are numerous, has been adduced as an additional argument, inasmuch as volcanic vents, though existing in those regions, are very inferior in importance to those in the Pacific and Indian seas.* It may be objected that the circles formed by some coral reefs or groups of coral islets, varying as they do from ten to thirty miles and upwards in diameter, are so great as to preclude the idea of their being volcanic craters. In regard to this objection, I may refer to what I have said in a former volume respecting the size of the so-called craters of elevation, many of which, are, probably, the ruins of truncated cones. †

Openings into the Lagoons.—There is yet another phenomenon attending the circular reefs, to which I have not alluded, viz., the deep narrow passage which almost invariably leads from the sea into the lagoon, and is kept open by the efflux of the sea at low tides. It is sufficient that a reef should rise a few feet above

* De la Beche, Geol. Man., p. 141. first ed.

† See Vol. II. p. 160.

low-water mark to cause the waters to collect in the lagoon at high tide, and, when the sea falls, to rush out violently at one or more points where the reef happens to be lowest or weakest. At first there are probably many openings; but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge; so that their number is gradually reduced to a few, and often finally to one. This event is strictly analogous to that witnessed in our estuaries, where a body of salt water accumulated during the flow, issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river.

In controverting Von Buch's theory of "elevation craters," I mentioned, that a single deep gorge is described as always connecting the central cavity of such craters with the sea. The origin of this channel may be sought in the action of the tides, which may, in many cases, afford a satisfactory explanation. Suppose a volcanic cone, having a deep crater, to be at first submarine, and to be then *gradually* elevated by earthquakes in an ocean where tides prevail, a ravine may be cut like that which penetrates into the Caldera of the isle of Palma. The opening would at first be made on that side where the rim of the crater was originally lowest, and it would afterwards be deepened as the island rose, so as always to descend somewhat lower than the level of the sea.

In the coral reefs surrounding those volcanic islands in the Pacific, which are large enough to feed small rivers, there is generally an opening or channel opposite the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds

twenty-five feet, and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations.*

Why the windward side highest. — But there is yet another peculiarity of the low coral islands, the explanation of which is by no means so obvious. They follow one general rule in having their windward side higher and more perfect than the other. "At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water; where, however, they might be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the direction of the wind, as at Bow Island, yet there are none to windward." These observations of Captain Beechey accord perfectly with those which Captain Horsburgh, and other hydrographers, have made in regard to the coral islands of other seas. Thus the Chagos Isles in the Indian Ocean are chiefly of a hore-shoe form, the openings being to the northwest; whereas the prevailing wind blows regularly from the south-east. From this fortunate circumstance ships can enter and sail out again with ease; whereas, if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours, depends entirely on this fortunate peculiarity in their structure.

* Voyage to the Pacific, &c., p. 194.

In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there are a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side. *

I am informed by Captain King, that, on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west moonsoons prevail alternatively, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But, the difficulty will, perhaps, be removed, if we call in another part of the volcanic agency — subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves

* Voyage to the Pacific, &c., p. 189.

to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearences described would then be presented by the submerged reef. A repetition of such operations, by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy), might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef; while the action of the breakers contributes to raise the windward barrier.

Stratification of coral formations. — The calcareous formations of the Pacific are probably all stratified, although single beds may sometimes attain a great thickness. The occasional drifting of sand from the exposed parts of a reef into the lagoon or the surrounding sea, would suffice to form occasional lines of partition, especially during violent tempests, which occur annually among the South Sea islands. The decomposition of felspathic lavas may supply the current which washes and undermines the cliffs of some islands with fine clay, and this may be carried to great distances and deposited in distinct layers between calcareous masses, or may be mingled with them and form argillaceous limestones. Other divisions will arise from the arrangement of different species of testacea and zoophytes, which inhabit water of various depths, and which succeed each other as the sea is deepened by the fall of its bed during earthquakes, or in proportion as in grows shallower by elevation due to the same cause, or by the accumulation of organic substances raising the bottom.

To these causes of minor subdivision must be added

another of great importance — the ejection of volcanic ashes and sand, often carried by the wind over wide areas, and the flowing of horizontal sheets of lava, which may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the Isle of France, where a bed of coral, ten feet thick, intervenes between two currents of lava*, and in the West Indies, in the island of Dominica, Maclure observes, that "a bed of coral and madrepore limestone, with shells, lies horizontally on a bed of cinders, about two or three hundred feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height." †

Reefs in the Pacific. — The reefs in the Pacific are sometimes of great extent: thus the inhabitants of Disappointment Islands, and those of Duff's Group, pay visits to each other by passing over long lines of reefs from island to island, a distance of six hundred miles and upwards. When on their route, they present the appearence of troops marching upon the surface of the ocean. ‡

A series of ordinary earthquakes might, in the course of a few centuries, convert such a tract of sea into dry land; and it is therefore a remarkable circumstance that there should be so vast an area in eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belong to such islands as Otaheite, Owhyhee, and a few

* De la Beche, Geol. Man., p. 142. Quoy and Gaimard, Ann. des Sci. Nat., tome vi.

† Observ. on Geology of the West Indian Islands, Journ. of Sci., &c., No. x. p. 318.

‡ Malte-Brun's Geog., vol. iii. p. 401.

others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

Suppose the shoal, above described as six hundred miles in length, to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case the new coral formed since the first subsidence will constitute an island six hundred miles long. An analogous result would have occurred if a lava-current fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific seems to show that the amount of subsidence by earthquakes exceeds in that quarter of the globe at present the elevation due to the same cause.

Elizabeth or Henderson's Island.—I mentioned that one of the thirty-two islands examined by our navigators in the late expedition was raised about eighty feet above the level of the sea. * It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and, on all sides except the north, is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honey-combed at the surface, and

* According to some accounts, between sixty and seventy feet.

hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those

No. 50.

Elizabeth or Henderson's Island.

which are less injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods, but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion.*

At the distance of a few hundred yards from this island, no bottom could be gained with two hundred fathoms of line. It will be seen, from the annexed sketch, communicated to me by Lieutenant Smith, of the Blossom, that the trees come down to the beach towards the centre of the isle; a break which at first sight resembles the openings which usually lead into lagoons: but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived. The reader will remark, that such a mass of limestone represents exactly those horizontal cappings of calcareous strata which we sometimes find on hills which have tabular summits.

As earthquakes are now felt from time to time in this part of the Pacific, and as indications of very re-

* Beechey's Voyage to the Pacific, &c., p. 46.

cent changes of level are not wanting *, the era of the elevation of Henderson's Island may not be very remote.

Vast area of coral formations.—The calcareous masses above considered constitute, together with the associated volcanic formations, the most extensive of the groups of rocks which can be demonstrated to be now in progress. The space in the sea which they occupy is so vast, that we may safely infer that they exceed in area any group of ancient rocks which can be proved to have been of contemporaneous origin. It is true that each of the great archipelagos of the Pacific are separated by unfathomable abysses, where no zoophytes may live, and no lavas flow; where not even a particle of coral sand or volcanic scoriæ may be drifted: but still, if we confine our view to the extent of reef ascertained to exist, and assume that a certain space around each volcanic or coral isle has been covered with ejections, or matter from the waste of cliffs, it will then be seen that the space occupied by these formations may equal, and perhaps exceed in area that part of our continents which has been accurately explored by geologists.

That the increase of these calcareous masses should be principally, if not entirely, confined to the shallower parts of the ocean, or, in other words, to the summits of submarine ranges of mountains and elevated platforms, is a circumstance of the highest interest to the geologist; for if parts of the bed of such an ocean should be upraised, so as to form large continents, mountain-chains might appear, capped and flanked by calcareous strata of great thickness, and replete with organic

* See Captain Beechey's Voyage to the Pacific, &c., pp. 159 and 191.

remains; while in the intervening lower regions no rocks of contemporary origin would ever have existed.

Lime, whence derived.— A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary; and this may have some connexion with the rarity of testaceous animals in the ancient ocean. He further infers, that, in consequence of the operations of animals, " the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that, as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata."*

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem the speculation improbable; but, when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, I can discover no sufficient grounds for such an hypothesis, and many facts which militate against it.

If a large pond be made, in almost any soil, and filled with rain-water, it may usually become tenanted by testacea; for carbonate of lime is almost universally diffused in small quantities. But if no calcareous mat-

* Macculloch's Syst. of Geol., vol. i. p. 219.

ter be supplied by waters flowing from the surrounding high grounds, or by springs, no tufa or shell-marl are formed. The thin shells of one generation of molluscs decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl, have been the sites of springs which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Loch Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of calcareous matter in their stems to abound near springs impregnated with carbonate of lime. We know that, if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents: and some birds eat chalk greedily during the breeding season.

If, on the other hand, we turn to the phenomena of inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, either free, in a gaseous form, or mixed with water; and the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map recently constructed by Targioni, to show the principal

sites of mineral springs, can doubt for a moment, that, if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea ; and a geologist might as well assume the mass of alluvium formed in a few years in the bed of the Po, or the Ganges, to be the measure of the quantity deposited in the course of centuries in the deltas of those rivers, as conceive that the influence of the carbonated springs in Italy can be estimated by the mass of tufa precipitated by them near their sources.

It is generally admitted that the abundance of carbonate of lime given out by springs, in regions where volcanic eruptions or earthquakes prevail, is referrible to the solvent power of carbonic acid. For, as the acidulous waters percolate calcareous strata, they take up a certain portion of lime and carry it up to the surface, where, under diminished pressure in the atmosphere, it may be deposited, or, being absorbed by animals and vegetables, may be secreted by them. In Auvergne, springs charged with carbonate of lime rise through granite, in which case we must suppose the calcareous matter to be derived from some primary rock, unless we imagine it to rise up from the volcanic foci themselves.

We see no reason for supposing that the lime now on the surface, or in the crust of the earth, may not, as well as the silex, alumine, or any other mineral

substance, have existed before the first organic beings were created, if it be assumed that the arrangement of the inorganic materials of our planet preceded in the order of time the introduction of the first organic inhabitants.

But if the carbonate of lime secreted by the testacea and corals of the Pacific, be chiefly derived *from below*, and if it be a very general effect of the action of subterranean heat to subtract calcareous matter from the *inferior* rocks, and to cause it to ascend to the surface, no argument can be derived in favour of the progressive increase of limestone from the magnitude of coral reefs, or the greater proportion of calcareous strata, in the more modern formations. A constant transfer of carbonate of lime from the inferior parts of the earth's crust to its surface, would cause throughout all future time, and for an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer, as contrasted with the older formations.

BOOK IV.

CHAPTER I.

PRELIMINARY OBSERVATIONS.

System of inquiry adopted in this work how differing from that of preceding writers—Illustrations from the history of Geology of the respective merits of the two systems — Reasons for prefixing to a work on Geology treatises respecting the changes now in progress in the animate and inanimate world.

Having considered, in the preceding books, the actual operation of the causes of change which affect the earth's surface and its inhabitants, we are now about to enter upon a new division of our inquiry, and I shall therefore offer a few preliminary observations, to fix in the reader's mind the connexion between two distinct parts of this work, and to explain in what manner its plan differs from that usually followed by preceding writers on Geology.

All naturalists who have carefully examined the arrangement of the mineral masses composing the earth's crust, and who have studied their internal structure and fossil contents, have recognized therein the signs of a great succession of former changes; and the causes of these changes have been the object of anxious inquiry. As the first theorists possessed but a scanty acquaintance with the present economy of the animate and inanimate world, and the vicissitudes to which these are subject, we find them in the situation of novices, who attempt to read a history

written in a foreign language, doubting about the meaning of the most ordinary terms; disputing, for example, whether a shell was really a shell,—whether sand and pebbles were the result of aqueous trituration,—whether stratification was the effect of successive deposition from water; and a thousand other elementary questions, which now appear to us so easy and simple, that we can hardly conceive them to have once afforded matter for warm and tedious controversy.

In the first book, I enumerated many of the prepossessions which biassed the minds of the earlier inquirers, and checked an impartial desire of arriving at truth. But of all the causes alluded to, no one contributed so powerfully to give rise to a false method of philosophizing, as the entire unconsciousness of the first geologists of the extent of their own ignorance respecting the operations of the existing agents of change.

They imagined themselves sufficiently acquainted with the mutations now in progress in the animate and inanimate world, to entitle them at once to determine, whether the solution of certain problems in geology could ever be derived from the observation of the actual economy of nature; and, having decided that they could not, they felt themselves at liberty to indulge their imaginations, in guessing at what *might be*, rather than in inquiring *what is;* in other words, they employed themselves in conjecturing what might have been the course of nature at a remote period, rather than in the investigation of what was the course of nature in their own times.

It appeared to them more philosophical to speculate on the possibilities of the past, than patiently to ex-

plore the realities of the present; and having invented theories under the influence of such maxims, they were consistently unwilling to test their validity by the criterion of their accordance with the ordinary operations of nature. On the contrary, the claims of each new hypothesis to credibility appeared enhanced by the great contrast of the causes or forces introduced to those now developed in our terrestrial system during a period, as it has been termed, of *repose*.

Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change. It produced a state of mind unfavourable in the highest conceivable degree to the candid reception of the evidence of those minute but incessant mutations, which every part of the earth's surface is undergoing, and by which the condition of its living inhabitants is continually made to vary. The student, instead of being encouraged with the hope of interpreting the enigmas presented to him in the earth's structure,—instead of being prompted to undertake laborious inquiries into the natural history of the organic world, and the complicated effects of the igneous and aqueous causes now in operation, was taught to despond from the first. Geology, it was affirmed, could never rise to the rank of an exact science,—the greater number of phenomena must for ever remain inexplicable, or only be partially elucidated by ingenious conjectures. Even the mystery which invested the subject was said to constitute one of its principal charms, affording, as it did, full scope to the fancy to indulge in a boundless field of speculation.

The course directly opposed to these theoretical views consists in an earnest and patient endeavour to reconcile the former indications of change with the evidence of gradual mutations now in progress; restricting us, in the first instance, to known causes, and then speculating on those which may be in activity in regions inaccessible to us. It seeks an interpretation of geological monuments, by comparing the changes of which they give evidence with the vicissitudes now in progress, or *which may be* in progress.

I shall give a few examples in illustration of the practical results already derived from the two distinct methods of theorizing, for we have now the advantage of being enabled to judge of their respective merits by the relative value of the fruits which they have produced.

From the historical sketch before given of the progress of geology, the reader has seen that a controversy was maintained for more than a century respecting the origin of fossil shells and bones—were they organic or inorganic substances? That the latter opinion should for a long time have prevailed, and that these bodies should have been supposed to be fashioned into their present form by a plastic virtue, or some other mysterious agency, may appear absurd; but it was, perhaps, as reasonable a conjecture as could be expected from those who did not appeal, in the first instance, to the analogy of the living creation, as affording the only source of authentic information. It was only by an accurate examination of living testacea, and by a comparison of the osteology of the existing vertebrated animals with the remains found entombed in ancient strata, that this favourite dogma was exploded, and all were, at length, persuaded that these substances were exclusively of organic origin.

In like manner, when a discussion had arisen as to the nature of basalt and other mineral masses, evidently constituting a particular class of rocks, the popular opinion inclined to a belief that they were of aqueous, not of igneous origin. These rocks, it was said, might have been precipitated from an aqueous solution, from a chaotic fluid, or an ocean which rose over the continents, charged with the requisite mineral ingredients. All are now agreed, that it would have been scarcely possible for human ingenuity to invent a theory more distant from the truth; yet we must cease to wonder that it gained so many proselytes, when we remember, that its claims to probability arose partly from the very circumstance of its confirming the assumed want of all analogy between geological causes and those now in action.

By what train of investigation were all theorists brought round, at length, to an opposite opinion, and induced to assent to the igneous origin of these formations? By an examination of the structure of active volcanos, the mineral composition of their lavas and ejections, and by comparing the undoubted products of fire with the ancient rocks in question.

I shall conclude with one more example. When the organic origin of fossil shells had been conceded, their occurrence in strata forming some of the loftiest mountains in the world was admitted as a proof of a great alteration of the relative level of sea and land; and the question then arose, whether this change was to be accounted for by the partial drying up of the ocean, or by the elevation of the solid land. The former hypothesis, although afterwards abandoned by general consent, was at first embraced by a vast majority. A multitude of ingenious speculations were

hazarded, to show how the level of the ocean might have been depressed; and when these theories had all failed, the inquiry, as to what vicissitudes of this nature might now be taking place, was, as usual, resorted to in the last instance. On inquiring, whether any changes in the level of sea and land had occurred during the historical period, it was soon discovered, by patient research, that considerable tracts of land had been permanently elevated and depressed, while the level of the ocean remained unaltered. It was therefore necessary to reverse the doctrine which had acquired so much popularity, and the unexpected solution of a problem at first regarded as so enigmatical gave, perhaps, the strongest stimulus ever yet afforded to investigate the ordinary operations of nature.

Of late years, the points of discussion in geology have been transferred to new questions, and those, for the most part, of a higher and more general nature. We are now, for the most part, agreed as to what rocks are of igneous, and what of aqueous origin,—in what manner fossil shells, whether of the sea or of lakes, have been imbedded in strata,—how sand may have been converted into sandstone,—and are unanimous as to other propositions which are not of a complicated nature; but when we ascend to those of a higher order, we find as little disposition as formerly to make a strenuous effort, in the first instance, to search out an explanation in the ordinary economy of Nature. If, for example, we seek for the causes why mineral masses are associated together in certain groups; why they are arranged in a certain order, which is never inverted; why there are many breaks in the continuity of the series; why different organic

remains are found in distinct sets of strata; why there is often an abrupt passage from an assemblage of species contained in one formation to that in another immediately superimposed,—when these, and other topics of an equally extensive kind are discussed, we find the habit of indulging conjectures, respecting irregular and extraordinary causes, to be still in full force.

We hear of sudden and violent revolutions of the globe—of the instantaneous elevation of mountain chains—of paroxysms of volcanic energy, declining, according to some, and, according to others, increasing in violence, from the earliest to the latest ages. We are also told of general catastrophes, and a succession of deluges—of the alternation of periods of repose and disorder—of the refrigeration of the globe—of the sudden annihilation of whole races of animals and plants—and other hypotheses are offered to us, in which we see the ancient spirit of speculation revived, and a desire manifestly shewn to cut, rather than patiently to untie, the Gordian knot.

In my attempt to unravel these difficult questions, I shall adopt a different course, restricting myself to the known or possible operations of existing causes; feeling assured that we have not yet exhausted the resources which the study of the present course of nature may provide, and therefore, that we are not authorized, in the infancy of our science, to recur to extraordinary agents. I shall adhere to this plan, not only on the grounds explained in the first book, but because, as I have just stated, the history of the science informs us, that this method has always put geologists on the road that leads to truth,—suggesting views which, although imperfect at first, have been

found capable of improvement, until at last adopted by universal consent. On the other hand, the opposite method, that of speculating on a former distinct state of things, has led invariably to a multitude of contradictory systems, which have been overthrown one after the other,—which have been found quite incapable of modification,—and which are often required to be precisely reversed.

In regard to the subjects treated of in the last two books,—the recent changes of the organic and inorganic world,—they may be said to constitute the alphabet and grammar of geology. If I had found systematic treatises previously written on these topics, I should willingly have entered at once upon the description of geological monuments properly so called: in which case, I should have referred to other authors for the elucidation of elementary and collateral questions, just as I shall now appeal to the best authorities in conchology and comparative anatomy for the proof of positions which, but for the labours of naturalists devoted to those departments, would have demanded long digressions.

CHAPTER II.

GENERAL ARRANGEMENT OF THE MATERIALS COMPOSING THE EARTH'S CRUST.

The existing continents chiefly composed of subaqueous deposits — Distinction between sedimentary and volcanic rocks — Between primary, secondary, and tertiary — Origin of the rocks usually termed primary — Transition formations — Difference between secondary and tertiary strata — Discovery of tertiary groups of successive periods — Paris basin — London and Hampshire basins — Tertiary strata of Bordeaux, Piedmont, Touraine, &c. — Subapennine beds — English crag — More recent deposits of Sicily, &c.

When we examine into the structure of the earth's crust (by which is meant the small portion of the exterior of our planet accessible to human observation), whether we pursue our inquiries by aid of mining operations, or by observing the sections laid open in the sea cliffs, or in the deep ravines of mountainous countries, we discover everywhere a series of mineral masses, which are not thrown together in a confused heap, but arranged with considerable order; and even where their original position has undergone great subsequent disturbance, there still remain proofs of the order that once reigned.

If we drain a lake, we frequently find at the bottom a series of recent deposits disposed with great regularity one above the other; the uppermost, perhaps, may be a stratum of peat, next below a more compact variety of the same, still lower a bed of laminated shell marl, alternating with peat, and then other beds of

marl, divided by layers of clay. Now if a second pit be sunk through the same continuous lacustrine deposit, at some distance from the first, we commonly meet with nearly the same series of beds, yet with slight variations; some, for example, of the layers of sand, clay, or marl may be wanting, one or more of them having thinned out and given place to others, or sometimes one of the masses, first examined, is observed to increase in thickness to the exclusion of other beds. At length we reach a point where the whole assemblage of lacustrine strata terminate, as for example when we arrive at the borders of the original lake-basin. Here the beds will come in contact with the rocks which form the boundary of, and, at the same time, pass under all the recent accumulations.

In almost every estuary, we may observe at low water phenomena analogous to those of lakes, where the current has cut away part of some newly-formed bank, consisting of a series of horizontal strata of peat, sand, clay, and, sometimes, interposed beds of shells. Each of these may often be traced over a considerable area, some extending farther than others, but all of necessity confined within the basin of the estuary. Similar remarks are applicable, on a much more extended scale, to the recent delta of great rivers, like the Ganges, after the periodical inundations have subsided, and when sections are exposed of the river-banks and the cliffs of numerous islands, in which horizontal beds of clay and sand may be traced over areas many hundred miles in length, and more than a hundred in breadth.

Subaqueous deposits.— The greater part of our continents are evidently composed of subaqueous deposits; and in the manner of their arrangement we

discover many characters precisely similar to those above described; but the different groups of strata are, for the most part, on a greater scale, both in regard to depth and area, than any observable in the formations of lakes, deltas, or estuaries. We find, for example, masses of limestone several hundred feet in thickness, containing corals and shells, and stretching from one country to another, yet always giving place, at length, to a distinct set of strata, which either rise up from beneath like the rocks before alluded to as forming the boundary of a lake, or cover and conceal them. In other places, we find beds of pebbles, and sand, or of clay of great thickness. The different formations composed of these materials usually contain some peculiar and appropriate organic remains; as, for example, certain species of shells and corals, or certain plants.

Volcanic rocks.—Besides these strata of aqueous origin, we find other rocks which are immediately recognized to be the products of fire, from their exact resemblance to those which have been produced in modern times by volcanos, and thus we immediately establish two distinct orders of mineral masses composing the crust of the globe — the sedimentary and the volcanic.

Rocks commonly called primary.—But if we examine a large portion of a continent which contains within it a lofty mountain range, we rarely fail to discover another class of rocks very distinct from either of those above alluded to, and which we can neither assimilate to deposits such as are now accumulated in lakes or seas, nor to those generated by ordinary volcanic action. This class consists of granite, granitic schist, roofing slate, and many other rocks, of a much more compact

and crystalline texture than the sedimentary and volcanic divisions before mentioned. In the unstratified portion of these crystalline masses, as in the granite, for example, no organic fossil remains have ever been discovered, and only a few faint traces of them in some of the *stratified* groups of the same class; for I may remark, that a considerable portion of these rocks are divided, not only into strata, but into laminæ, so closely imitating the internal arrangement of well-known aqueous deposits, as to leave scarcely any reasonable doubt that they owe this part of their texture to similar causes.

These remarkable formations have been called *primitive*, from their having been supposed to constitute the most ancient mineral productions known to us, and from a notion that they originated before the earth was inhabited by living beings, and while yet the planet was in a nascent state. The high relative antiquity of some of them is indisputable; for in the oldest sedimentary strata, containing organic remains, we often meet with rounded pebbles of the crystalline rocks, which must therefore have been consolidated before the derivative strata were formed out of their ruins. The members of this group generally rise up from beneath the rocks of mechanical origin, entering into the structure of lofty mountains, so as to occupy, at the same time, the lowest and most elevated position in the crust of the globe.

Origin of rocks called primary.—Nothing strictly analogous to these ancient formations can now be seen in the progress of formation on the habitable surface of the earth—nothing, at least, within the range of human observation. The first speculators, however, in Geology, found no difficulty in explaining their

origin, by supposing a former condition of the planet perfectly distinct from the present, when certain chemical processes were developed on a great scale, whereby crystalline precipitates were formed, some more suddenly, in huge amorphous masses, such as granite; others by successive deposition and with a foliated and stratified structure, as in the rocks termed gneiss and mica-schist. A great part of these views have since been entirely abandoned, more especially with regard to the origin of granite, but it is interesting to trace the train of reasoning by which they were suggested. First, the stratified primitive rocks exhibited, as was before mentioned, well-defined marks of successive accumulation, analogous to those so common in ordinary subaqueous deposits. As the latter formations were found divisible into natural groups, characterized by certain peculiarities of mineral composition, so also were the primitive. In the next place, there were discovered, in many districts, certain members of the so-called primitive series, either alternating with, or passing by intermediate gradations into rocks of a decidedly mechanical origin, containing traces of organic remains. From such gradual passage the aqueous origin of the stratified crystalline rocks was fairly inferred; and as we find in the different strata of subaqueous origin every gradation between a mechanical and a purely crystalline texture; between sand, for example, and saccharoid gypsum, so it was imagined that, in a former state of the planet, the different degrees of crystallization in the older rocks might have been dependent on the varying conditions of the menstruum from which they were precipitated.

The presence however of certain crystalline ingredients in the composition of many of the primary rocks

rendered it necessary to resort to many arbitrary hypotheses, in order to explain their precipitation from aqueous solution; and for this reason a difference in the condition of the planet, and in the pristine energy of chemical causes, was assumed. A train of speculation originally suggested by the observed effects of aqueous agents was thus pushed beyond the limits of analogy, and it was not until a different and almost opposite course of induction was pursued, beginning with an examination of volcanic products, that more sound theoretical views were established.

Granite of igneous origin.—As I am merely desirous, in this chapter, of fixing in the reader's mind the leading divisions of the rocks composing the earth's crust, I shall not enter at present into any details, but shall only observe, that a passage was first traced from lava into other more crystalline igneous rocks, and from these again to granite, which last was found to send forth dikes and veins, into the contiguous strata, in a manner strictly analogous to that observed in volcanic rocks, and to produce at the point of contact such changes as might be expected to result from the influence of a heated mass cooling down slowly under great pressure from a state of fusion. The want of stratification in granite supplied another point of analogy in confirmation of its igneous origin; and as some masses were found to send out veins through others, it was evident that there were granites of different ages, and that instead of forming in all cases the oldest part of the earth's crust, as had at first been supposed, some granites were of comparatively recent origin, and newer than the stratified rocks which covered them.

Stratified crystalline rocks.—The theory of the origin

of the other crystalline rocks was soon modified by these new views respecting the nature of granite. First it was shown, by numerous examples, that ordinary volcanic dikes might produce great alterations in the sedimentary strata which they traversed, causing them to assume a more crystalline texture, and nearly obliterating all traces of organic remains, without, at the same time, destroying the surfaces of stratification. It was also found, that granite dikes and veins produced analogous, though somewhat different changes; and hence it was suggested as highly probable, that the effects to which small veins gave rise, to the distance of a few yards, might be superinduced on a much grander scale where vast masses of fused rock, intensely heated for ages, came in contact at great depths from the surface with sedimentary formations. The slow action of heat in such cases, it was thought, might occasion a state of semi-fusion, so that, on the cooling down of the masses, the different materials might be arranged in new forms, according to their chemical affinities, and all traces of organic remains might disappear, while the stratiform and lamellar texture remained.

According to these views, the primary strata may have assumed their crystalline structure at as many successive periods as there have been distinct eras of the formation of granite, and their difference of mineral composition may be attributed, not to an original difference of the conditions under which they were deposited at the surface, but to subsequent modifications superinduced by heat and other causes at great depths below the surface.

The strict propriety of the term primitive, as applied to granite and to the granitiform and associated rocks,

thus became questionable, and the term primary was very generally substituted, as simply expressing the fact, that the crystalline rocks, as a mass, were older than the *secondary*, or those which are unequivocally of a mechanical origin and contain organic remains.

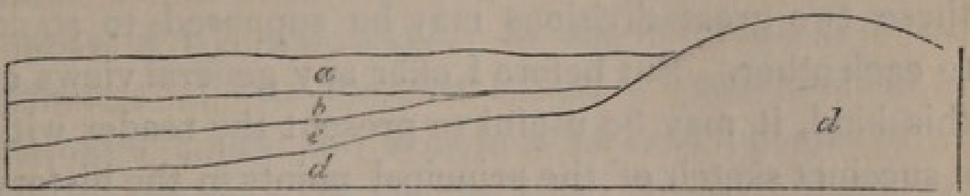
Transition formations.—The reader may readily conceive, even from the hasty sketch which I have thus given of the supposed origin of the stratified primary rocks, that they may occasionally graduate into the secondary; accordingly, an attempt was made, when the classification of rocks was chiefly derived from mineral structure, to institute an order called *transition*, the characters of which were intermediate between those of the primary and secondary formations. Some of the shales, for example, associated with these strata, often passed insensibly into clay slates, undistinguishable from those of the granitic series; and it was often difficult to determine whether some of the compound rocks of this transition series, called greywacke, were of mechanical or chemical origin. The imbedded organic remains were rare, and sometimes nearly obliterated; but by their aid the groups first called transition were at length identified with rocks, in other countries, which had undergone much less alteration, and wherein shells and zoöphytes were abundant.

The term transition, however, was still retained, although no longer applicable in its original signification. It was now made to depend on the identity of certain species of organized fossils; yet reliance on mineral peculiarities was not fairly abandoned, as constituting part of the characters of the group.

Order of succession of stratified masses.—When the subaqueous strata above alluded to as overlying the

primary were found to be divisible into different groups, characterized by certain organic remains and mineral peculiarities, the relative position of these groups became a matter of high interest. It was soon ascertained that the order of succession was never inverted, although the different formations were not coextensively distributed;

No. 51.



so that, if there be four different formations, as *a*, *b*, *c*, *d*, in the annexed diagram (No. 51), which, in certain localities, may be seen in vertical superposition, the uppermost or newest of them, *a*, will in other places be in contact with *c*, or with the lowest of the whole series, *d*, all the intermediate formations being absent.

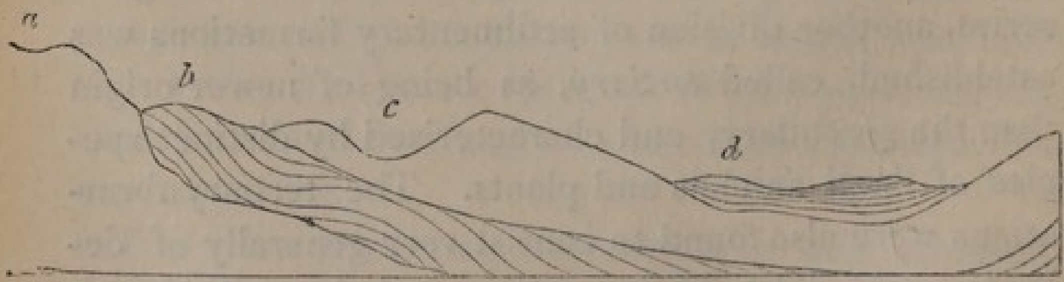
Tertiary formations. — After some progress had been made in classifying the secondary rocks, and in assigning to each its relative place in a chronological series, another division of sedimentary formations was established, called *tertiary*, as being of newer origin than the secondary, and characterized by distinct species of fossil animals and plants. The tertiary formations were also found to consist very generally of detached and isolated masses, surrounded on all sides by primary and secondary rocks, and occupying a position, in reference to the latter, very like that of the waters of lakes, inland seas, and gulfs, in relation to a continent, and, like such waters, being often of great depth, though of limited area. The imbedded organic remains were chiefly those of marine animals, but with

frequent intermixtures of terrestrial and freshwater species which are rarely found among the secondary fossils. Frequently there was evidence of the deposits having been purely lacustrine, a circumstance never clearly ascertained in regard to any secondary group.

I shall consider more particularly, in the next chapter, how far this distinction of rocks into secondary and tertiary is founded in nature, and in what relation these two great divisions may be supposed to stand to each other. But before I offer any general views of this kind, it may be useful to present the reader with a succinct sketch of the principal points in the history of the discovery and classification of the tertiary strata.

Paris Basin. — The first series of deposits belonging to this class, of which the characters were accurately determined, were those which occur in the neighbourhood of Paris, first described by MM. Cuvier and Brongniart.* They were ascertained to fill a

No. 52.



a. Primary rocks.
b. Older secondary formations. *c.* Chalk.
d. Tertiary formation.

depression in the chalk (as the beds *d*, in diagram No. 52, rest upon *c*), and to be composed of different

* Environs de Paris, 1811.

materials, sometimes including the remains of marine and sometimes of freshwater animals. By the aid of these fossils, several distinct alternations of marine and freshwater formations were clearly shown to lie superimposed upon each other, and various speculations were hazarded respecting the manner in which the sea had successively abandoned and regained possession of tracts which had been occupied in the intervals by the waters of rivers or lakes. In one of the subordinate members of this Parisian series, a great number of scattered bones and skeletons of land animals were found entombed, the species being perfectly dissimilar from any known to exist, as indeed were those of almost all the animals and plants of which any portions were discovered in the associated deposits.

I must defer, to another part of this work, a more detailed account of this interesting formation, and shall merely observe, in this place, that the investigation of the fossil contents of these beds forms an era in the progress of the science. The French naturalists brought to bear upon their geological researches so much skill and proficiency in comparative anatomy and conchology, as to place in a strong light the importance of the study of organic remains, and the comparatively subordinate interest attached to the exclusive investigation of the structure and mineral ingredients of rocks.

A variety of tertiary formations were soon afterwards found in other parts of Europe, as in the south-east of England, in Italy, Austria, and different parts of France, especially in the basins of the Loire and Gironde, all strongly contrasted with the secondary rocks. As in the latter class many different divisions had been observed to preserve the same mineral characters and

organic remains over wide areas, it was natural that an attempt should first be made to trace the different subdivisions of the Parisian tertiary strata throughout Europe, for some of these were not inferior in thickness to several of the secondary formations which had a wide range.

But in this case the analogy, however probable, was not found to hold good, and the error, though almost unavoidable, retarded seriously the progress of geology. As often as a new tertiary group was discovered, as that of Italy, for example, an attempt was invariably made, in the first instance, to discover in what characters it agreed with some one or more subordinate members of the Parisian type. Every fancied point of correspondence was magnified into undue importance, and such trifling circumstances, as the colour of a bed of sand or clay, were dwelt upon as proofs of identity, while the general difference in the mineral character and organic contents of the group from the whole Parisian series was slurred over and thrown into the shade.

By the influence of this illusion, the succession and chronological relations of different tertiary groups were kept out of sight. The difficulty of clearly discerning these arose from the frequent isolation of the position of the tertiary formations before described, since, in proportion as the areas occupied by them are limited, it is rare to discover a place where one set of strata overlap another, in such a manner that the geologist might be enabled to determine the difference of age by direct superposition.

ORIGIN OF THE EUROPEAN TERTIARY STRATA AT SUCCESSIVE PERIODS.

I shall now very briefly enumerate some of the principal steps which eventually led to a conviction of the necessity of referring the European tertiary formations to distinct periods, and the leading data by which such a chronological series may be established.

London and Hampshire Basins. — Very soon after the investigation, before alluded to, of the Parisian strata, those of Hampshire and of the basin of the Thames were examined in our own country. Mr. Webster found these English tertiary deposits to repose, like those in France, upon the chalk, or newest rock of the secondary series. He identified a great number of the shells occurring in the British and Parisian strata, and ascertained that, in the Isle of Wight, an alternation of marine and freshwater beds occurred, very analogous to that observed in the basin of the Seine.* But no two sets of strata could well be more dissimilar in mineral composition, and they were only recognized to belong to the same era, by aid of the specific identity of their organic remains. The discordance, in other respects, was as complete as could well be imagined, for the principal marine formation in the one country consisted of blue clay, in the other of white limestone; and a variety of curious rocks in the neighbourhood of Paris had no representatives whatever in the south of England.

Subapennine beds. — The next important discovery of tertiary strata was in Italy, where Brocchi traced them along the flanks of the Apennines, from one ex-

* Webster in Englefield's Isle of Wight and Geol. Trans., vol. ii. p. 161.

tremity of the peninsula to the other, usually forming a lower range of hills, called by him the Subapennines.* These formations, it is true, had been pointed out by the older Italian writers, and some correct ideas, as we have seen, had been entertained respecting their recent origin, as compared to the inclined secondary rocks on which they rested.† But accurate data were now for the first time collected, for instituting a comparison between them and other members of the great European series of tertiary formations.

Brocchi came to the conclusion that nearly one-half of several hundred species of fossil shells procured by him from these Subapennine beds were identical with those now living in existing seas, an observation which did not hold true in respect to the organic remains of the Paris basin. It might have been supposed that this important point of discrepancy would at once have engendered great doubt as to the identity, in age, of any part of the Subapennine beds with any one member of the Parisian series; but, for the reasons above alluded to, this objection was not thought of much weight, and it was supposed that a group of strata, called "the upper marine formation," in the basin of the Seine, might be represented by all the Subapennine clays and yellow sand.

English Crag. — Several years before, an English naturalist, Mr. Parkinson, had observed, that certain shelly strata, in Suffolk, which lay over the blue clay of London, contained distinct fossil species of testacea, and that a considerable portion of these might be identified with species now inhabiting the neighbouring

* Conch. Foss. Subap., 1814.

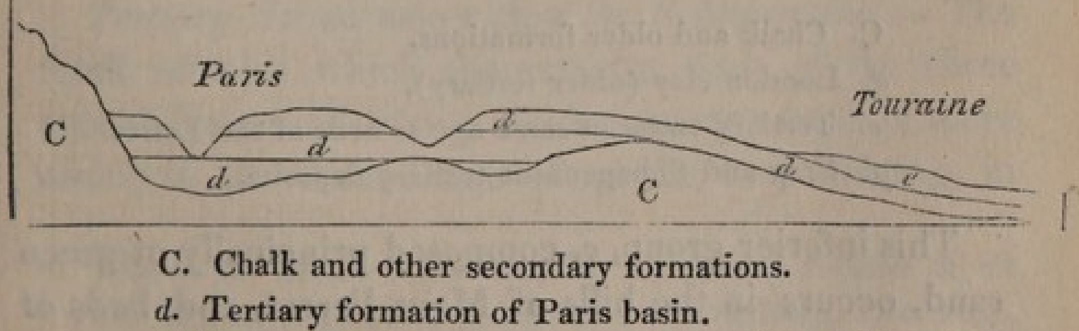
† See Vol. I. p. 73. for opinions of Odoardi, in 1761.

sea.* These overlying beds, which were provincially termed "crag," were of small thickness, and were not regarded as of much geological importance. But, when duly considered, they presented a fact worthy of great attention, viz., the superposition of a tertiary group, enclosing, like the Subapennine beds, a great intermixture of recent species of shells, upon beds wherein a very few remains of recent or living species were emtombed.

Mr. Conybeare, in his excellent classification of the English strata †, placed the crag as the uppermost of the British series; and several geologists began soon to entertain an opinion that this newest of our tertiary formations might correspond in age to the Italian strata described by Brocchi.

Tertiary Strata of Touraine. — The next step towards establishing a succession of tertiary periods was the evidence adduced to prove that certain formations more recent than the uppermost members of the Parisian series, were also older than the Subapennine beds, so that they constituted deposits of an age intermediate between the two types above alluded to. M. Desnoyers, for example, ascertained that a group

No. 53.



C. Chalk and other secondary formations.
d. Tertiary formation of Paris basin.
e. Superimposed marine tertiary beds of the Loire.

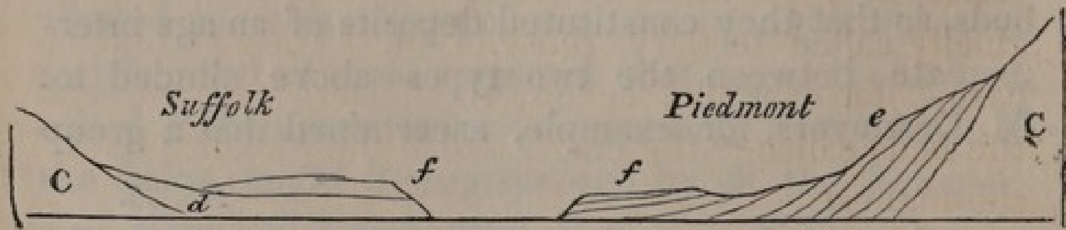
* Geol. Trans., vol. i. p. 324., 1811.

† Outlines of the Geology of England and Wales, 1822.

of marine strata, in Touraine, in the basin of the Loire (*e*, diagram No. 53.), rest upon the uppermost subdivision of the Parisian group *d*, which consists of a lacustrine formation, extending continuously throughout a platform which intervenes between the basin of the Seine and that of the Loire. These overlying marine strata, M. Desnoyers assimilated to the English crag, to which they bear some analogy, although their organic remains differ considerably, as will be afterwards shown.

A large tertiary deposit had already been observed in the south-west of France, around Bordeaux and Dax, and a description of its fossils had been published by M. de Basterot.* Many of the species were peculiar, and differed from those of the strata now called Subapennine; yet these same peculiar and characteristic fossils reappeared in Piedmont, in a series of strata inferior in position to the Subapennines (as *e* underlies *f*, diagram No. 54.).

No. 54.



C. Chalk and older formations.

d. London clay (older tertiary).

e. Tertiary strata of same age as beds of the Loire.

f. Crag and Subapennine tertiary deposits.

This inferior group, *e*, composed principally of green sand, occurs in the hills of Mont Ferrat, and beds of the same age are seen in the valley of the Bormida. They also form the hill of the Superga, near Turin,

* Mém. de la Soc. d'Hist. Nat. de Paris, tome ii., 1825.

where M. Bonelli formed a large collection of their fossils, and identified them with those discovered near Bordeaux and in the basin of the Gironde.*

But we are indebted to M. Deshayes for having proved, by a careful comparison of the entire assemblage of shells found in the above-mentioned localities, in Touraine, in the south-west of France, and in Piedmont, that the whole of these three groups possess the same zoological characters, and belong to the same epoch, as also do the shells described by M. Constant Prevost, as occurring in the basin of Vienna.†

Now the reader will perceive, by reference to the observations above made, and to the accompanying diagrams, that one of the formations of this intervening period, *e*, has been found superimposed upon the highest member of the Parisian series, *d;* while another of the same set has been observed to underlie the Subapennine beds, *f*. Thus the chronological series, *d*, *e*, *f*, is made out, in which the deposits, originally called tertiary, those of the Paris and London basins, for example, occupy the lowest position, and the beds called "the crag," and "the Subapennines," the highest.

Tertiary Strata newer than the Subapennine. — The fossil remains which characterize each of the three successive periods above alluded to, approximate more nearly to the assemblage of *species* now existing, in

* Professor Bronn has stated, in the second volume of his "Tour in Italy," p. 674., published at Heidelberg, Dec. 1831, that the shells of the Superga beds have a nearer connexion with those of Bordeaux than with any other tertiary formation.

† Sur la Constitution, &c. du Bassin de Vienne, Journ. de Phys., Nov. 1820.

proportion as their origin is less remote from our own era, or, in other words, the recent species are always more numerous, and the extinct more rare, in proportion to the low antiquity of the formation. But the discordance between the state of the organic world indicated by the fossils of the Subapennine beds and the actual state of things is still considerable, and we naturally ask, are there no monuments of an intervening period? — no evidences of a gradual passage from one condition of the animate creation to that which now prevails, and which differs so widely?

It will appear, in the sequel, that such monuments are not wanting, and that there are marine strata entering into the composition of extensive districts, and of hills of no trifling height, which contain the exuviæ of testacea and zoophytes, hardly distinguishable, as a group, from those now peopling the neighbouring seas. Thus the line of demarcation between the actual period and that immediately antecedent, is quite evanescent, and the newest members of the tertiary series will be often found to blend with the formations of the historical era.

In Europe, these modern strata have been found in the district around Naples, in the territory of Otranto and Calabria, and more particularly in the island of Sicily; and the bare enumeration of these localities cannot fail to remind the reader, that they belong to regions where the volcano and the earthquake are now active, and where we might have anticipated the discovery of emphatic proofs, that the conversion of sea into land had been of frequent occurrence at very modern periods.

CHAPTER III.

DIFFERENT CIRCUMSTANCES UNDER WHICH THE SECONDARY AND TERTIARY FORMATIONS MAY HAVE ORIGINATED.

Secondary series formed when the ocean prevailed; tertiary during the conversion of sea into land, and the growth of a continent — Origin of interruption in the sequence of formations — The areas where new deposits take place are always shifting — Causes of this — Denudation augments the discordance in the age of rocks in contact — Unconformability of overlying formations — In what manner the shifting of the areas of sedimentary deposition may combine with the gradual extinction and introduction of species to produce a series of deposits having distinct mineral and organic characters.

I HAVE already glanced at the origin of some of the principal points of difference in the characters of the primary and secondary rocks, and may now briefly consider the relation in which the secondary stand to the tertiary, and the causes of that succession of tertiary formations, which has been described in the last chapter.

It is evident that large parts of Europe must have been submerged simultaneously beneath the sea when different portions of the secondary series were formed, because we find homogeneous mineral masses, including the remains of similar marine animals, referrible to the secondary period, extending over great areas; whereas the detached and isolated position of the tertiary groups, in basins, or depressions bounded by secondary and primary rocks, favours the hypothesis of a sea interrupted by extensive tracts of dry land.

State of the Surface when the Secondary Strata were formed.

Let us consider the changes that must be expected to accompany the gradual conversion of part of the bed of an ocean into a continent, and the different characters that might be imparted to subaqueous deposits formed during the period when the sea prevailed, as contrasted with those that might belong to the subsequent epoch when the land should predominate. First, we may suppose a vast submarine region, such as the bed of the western Atlantic, to receive for ages the turbid waters of several great rivers, like the Amazon, Orinoco, or Mississippi, each draining a considerable continent. The sediment thus introduced might be characterized by a peculiar colour and composition, and the same homogeneous mixture might be spread out over an immense area by the action of a powerful current, like the Gulf-stream. First one submarine basin, and then another, might be filled, or rendered shallow, by the influx of transported matter, the same species of animals and plants still continuing to inhabit the sea; so that the organic, as well as the mineral characters, might be constant throughout the whole series of deposits.

In another part of the same ocean, let us suppose masses of coralline and shelly limestone to grow, like those of the Pacific, simultaneously over a space several thousand miles in length; and thirty or forty degrees of latitude in breadth, while volcanic eruptions give rise, at different intervals, to igneous rocks, having a common character in different parts of the vast area. It is evident that, during such a state of a certain quarter of the globe, limestone and other

rocks might be formed, and retain a common character over spaces equal to a large portion of Europe.

State of the Surface when the Tertiary Groups were formed.

But, when the area under consideration began to be converted into land, a very different condition of things must succeed. A series of subterranean movements might first give rise to small rocks and isles, and then, by subsequent elevations, to larger islands, by the junction of the former. These lands would consist partly of the mineral masses before described, whether coralline, sedimentary, or volcanic, and partly of the subjacent rocks, whatever they may have been, which constituted the original bed of the ocean. Now the degradation of these lands would commence immediately upon their emergence, the waves of the sea undermining the cliffs, and torrents flowing from the surface, so that new strata would begin to form in different places, at the bottom of the still remaining seas; and, in proportion as the lands increased, these deposits would augment.

At length, by the continued rising and sinking of different parts of the bed of the ocean, a number of distinct basins would be formed, wherein different kinds of sediment, each distinguished by some local character, might accumulate. Some of the groups of isles that had first risen would, in the course of ages, become the central mountain ranges of continents, and different lofty chains might thus be characterized by similar rocks of contemporaneous origin, the component strata having originated under analogous circumstances in the ocean before described.

Finally, when large tracts of land existed, there would

be a variety of disconnected gulfs, inland seas, and lakes, each receiving the drainage of distinct hydrographical basins, and becoming the receptacles of stratified matter, distinguished by marked peculiarities of mineral composition. The organic remains would also be more varied, for in one locality freshwater species would be imbedded, as in the deposits now forming in the lakes of Switzerland and the north of Italy; in another, marine species, as in the Aral and Caspian; in a third region, gulfs of brackish water would be converted into land, like those of Bothnia and Finland in the Baltic; in a fourth, there might be great fluviatile and marine formations along the borders of a chain of inland seas, like the deltas now growing at the mouths of the Don, Danube, Nile, Po, and Rhone, along the shores of the sea of Azof, the Euxine, and Mediterranean. These deposits would each partake more or less of the peculiar mineral character of adjoining lands, the degradation of which would supply sediment to the different rivers.

Now, if such be, in a great measure, the distinction between the circumstances under which the secondary and tertiary series originated, it is quite natural that particular tertiary groups should occupy areas of comparatively small extent—that they should frequently consist of littoral and lacustrine deposits, and that they should often contain those admixtures of terrestrial, freshwater, and marine remains, which are so rare in secondary rocks. It might also be expected, that the tertiary volcanic formations should be much less exclusively submarine; and this we accordingly find to be the case.

Causes of the Superposition of successive Formations having distinct Mineral and Organic Characters.

But we have still to account for those remarkable breaks in the series of superimposed formations, which are common both to the secondary and tertiary rocks, but are more particularly frequent in the latter. The elucidation of this curious point is the more important, because geologists of a certain school appeal to phenomena of this kind in support of their doctrine of sudden revolutions of the globe, and great catastrophes out of the ordinary course of nature.

It is only by carefully considering the combined action of all the causes of change now in operation, whether in the animate or inanimate world, that we can hope to explain such complicated appearances as are exhibited in the general arrangement of mineral masses. In attempting, therefore, to trace the origin of these violations of continuity, we must recur to many of the topics treated of in the two last books, such as the effects of the various agents of decay and reproduction, the imbedding of organic remains, and the extinction of species.

Shifting of the Areas of Sedimentary Deposition.— By reverting to our survey of the destroying and renovating agents, it will be seen that the surface of the terraqueous globe may be divided into two parts, one of which is undergoing repair, while the other, constituting, at any one period, by far the larger portion of the whole, is either suffering degradation, or remaining stationary without loss or increment. The reader will assent at once to this proposition, when he reflects that the dry land is, for the most part, wasting by the action of rain, rivers, and torrents; and that part of the bed

of the sea is exposed to the excavating action of currents, while the greater part, remote from continents and islands, receives no new deposits. For as a turbid river throws down all its sediment into the first lake which it traverses, so currents flowing from the land or from shoals purge themselves from foreign ingredients in the first deep basin which they enter, and beyond this the blue waters of the ocean may for ages remain clear to the greatest depths. If there are any relics of organic beings at the bottom, they may decompose like the leaves of the forest in autumn, leaving no vestige behind, but merely supplying nourishment, by their decomposition, to succeeding races of marine animals and plants.

The other part of the terraqueous surface is the receptacle of new deposits; and in this portion alone, as I pointed out in the last book, the remains of animals and plants become fossilized. Now the position of this area, where new formations are in progress, and where alone any memorials of the state of organic life are preserved, is always varying, and must for ever continue to vary; and, for the same reason, that portion of the terraqueous globe which is undergoing waste also shifts its position, and these fluctuations depend partly on the action of aqueous, and partly of igneous causes.

In illustration of these positions, I may observe, that the sediment of the Rhone, which is thrown into the lake of Geneva, is now conveyed to a spot a mile and a half distant from that where it accumulated in the tenth century, and six miles from the point where the delta began originally to form. We may look forward to the period when the lake will be filled up, and then a sudden change will take place in the distribution of the transported matter; for the mud and sand brought

down from the Alps will thenceforth, instead of being deposited near Geneva, be carried nearly two hundred miles southwards, where the Rhone enters the Mediterranean.

The additional matter thus borne down to the lower delta of the Rhone would not only accelerate its increase, but might affect the mineral character of the strata there deposited, and thus give rise to an upper group, or subdivision of beds, having a distinct character. But the filling up of a lake, and the consequent transfer of the sediment to a new place, may sometimes give rise to a still more abrupt transition from one group to another; as, for example, in a gulf like that of the St. Lawrence, at the head of which no deposits are now accumulated, the river being purged of all its impurities in its previous course through the Canadian lakes. Should the lowermost of these lakes be at any time filled up with sediment, or laid dry by earthquakes, the waters of the river would thenceforth become turbid, and strata would begin to be deposited in the gulf, where a new formation would immediately overlie the ancient rocks now constituting the bottom. In this case there would be an abrupt passage from the inferior and more ancient, to the newer superimposed formation.

The same sudden coming on of new sedimentary deposits, or the suspension of those which were in progress, must frequently occur in different submarine basins where the prevailing currents are always liable, in the course of ages, to change their direction. Suppose, for instance, a sea to be filling up in the same manner as the Adriatic, by the influx of the Po, Adige, and other rivers. The deltas, after advancing and converging, may at last come within the action of a trans-

verse current, which may arrest the further deposition of matter, and sweep it away to a distant point. Such a current now appears to prey upon the delta of the Nile, and to carry eastward the annual accessions of sediment that once added rapidly to the plains of Egypt.

On the other hand, if a current charged with sediment vary its course, — a circumstance which, as I have shown, must happen to all of them in the lapse of ages, — the accumulation of transported matter will at once cease in one region, and commence in another.

Although the causes which occasion the transference of the places of sedimentary deposition are continually in action in every region, yet they are particularly influential where subterranean movements alter, from time to time, the levels of land; and their effect must be very great during the successive elevations and depressions which must be supposed to accompany the rise of a great continent from the deep. A trifling change of level may sometimes throw a current into a new direction, or alter the course of a considerable river. Some tracts will be alternately submerged and laid dry by subterranean movements: in one place a shoal will be formed, whereby the waters will drift matter over spaces where they once threw down their burden, and new cavities will elsewhere be produced, both marine and lacustrine, which will intercept the waters bearing sediment, and thereby stop the supply once carried to some distant basin.

I have before stated, that a few earthquakes of moderate power might cause a subsidence which would connect the sea of Azof with a large part of Asia now below the level of the ocean.* This vast depression,

* See p. 75.

recently shown by Humboldt to extend over an area of eighteen thousand square leagues, surrounds Lake Aral and the Caspian; on the shores of which seas it sinks in some parts to the depth of about 350 feet below the level of the ocean. The whole area might thus suddenly become the receptable of new beds of sand and shells, probably differing in mineral character from the masses previously existing in that country; for an exact correspondence could only arise from a precise identity in the whole combination of circumstances which should give rise to formations produced at different periods in the same place.

Without entering into more detailed explanations, the reader will perceive that, according to the laws now governing the aqueous and igneous causes, distinct deposits must, at different periods, be thrown down on various parts of the earth's surface, and that, in the course of ages, the same area may become, again and again, the receptacle of such dissimilar sets of strata. During intervening periods, the space may either remain unaltered, or suffer what is termed *denudation;* in which case a superior set of strata are removed by the power of running water, and subjacent beds are laid bare, as happens wherever a sea encroaches upon a line of coast. By such means, it is obvious that the discordance in age of rocks in contact must often be greatly increased.

The frequent unconformability in the stratification of the inferior and overlying formation is another phenomenon in their arrangement, which may be considered as a natural consequence of those movements that accompany the gradual conversion of part of an ocean into land; for by such convulsions the older set of strata may become rent, shattered, inclined, and con-

torted to any amount. If the movement cease entirely, before a new deposit is formed in the same tract, the superior strata may repose horizontally upon the dislocated series. But even if the subterranean convulsions continue with increasing violence, the more recent formations must remain comparatively undisturbed, because they cannot share in the derangement previously produced in the older beds; while the latter, on the contrary, cannot fail to participate in all the movements subsequently communicated to the newer.

Change of Species every where in progress.—If, then, it be conceded, that the combined action of the volcanic and the aqueous forces would give rise to a succession of distinct formations, and that these would be sometimes unconformable, let us next inquire in what manner these groups might become characterized by different assemblages of fossil remains.

I endeavoured to show, in the last book, that the hypothesis of the gradual extinction of certain animals and plants, and the successive introduction of new species, was quite consistent with all that is known of the existing economy of the animate world; and if it is found to be the only hypothesis which is reconcilable with geological phenomena, we shall have strong grounds for conceiving that such is the order of nature.

Fossilization of Plants and Animals partial.— We have seen that the causes which limit the duration of species are not confined, at any one time, to a particular part of the globe; and, for the same reason, if we suppose that their place is supplied, from time to time, by new species, we may suppose their introduction to be no less generally in progress. It would follow, therefore, from all the foregoing premises, that the change of species would be in simultaneous ope-

ration every where throughout the habitable surface of sea and land; whereas the fossilization of plants and animals must always be confined to those areas where new strata are produced. These areas, as I have proved, are always shifting their position, so that the fossilizing process, whereby the commemoration of the particular state of the organic world, at any given time, is effected, may be said to move about, visiting and revisiting different tracts in succession.

In order more distinctly to elucidate my idea of the working of this machinery, I shall compare it to a somewhat analogous case that might easily be imagined to occur in the history of human affairs. Let the mortality of the population of a large country represent the successive extinction of species, and the births of new individuals the introduction of new species. While these fluctuations are gradually taking place everywhere, suppose commissioners to be appointed to visit each province of the country in succession, taking an exact account of the number, names, and individual peculiarities of all the inhabitants, and leaving in each district a register containing a record of this information. If, after the completion of one census, another is immediately made on the same plan, and then another, there will, at last, be a series of statistical documents in each province. When these are arranged in chronological order, the contents of those which stand next to each other will differ according to the length of the intervals of time between the taking of each census. If, for example, all the registers are made in a single year, the proportion of deaths and births will be so small during the interval between the compiling of two consecutive documents, that the individuals described in each will be nearly identical;

whereas, if there are sixty provinces, and the survey of each requires a year, there will be an almost entire discordance between the persons enumerated in the same province in two consecutive registers. There are undoubtedly other causes besides the mere quantity of time, which may augment or diminish the amount of discrepancy. Thus, at some periods a pestilential disease may have lessened the average duration of human life, or a variety of circumstances may have caused the births to be unusually numerous, and the population to multiply; or, a province may be suddenly colonized by persons migrating from surrounding districts.

I must also remind the reader, that I do not propose the case as an exact parallel to those geological phenomena which I desire to illustrate; for the commissioners are supposed to visit the different provinces in rotation; whereas the commemorating processes by which organic remains become fossilized, although they are always shifting from one area to another, are yet very irregular in their movements. They may abandon and revisit many spaces again and again, before they once approach another district; and, besides this source of irregularity, it may often happen that, while the depositing process is suspended, denudation may take place, which may be compared to the occasional destruction of some of the statistical documents before mentioned. It is evident that, where such accidents occur, the want of continuity in the series may become indefinitely great, and that the monuments which follow next in succession will by no means be equidistant from each other in point of time.

If this train of reasoning be admitted, the distinctness of the fossil remains, in formations immediately

in contact, would be a necessary consequence of the existing laws of sedimentary deposition, and of a constant mortality and renovation of species.

I have already stated, that we should naturally look for a change in the mineral character in strata thrown down at distant intervals in the same place; and, in like manner, we must also expect, for the reason last set fourth, to meet occasionally with sudden transitions from one set of organic remains to another. But the causes which have given rise to such differences in mineral characters have no necessary connexion with those which have produced a change in the species of imbedded plants and animals.

When the lowest of two sets of strata are much dislocated throughout a wide area, the upper being undisturbed, there is usually a considerable discordance in the organic remains of the two groups; but the coincidence, in this instance, of the point where the fossils and the stratification change their character, must not be ascribed to the agency of the disturbing forces, as if they had exterminated the living inhabitants of the surface. The *lapse of time* assumed to be requisite for the development of so great a series of subterranean movements has, in such cases, allowed the species also throughout the globe to vary, and hence the two phenomena are usually concomitant.

Although these inferences appear to me very obvious, I am aware that they are directly opposed to many popular theories respecting catastrophes; I shall, therefore, endeavour to illustrate these views still more clearly by another analogous case. Suppose we had discovered two buried cities at the foot of Vesuvius, immediately superimposed upon each other, with a great mass of tuff and lava intervening, just as Portici

and Resina, if now covered with ashes, would overlie Herculaneum. An antiquary might possibly be entitled to infer, from the inscriptions on public edifices, that the inhabitants of the inferior and older town were Greeks, and those of the modern, Italians. But he would reason very hastily, if he also concluded, from these data, that there had been a sudden change from the Greek to the Italian language in Campania. Suppose he afterwards found *three* buried cities, one above the other, the intermediate one being Roman, while, as in the former example, the lowest was Greek, and the uppermost Italian; he would then perceive the fallacy of his former opinion, and would begin to suspect that the catastrophes, whereby the cities were inhumed, might have no relation whatever to the fluctuations in the language of the inhabitants; and that, as the Roman tongue had evidently intervened between the Greek and Italian, so many other dialects may have been spoken in succession, and the passage from the Greek to the Italian may have been very gradual; some terms growing obsolete, while others were introduced from time to time.

If this antiquary could have shown that the volcanic paroxysms of Vesuvius were so governed as that cities should be buried one above the other, just as often as any variation occurred in the language of the inhabitants, then, indeed, the abrupt passage from a Greek to a Roman, and from a Roman to an Italian city, would afford proof of fluctuations no less sudden in the language of the people.

So, in Geology, if we could assume that it is part of the plan of nature to preserve, in every region of the globe, an unbroken series of monuments to commemorate the vicissitudes of the organic creation, we might

infer the sudden extirpation of species, and the simultaneous introduction of others, as often as two formations in contact are found to include dissimilar organic fossils. But we must shut our eyes to the whole economy of the existing causes, aqueous, igneous, and organic, if we fail to perceive *that such is not the plan of Nature.*

CHAPTER IV.

DETERMINATION OF THE RELATIVE AGES OF ROCKS.

Chronological relations of mineral masses — Superposition proof of more recent origin — Exceptions — Relative age proved by included fragments of older rocks — Proofs of contemporaneous origin derived from mineral characters — Recurrence of distinct rocks at successive periods — Proofs of contemporaneous origin derived from organic remains — Zoological provinces of limited extent — Different modes whereby dissimilar mineral masses and distinct groups of species may be proved to have been contemporaneous.

In attempting to classify the mineral masses which compose the crust of the earth, the principal object which the geologist must keep in view, is to determine with accuracy their chronological relations; for it is abundantly clear, that different rocks have been formed in succession; and, in order thoroughly to comprehend the manner in which they enter into the structure of our continents, we must study them with reference to the time and mode of their formation.

Proofs of relative Age by Superposition.

It is evident that, where we find a series of horizontal strata of sedimentary origin, the uppermost bed must be newer than those which it overlies; and that, when we observe one distinct set of strata reposing upon another, the inferior is the older of the two. In countries where the original position of mineral masses has been disturbed, at different periods, by convulsions of extraordinary violence, as in the

Alps, and other mountainous districts, there are instances where the original position of strata has been reversed. Such exceptions, however, are rare, and usually on a small scale; and an experienced observer can generally ascertain the true relations of the rocks in question, by examining some adjoining districts where the derangement has been less extensive.

In regard to volcanic formations, if we find a stratum of tuff or ejected matter, or a stream of lava covering sedimentary strata, we may infer, with confidence, that the igneous rock is the more recent; but, on the other hand, the superposition of aqueous deposits to a volcanic mass does not always prove the former to be of newer origin. If, indeed, we discover strata of tuff with imbedded shells, or, as in the Vicentine and other places, rolled blocks of lava, with adhering shells and corals, we may then be sure that these masses of volcanic origin covered the bottom of the sea before the superincumbent strata were thrown down. But, as lava rises from below, and does not always reach the surface, it may sometimes penetrate a certain number of strata, and then cool down, so as to constitute a solid mass of newer origin, although inferior in position. It is, for the most part, by the passage of veins proceeding from such igneous rocks through contiguous sedimentary strata, or by such hardening and other alteration of the overlying bed, as might be expected to result from contact with a heated mass, that we are enabled to decide whether the volcanic matter was previously consolidated, or subsequently introduced.

Proofs by included Fragments of older Rocks.

A geologist is sometimes at a loss, after investigating a district composed of two distinct formations,

to determine the relative ages of each, from want of sections exhibiting their superposition. In such cases, another kind of evidence, of a character no less conclusive, can sometimes be obtained. One group of strata has frequently been derived from the degradation of another in the immediate neighbourhood, and may be observed to include within it fragments of such older rocks. Thus, for example, we may find chalk with flints; and, in another part of the same country, a distinct series, consisting of alternations of clay, sand, and pebbles. If some of these pebbles consist of flints, with fossil shells of the same species as those in the chalk, we may confidently infer, that the chalk is the oldest of the two formations.

I remarked, in the second chapter, that some granite must have existed before the most ancient of our secondary rocks, because some of the latter contain rounded pebbles of granite. But for the existence of such evidence, we might not have felt assured that all the granite which we see was not protruded from below in a state of fusion, subsequently to the origin of the secondary strata.

Proofs of contemporaneous origin derived from Mineral characters.

When we have established the relative age of two formations in a given place, from direct superposition, or by other evidence, a far more difficult task remains, to trace the continuity of the same formation, or, in other cases, to find means of referring detached groups of rocks to a contemporaneous origin. Such identifications of age are chiefly derivable from two sources, —mineral character and organic contents; but the utmost skill and caution are required in the application

of these tests, for scarcely any general rules can be laid down respecting either, that do not admit of important exceptions.

If, at certain periods of the past, rocks of peculiar mineral composition had been precipitated simultaneously upon the floor of an "universal ocean," so as to invest the whole earth in a succession of concentric coats, the determination of relative dates in geology might have been a matter of the greatest simplicity. To explain, indeed, the phenomenon would have been difficult, or, rather, impossible, as such appearances would have implied a former state of the globe, without any analogy to that now prevailing. Suppose, for example, there were three masses extending over every continent, — the upper of chalk and chloritic sand; the next below, of blue argillaceous limestone; and the third and lowest, of red marl and sandstone; we must imagine that all the rivers and currents of the world had been charged, at the first period, with red mud and sand; at the second, with blue calcareo-argillaceous mud; and at a subsequent epoch, with chalky sediment and chloritic sand.

But, if the ocean were universal, there could have been no land to waste away by the action of the sea and rivers, and, therefore, no known source whence the homogeneous sedimentary matter could have been derived. Few, perhaps, of the earlier geologists went so far as to believe implicitly in such universality of formations, but they inclined to an opinion, that they were continuous over areas almost indefinite; and since such a disposition of mineral masses would, if true, have been the least complex, and most convenient for the purposes of classification, it is probable that a belief in its reality was often promoted by the hope

that it might prove true. As to the objection, that such an arrangement of mineral masses could never result from any combination of causes now in action, it never weighed with the earlier cultivators of the science, since they indulged no expectation of being ever able to account for geological phenomena by reference to the known economy of nature. On the contrary, they set out, as we have already seen, with the assumption that the past and present conditions of the planet were too dissimilar to admit of exact comparison.

But, if we inquire into the true composition of any stratum, or set of strata, and endeavour to pursue these continuously through a country, we often find that the character of the mass changes gradually, and becomes at length so different, that we should never have suspected its identity, if we had not been enabled to trace its passage from one form to another.

We soon discover that rocks dissimilar in mineral composition have originated simultaneously: we find, moreover, evidence in certain districts, of the recurrence of rocks of precisely the same mineral character at very different periods; as, for example, two formations of red sand-stone, with a great series of other strata intervening between them. Such repetitions might have been anticipated, since these red sandstones are produced by the decomposition of granite, gneiss, and mica-schist; and districts composed exclusively of these, must again and again be exposed to decomposition, and to the erosive action of running water.

But, notwithstanding the variations before alluded to in the composition of one continuous set of strata, many rocks retain the same homogeneous structure

and composition throughout considerable areas, and frequently, after a change of mineral character, preserve their new peculiarities throughout other tracts of great extent. Thus, for example, we may trace a limestone for a hundred miles, and then observe that it becomes more arenaceous, until it finally passes into sand or sandstone. We may then follow the last-mentioned formation throughout another district as extensive as that occupied by the limestone first examined.

Proofs of contemporaneous origin derived from organic remains.

I devoted several chapters in the last book to show that the habitable surface of the sea and land may be divided into a considerable number of distinct provinces, each peopled by a peculiar assemblage of animals and plants, and I endeavoured to point out the origin of these separate divisions. It was shown that climate is only one of many causes on which they depend, and that difference of longitude, as well as latitude, is generally accompanied by a dissimilarity of indigenous species of organic beings.

As different seas, therefore, and lakes are inhabited, at the same period, by different species of aquatic animals and plants, and as the lands adjoining these may be peopled by distinct terrestrial species, it follows that distinct organic remains are imbedded in contemporaneous deposits. If it were otherwise — if the same species abounded in every climate, or even in every part of the globe where a corresponding temperature, and other conditions favourable to their existence, were found, the identification of mineral masses of the same age, by means of their included

organic contents, would be a matter of much greater facility. But, fortunately, the extent of the same zoological provinces, especially those of marine animals, is very great; so that we are entitled to expect, from analogy, that the identity of fossil species, throughout large areas, will often enable us to connect together a great variety of detached formations.

Thus, for example, it will be seen, by reference to the second book, that deposits now forming in different parts of the Mediterranean, as in the deltas of the Rhone and the Nile, are distinct in mineral composition; for calcareous rocks are precipitated from the waters of the former river, while pebbles are carried into its delta, and there cemented, by carbonate of lime, into a conglomerate; whereas strata exclusively of soft mud and fine sand are formed in the Nilotic delta. The Po, again, carries down fine sand and mud into the Adriatic; but since this sediment is derived from the degradation of a different assemblage of mountains from those drained by the Rhone or the Nile, we may safely assume that there will never be an exact identity in their respective deposits.*

If we pass to another quarter of the Mediterranean, as, for example, to the sea on the coast of Campania, or near the base of Etna in Sicily, or to the Grecian archipelago, we find in all these localities that distinct combinations of rocks are in progress. Occasional showers of volcanic ashes are falling into the sea, and streams of lava are overflowing its bottom; and in the intervals between volcanic eruptions, beds of sand and clay are frequently derived from the waste of cliffs, or the turbid waters of rivers. Limestones, moreover, such as the Italian travertins, are here and

* Vol. I. pp. 340. 344. 348.

there precipitated from the waters of mineral springs, while shells and corals accumulate in various localities. Yet the entire Mediterranean, where the above-mentioned formations are simultaneously in progress, may be considered as one zoological province; for, although certain species of testacea and zoophytes may be very local, and each region may probably have some species peculiar to it, still a considerable number are common to the whole sea. If, therefore, at some future period, the bed of this inland sea should be converted into land, the geologist might be enabled, by reference to organic remains, to prove the contemporaneous origin of various mineral masses throughout a space equal in area to a great portion of Europe. The Black Sea, moreover, is inhabited by so many identical species, that the deltas of the Danube and the Don might, by the same evidence, be shown to have originated simultaneously.

Such identity of fossils, I may remark, not only enables us to refer to the same era, distinct rocks widely separated from each other in the horizontal plane, but also others which may be considerably distant in the vertical series. Thus, for example, we may find alternating beds of clay, sand, and lava, two thousand feet in thickness, the whole of which may be proved to belong to the same epoch, by the specific identity of the fossil shells dispersed throughout the whole series.

The reader, however, will perceive, by referring to what was before said of zoological provinces *, that they are sometimes separated from each other by very narrow barriers, and for this reason contiguous

* See p. 27.

rocks may be formed at the same time, differing widely both in mineral contents and organic remains. Thus, for example, the testacea, zoophytes, and fish of the Red Sea are, as a group, very distinct from those inhabiting the adjoining parts of the Mediterranean, although the two seas are only separated by the narrow isthmus of Suez. Calcareous formations have accumulated, on a great scale, in the Red Sea, in modern times*, and fossil shells of existing species are well preserved therein; and we know that, at the mouth of the Nile, large deposits of mud are amassed, including the remains of Mediterranean species. Hence it follows that if, at some future period, the bed of the Red Sea should be laid dry, the geologist might experience great difficulties in endeavouring to ascertain the relative age of these formations, which, although dissimilar both in organic and mineral characters, were of synchronous origin.

But we must not forget that the north-western shores of the Arabian Gulf, the plains of Egypt, and the isthmus of Suez, are all parts of one province of *terrestrial* species. Small streams, therefore, occasional land-floods, and those winds which drift clouds of sand along the deserts, might carry down into the Red Sea the same shells of fluviatile and land testacea, which the Nile is sweeping into its delta, together with some remains of terrestrial plants, whereby the groups of strata, before alluded to, might, notwithstanding the discrepancy of their mineral composition, and *marine* organic fossils, be shown to have belonged to the same epoch.

In like manner, the rivers which descend into the

* See chap. x.

Caribbean Sea and Gulf of Mexico on one side, and into the Pacific on the other, carry down the same fluviatile and terrestrial spoils into seas which are inhabited by different groups of marine species.

But it will much more frequently happen, that the coexistence of *terrestrial* species of distinct zoological and botanical provinces will be proved by the specific identity of the *marine* organic remains which inhabited the intervening space. Thus, for example, the distinct terrestrial species of the south of Europe, north of Africa, and north-west of Asia, might all be shown to have been contemporaneous, if we suppose the rivers flowing from those three countries to carry the remains of different species of the animal and vegetable kingdoms into the Mediterranean.

In like manner, the sea intervening between the northern shores of Australia and the islands of the Indian ocean contains a great proportion of the same species of corallines and testacea, yet the *land animals and plants* of the two regions are very dissimilar, even the islands nearest to Australia, as Java, New Guinea, and others, being inhabited by a distinct assemblage of terrestrial species. It is well known that there are calcareous rocks, volcanic tuff, and other strata in progress, in different parts of these intermediate seas, wherein marine organic remains might be preserved and associated with the terrestrial fossils above alluded to.

As it frequently happens that the barriers between different provinces of animals and plants are not very strongly marked, especially where they are determined by differences of temperature, there will usually be a passage from one set of species to another, as in a sea extending from the temperate to the tropical zone. In such cases, we may be enabled to prove, by the fossils

of intermediate deposits, the connexion between the distinct provinces, since these intervening spaces will be inhabited by many species, common both to the temperate and equatorial seas.

On the other hand, we may be sometimes able, by aid of a peculiar homogeneous deposit, to prove the former coexistence of distinct animals and plants in distant regions. Suppose, for example, that in the course of ages the sediment of a river, like that of the Red River in Louisiana, is dispersed over an area several hundred leagues in length, so as to pass from the tropics into the temperate zone, the fossil remains imbedded in red mud might indicate the different forms which inhabited, at the same period, those remote regions of the earth.

It appears, then, that mineral and organic characters, although often inconstant, may, nevertheless, enable us to establish the contemporaneous origin of formations in distant countries. The same species of organic beings probably extend over wider areas than deposits of homogeneous composition, and if so they will be of more importance in geological classification even than mineral peculiarities; but it fortunately may happen, that where the one criterion fails, we may often avail ourselves of the other. Thus, for example, sedimentary strata are as likely to preserve the same colour and composition in a part of the ocean reaching from the borders of the tropics to the temperate zone, as in any other quarter of the globe; but in such spaces the variation of species is always most considerable.

In conclusion, it may be observed, that in endeavouring to prove the contemporaneous origin of strata in remote countries by organic remains, we must form our conclusions from a great number of species, since

a single species may be enabled to survive vicissitudes in the earth's surface, whereby thousands of others are exterminated. When a change of climate takes place, some may migrate and inhabit other latitudes, and so abound there, as to become characteristic in those regions of strata of a subsequent era.

CHAPTER V.

CLASSIFICATION OF TERTIARY FORMATIONS IN CHRONOLOGICAL ORDER.

Comparative value of different classes of organic remains — Fossil remains of testacea the most important — Necessity of accurately determining species — Four subdivisions of the tertiary epoch proposed — Recent formations — Newer Pliocene period — Older Pliocene period — Miocene period — Eocene period — The distinct zoological characters of these periods may not imply sudden changes in the animate creation — Numerical proportion of recent species of shells in different tertiary periods — The recent strata form a common point of departure in distant regions — Mammiferous remains — Synoptical table of recent and tertiary formations.

In the last chapter I explained the principles on which the relative ages of different formations may be ascertained, and the distinctive character was found to be chiefly derivable from superposition, mineral structure, and organic remains. It is by combining the evidence deducible from all these sources, that we are enabled to determine the chronological succession of distinct formations.

It will be seen, that in proportion as investigations have been extended over a larger area, it has become necessary to intercalate new groups of an age intermediate between those first examined, and we have every reason to expect that, as the science advances, new links in the chain will be supplied, and that the passage from one period to another will become less abrupt. We may even hope, without travelling to distant regions,—without even transgressing the limits of western Europe, to render the series far more complete.

The fossil shells, for example, of many of the Subalpine formations, on the northern limits of the plain of the Po, have not yet been carefully collected and compared with those of other countries, and we are almost entirely ignorant of many deposits known to exist in Spain and Portugal.

The views developed in the last chapter, respecting breaks in the sequence of geological monuments, will explain our reasons for anticipating the discovery of intermediate gradations as often as new regions of great extent are explored.

Comparative value of different classes of organic remains.

In the mean time, we must endeavour to make the most systematic arrangement in our power of those formations which are already known ; and in attempting to classify these in chronological order, we must chiefly depend on the evidence afforded by their fossil organic contents. In the execution of this task, we have first to consider what class of remains are most useful, for although every kind of fossil animal and plant is interesting, and cannot fail to throw light on the former history of the globe at a certain period, yet those classes of remains which are of rare and casual occurrence are absolutely of no use for the purposes of general classification. If we have plants alone in one assemblage of strata, and the bones of mammalia in another, we can draw no conclusion respecting the number of species of organic beings common to two epochs ; or if we have plants and vertebrated animals in one series, and only shells in another, we can form no opinion respecting the re-

moteness or proximity of the two eras. We might, perhaps, draw some conclusions as to relative antiquity, if we could compare each of the two formations to a third; as, for example, if the species of shells should be almost all identical with those now living, while the plants and vertebrated animals were all extinct; for we might then infer that the shelly deposit was the most recent of the two. But in this case the information would flow, from a direct comparison of the species of corresponding orders of the animal and vegetable kingdoms, — of plants with plants, and shells with shells; the only mode of making a systematic arrangement by reference to organic remains.

Although the bones of mammalia in the tertiary strata, and those of reptiles in the secondary, afford us instruction of the most interesting kind, yet the species are too few, and confined to too small a number of localities, to be of much value in characterizing the subdivisions of geological formations. Skeletons of fish are by no means frequent in a good state of preservation, and the science of ichthyology must be farther advanced, before we can hope to determine their specific character with precision.* The same may be said of fossil botany, notwithstanding the great progress that has recently been made in that department; and even in regard to zoophytes, which are so much more abundant in a fossil state than any of the classes above enumerated, we are still impeded in our endeavour to classify strata by their aid, in consequence of the smallness of the number of recent species which have

* Since the first edition of this volume was published, the first number of M. Agassiz's invaluable work on Fossil Fish has appeared.

been examined from those tropical seas where they occur in the greatest profusion.

Fossil remains of testacea of chief importance.—The testacea then are by far the most important class of organic beings which have left their spoils in the subaqueous deposits; and they have been truly said to be the medals which nature has chiefly selected to record the history of the former changes of the globe. There is scarcely any great series of strata that does not contain some marine or freshwater shells, and these fossils are often found so entire, especially in the tertiary formations, that when disengaged from the matrix, they have all the appearance of having been just procured from the sea. Their colour, indeed, is usually wanting, but the parts whereon specific characters are founded remain unimpaired; and though the animals themselves are gone, their form and habits can generally be inferred from the shell which covered them.

The utility of the testacea, in geological classification, is greatly enhanced by the circumstance, that some forms are proper to the sea, others to the land, and others to fresh water. Rivers scarcely ever fail to carry down into their deltas some land shells, together with species which are at once fluviatile and lacustrine. The Rhone, for example, receives annually, from the Durance, many shells which are drifted in an entire state from the higher Alps of Dauphiny, and these species, such as *Bulimus montanus*, are carried down into the delta of the Rhone to a climate very different from that of their native habitation. The young hermit crabs may often be seen on the shores of the Mediterranean, near the mouth of the Rhone, inhabiting these univalves, brought down to them from so great

a distance.* At the same time that some freshwater and land shells are carried into the sea, other individuals of the same species become fossil in inland lakes, and by this means we learn what species of freshwater and marine testacea coexisted at particular eras. We also make out the connexion between various plants and mammifers imbedded in those lacustrine deposits, and the testacea which lived at the same time in the ocean.

There are two other characters of the molluscous animals which render them extremely valuable in settling chronological questions in Geology. The first of these is a wide geographical range, and the second (probably a consequence of the former), is the superior duration of species in this class. It is evident that if the habitation of a species be very local, it cannot aid us greatly in establishing the contemporaneous origin of distant groups of strata, in the manner pointed out in the last chapter; and if a wide geographical range be useful in connecting formations far separated in space, the longevity of species is no less serviceable in establishing the relations of strata considerably distant from each other in point of time.

I shall revert in the sequel to the curious fact, that in tracing back the series of tertiary deposits from the newer to the older, many existing species of testacea accompany us after the disappearance of all fossil remains of the recent mammalia. We even find the skeletons of extinct quadrupeds in deposits wherein all the land and freshwater shells are of living species.†

* M. Marcel de Serres pointed out this curious fact to me when I visited Montpellier, July, 1828.

† See Vol. I. p. 145. and Book IV. chap. 11.

Necessity of accurately determining species.—The reader will already perceive that the systematic arrangement of strata, so far as it rests on organic remains, must depend essentially on the accurate determination of *species*, and the geologist must therefore have recourse to the ablest naturalists, devoted to the study of certain departments of organic nature. It is scarcely possible that they who are continually employed in laborious investigations in the field, and in ascertaining the relative position and characters of mineral masses, should have leisure to acquire a profound knowledge of fossil osteology, conchology, and other branches of zoological enquiry; but it is desirable that, in these sciences they should become acquainted with the principles at least on which specific characters are determined, and the habits of species inferred from their peculiar forms.

When the specimens of shells are in an imperfect state of preservation, or happen to belong to genera in which it is difficult to decide on the species, except the inhabitant itself be present, or when any other grounds of ambiguity arise, we must reject, or lay small stress upon, the evidence, lest we vitiate our general results by false identifications and analogies. We cannot do better than consider the steps by which the science of botanical geography has reached its present stage of advancement, and endeavour to introduce the same severe comparison of the specific characters, in drawing all our geological inferences.

SUBDIVISIONS OF THE TERTIARY EPOCH.

I shall now proceed to consider the subdivisions of tertiary strata which may be founded on the results of a comparison of their respective fossils, and to give names to the periods to which they may be severally

referred. But first it will be necessary to explain the difference between the *tertiary* phenomena and those described in the last two books. In the present work all those geological monuments are called tertiary which are newer than the secondary formations, and which on the other hand cannot be proved to have originated since the earth was inhabited by man. Part of the changes, whether of the animate or inanimate world, considered in the preceding books, was ascertained by historical testimony to have taken place within the human epoch; as, for example, the accumulation of the newer portion of the deltas of the Po, Rhone, and Nile. Another part where history was silent was proved to belong to the same epoch by the evidence of the fossil remains of man or his works. All formations, whether igneous or aqueous, which can be shown by any such proofs to be of a date posterior to the introduction of man will be called *Recent.* Some authors have applied the term *contemporaneous* in the same sense; but as this word is so frequently in use to express the synchronous origin of distinct rocks of every age, it would be a source of great inconvenience and ambiguity if we were to confine it to a technical meaning.

The European tertiary strata may be referred to four successive periods, each characterized by containing a very different proportion of fossil shells of *recent* species.* These four periods will be called, Newer Pliocene, Older Pliocene, Miocene, and Eocene.

* I have stated in the preface that I had conceived this idea of a fourfold division in 1828, and found, on my return to Paris in Feb. 1829, that the discoveries of M. Desnoyers (see Book iv. chap. ii.) had confirmed the distinctness in age of the formations of the first and second periods; as also that M. Deshayes had deduced from a comparison of the fossil shells in his collection, the conclusion

In the older groups we find an extremely small number of fossils identifiable with species now living* ; but as we approach the superior and newer sets, we find the remains of recent testacea in abundance. In no instance where we have an opportunity of observing two distinct formations in contact, the one superimposed upon the other, do we meet with an assemblage of organic remains in the uppermost differing more widely from the existing creation than the fossils of the inferior group. If there is occasionally an apparent exception to the rule, it is only where the remains belong to distinct classes of the animal kingdom ; as, for example, where a deposit containing the bones of quadrupeds for the most part extinct, overlies a stratum in which the imbedded shells are mostly recent—such exceptions seem to point to a difference in the comparative duration of species in different classes, but do not invalidate the general proposition before laid down.

Newer Pliocene period.—The latest of the four periods before alluded to is that which immediately

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that three tertiary periods might be established, the third or most modern of which comprehended the two last of my intended divisions. By the assistance of M. Deshayes, I was enabled, in a former edition, to present in a tabular form the results obtained from an examination of about eight thousand tertiary and recent shells on which the classification adopted in this work has been founded. These tables have not been reprinted, for reasons explained in the preface. When I published my third volume in 1833, I had not studied the second volume of Professor Bronn's "Journey in Italy," published in Dec. 1831, in which he remarks, that the distinctive character of the older as compared to the newer tertiary formations of Italy, consisted in the much smaller proportion of living species in the former.—Bronn's Reisen, part ii. p. 678.

* See p. 267

preceded the recent era. To this more modern period may be referred a portion of the strata of Sicily, the district round Naples, and several others to be considered in the sequel. They are characterized by a great preponderance of fossil shells referable to species still living, and may be called the Newer Pliocene strata, the term Pliocene being derived from πλειων major, and καινος recens, as the major part of the fossil shells are of recent species.*

Out of 226 fossil species brought from the Sicilian beds above alluded to, M. Deshayes found that no less than 216 were of species still living, and, for the most part, in the Mediterranean, whereas ten only were of extinct or unknown species. I do not imagine that any of the groups referred to this period in the present work contain much more than the proportion of one in ten of extinct species of shells. Nevertheless, the antiquity of some Newer Pliocene strata of Sicily, as contrasted with our most remote historical eras, must be very great, embracing perhaps myriads of years.† There are no data for supposing that there is any break, or strong line of demarcation, between the strata and fossils of this and the Recent epoch; but, on the

* In this and the other names which I have adopted, it will be seen that the nomenclature has always reference to the relative proportion of recent species in the fossils of each period. In the terms Pliocene, Miocene, and Eocene, the Greek diphthongs *ei* and *ai* are changed into the vowels *i* and *e*, in conformity with the idiom of our language. My friend, the Rev. W. Whewell, to whom I have been much indebted for assisting me in inventing and anglicizing these terms, reminds me that we have Encenia, an inaugural ceremony, derived from εν and καινος, recens; and as examples of the conversion of *ei* into *i*, we have icosahedron.

† See chapters 6, 7, 8, and 9.

contrary, the monuments of the one seem to pass insensibly into those of the other.

Older Pliocene period.—The formations termed Subapennine in the north of Italy and in Tuscany contain among their fossil shells a large number which have been identified with living species. The proportion of *recent* shells, even where least considerable, usually approaches to one half. Out of 569 species examined from these strata in Italy, 238 were found to be still living, and 331 extinct or unknown. Out of 111 from the English crag, M. Deshayes determined forty-five, to be recent species, and sixty-six to be extinct or unknown. The relative position of these Older Pliocene beds is explained in diagram No. 54. p. 266. where they are designated by the letter *f.*

The plurality of species indicated by the name Pliocene must not in this instance be understood to imply an absolute majority of *recent* fossil shells in all cases, but a comparative preponderance whenever the Older Pliocene are contrasted with strata of the period immediately preceding.

Miocene period.—This antecedent tertiary epoch I shall name Miocene, from μειων, minor, and καινος, recens, a small minority only of fossil shells imbedded in its formations being referable to living species. After examining 1021 Miocene shells, M. Deshayes found that 176 only were recent, being in the proportion of rather less than eighteen in one hundred. As there are a certain number of fossil species which are exclusively confined to the Pliocene period, so also there are many shells equally characteristic of the Miocene. The species which pass from the Miocene into the Pliocene period, or which are common to both, are in number 196, of which 114 are

living, and eighty-two extinct. The Miocene strata are largely developed in Touraine, and in the South of France near Bordeaux, in Piedmont, in the basin of Vienna, and other localities, and their relative position has been shown in diagrams Nos. 53. and 54., where they are designated by the letter *e*.

Eocene period.—The period next antecedent may be called Eocene, from ἠως, aurora, and καινος, recens, because the very small proportion of living species contained in these strata indicates what may be considered the first commencement, or *dawn*, of the existing state of the animate creation. To this era the formations first called tertiary, of the Paris and London basins, are referable. Their position is shown in the diagrams Nos. 53. and 54., letter *d*, in the second chapter.

The total number of fossil shells of this period already known, when the tables of M. Deshayes, before alluded to, were constructed, was 1238, of which number forty-two only are living species, being nearly in the proportion of three and a half in one hundred. Of fossil species, not known as recent, forty-two were found to be common to the Eocene and Miocene epochs.

The present geographical distribution of those recent species which are found fossil in formations of such high antiquity as those of the Paris and London basins, is a subject of the highest interest. In the more modern formations, where so large a proportion of the fossil shells belong to species still living, they also belong, for the most part, to species now inhabiting the seas immediately adjoining the countries where they occur fossil; whereas the recent species, found in the older tertiary strata, are frequently inhabitants

of distant latitudes, and usually of warmer climates. Of the forty-two Eocene species, which occur fossil in England, France, and Belgium, and which are still living, about half now inhabit the seas within or near the tropics, and almost all the rest are inhabitants of the more southern parts of Europe. If some Eocene species still flourish in the same latitudes where they are found fossil, they are species which, like *Lucina divaricata*, are now found in many seas, even those of different quarters of the globe; and this wide geographical range indicates a capacity of enduring a variety of external circumstances, which may enable a species to survive considerable changes of climate and other revolutions of the earth's surface. One fluviatile species (*Melania inquinata*), fossil in the Paris basin, is now known only in the Philippine islands, and, during the lowering of the temperature of the earth's surface, may perhaps have escaped destruction by migrating to the south. I have pointed out in the third book*, how rapidly the eggs of freshwater species might, by the instrumentality of water-fowl, be transported from one region to another. Other Eocene species, which still survive and range from the temperate zone to the equator, may formerly have extended from the pole to the temperate zone; and what was once the southern limit of their range may now be the most northern.

Even if geologists had not established several remarkable facts in attestation of the longevity of certain tertiary species, we might still have anticipated that the duration of the living species of aquatic and terrestrial testacea would be very unequal. For it is

* See p. 6.

clear, that those which have a wide range, and inhabit many different regions and climates, may survive the influence of destroying causes, which might extirpate the greater part of species now their contemporaries. The increase of existing species, and gradual disappearance of the extinct, as we trace the series of formations from the older to the newer, is somewhat analogous, as was before observed, to the fluctuations of a population such as might be recorded at successive periods, from the time when the oldest of the individuals now living was born, to the present moment; and those Eocene testacea which still flourish may be said to have outlived several successive states of the organic world, just as Nestor survived three generations of men.

It appears, then, that the numerical proportion of recent to extinct species of fossil shells in the different tertiary periods may be thus expressed.—In the

Newer Pliocene period . . .	90 to 95	per cent. of *recent* fossils.
Older Pliocene period . . .	35 to 50	
Miocene period	18	
Eocene period	$3\frac{1}{2}$	

The distribution of the fossil species from which the above results were obtained by M. Deshayes was as follows:

In the formations of the Pliocene periods, older and newer	777
In the Miocene	1021
In the Eocene	1238
	3036

Only seventeen species of shells were found to be common to the three epochs, which may therefore be said to characterize the entire tertiary formations of

Europe. Thirteen of them are species still living, while four are only known as fossil. The thirteen living species are

1. Dentalium entalis.
2. ——— strangulatum.
3. Fissurella græca.
4. Bulla lignaria.
5. Rissoa cochlearella.
6. Murex fistulosus.
7. ——— tubifer.
8. Polymorphina gibba.
9. Triloculina oblonga.
10. Lucina divaricata.
11. ——— gibbosula.
12. Isocardia cor.
13. Nucula margaritacca.

The four extinct species are

1. Dentalium coarctatum.
2. Tornatella inflata.
3. Bulimus terebellatus.
4. Corbula complanata.

These numbers, however, must merely be regarded as the results obtained from a careful examination of the first groups which chance has thrown in our way, or which lie in the most accessible parts of Europe.

Many geologists are desirous of connecting divisions such as these with sudden and violent interruptions in the ordinary course of events, and they regard them as indicative of successive changes in the organic world, accompanying revolutions equally important in the physical geography of the earth's surface. But I have already attempted to show, that such apparent breaks in the geological series may be accounted for partly by the mode in which the commemorative processes operate*, partly by the removal of strata by denudation, and that they arise, in part, from the small progress which we have hitherto made in the discovery and study of such deposits as are preserved.

* See p. 273.

From the experience of the last few years, we may anticipate the discovery of many intermediate gradations between the boundary lines first drawn; and if formations are brought to light intervening between the Eocene and Miocene, or between those of the last period and the Pliocene, we may still find an appropriate place for all, by forming subdivisions, on the same principle as that which has determined the separation of the lower from the upper Pliocene groups. Thus, for example, we might have three divisions of the Eocene epoch,—the older, middle, and newer; and three similar subdivisions, both of the Miocene and Pliocene epochs. In that case, the formations of the middle period must be considered as the types from which the assemblage of organic remains in the groups on both sides will diverge.

When we institute a new genus in natural history, and intend it to occupy a place intermediate between two genera previously established, as the genus B, for example, between A and C, we select a particular species *b*, as the generic type of B, and then determine to refer all other species to the same genus, provided they approach nearer to *b* than the types of A or C. On comparing together the species of B, we discover that they deviate in various ways and degrees from the typical species, some of them approaching somewhat nearer to the characters of the genus A which precedes, others to C which stands next, in the series. By due attention to these shades of difference we may arrange all the congeners in order, according to their natural affinities.

In like manner, when we desire to class geological formations in a chronological series, we may select a certain set of strata as *b*, and consider it as typical

of a particular period B.—We may then refer other formations to B, if they resemble in their organic contents the normal group *b* more nearly than the types of the antecedent or subsequent epochs A and C. And we may consider the strata which in departing slightly from *b* approximate to A as being the older divisions of the period B, and those which depart from the type *b* in the direction of C as the newer deposits of the same era.

In determining originally the order of succession of A, B, and C, we must be guided, as far as possible, by the evidence of superposition by which the relative age of the principal groups may generally be decided with certainty.

It must not be inferred from any thing above advanced, that the four-fold division of the tertiary epoch is purely arbitrary, or that any other number of periods might in the present state of the science have been chosen with equal propriety. For, though it be true that zoological periods in geology like genera and orders in Natural History, are purely artificial divisions; yet we have at present no alternative but to accept those lines of separation which we find in the series of monuments first brought to light.

It is a comparatively easy task to establish genera in departments of zoology and botany which have been enriched with only a small number of species, and where there is as yet no tendency in one set of characters to pass almost insensibly, by a multitude of connecting links, into another. So, in geology, our facilities of systematic arrangement are perhaps greater now than they will be hereafter, when we are under the necessity of intercalating new periods between those first established.

In conclusion, I may observe, that although the lapse of ages comprised within a single period is very much narrowed by the four-fold subdivision above explained, yet when all the Eocene or Miocene deposits are said to be *contemporaneous*, this term must be received with a good deal of latitude. Considerable intervals of time may have elapsed without giving rise to any marked distinction in the imbedded organic remains. Suppose the growth of the delta of the Nile to cease from this moment, and some new river to begin to transport sediment into the Mediterranean at any other point and to form a delta, this last formation might contain the same fossils as the marine and fluviatile deposits of the Nile previously accumulated in Lower Egypt; the difference at least might be so trifling that future geologists would regard them as contemporaneous, if they followed the same rules of classification as those laid down in this chapter.

The recent strata form a common point of departure in all countries.—We derive one great advantage from beginning our classification of formations by a comparison of the fossils of the more recent strata with the species now living, namely, the acquisition of a common point of departure in every region of the globe. Thus, for example, if strata should be discovered in India or South America, containing the same small proportion of recent shells as are found in the Paris basin, *they* also might be termed Eocene, and, on analogous data, an approximation might be made to the relative dates of strata placed in the arctic and tropical regions, or the comparative age might be ascertained of European deposits, and those at the antipodes. There might be no species common to the two groups; yet we might infer their synchronous origin from the

common relation which they bear to the existing state of the animate creation. We may afterwards avail ourselves of the dates thus established, as eras to which the monuments of preceding periods may be referred.

Mammiferous remains of successive tertiary eras.— But although a thirtieth part of the Eocene testacea have been identified with species now living, none of the associated mammiferous remains belong to species which now exist, either in Europe or elsewhere. Some of these equalled the horse, and others the rhinoceros, in size, and they could not possibly have escaped observation, had they survived down to our time. More than forty of these Eocene mammifers are referrible to a division of the order Pachydermata, which has now only four living representatives on the globe. Of these, not only the species but the genera are distinct from any of those which have been established for the classification of living animals.

In the Miocene mammalia we find a few of the generic forms most frequent in the Eocene strata associated with some of those now existing, and in the Pliocene we find an intermixture of extinct and recent species of quadrupeds. There is, therefore, a considerable degree of accordance between the results deducible from an examination of the fossil testacea, and those derived from the mammiferous fossils. But although the latter are more important in respect to the unequivocal evidence afforded by them of the extinction of species, yet, for reasons before explained, they are of comparatively small value in the general classification of strata in geology.*

* See p. 297.

We have seen that the imbedding of mammiferous remains depends on rare casualties, and that they are, for the most part, preserved in detached alluvions covering the emerged land, or in osseous breccias and stalagmites formed in caverns and fissures, or in isolated lacustrine formations.* These fissures and caves may probably have remained open during successive geological periods; and the alluvions, spread over the surface, may have been disturbed, again and again, until the mammalia of successive epochs were mingled and confounded together. Hence we must be careful, when we endeavour to refer the remains of mammalia to certain tertiary periods, that we ascertain, not only their association with testacea of which the date is known, but, also, that the remains were intermixed in such a manner as to leave no doubt of the former co-existence of the species.

In the next page will be found a Synoptical Table of the Recent and Tertiary Formations alluded to in this chapter.

* Book iii. chaps. xiii. and xiv.

Synoptical Table of Recent and Tertiary Formations.

	PERIODS.	Character of Formations.	Localities of the different Formations.
I. Recent.	. . . . .	Marine.	Coral formations of Pacific. Delta of Po, Ganges, &c.
		Freshwater.	Modern deposits in Lake Superior—Lake of Geneva—Marl lakes of Scotland—Italian travertin, &c.
		Volcanic.	Jorullo—Monte Nuovo—Modern lavas of Iceland, Etna, Vesuvius, &c.
II. Tertiary.	1. Newer Pliocene.	Marine.	Strata of the Val di Noto in Sicily. Ischia.
		Freshwater.	Valley of the Elsa around Colle in Tuscany.
		Volcanic.	Older parts of Vesuvius, Etna, and Ischia—Volcanic rocks of the Val di Noto in Sicily.
	2. Older Pliocene.	Marine.	Northern Subapennine formations, as at Parma, Asti, Sienna, Perpignan, Nice—English Crag.
		Freshwater.	Alternating with marine beds near the town of Sienna.
		Volcanic.	Volcanos of Tuscany and Campagna di Roma.
	3. Miocene.	Marine.	Strata of Touraine, Bordeaux, Valley of the Bormida, and the Superga near Turin—Basin of Vienna.
		Freshwater.	Alternating with marine at Saucats, twelve miles south of Bordeaux.
		Volcanic.	Hungarian and Transylvanian volcanic rocks. Part of the volcanos of Auvergne, Cantal, and Velay?
	4. Eocene.	Marine.	Paris and London Basins.
		Freshwater.	Alternating with marine in Paris basin—Isle of Wight—purely lacustrine in Auvergne, Cantal, and Velay.
		Volcanic.	Oldest part of volcanic rocks of Auvergne.

CHAPTER VI.

NEWER PLIOCENE FORMATIONS—SICILY.

Reasons for considering, in the first place, the more modern periods — Geological structure of Sicily — Formations of the Val di Noto — Divisible into three groups — Great limestone — Schistose and arenaceous limestone — Blue marl with shells — Strata subjacent to the above — Volcanic rocks of the Val di Noto — Dikes — Tuffs and Peperinos — Volcanic conglomerates — Proofs of long intervals between volcanic eruptions — Dip and direction of newer Pliocene strata of Sicily.

Having endeavoured, in the last chapter, to explain the principles on which the different tertiary formations may be arranged in chronological order, I shall now proceed to consider in detail the newest division, or that which has been named the newer Pliocene.

It may appear, to some readers, that I reverse the natural order of historical research by thus describing, in the first place, the monuments of a period which immediately preceded our own era, and then passing to the events of antecedent ages. But, in the present state of our science, this retrospective order of inquiry is the only one which can conduct us gradually from the known to the unknown, from the simple to the more complex phenomena. I have already explained my reasons for commencing with an examination, in the last two books, of the events of the *recent* epoch, from which the greater number of rules of interpretation in geology may be derived. The formations of the newer Pliocene period will be considered next in order, because these have

undergone the least degree of alteration, both in position and internal structure, subsequently to their origin. They are monuments of which the characters are more easily deciphered than those belonging to more remote periods, for they have been less mutilated by the hand of time. The organic remains, more especially of this era, are most important, not only as being in a more perfect state of preservation, but also as being chiefly referrible to species now living; so that their habits are known to us by direct comparison, and not merely by inference from analogy, as in the case of extinct species.

Geological structure of Sicily. — I shall first describe an extensive district in Sicily, where the newer Pliocene strata are largely developed, and where they are raised to considerable heights above the level of the sea. After presenting the reader with a view of these formations, I shall endeavour to explain the manner in which they originated, and shall speculate on the subterranean changes of which their present position affords evidence.

The island of Sicily consists partly of primary and secondary rocks, which occupy, perhaps, about two thirds of its superficial area; and the remaining part is covered by tertiary formations, which are of great extent in the southern and central parts of the island, while portions are found bordering nearly the whole of the coasts.

Formations of the Val di Noto. — If we first turn our attention to the Val di Noto, a district which intervenes between Etna and the southern promontory of Sicily, we find a considerable tract, containing within it hills which are from one to two thousand feet in height, entirely composed of limestone, marl, sand-

stone, and associated volcanic rocks, which belong to the newer Pliocene era. The recent shells of the Mediterranean abound throughout the sedimentary strata, and there are abundant proofs that the igneous rocks were the produce of successive submarine eruptions, repeated at intervals during the time when the subaqueous formations were in progress.

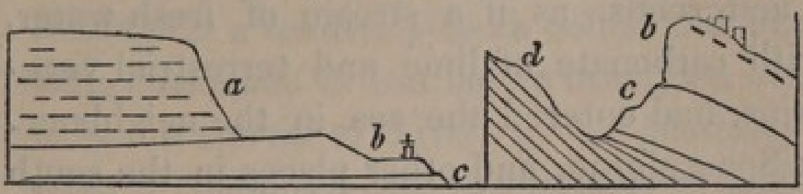
These rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata whereon it rests, by the low level plain of Catania, just elevated above the level of the sea, and watered by the Simeto. The traveller who passes from Catania to Syracuse has an opportunity of observing, on the sides of the valley, many deep sections of the modern formations above described, especially if he makes a slight detour by Sortino and the valley of Pentalica.

The whole series of strata, in the Val di Noto, is divisible into three principal groups, exclusive of the associated volcanic rocks. The uppermost mass consists of limestone, which sometimes acquires the enormous thickness of seven or eight hundred feet, below which is a series much inferior in thickness, consisting of a calcareous sandstone, conglomerate and schistose limestone, and beneath this again, blue marl. The whole of the above groups contain shells and zoophytes, nearly all of which are referrible to species now inhabiting the contiguous sea.

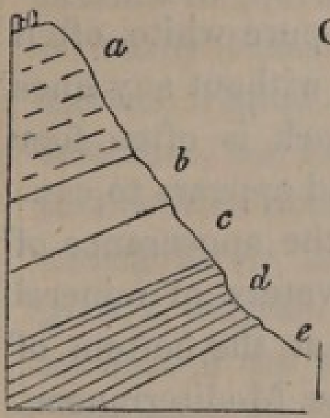
Great limestone formation (*a*, diagram No. 55.).— In mineral character this rock often corresponds to the yellowish white building-stone of Paris, well known by the name of *Calcaire grossier*, but it often passes into a much more compact stone. In the deep ravine-like valleys of Sortino and Pentalica, it is seen

in nearly horizontal strata, as solid and as regularly bedded as the greater part of our ancient secondary formations. It abounds in natural caverns, which, in many places, as in the valley of Pentalica, have been enlarged by artificial excavations.

No. 55. Syracuse. Girgenti.



No. 56.



Castrogiovanni.

a. Great limestone of Val di Noto.
b. Schistose and arenaceous limestone of Floridia, &c.
c. Blue marl with shells.
d. White laminated marl.
e. Blue clay and gypsum, &c. without shells.

The shells in the limestone are often very indistinct, sometimes nothing but casts remaining; but in many localities, especially where there is a slight intermixture of volcanic sand, they are more entire, and, as I have already stated, can almost all be identified with recent Mediterranean testacea. Several species of the genus Pecten are exceedingly numerous, particularly the large scallop (*P. Jacobæus*), now so common on the coasts of Sicily. The shells which I collected from this limestone at Syracuse, Villasmonde, Militello (V. di Noto), and Girgenti, have been examined by M. Deshayes, and found, with three or four exceptions, to be all referrible to species now living.*

* I procured at Villasmonde, seven species; at Militello, ten; in the limestone of Girgenti, of which the ancient temples are

The mineral characters of this great calcareous formation vary considerably in different parts of the island. In the south, near the town of Noto, the rock puts on the compactness, together with the spheroidal concretionary structure, of some of the Italian travertins. At the same place, also, it contains the leaves of plants and reeds, as if a stream of fresh water, charged with carbonate of lime and terrestrial vegetable remains, had entered the sea in the neighbourhood. At Spaccaforno, and other places in the south of Sicily, a similar compact variety of the limestone occurs, where it is for the most part pure white, often very thick bedded, and occasionally without any lines of stratification. This hard white rock is often four or five hundred feet in thickness, and appears to contain no fossil shells. It has much the appearance of having been precipitated from the waters of mineral springs, such as frequently rise up at the bottom of the sea in the volcanic regions of the Mediterranean. As these springs give out an equal quantity of mineral matter at all seasons, they are much more likely to give rise to unstratified masses, than a river which is swoln and charged with sedimentary matter of different kinds, and in unequal quantities, at particular seasons of the year.

The great limestone, above mentioned, prevails not only in the Val di Noto, but reappears in the centre of the island, capping the hill of Castrogiovanni, at the height of three thousand feet above the

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built, ten species; from the limestone and subjacent clay at Syracuse, twenty-six species; in the limestone and clay near Palermo, also belonging to the newer Pliocene formation, one hundred species, the names of which were published in Appendix II. of the former edition.

level of the sea. It is cavernous there, as at Sortino and Syracuse, and contains fossil shells and casts of shells of the same species.*

Schistose and arenaceous limestone, &c. (*b*, diagram No. 55.). — The limestone above mentioned passes downwards into a white calcareous sand, which has sometimes a tendency to an oolitic and pisolitic structure, analogous to that before described when speaking of the travertin of Tivoli. † At Floridia, near Syracuse, it contains a sufficient number of small calcareous pebbles to constitute a conglomerate, where also beds of sandy limestone are associated, replete with numerous fragments of shells, and much resembling, in structure, the English corn-brash. A diagonal lamination is often observable in the calcareous sandy beds analogous to that represented in the first volume (p. 372. diagram No. 7.), and to that exhibited in many sections of the English crag. ‡

In some parts of Sicily, this sandy calcareous division, *b*, seems to be represented by yellow sand, exactly resembling that so frequently superimposed on the blue shelly marl of the Subapennines in the Italian peninsula. Thus, near Grammichele, on the road to Caltagirone, beds of incoherent yellow sand, several hundred feet in thickness, with occasional layers of shells, repose upon the blue shelly marl of Caltagirone.

When we consider the arenaceous character of this formation, the disposition of the laminæ, and the broken shells sometimes imbedded in it, it is difficult not

* Dr. Daubeny correctly identified the Val di Noto limestone of Syracuse with that of the summit of Castrogiovanni.—Jameson, Ed. Phil. Journ., No. xxv. p. 107. July, 1825.

† Vol. I. p. 308.

‡ See chap. xiii.

to suspect that it was formed in shallower water, and nearer the action of superficial currents, than the superincumbent limestone, which was evidently accumulated in a sea of considerable depth. If we adopt this view, we must suppose a subsidence of the bed of the sea, subsequent to the deposition of the arenaceous beds in the Val di Noto.

Blue marl with shells (*c*, diagrams Nos. 55, 56.).— Under the sandy beds, last mentioned, is found an argillaceous deposit of variable thickness, called *Creta* in Sicily. It resembles the blue marl of the Subapennine hills, and, like it, encloses fossil shells and corals in a beautiful state of preservation. Of these I collected a great abundance from the clay, on the south side of the harbour of Syracuse, and twenty species in the environs of Caltanisetta, all of which, with three exceptions, M. Deshayes was able to identify with recent species. From similar blue marl, alternating with yellow sand, at Caltagirone, at an elevation of about five hundred feet above the level of the sea, I obtained forty species of shells, of which all but six were recognized as identical with recent species.* The position of this argillaceous formation is well seen at Castrogiovanni and Girgenti, as represented in the sections, diagrams Nos. 55, 56. In both of these localities, the limestone of the Val di Noto reappears, passing downwards into a calcareous sandstone, below which is a shelly blue clay.

Strata beneath the blue marl.—The clay rests, in both localities, on an older series of white and blue marls, probably belonging to the tertiary period, but of which I was unable to determine the age, having pro-

* Lists of these shells were given in Appendix II. of the former edition.

cured from it no organic remains save the skeletons of fish which I found in the white thinly laminated marls.*

These marls are sometimes gypseous, and belong to a great argillaceous formation which stretches over a considerable part of Sicily, and contains sulphur and salt in great abundance. The strata of this group have been in some places contorted in the most extraordinary manner, their convolutions often resembling those seen in the most disturbed districts of primary clay slate.

But I wish, at present, to direct the reader's exclusive attention to strata decidedly referrible to the newer Pliocene era, and I have yet to mention the igneous rocks associated with the sedimentary formations already alluded to.

Volcanic Rocks of the Val di Noto.—The volcanic rocks occasionally associated with the limestones, sands, and marls already described, constitute a very prominent feature throughout the Val di Noto. Great confusion might have been expected to prevail, where lava and ejected sand and scoriæ are intermixed with the marine strata, and, accordingly, we find it often impossible to recognize the exact part of the series to which the beds thus interfered with belong.

Sometimes there are proofs of the posterior origin of the lava, and sometimes of the newer date of the stratified rock, for we find dikes of lava intersecting both the marl and limestone, while, in other places,

* I found these fossil fish in great abundance on the road, half a mile north-west of Radusa, on my way to Castrogiovanni, where the marls are fetid, and near Castrogiovanni in gypseous marls, at the mile-stone No. 88., and between that and No. 89.

calcareous beds repose upon lava, and are unaltered at the point of contact. Thus the shelly limestone of Capo Santa Croce rests in horizontal strata upon a mass of lava, which had evidently been long exposed to the action of the waves, so that the surface has been worn perfectly smooth. The limestone is unchanged at its junction with the igneous rock, and incloses within it pebbles of the lava.*

The volcanic formations of the Val di Noto usually consist of the most ordinary variety of basalt with or without olivine. The rock is sometimes compact, often very vesicular. The vesicles are occasionally empty, both in dikes and currents, and are in some localities filled with calcareous spar, arragonite, and zeolites. The structure is, in some places, spheroidal, in others, though rarely, columnar. I found dikes of amygdaloid, wacke, and prismatic basalt, intersecting the limestone at the bottom of the hollow called Gozzo degli Martiri, below Melilli.

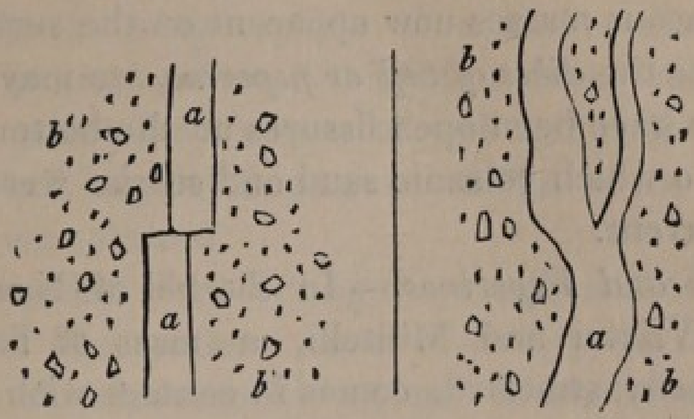
Dikes.—Dikes of vesicular and amygdaloidal lava are also seen traversing peperino, west of Palagonia, near a mill by the road side.

In these cases we may suppose the peperino to have resulted from showers of volcanic sand and scoriæ, together with fragments of limestone thrown out by a submarine explosion, similar to that which lately gave rise to the volcanic island off Sciacca. When the mass was, to a certain degree, consolidated, it may have been rent open, so that the lava ascended through fissures, the walls of which were perfectly even and parallel. After the melted matter that filled the rent in No. 57.

* This locality is described by Professor Hoffmann, Archiv für Mineralogie, &c. Berlin, 1831.

had cooled down, it must have been fractured and shifted horizontally by a lateral movement.

No. 57. No. 58.



Horizontal section of Dikes near Palagonia.

a. Lava.

b. Peperino, consisting of volcanic sand, mixed with fragments of lava and of limestone.

In the second figure, No. 58., the lava has more the appearance of a vein which forced its way through the peperino, availing itself, perhaps, of a slight passage opened by rents caused by earthquakes. Some of the pores of the lava, in these dikes, are empty, while others are filled with carbonate of lime.

The annexed diagrams (Nos. 57. and 58.) represent a ground plan of the rocks as they are exposed to view on a horizontal surface. It is highly probable that similar appearances would be seen, if we could examine the floor of the sea in that part of the Mediterranean where the waves have recently washed away the new volcanic island; for when a superincumbent mass of ejected fragments has been removed by denudation, we may expect to see sections of dikes traversing tuff, or, in other words, sections of the channels of communication by which the subterranean lavas reached the surface. *

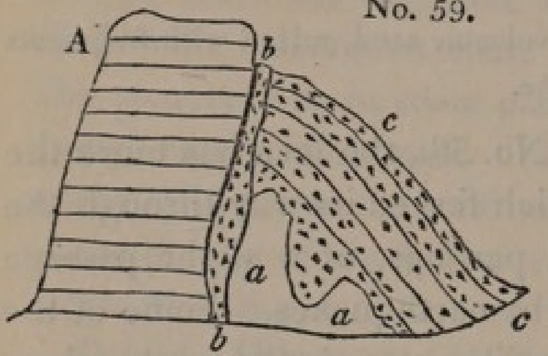
On the summit of the limestone platform of the Val di

* See Vol. II. p. 148.

Noto I more than once saw analogous dikes, not only of lava but of volcanic tuff, rising vertically through the horizontal strata, and having no connection with any igneous masses now apparent on the surface. In regard to the *dikes of tuff or peperino*, we may suppose them to have been open fissures at the bottom of the sea, into which volcanic sand and scoriæ were drifted by a current.

Tuffs and Peperinos.—In the hill of Novera, between Vizzini and Militelli, a mass of limestone, horizontally stratified, comes in contact with inclined strata of tuff (see diagram No. 59.) while a mixed cal-

No. 59.



A. Limestone.
aa. Calcareous breccia with fragments of lava.
b. Black tuff.
c. Tuff.

careous and volcanic breccia, *a a*, supports the inclined layers of tuff, *c*. The vertical fissure, *b b*, is filled with volcanic sand of a different colour. An inspection of this section will convince the reader that the limestone must have been greatly dislocated during the period of the submarine eruptions.

At the town of Vizzini a dike of lava intersects the argillaceous strata, and converts them into siliceous schist, which has been contorted and shivered into an immense number of fragments.

I have stated that the beds of limestone, clay, and sand, in the Val di Noto, are often partially intermixed with volcanic ejections, such as may have been showered down into the sea during eruptions, or may have been swept by rivers from the land. When the volcanic

matter predominates, these compound rocks constitute the peperinos of the Italian mineralogists, some of which are highly calcareous, full of shells, and extremely hard, being capable of a high polish like marble. In some parts of the Val di Noto they are variously mottled with spots of red and yellow, and contain small angular fragments, similar to the lapilli thrown from volcanos.

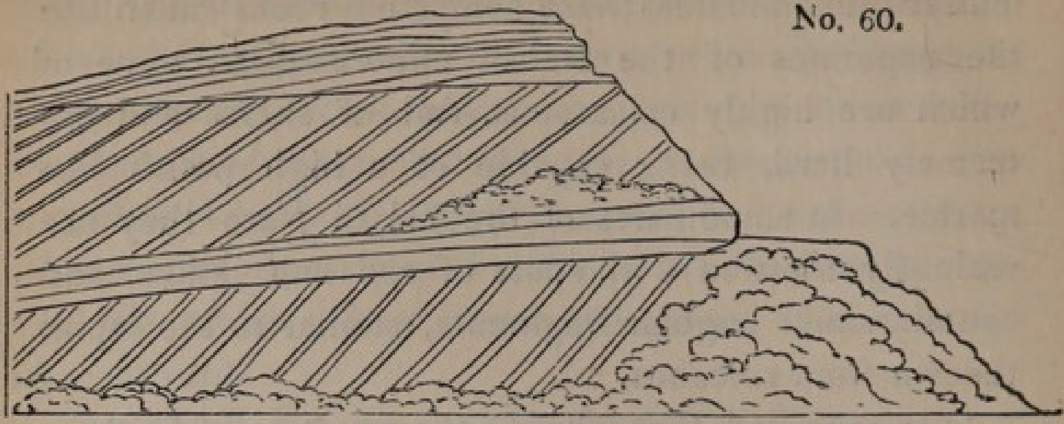
It is recorded that, during the eruption of Graham island * off the southern coast of Sicily, the sea was in a state of violent ebullition, and filled, for several weeks continuously, with red or chocolate-coloured mud, consisting of finely-comminuted scoriæ. During this period, it is clear that the waves and currents that have since had power to sweep away the island, and disperse its materials far and wide over the bed of the sea, must with still greater ease have carried to vast distances the fine red mud, which was seen boiling up from the bottom, so that it may have entered largely into the composition of modern peperinos.

Professor Hoffmann relates that, during the eruption, (June, 1831,) the surface of the sea was strewed over, at the distance of thirty miles from the new volcano, with so dense a covering of scoriæ, that the fishermen were obliged to part it with their oars, in order to propel their boats through the water. It is, therefore, quite consistent with analogy, that we should find the ancient tuffs and peperinos so much more generally distributed than the submarine lavas.

In the road which leads from Palagonia to Lago Naftia, and at the distance of about a mile and a half from the former place, there is a small pass where the hills, on both sides, consist of a calcareous grit, intermixed with some grains of volcanic sand.

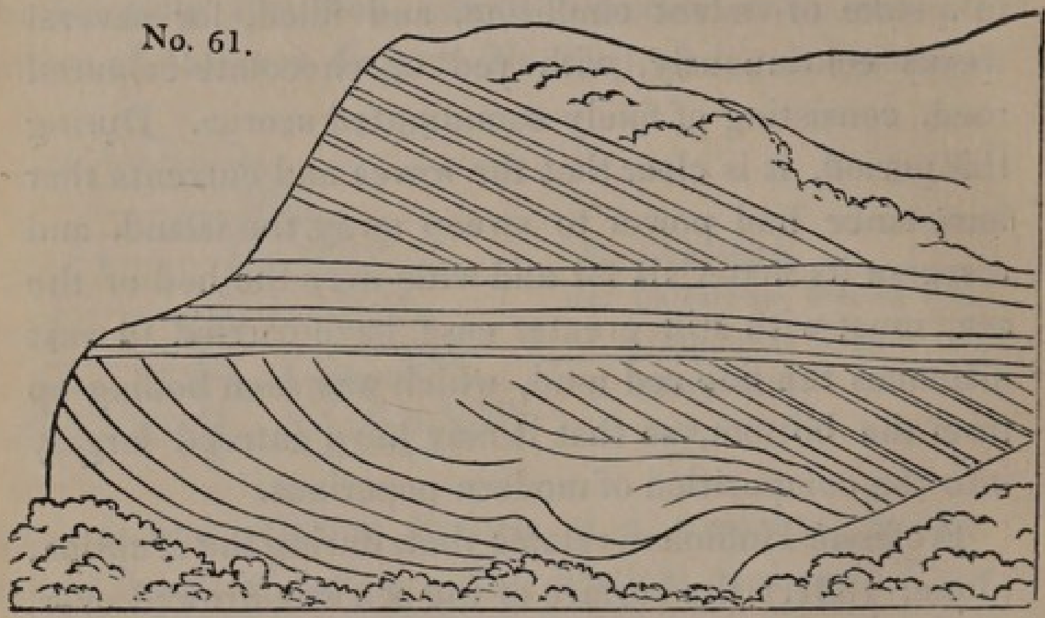
* Vol. II. p. 145.

No. 60.



Section of calcareous grit and peperino, east of Palagonia. South side of pass. Vertical height about thirty feet.

No. 61.



Section of the same beds on the north side of the pass.

The disposition of the strata, on both sides of the pass, is most singular, and remarkably well exposed, as the harder layers have resisted the weathering of the atmosphere and project in relief. The sections exhibited on both sides of the pass are nearly vertical, and do not exactly correspond, as will be seen in the annexed diagrams (Nos. 60. and 61.). It is somewhat difficult to conceive in what manner this arrangement of the layers was occasioned, but we may, perhaps, suppose it to have arisen from the throwing down of calcareous sand and volcanic matter, upon steep slanting banks at the bottom of the sea, in which case they might have ac-

cumulated at various angles of between thirty and fifty degrees, as may be frequently seen in the sections of volcanic cones in Ischia and elsewhere. The denuding power of the waves may, then, have cut off the upper portion of these banks, so that nearly horizontal layers may have been superimposed unconformably, after which another bank may have been formed in a similar manner to the first.

Volcanic conglomerates.—In the Val di Noto we sometimes meet with conglomerates entirely composed of volcanic pebbles. They usually occur in the neighbourhood of masses of lava, and may, perhaps, have been the shingle produced by the wasting cliffs of small islands in a volcanic archipelago. The formation of similar beds of volcanic pebbles may now be seen in progress on the beach north of Catania, where the waves are undermining one of the modern lavas of Etna; and the same may also be seen on the shores of Ischia.

Proofs of gradual accumulation.—In one part of the great limestone formation near Lentini, I found some imbedded volcanic pebbles, covered with full-grown serpulæ, supplying a beautiful proof of a considerable interval of time having elapsed between the rounding of these pebbles and their inclosure in a solid stratum. I also observed, not far from Vizzini, a very striking illustration of the length of the intervals which occasionally separated the distinct lava currents. A bed of oysters, perfectly identifiable with our common eatable species, no less than *twenty feet in thickness*, is there seen resting upon a current of basaltic lava; upon the oyster-bed again is superimposed a second mass of lava, together with tuff or peperino. Near Galieri, not far from the same locality, a horizontal bed, about a foot and a half in thickness, composed

entirely of a common Mediterranean coral (*Caryophyllia cespitosa*, Lam.), is also seen in the midst of the same series of alternating igneous and aqueous formations. These corals stand erect as they grew; and after being traced for hundreds of yards are again found at a corresponding height on the opposite side of the valley.

Dip and direction.—The disturbance which the newer Pliocene strata have undergone in Sicily, subsequent to their deposition, varies greatly in degree in different places; in general, however, they are nearly horizontal, and are not often highly inclined. The calcareous schists, on which part of the town of Lentini is built, are much fractured, and dip at an angle of twenty-five degrees to the north-west. In some of the valleys in the neighbourhood an anticlinal dip is seen, the beds on one side being inclined to the north-west, and on the other to the south-east.

Throughout a considerable part of Sicily which I examined, the dips of the tertiary strata were north-east and south-west; as, for example, in the district included between Terranuova, Girgenti, Caltanisetta, and Piazza, where there are several parallel lines, or ridges of elevation, which run from north-west to south-east. *

* I have reprinted this chapter without additions, and almost without alterations, and nearly as I wrote it soon after my tour in Sicily, in 1828. We may shortly expect a fuller account of the geology of Sicily from Professor Hoffmann of Berlin, who has devoted more than a year to its examination; as also from M. C. Prevost, who has lately explored the island. The last-mentioned geologist is now aware that he was mistaken in supposing that I had ever expressed an opinion, that the hippurite limestone of Cape Passero (which he regards as chalk) was of the age of the tertiary limestone of the Val di Noto. See Bulletin de la Soc. Géol. de France, tom. ii. p. 114.

CHAPTER VII.

NEWER PLIOCENE FORMATIONS — ETNA.

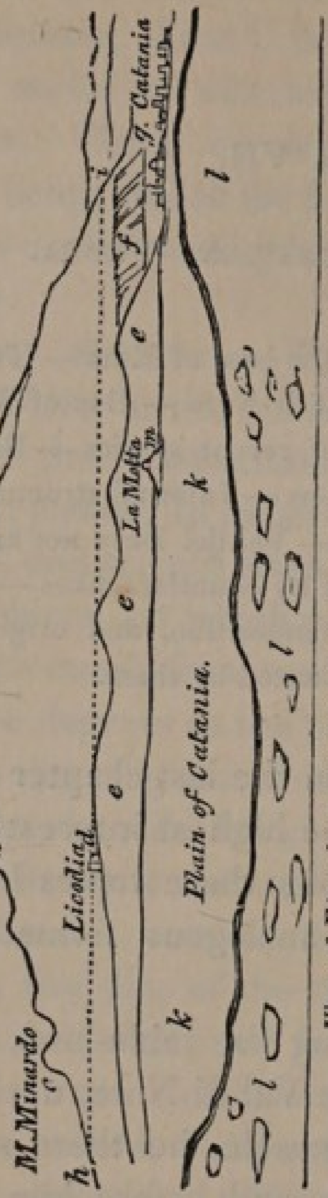
Marine and volcanic formations at the base of Etna — Their connection with the strata of the Val di Noto — Bay of Trezza — Cyclopian isles — Fossil shells of recent species — Basalt and altered rocks in the Isle of Cyclops — Internal structure of the cone of Etna — Val di Calanna — Val del Bove not an ancient crater — its precipices intersected by countless dikes — Scenery of the Val del Bove — Form, composition, and origin of the dikes — Lavas and breccias intersected by them.

The phenomena considered in the last chapter suggest many theoretical views of the highest interest in geology; but before entering upon these topics I am desirous of describing some analogous formations in Valdemone.

If the traveller passes along the table-land, formed by the great limestone of the Val di Noto, until it terminates suddenly near Primosole, he there sees the plain of Catania at his feet, and before him, to the north, the cone of Etna (see diagram No. 62.). At the base of the cone he beholds a low line of hills, *e e* (No. 62.), formed of clays and marls, associated with yellowish sand, similar to the formation provincially termed " Creta," in various parts of Sicily.

This marine formation, which is composed partly of volcanic and partly of sedimentary rocks, is seen to lie below the modern lavas of Etna. To what extent it forms the base of the mountain cannot be observed, for want of sections of the lower part of the cone; but

No. 62.



View of Etna from the summit of the limestone platform of Primosole.

a. Highest cone. *b.* Montagnuola.
c. Monte Minardo, with smaller lateral cones above.
d. Town of Licodia dei Monaci.
e. Marine formation called creta, argillaceous and sandy beds with a few shells, and associated volcanic rocks.
f. Escarpment of stratified subaqueous volcanic tuff, &c., north-west of Catania.
g. Town of Catania.
h. i. Dotted line expressing the highest boundary along which the marine strata are occasionally seen. *k.* Plain of Catania.
l. Limestone platform of Primosole of the newer Pliocene.
m. La Motta di Catania.

the marine sub-Etnean beds are not seen to rise to a greater elevation than eight hundred, or, at the utmost, one thousand, feet above the level of the sea. The annexed drawing is not a section, but an outline view of Etna, as seen from Primosole, so that the proportional height of the volcanic cone, which is, in reality, ten times greater than that of the hills of "Creta," at its base, is not expressed, the summit of the cone being ten or twelve miles more distant from the plain of Catania than Licodia.

Connection of the sub-Etnean strata with those of the Val di Noto.— These marine strata are found both on the southern and eastern foot of Etna, and it is impossible not to infer that they belong to the inferior argillaceous series of the Val di Noto, which they resemble both in mineral and organic characters. In one locality they appear on the opposite sides of the Valley of the Simeto, covered on the north by the lavas of Etna, and on the south by the Val di Noto limestone.

Val di Noto. No. 63. Etna.

Section from Paternò by Lago di Naftìa to Palagonìa.

a. Plain of the Simeto.
b. Base of the cone of Etna, composed of modern lavas.
c. Limestone of the Val di Noto.
d. Clay, sand, and associated submarine volcanic rocks.

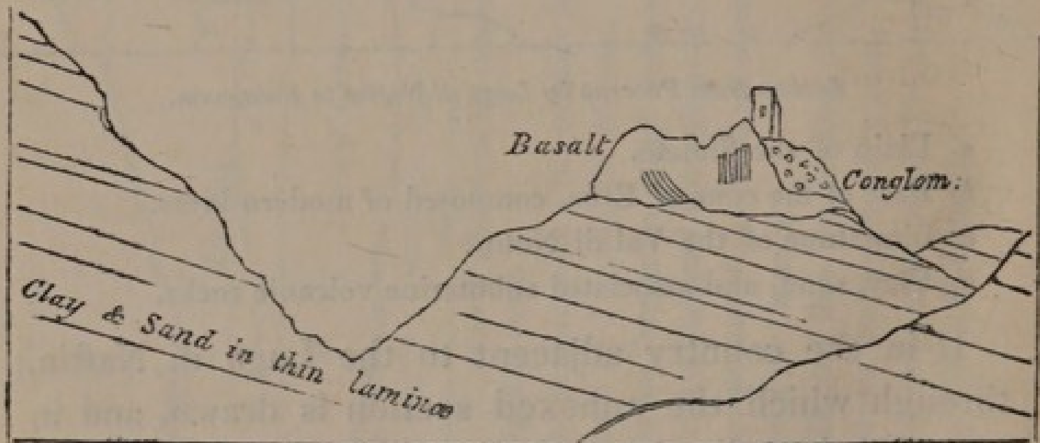
If in the country adjacent to the Lago di Naftia, through which the annexed section is drawn, and in several other districts where the "creta" prevails, together with associated submarine lavas, and where there is no limestone capping, a volcano should now burst forth, and give rise to a great cone, the position of such a cone would exactly correspond to that of the modern Etna, with relation to the rocks on which it rests.

Southern base of Etna. — The marine strata of clay and sand already alluded to, alternate in thin layers at the southern base of Etna, sometimes attaining a thickness of three hundred feet, or more, without any intermixture of volcanic matter. Crystals of selenite

are dispersed through the clay, accompanied by a few shells, almost entirely of recent Mediterranean species. This formation of blue marl and yellow sand greatly resembles in character that of the Italian Subapennine beds, and, like them, often presents a surface denuded of vegetation, in consequence of the action of the rains on soft incoherent materials.

In travelling by Paternò, Misterbianco, and La Motta, we pass through deep narrow valleys excavated through these beds, which are sometimes capped, as at La Motta, by columnar basalt, accompanied by strata of tuff and volcanic conglomerate. (Diagram No. 64.)

No. 64.



La Motta near Catania.

The latter rock is here composed of rolled masses of basalt, which may have originated either when first the lava was produced in a volcanic archipelago, or subsequently when the whole country was rising from beneath the level of the sea. Its occurrence in this situation is striking, as not a single pebble can be observed in the entire thickness of subjacent beds of sand and clay.

The dip of the marine strata, at the base of Etna, is by no means uniform; on the eastern side, for ex-

ample, they are sometimes inclined towards the sea, and at others towards the mountain. Near the aqueduct at Aderno, on the southern side, I observed two sections, in quarries not far distant from each other, where beds of clay and yellow sand dipped, in one locality, at an angle of forty-five degrees to the east-south-east, and in the other at a much higher inclination in the opposite direction. These facts would be of small interest, if these mixed marine and volcanic deposits, which encircle part of the base of Etna, had not been considered by a geologist of high authority as the outer margin of an erhebungs crater.*

Near Catania the marine formation, consisting chiefly of volcanic tuff thinly laminated, terminates in a steep inland cliff, or escarpment, which is from six hundred to eight hundred feet in height. A low flat, composed of recent lava and volcanic sand, intervenes between the sea and the base of this escarpment, which may be well seen at Fasano. (*f*, diagram. No. 62.)

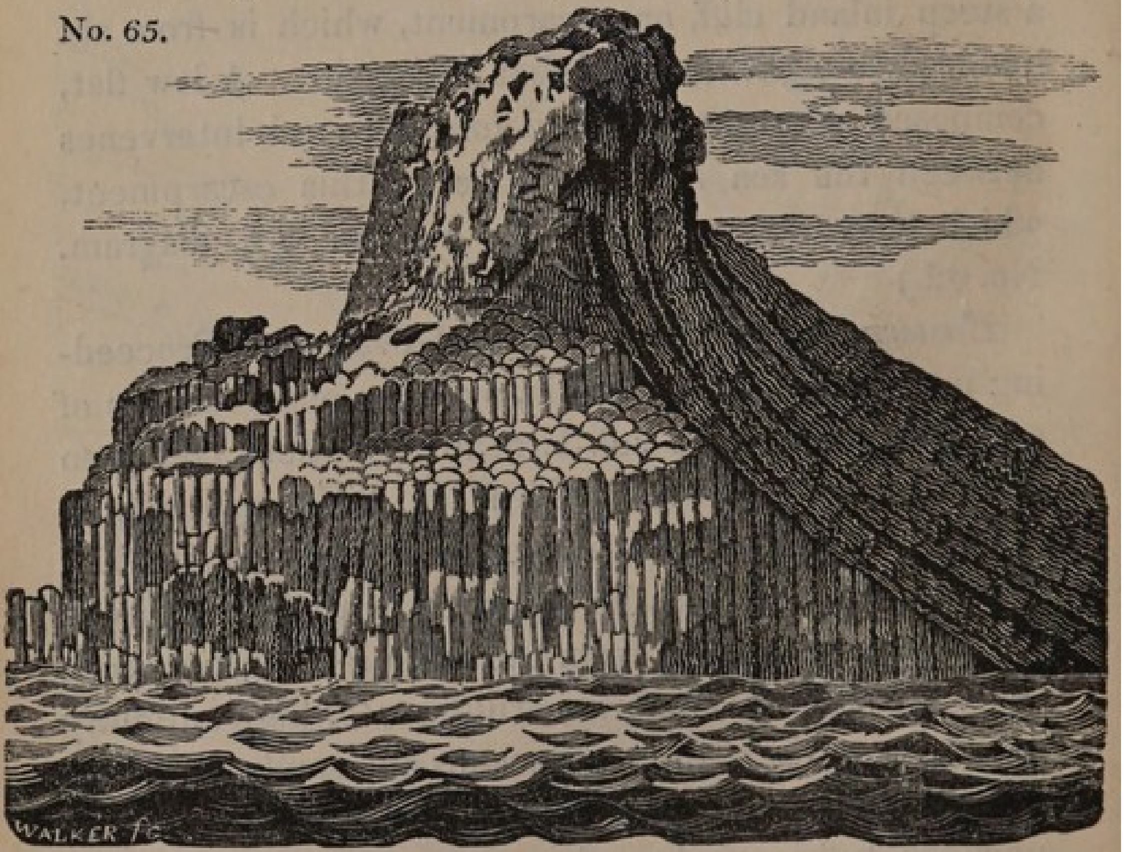
Eastern side of Etna — Bay of Trezza. — Proceeding northwards from Catania, we have opportunities of examining the same sub-Etnean formations laid open more distinctly in the modern sea cliffs, especially in the Bay of Trezza and in the Cyclopian islands (Dei Faraglioni), which may be regarded as the extremity of a promontory severed from the main land. Numerous are the proofs of submarine eruptions of high antiquity in this spot, where the argillaceous and sandy beds have been invaded and intersected by lava, and where those peculiar tufaceous breccias occur which result from ejections of fragmentary matter, projected from a volcanic vent. I observed many angular and hardened fragments of laminated clay (creta), in different

* See Vol. II. p. 160.

states of alteration, between La Trezza and Nizzitta, and in the hills above Aci Castello, a town on the main land contiguous to the Cyclopian isles, which could not be mistaken by one familiar with Somma and the minor cones of Ischia, for any thing but masses thrown out by volcanic explosions. From the tuffs and marls of this district I collected a great variety of marine shells *, almost all of which have been identified with species now inhabiting the Mediterranean, and, for the most part, now frequent on the coast immediately adjacent. Some few of these fossil shells retain part of their colour, which is the same as in their living analogues.

The largest of the Cyclopian islets, or rather rocks,

No. 65.



View of the Isle of Cyclops in the Bay of Trezza.

* A list of sixty-five species of shells, named by M. Deshayes, which I procured from the hills called Monte Cavalaccio, Rocca di Ferro, and Rocca di Bempolere (or Borgia), was published in App. II. of 1st edit.

is distant two hundred yards from the land, and is only three hundred yards in circumference, and about two hundred feet in height. The summit and northern sides are formed of a mass of stratified marl (creta), the laminæ of which are occasionally subdivided by thin arenaceous layers. These strata rest on a mass of columnar lava (see wood-cut, No. 65.) *, which appears to have forced itself into, and to have heaved up, the stratified mass. This theory of the intrusion of the basalt is confirmed by the fact,

No. 66.

Contortions in the newer Pliocene strata, Isle of Cyclops.

* This view of the Isle of Cyclops is from an original drawing by my friend Capt. W. H. Smyth, R.N.

that in some places the clay has been greatly altered, and hardened by the action of heat, and occasionally contorted in the most extraordinary manner, the lamination not having been obliterated, but, on the contrary, rendered much more conspicuous, by the indurating process.

The annexed wood-cut (No. 66.) is a careful representation of a portion of the altered rock, a few feet square, where the alternate thin laminæ of sand and clay have put on the appearance which we often observe in some of the most contorted of the primary schists.

A great fissure, running from east to west, nearly divides the island into two parts, and lays open its internal structure. In the section thus exhibited, a dike of lava is seen, first cutting through an older mass of lava, and then penetrating the superincumbent tertiary

No. 67.

Newer Pliocene strata invaded by lava, Isle of Cyclops (horizontal section).

a. Lava. *b.* Laminated clay and sand. *c.* The same altered.

strata. In one place, the lava ramifies and terminates in thin veins, from a few feet to a few inches in thickness (see diagram No. 67.).

The arenaceous laminæ are much hardened at the point of contact, and the clays are converted into siliceous schist. In this island the altered rocks assume a honeycombed structure on their weathered surface, singularly contrasted with the smooth and even outline which the same beds present in their usual soft and yielding state.

The pores of the lava are sometimes coated, or entirely filled, with carbonate of lime, and with a zeolite resembling analcime, which has been called cyclopite. The latter mineral has also been found in small fissures traversing the altered marl, showing that the same cause which introduced the minerals into the cavities of the lava, whether we suppose sublimation or aqueous infiltration, conveyed it also into the open rents of the contiguous sedimentary strata.

Lavas of the Cyclopian Isles not currents from Etna. —The phenomena of the Bay of Trezza are very important, for it is evident that the submarine lavas were produced by eruptions on the spot, an inference which follows not only from the presence of dikes and veins, but from those tuffs above Castello d'Aci, which contain angular fragments of hardened marl, evidently thrown up, together with the sand and scoriæ, by volcanic explosions. We may, therefore, suppose this volcanic action to have been as independent of the modern vents of Etna, as that which gave rise to the analogous formations in the Val di Noto. It is quite evident that the lavas of the Cyclopian isles are not the lower extremities of currents which flowed down from the highest crater of Etna, or from the region

where lateral eruptions are now frequent, — lavas which, after entering the sea, were afterwards upraised into their present position. It is more probable that the basalts of the Bay of Trezza, and those along the southern foot of Etna, at La Motta, Adernò, Paternò, Licodia, and other places, originated in the same sea in which the eruptions of the Val di Noto took place.

There are, however, no sections to prove that the central and oldest parts of Etna repose on similar submarine formations. The modern lavas of the volcano are continually extending their area, and covering, from time to time, a larger portion of the marine strata; but we know not where this operation commenced, so that we cannot demonstrate the posteriority of the whole cone to these newer Pliocene strata.

We might imagine that when the volcanos of the Val di Noto were in activity, and when the eruptions of the Bay of Trezza were taking place, Etna already existed as a volcano, the upper part only of the cone projecting above the level of the waters, as in the case of Stromboli at present. By such an hypothesis, we might refer the origin of the older part of Etna to the same period as that of the sedimentary strata and volcanic rocks of the Val di Noto.

But there are no obvious grounds for inclining to such a theory, for we must admit that a sufficient series of ages has elapsed since the limestone of the Val di Noto was deposited, to allow it to be elevated to the height of from two thousand to three thousand feet, in which case there may also have been sufficient time for the growth of a volcanic pile like Etna, since the period when the newer Pliocene strata now seen at the base of the volcano originated.

Internal Structure of the Cone of Etna.

In the second book I merely described that part of Etna which is known to have been formed during the historical era*; an insignificant portion of the whole mass. Nearly all the remainder may be referred to the tertiary period immediately antecedent to the *recent* epoch. The great cone is, in general, of a very symmetrical form, but is broken, on its eastern side, by a deep valley, called the Val del Bove†, which, com-

* Vol. II. p. 111.

† In the provincial dialect of the peasants called "Val del Bué," for here the herdsman

——— "in reductâ valle *mugientium*
Prospectat errantes greges."

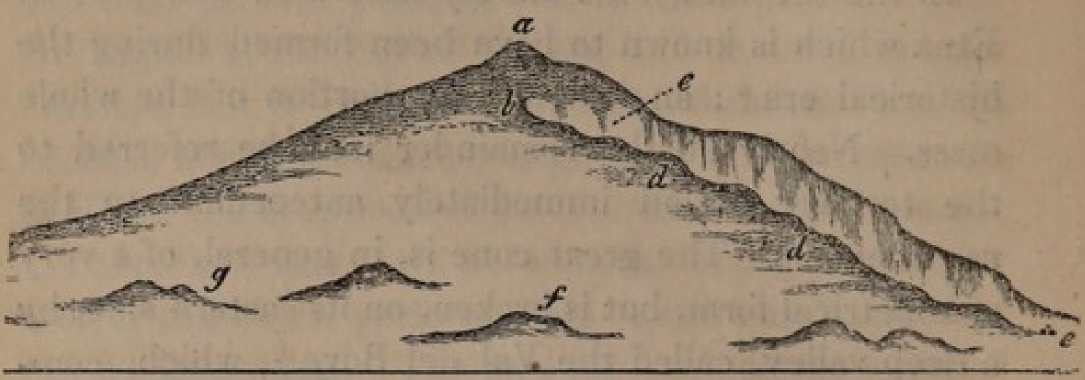
Dr. Buckland was, I believe, the first English geologist who examined this valley with attention, and I am indebted to him for having described it to me, before my visit to Sicily, as more worthy of attention than any single spot in that island, or perhaps in Europe. In the accompanying view of the valley I have introduced two colours, the grey to express that part of the mountain which may have been formed before the origin of the "Val del Bove," the red to indicate the part which has resulted from eruptions subsequent to the formation of the valley. The great lava-currents of 1819 and 1811, are seen pouring down from the higher parts of the valley, over-running the forests of the great plain, and rising up in the foreground on the left with a rugged surface, on which small hillocks and depressions are seen, such as often characterize a lava-current immediately after its consolidation.

The small cone, No. 7., was formed in 1811, and was still smoking when I saw it in 1828. Immediately in front of it is seen another cone, formed during the same eruption. The other small volcano to the left, from which vapour is issuing, was formed, I believe, in 1819.

This sketch, which forms part of a panoramic drawing which I made in November, 1828, is merely intended to assist the reader

mencing near the summit of the mountain, descends into the woody region, and is then continued, on one

No. 68.



Great Valley on the east side of Etna.

a. Highest cone.
b. Montagnuola.
c. Head of Val del Bove.
d, d. Serre del Solfizio.
e. Zaffarana.
f. One of the lateral cones.
g. Monti Rossi.

side, by a second and narrower valley, called the Va di Calanna. Below the latter another, named the Va di St. Giacomo, begins,—a long narrow ravine, which is prolonged to the neighbourhood of Zaffarana (*e*, No. 68.), on the confines of the fertile region. These natural incisions, into the side of the volcano, are of such depth that they expose to view a great part of the structure of the entire mass, which, in the Val del Bove, is laid open to the depth of from four thousand to five thousand feet from the summit of Etna. The geologist thus enjoys an opportunity of ascertaining how far the internal conformation of the cone corresponds with what he might have anticipated as the

in comprehending geological details, but will give no idea of the picturesque grandeur of the scene. Nor is the view sufficiently extensive to exhibit the entire form of the vast amphitheatre, part only of the northern, and scarcely any of the southern, boundary of which is included.

result of that mode of increase which has been witnessed during the historical era.

It is clear, from what was before said of the gradual manner in which the principal cone increases, partly by streams of lava and showers of volcanic ashes ejected from the summit, partly by the throwing up of minor hills and the issuing of lava-currents on the flanks of the mountain, that the whole cone must consist of a series of cones enveloping others, the regularity of each being only interrupted by the interference of the lateral volcanos.

We might, therefore, have anticipated that a section of Etna, as exposed in a ravine which should begin near the summit and extend nearly to the sea, would correspond very closely to the section of the ancient Vesuvius, commencing with the escarpment of Somma, and ending with the Fossa Grande; but with this difference, that where the ravine intersects the woody region of Etna, indications must appear of changes brought about by lateral eruptions. Now the section, which can be traced from the head of the Val del Bove to the inferior borders of the woody region, fully answers such expectations. We find, almost every where, a series of layers of tuff and breccia interstratified with lavas, which slope gently to the sea, at an angle of from twenty to thirty degrees; and as we rise to the parallel of the zone of lateral eruptions, and still more as we approach the summit, we discover indications of disturbances, occasioned by the passage of lava from below, and the successive inhumation of lateral cones.

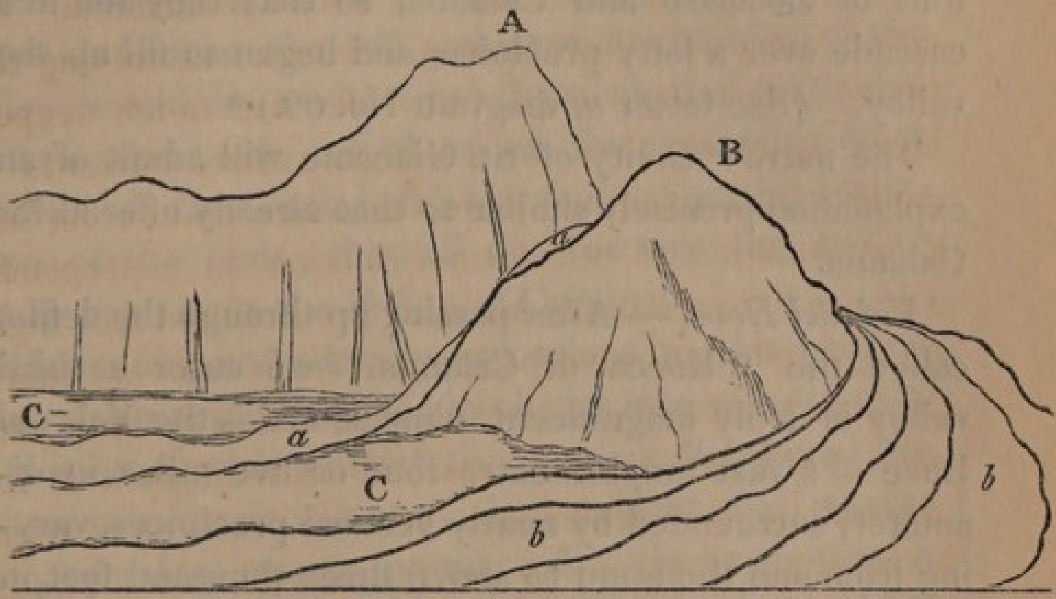
Val di Calanna.—On leaving Zaffarana, on the borders of the fertile region, we enter the ravine-like valley of St. Giacomo, and see on the north side, or on

our right as we ascend, rising ground composed of the modern lavas of Etna. On our left, a lofty cliff, wherein a regular series of beds is exhibited, composed of tuffs and lavas, descending with a gentle inclination towards the sea. In this lower part of the section there are no intersecting dikes, nor any signs of minor cones interfering with the regular slope of the alternating volcanic products. If we then pass upwards through a defile, called the "Portello di Calanna," we enter a second valley, that of Calanna, resembling the ravine before mentioned, but wider and much deeper. Here again we find, on our right, many currents of modern lava, piled one upon the other, and on our left a continuation of our former section, in a perpendicular cliff from four hundred to five hundred feet high. As this lofty wall sweeps in a curve, it has very much the appearance of the escarpment which Somma presents towards Vesuvius, and this resemblance is increased by the occurrence of two or three vertical dikes which traverse the gently-inclined volcanic beds. When I first beheld this precipice, I fancied that I had entered a lateral crater, but was soon undeceived, by discovering that on all sides, both at the head of the valley, in the hill of Zocolaro, and at its side and lower extremity, the dip of the beds was always in the same direction, all slanting to the east, or towards the sea, instead of sloping to the north, east, and south, as would have been the case had they constituted three walls of an ancient crater.

It is not difficult to explain how the valleys of St. Giacomo and Calanna originated, when once the line of lofty precipices on the north side of them had been formed. Many lava currents flowing down successively from the higher regions of Etna, along the foot of a

great escarpment of volcanic rock, have at length been turned by a promontory at the head of the valley of Calanna, which runs out at right angles to the great line of precipices. This promontory consists of the hills called Zocolaro and Calanna, and of a ridge of inferior height which connects them. (See diagram No. 69.)

No. 69.



A. Zocolaro. B. Monte di Calanna.
C. Plain at the head of the Valley of Calanna.
a. Lava of 1819 descending the precipice and flowing through the valley.
b. Lavas of 1811 and 1819 flowing round the hill of Calanna.

The flows of melted matter have been deflected from their course by this projecting mass, just as a tidal current, after setting against a line of sea cliffs. is often thrown off into a new direction by some rocky headland.

Lava streams, it is well known, become solid externally, even while yet in motion, and their sides may be compared to two rocky walls, which are sometimes inclined at an angle of forty-five degrees. When such

streams descend a considerable slope at the base of a line of precipices, and are turned from their course by a projecting rock, they move right onwards in a new direction, so as to leave a considerable space (as in the Valley of Calanna) between them and the cliffs which may be continuous below the point of deflection.

It happened in 1811 and 1819, that the flows of lava overtopped the ridge intervening between the hills of Zocolaro and Calanna, so that they fell in a cascade over a lofty precipice, and began to fill up the valley. (See letter *a*, diagram No. 69.) *

The narrow cavity of St. Giacomo will admit of an explanation precisely similar to that already offered for Calanna.

Val del Bove. — After passing up through the defile, called the " Rocca di Calanna," we enter a third valley of truly magnificent dimensions — the Val del Bove — a vast amphitheatre four or five miles in diameter, surrounded by nearly vertical precipices, varying from one thousand to above three thousand feet in height, the loftiest being at the upper end, and the height gradually diminishing on both sides. The feature which first strikes the geologist as distinguishing this valley from those before mentioned, is the prodigious multitudes of vertical dikes, which are seen in all directions traversing the volcanic beds. The circular form of this great chasm, and the occurrence of these countless dikes, amounting perhaps to several thousands in number, so forcibly recalled to my mind the phenomena of the Atrio del Cavallo, on Vesuvius, that I imagined once more that I had entered a vast crater, on a scale as far exceeding that of Somma, as Etna surpasses Vesuvius in magnitude.

* This is the cascade mentioned above, Vol. II. p. 121.

But having already been deceived in regard to the crescent-shaped precipice of the valley of Calanna, I began attentively to explore the different sides of the great amphitheatre, in order to satisfy myself whether the semicircular wall of the Val del Bove had ever formed the boundary of a crater, and whether the beds had the same quâquâ-versal dip which is so beautifully exhibited in the escarpment of Somma. If the supposed analogy between Somma and the Val del Bove should hold true, the tuffs and lavas, at the head of the valley, would dip to the west, those on the north side towards the north, and those on the southern side to the south. But such I did not find to be the inclination of the beds; they all dip towards the sea, or nearly east, as in the Valley of Calanna.

There are undoubtedly exceptions to this general rule, which might deceive a geologist who was strongly prepossessed with a belief that he had discovered the hollow of an ancient crater. It is evident that, where-ever lateral cones are intersected in the precipices, a series of tuffs and lavas, very similar to those which enter into the structure of the great cone, will be seen dipping at a much more rapid angle.

The lavas and tuffs, which have conformed to the sides of Etna, dip at angles of from fifteen to twenty-five degrees, while the slope of the lateral cones is from thirty-five to fifty degrees. Now, wherever we meet with sections of these buried cones in the precipices bordering the Val del Bove, (and they are frequent in the cliffs called the Serre del Solfizio, and in those near the head of the valley not far from the rock of Musare,) we find the beds dipping at high angles and inclined in various directions.

Scenery of the Val del Bove. — Without entering at present into any further discussions respecting the origin of the Val del Bove, I shall proceed to describe some of its most remarkable features. Let the reader picture to himself a large amphitheatre, five miles in diameter, and surrounded on three sides by precipices from two thousand to three thousand feet in height. If he has beheld that most picturesque scene in the chain of the Pyrenees, the celebrated " cirque of Gavarnie," he may form some conception of the magnificent circle of precipitous rocks which inclose, on three sides, the great plain of the Val del Bove. This plain has been deluged by repeated streams of lava, and although it appears almost level when viewed from a distance, it is, in fact, more uneven than the surface of the most tempestuous sea. Besides the minor irregularities of the lava. the valley is in one part interrupted by a ridge of rocks, two of which, Musara and Capra, are very prominent. It can hardly be said that they

——— " like giants stand
To sentinel enchanted land;"

for although, like the Trosachs in the Highlands of Scotland, they are of gigantic dimensions, and appear almost isolated as seen from many points, yet the stern and severe grandeur of the scenery which they adorn is not such as would be selected by a poet for a vale of enchantment. The character of the scene would accord far better with Milton's picture of the infernal world; and if we imagine ourselves to behold in motion, in the darkness of the night, one of those fiery currents, which have so often traversed the great valley, we may well recall

——— " yon dreary plain, forlorn and wild,
The seat of desolation, void of light

> Save what the glimmering of these livid flames
> Cast pale and dreadful."

The face of the precipices already mentioned is broken in the most picturesque manner by the vertical walls of lava which traverse them. These masses usually stand out in relief, are exceedingly diversified in form, and of immense altitude. In the autumn, their black outline may often be seen relieved by clouds of fleecy vapour which settle behind them, and do not disperse until mid-day, continuing to fill the valley while the sun is shining on every other part of Sicily, and on the higher regions of Etna.

As soon as the vapours begin to rise, the changes of scene are varied in the highest degree, different rocks being unveiled and hidden by turns, and the summit of Etna often breaking through the clouds for a moment with its dazzling snows, and being then as suddenly withdrawn from the view.

An unusual silence prevails; for there are no torrents dashing from the rocks, nor any movement of running water in this valley, such as may almost invariably be heard in mountainous regions. Every drop of water that falls from the heavens, or flows from the melting ice and snow, is instantly absorbed by the porous lava; and such is the dearth of springs, that the herdsman is compelled to supply his flocks, during the hot season, from stores of snow laid up in hollows of the mountain during winter.

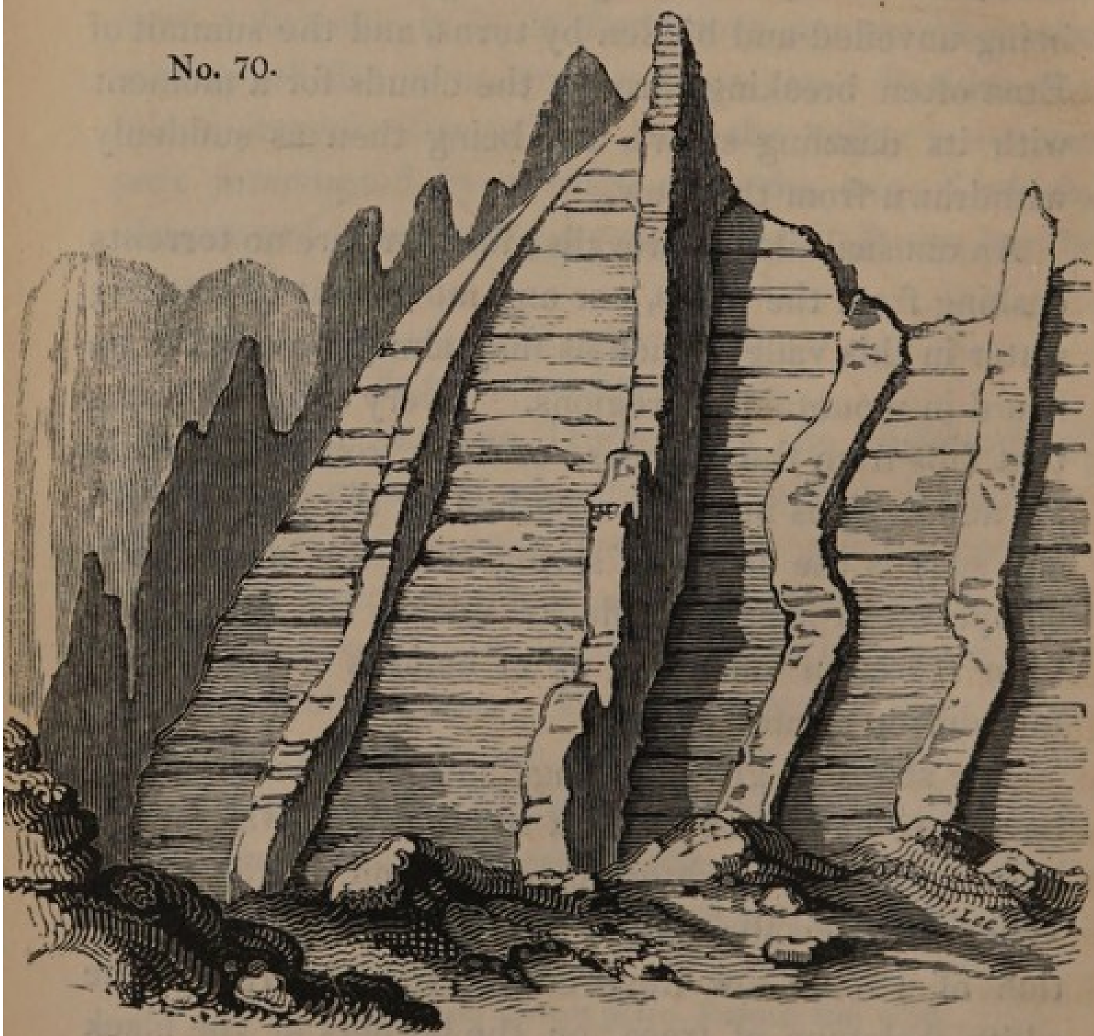
The strips of green herbage and forest land, which have here and there escaped the burning lavas, serve, by contrast, to heighten the desolation of the scene. When I visited the valley, nine years after the eruption of 1819, I saw hundreds of trees, or rather the white skeletons of trees, on the borders of the black

lava, the trunks and branches being all leafless, and deprived of their bark by the scorching heat emitted from the melted rock; an image recalling those beautiful lines:—

——— "As when heaven's fire
Hath scath'd the forest oaks, or mountain pines,
With singed top their stately growth, though bare,
Stands on the blasted heath."

Form, composition, and origin of the Dikes. — But without indulging the imagination any longer in descriptions of scenery, I may observe, that the dikes before mentioned form unquestionably the most interesting geological phenomenon in the Val de Bove.

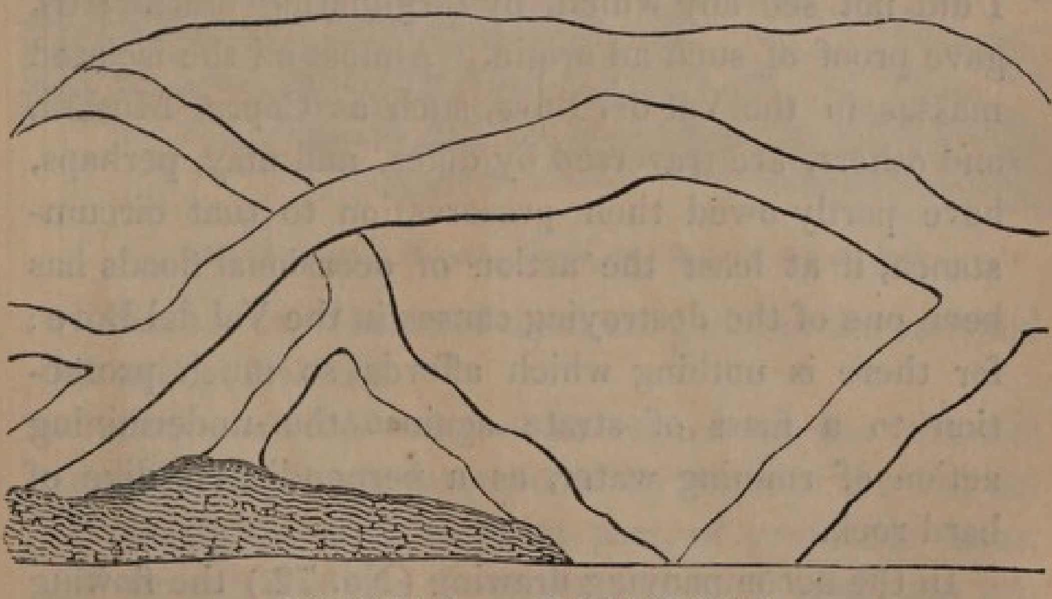
No. 70.



Dikes at the base of the Serre de Solfizio, Etna.

Some of these are composed of trachyte, others of compact blue basalt with olivine. They vary in breadth from two to twenty feet and upwards, and usually project from the face of the cliffs, as represented in the annexed drawing (No. 70.). They consist of harder materials than the strata which they traverse, and therefore waste away less rapidly under the influence of that repeated congelation and thawing to which the rocks in this zone of Etna are exposed. The dikes are, for the most part, vertical, but sometimes they run in a tortuous course through the tuffs and breccias, as represented in diagram, No. 71. In the

No. 71.



Veins of Lava. Punto di Guimento.

escarpment of Somma, where similar walls of lava cut through alternating beds of sand and scoriæ, a coating of coal-black rock, approaching in its nature and appearance to pitch-stone, is seen at the contact of the dike with the intersected beds. I did not observe such parting layers at the junction of the Etnean dikes which I examined, but they may perhaps be discoverable.

The geographical position of these dikes is most interesting, as they occur in that zone of the mountain where lateral eruptions are frequent; whereas, in the valley of Calanna, which is below that parallel, and in a region where lateral eruptions are extremely rare, scarcely any dikes are seen, and none whatever still lower in the valley of St. Giacomo. This is precisely what we might have expected, if we consider the vertical fissures now filled with rock to have been the feeders of lateral cones, or, in other words, the channels which gave passage to the lava currents and scoriæ that have issued from vents in the forest zone.

Some fissures may have been filled from above, but I did not see any which, by terminating downwards, gave proof of such an origin. Almost all the isolated masses in the Val del Bove, such as Capra, Musara, and others, are traversed by dikes, and may, perhaps, have partly owed their preservation to that circumstance, if at least the action of occasional floods has been one of the destroying causes in the Val del Bove; for there is nothing which affords so much protection to a mass of strata against the undermining action of running water, as a perpendicular dike of hard rock.

In the accompanying drawing (No. 72.) the flowing of the lavas of 1811 and 1819, between the rocks Finochio, Capra, and Musara, is represented. The height of the two last-mentioned isolated masses has been much diminished by the elevation of their base, caused by these currents. They may, perhaps, be the remnants of cones, which existed before the Val del Bove was formed, and may hereafter be once more buried by the lavas that are now accumulating in the valley.

From no point of view are the dikes more conspicuous than from the summit of the highest cone of

No. 72.

View of the rocks Finochio, Capra, and Musara, Val del Bove.

Etna; a view of some of them are given in the annexed drawing (No. 73.).

Lavas and breccias.—In regard to the volcanic masses which are intersected by dikes in the Val del Bove, they consist, in great part, of greystone lavas, of an intermediate character between basalt and trachyte, and partly of the trachytic varieties of lava. Beds of scoriæ and sand, also, are very numerous, alternating with breccias formed of angular blocks of igneous rock. It is possible that some of the breccias may be referred to aqueous causes, as we have before seen that great floods do occasionally sweep down the flanks of Etna when eruptions take place in winter, and when the snows are melted by lava.

Many of the angular fragments may have been

No. 73.

View from the summit of Etna into the Val del Bove.

The small cone and crater immediately below were among those formed during the eruptions of 1810 *and* 1811. *

* This drawing is part of a panoramic sketch which I made from the summit of the cone, December 1. 1828, when every part of Etna was free from clouds except the Val del Bove.

thrown out by volcanic explosions, which, falling on the hardened surface of moving lava currents, may have been carried to a considerable distance. It may also happen, that when lava advances very slowly, in the manner of the flow of 1819, described in the second volume *, the angular masses resulting from the frequent breaking of the mass, as it rolls over upon itself, may produce these breccias. It is at least certain, that the upper portion of the lava currents of 1811 and 1819 now consist of angular masses to the depth of many yards.

D'Aubuisson has compared the surface of one of the ancient lavas of Auvergne to that of a river suddenly frozen over by the stoppage of immense fragments of drift-ice, a description perfectly applicable to these modern Etnean flows.

* P. 121.

CHAPTER VIII.

NEWER PLIOCENE FORMATIONS — ETNA, *continued*.

Speculations on the origin of the Val del Bove on Etna — Subsidences — Antiquity of the cone of Etna — Mode of computing the age of volcanos — Their growth analogous to that of exogenous trees — Period required for the production of the lateral cones of Etna — Whether signs of Diluvial Waves are observable on Etna.

Origin of the Val del Bove.

Before concluding my observations on the cone of Etna, the structure of which has been considered in the last chapter, I desire to call the reader's attention to several questions: — first, in regard to the probable origin of the great valley already described; secondly, whether any estimate can be made of the length of the period required for the accumulation of the great cone; and, thirdly, whether there are any signs on the surface of the older parts of the mountain, of those devastating waves which, according to the theories of some geologists, have swept again and again over our continents.

Origin of the Val del Bove. — I explained in the last chapter my reasons for not assenting to the opinion, that the great cavity on the eastern side of Etna was the hollow of a vast crater, from which the volcanic masses of the surrounding walls were produced. On the other hand, it seems impossible to ascribe the valley to the action of running water alone; for if it had been excavated exclusively by that power, its

depth would have increased in the descent; whereas, on the contrary, the precipices are most lofty at the upper extremity, and diminish gradually on approaching the lower region of the volcano.

The structure of the surrounding walls is such as we should expect to see exhibited on any other side of Etna, if a cavity of equal depth should be caused, whether by subsidence, or by the blowing up of part of the flanks of the volcano, or by either of these causes co-operating with the removing action of running water.

It is recorded, as was stated in the history of earthquakes *, that in the year 1772 a great subsidence took place on Papandayang, the largest volcano in the island of Java, an extent of ground, *fifteen miles in length and six in breadth*, covered by no less than forty villages, was engulphed, and the cone lost four thousand feet of its height.

Now we might imagine a similar event, or a series of subsidences to have formerly occurred on the eastern side of Etna, although such catastrophes have not been witnessed in modern times, or only on a very trifling scale. A narrow ravine, about a mile long, twenty feet wide, and from twenty to thirty-six in depth, has been formed, within the historical era, on the flanks of the volcano, near the town of Mascalucia; and a small circular tract, called the Cisterna, near the summit, sank down in the year 1792, to the depth of about forty feet, and left on all sides of the chasm a vertical section of the beds, exactly resembling those which are seen in the precipices of the Val del Bove. At some remote periods, therefore,

* Vol. II. p. 236.

we might suppose more extensive portions of the mountain to have fallen in during great earthquakes.

But some geologists will, perhaps, incline to the opinion, that the removed mass was blown up by paroxysmal explosions, such as that which, in the year 79, destroyed the ancient cone of Vesuvius, and gave rise to the escarpment of Somma. The Val del Bove, it will be remembered, lies within the zone of lateral eruptions, so that a repetition of volcanic explosions might have taken place, after which the action of running water may have contributed powerfully to degrade the rocks, and to transport the materials to the sea. I have before alluded to the effects of a violent flood, which swept through the Val del Bove in the year 1755, when a fiery torrent of lava had suddenly overflowed a great depth of snow in winter.*

In the present imperfect state of our knowledge of the history of volcanos, we have some difficulty in deciding on the relative probability of these hypotheses; but if we embrace the theory of explosions from below, the cavity would still by no means accord with the theory of the so-called "elevation craters."

Antiquity of the Cone of Etna.

It was before remarked, that confined notions in regard to the quantity of past time have tended, more than any other prepossessions, to retard the progress of sound theoretical views in Geology †; the inadequacy of our conceptions of the earth's antiquity having cramped the freedom of our speculations in this science, very much in the same way as a belief in the existence of a vaulted firmament once retarded the

* Vol. II. p. 122. † Vol. I. p. 110.

progress of astronomy. It was not until Descartes assumed the indefinite extent of the celestial spaces, and removed the supposed boundaries of the universe, that just opinions began to be entertained of the relative distances of the heavenly bodies; and until we habituate ourselves to contemplate the possibility of an indefinite lapse of ages having been comprised within each of the more modern periods of the earth's history, we shall be in danger of forming most erroneous and partial views in Geology.

Mode of computing the age of volcanos. — If history had bequeathed to us a faithful record of the eruptions of Etna, and a hundred other of the principal active volcanos of the globe, during the last three thousand years, — if we had an exact account of the volume of lava and matter ejected during that period, and the times of their production, — we might, perhaps, be able to form a correct estimate of the average rate of the growth of a volcanic cone. For we might obtain a mean result from the comparison of the eruptions of so great a number of vents, however irregular might be the development of the igneous action in any one of them, if contemplated singly during a brief period.

It would be necessary to balance protracted periods of inaction against the occasional outburst of paroxysmal explosions. Sometimes we should have evidence of a repose of seventeen centuries, like that which was interposed in Ischia, between the end of the fourth century, B. C., and the beginning of the fourteenth century of our era.* Occasionally a tremendous eruption, like that of Jorullo, would be re-

* See Vol. II. p. 71.

corded, giving rise, at once, to a considerable mountain.

If we desire to approximate to the age of a cone such as Etna, we ought first to obtain some data in regard to the thickness of matter which has been added during the historical era, and then endeavour to estimate the time required for the accumulation of such alternating lavas and beds of sand and scoriæ as are superimposed upon each other in the Val del Bove; afterwards we should try to deduce, from observations on other volcanos, the more or less rapid increase of burning mountains in all the different stages of their growth.

Mode of increase of volcanos analogous to that of exogenous trees. — There is a considerable analogy between the mode of increase of a volcanic cone and that of trees of *exogenous* growth. These trees augment, both in height and diameter, by the successive application externally of cone upon cone of new ligneous matter, so that if we make a transverse section near the base of the trunk, we intersect a much greater number of layers than nearer to the summit. When branches occasionally shoot out from the trunk they first pierce the bark, and then, after growing to a certain size, if they chance to be broken off, they may become inclosed in the body of the tree, as it augments in size, forming knots in the wood, which are themselves composed of layers of ligneous matter, cone within cone.

In like manner, a volcanic mountain, as we have seen, consists of a succession of conical masses enveloping others, while lateral cones, having a similar internal structure, often project, in the first instance, like branches from the surface of the main cone, and

then becoming buried again, are hidden like the knots of a tree.

We can ascertain the áge of an oak or pine, by counting the number of concentric rings of annual growth, seen in a transverse section near the base, so that we may know the date at which the seedling began to vegetate. The Baobab-tree of Senegal (*Adansonia digitata*) is supposed to exceed almost any other in longevity; Adanson inferred that one which he measured, and found to be thirty feet in diameter, had attained the age of 5150 years. Having made an incision to a certain depth, he first counted three hundred rings of annual growth, and observed what thickness the tree had gained in that period. The average rate of growth of younger trees, of the same species, was then ascertained, and the calculation made according to a supposed mean rate of increase. De Candolle considers it not improbable, that the celebrated Taxodium of Chapultepec, in Mexico (*Cupressus disticha*, Linn.), which is 117 feet in circumference, may be still more aged.*

It is, however, impossible, until more data are collected respecting the average intensity of the volcanic action, to make any thing like an approximation to the age of a cone like Etna; because, in this case, the successive envelopes of lava and scoriæ are not continuous, like the layers of wood in a tree, and afford us no definite measure of time. Each conical envelope is made up of a great number of distinct lava currents and showers of sand and scoriæ, differing in quantity, and which may have been accumulated in unequal periods of time. Yet we cannot fail to form

* On the Longevity of Trees, Bibliot. Univ., May, 1831.

the most exalted conception of the antiquity of this mountain, when we consider that its base is about ninety miles in circumference; so that it would require ninety flows of lava, each a mile in breadth at their termination, to raise the present foot of the volcano as much as the average height of one lava current.

There are no records within the historical era which lead to the opinion, that the altitude of Etna has materially varied within the last two thousand years. Of the eighty most conspicuous minor cones which adorn its flanks, only one of the largest, Monti Rossi, has been produced within the times of authentic history. Even this hill, thrown up in the year 1669, although 450 feet in height, only ranks as a cone of second magnitude. Monte Minardo, near Bronte, rises, even now, to the height of 750 feet, although its base has been elevated by more modern lavas and ejections. The dimensions of these larger cones appear to bear testimony to *paroxysms* of volcanic activity, after which we may conclude, from analogy, that the fires of Etna remained dormant for many years — since nearly a century of rest has sometimes followed a violent eruption in the historical era. It must also be remembered, that of the small number of eruptions which occur in a century, one only is estimated to issue from the summit of Etna for every two that proceeds from the sides. Nor do all the lateral eruptions give rise to such cones as would be reckoned amongst the smallest of the eighty hills above enumerated; some of them produce merely insignificant monticules, which are soon afterwards buried by showers of ashes.

How many years then must we not suppose to have

been expended in the formation of the eighty cones? It is difficult to imagine that a fourth part of them have originated during the last thirty centuries. But if we conjecture the whole of them to have been formed in twelve thousand years, how inconsiderable an era would this portion of time constitute in the history of the volcano! If we could strip off from Etna all the lateral monticules now visible, together with the lavas and scoriæ that have been poured out from them, and from the highest crater, during the period of their growth, the diminution of the entire mass would be extremely slight! Etna might lose, perhaps, several miles in diameter at its base, and some hundreds of feet in elevation, but it would still be the loftiest of Sicilian mountains, studded with other cones, which would be recalled, as it were, into existence by the removal of the rocks under which they are now buried.

There seems nothing in the deep sections of the Val del Bove to indicate that the lava currents of remote periods were greater in volume than those of modern times; and there are abundant proofs that the countless beds of solid rock and scoriæ were accumulated, as now, in succession. On the grounds, therefore, already explained, we must infer that a mass, eight thousand or nine thousand feet in thickness, must have required an immense series of ages anterior to our historical periods, for its growth; yet the whole must be regarded as the product of a modern portion of the newer Pliocene epoch. Such, at least, is the conclusion that seems to follow from the geological data already detailed, which show that the oldest parts of the mountain, if not of posterior date to the marine strata around its base, were at least of coeval origin.

Whether signs of Diluvial Waves are observable on Etna. — Some geologists contend, that the sudden elevation of large continents from beneath the waters of the sea have again and again produced waves which have swept over vast regions of the earth, and left enormous rolled blocks strewed upon the surface.* That there are signs of local floods of extreme violence, on various parts of the surface of the dry land, is incontrovertible, and I have endeavoured to point out causes which must for ever continue to give rise to such phenomena; but such appearances afford no geological proof of a general cataclysm. It is clear that no devastating wave has passed over the forest zone of Etna, since any of the lateral cones before mentioned were thrown up; for none of these heaps of loose sand and scoriæ could have resisted for a moment the denuding action of a violent flood.

To some, perhaps, it may appear that hills of such incoherent materials cannot be of very great antiquity, because the mere action of the atmosphere must, in the course of several thousand years, have obliterated their original forms. But there is no weight in this objection; for the older hills are covered with trees and herbage, which protect them from waste; and in regard to the newer ones, such is the porosity of their component materials, that the rain which falls upon them is instantly absorbed, and, for the same reason that the rivers on Etna have a subterranean course, there are none descending the sides of the minor cones.

No sensible alteration has been observed in the

* Sedgwick, Anniv. Address to the Geol. Soc., p. 35. Feb. 1831.

form of these cones since the earliest periods of which there are memorials; and there seems no reason for anticipating, that in the course of the next ten thousand or twenty thousand years they will undergo any great alteration in their appearance, unless they should be shattered by earthquakes or covered by volcanic ejections.

I shall hereafter point out, that, in other parts of Europe, similar loose cones of scoriæ, probably of higher antiquity than the whole mass of Etna, stand uninjured, at inferior elevations above the level of the sea.

CHAPTER IX.

NEWER PLIOCENE FORMATIONS OF SICILY.

Growth of submarine formations gradual — Their rise above the level of the sea — Their present position proves modifications of the earth's crust at great depths, during the newer Pliocene period — Alterations of the surface of Sicily during and since its emergence — Forms of the Sicilian valleys — Sea cliffs — Proofs of successive elevation — Valleys in the newer Pliocene districts correspond in form to those of other regions — Migrations of animals and plants since the emergence of the newer Pliocene strata — Some species older than the stations they inhabit — Recapitulation.

Having in the last two chapters described the tertiary formations of the Val di Noto and Valdemone, both igneous and aqueous, I shall now proceed more fully to consider their origin, and the manner in which they may be supposed to have assumed their present position. The consideration of this subject may be naturally divided into three parts: first, we may inquire in what manner the submarine formations were accumulated beneath the waters; secondly, whether they emerged slowly or suddenly, and to what modifications in the earth's crust, at considerable depths below the surface, their rise may be attributed; thirdly, the mutations which the surface and its inhabitants have undergone during and since the period of emergence.

Growth of submarine formations. — First, then, we are to inquire in what manner the subaqueous masses, whether volcanic or sedimentary, may have been

formed. On this subject a few observations will suffice; for by reference to the two last books, the reader will learn how a single stratum, whether of sand, clay, or limestone, may be thrown down at the bottom of the sea, and how shells and other organic remains may become imbedded in it. He will also understand how one sheet of lava, or one bed of scoriæ and volcanic sand, may be spread out over a wide area, and how, at a subsequent period, a second bed of sand, clay, or limestone, or a second lava stream may be superimposed, so that in the lapse of ages a mountain mass shall be produced.

It is enough that we should behold a single course of bricks or stones laid by the mason upon another, in order to comprehend how a massive edifice, such as the Coliseum at Rome, was erected; and we can have no difficulty in conceiving that a sea, three hundred or four hundred fathoms deep, might be filled up by sediment and lava, provided we admit an indefinite lapse of ages for the accumulation of the materials.

The sedimentary and volcanic masses of the newer Pliocene era, which, in the Val di Noto, attain the thickness of two thousand feet, are subdivided into a vast number of strata and lava streams, each of which were originally formed on the subaqueous surface, just as the tuffs and lavas, whereof sections are laid open in the Val del Bove, were each in their turn external additions to the Etnean cone.

It is also clear, that before any part of the mass of submarine origin began to rise above the waters, the uppermost stratum of the whole must have been deposited; so that if the date of the origin of these masses be comparatively recent, still more so is the period of their rise above the level of the sea.

Subaqueous formations how raised.— In what manner, then, and by what agency, did this rise of the subaqueous formations take place? We have seen that, since the commencement of the present century, a tract of country in Cutch, more than fifty miles long and sixteen broad, was permanently upraised to the height of ten feet above its former position, and the earthquake which accompanied this wonderful variation of level is reported to have terminated by a volcanic eruption at Bhooj. We have also seen*, that when the Monte Nuovo was thrown up, in the year 1538, a large fissure approached the small town of Tripergola, emitting a vivid light, and throwing out ignited sand and scoriæ. At length this opening reached a shallow part of the sea close to the shore, and then widened into a large chasm, out of which were discharged blocks of lava, pumice, and ashes. But no current of melted matter flowed from the orifice, although it is perfectly evident that lava existed below in a fluid state, since so many portions of it were cast up in the form of scoriæ into the air. It will be remembered that the coast near Puzzuoli rose, at that time, to the height of more than twenty feet above its former level, and that it has remained permanently upheaved to this day.†

On a review of the whole phenomena, it appears most probable that the elevated country was forced upwards by lava which did not escape, but which, after causing violent earthquakes, during several preceding months, produced at length a fissure from whence it discharged gaseous fluids, together with sand and scoriæ. The intruded mass then cooled

* Vol. II. p. 72. † Vol. II. p. 266.

down at a certain distance below the uplifted surface, and constituted a solid and permanent foundation.

If an habitual vent had previously existed near Puzzuoli, such as we may suppose to remain always open in the principal ducts of Vesuvius or Etna, the lava might, perhaps, have flowed over upon the surface, instead of heaving upwards the superficial strata. In that case there might have been the same conversion of sea into land, the only difference being, that the lava would have been uppermost, instead of the tufaceous strata containing shells, now seen in the plain of La Starza, and on the site of the Temple of Serapis.

But when we remember that the tertiary strata of the Val di Noto have attained the height of from fifty to two thousand feet, and in the central parts of Sicily, as at Castrogiovanni, an elevation of about three thousand feet above the level of the sea, are we prepared to suppose a solid support of igneous rock, equal in volume to the upraised tract, to have been generated below since the newer Pliocene strata were formed? In reply to this question I may remark, that the entire mass of Iceland is said to be volcanic, an island 260 miles long by two hundred in breadth, and which rises, in some spots, to the height of six thousand feet. Had the melted matter in this case been prevented from reaching the surface by the weight and tenacity of superincumbent rocks, it might, perhaps, have heaved up a district three times as extensive as Sicily. But whether we adopt this or any other hypothesis as the cause of elevation, whether we introduce the evolution of gases, the liquefaction of rocks, or their expansion by heat, or any other mode of operation, it is still impossible to escape from

the conclusion, that some very extraordinary change has taken place in part of the earth's crust immediately underneath Sicily, since the Mediterranean was inhabited by the existing species of testacea. We must surely admit that the permanent upheaving of a country two or three thousand square miles in area, to an additional height of several hundred yards, implies either the intrusion of new mineral matter into the fundamental rocks, or a modification in their character.

It would be superfluous to repeat here what has been said of the probable causes of volcanic agency, operating at considerable depths, or what has been called by some geologists *plutonic action*.* But it is important to reflect, that the position of the newer Pliocene strata, in Sicily and elsewhere, indicate that this action has been developed on a great scale since the recent species of testacea abounded. The formation of a cone, such as Etna, or of the sedimentary and volcanic rocks of the Val di Noto, are superficial mutations which are perfectly insignificant in a geological point of view when compared with the contemporaneous changes above alluded to which must have been going on *out of sight*. The result of these operations may one day be exposed to view; but a great lapse of time will probably be required before masses formed or altered at great depths can be brought up to the surface.

> Quicquid sub terrâ est, in apricum proferet ætas
> Defodiet condetque nitentia.

The deposits of our own period may sink down, and be hidden in the depths of the earth, when the plutonic formations of the newer Pliocene era shall

* See book ii. part ii. chaps. 9. and 10.

have become visible; and it may then be impossible to ascertain, by geological evidence, the relative date of rocks formed in the subterranean regions during the newer Pliocene ages, and to prove that they were produced at precisely the same time with the limestone and argillaceous strata of the Val di Noto.

Changes of the Surface during and since the Emergence of the newer Pliocene Strata.

Valleys.— Geologists who are accustomed to attribute a great proportion of the inequalities of the earth's surface to the excavating power of running water during a long series of ages, will probably look for the signs of remarkable freshness in the aspect of countries so recently elevated as the parts of Sicily already described. There is, however, nothing in the external configuration of that country which would strike the eye of the most practised observer, as peculiar and distinct in character from any other districts in Europe which are of much higher antiquity. The general outline of the hills and valleys would accord perfectly well with what may often be observed in regard to other regions of equal altitude above the level of the sea.

It is true that, towards the central parts of the island where the argillaceous deposits are of great thickness, as around Castrogiovanni, Caltanisetta, and Piazza, the torrents are observed annually to deepen the ravines in which they flow, and the traveller occasionally finds that the narrow mule-path, instead of winding round the head of a ravine, terminates abruptly in a deep trench which has been hollowed out, during the preceding winter, through soft clay. But

throughout a great part of Italy, where the marls and sands of the Subapennine hills are elevated to considerable heights, the same rapid degradation is often perceived.

In the limestone districts of the Val di Noto, the strata are for the most part nearly horizontal, and on each side of the valley form a succession of ledges or small terraces, instead of descending in a gradual slope towards the river-plain in the manner of the argillaceous formations. When there is a bend in the valley, the exact appearance of an amphitheatre with a range of marble seats is produced. A good example of this configuration occurs near the town of Melilli, in the Val di Noto, as seen in the annexed view (No. 74.). In the south of the island, as near Spaccaforno,

No. 74.

Valley called Gozzo degli Martiri, below Melilli.

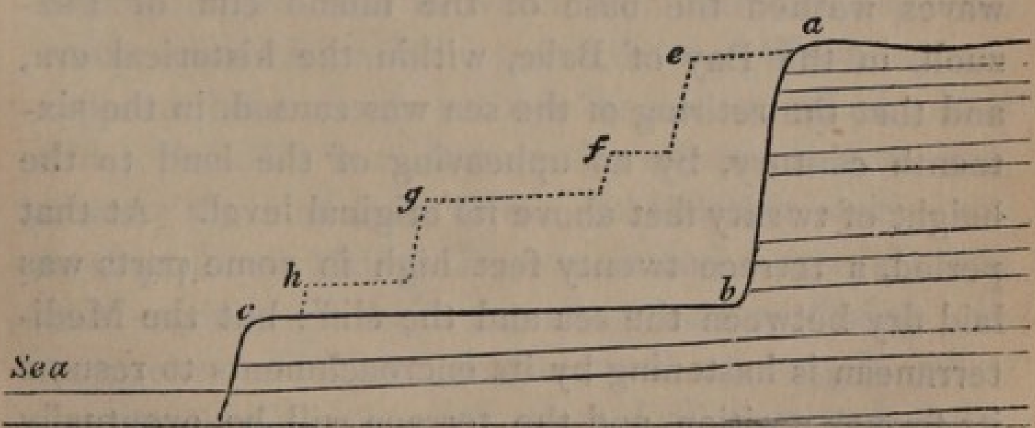
Scicli, and Modica, precipitous rocks of white limestone, ascending to the height of five hundred feet, have been carved out into the same form.

The line of some of the valleys near Lentini has

evidently been determined mainly by the direction of the elevatory force, as there is an anticlinal dip in the strata on either side of the valley. The same is, probably, the case in regard to the great valley of the Anapo, which terminates at Syracuse.

Sea-cliffs — proofs of successive elevation. — No decisive evidence could be looked for in the form of the valleys to determine the question, whether the subterranean movements which upheaved the newer Pliocene strata in Sicily were very numerous or few in number. But we find the signs of two periods of elevation in a long range of inland cliff on the east side of the Val di Noto, both to the north of Syracuse, beyond Melilli, and to the south beyond the town of Noto. The great limestone formation above mentioned terminates suddenly towards the sea in a lofty precipice, *a*, *b*, which varies in height from five hundred to seven

No. 75.



hundred feet, and may remind the English geologist of some of the most perpendicular escarpments of our chalk and oolite. Between the base of the precipice *a*, *b* and the sea is an inferior platform *c*, *b*, consisting of similar white limestone. All the strata dip towards the sea, but are usually inclined at a very slight angle; they are seen to extend uninterruptedly from the base

of the escarpment into the platform, showing distinctly that the lofty cliff was not produced by a fault or vertical shift of the beds, but by the removal of a considerable mass of rock. Hence we may conclude that the sea, which is now undermining the cliffs of the Sicilian coast, reached at some former period the base of the precipice *a*, *b*, at which time the surface of the terrace *c*, *b* must have constituted the bottom of the Mediterranean. Here, then, we have proofs of at least two elevations, but there may have been many others.

Suppose, for example, that a series of escarpments, *e*, *f*, *g*, *h*, once existed, and that during a long interval, free from subterranean movements, the sea advances along the line *c*, *b*, all preceding cliffs must have been swept away one after the other, and reduced to the single precipice *a*, *b*.

I have stated, in the second volume*, that the waves washed the base of the inland cliff of Puzzuoli, in the Bay of Baiæ, within the historical era, and that the retiring of the sea was caused, in the sixteenth century, by an upheaving of the land to the height of twenty feet above its original level. At that period, a terrace twenty feet high in some parts was laid dry between the sea and the cliff; but the Mediterranean is hastening by its encroachments to resume its former position, and the terrace will be eventually destroyed, and every trace of the *successive* rise of the land obliterated.

I have been led into these observations, in order to show that the principal features in the physical geography of Sicily are by no means inconsistent with

* P. 267.

the hypothesis of the successive elevation of the country by the intermittent action of ordinary earthquakes. On the other hand, the magnitude of the valleys, and their correspondence in form with those of other parts of the globe, seem to lend countenance to the theory of the slow and gradual rise of subaqueous strata.

The excavation of valleys, as was before remarked*, must always proceed with the greatest rapidity when the levels of a country are undergoing alteration from time to time by earthquakes; and it is principally when a country is rising or sinking by successive movements, that the power of aqueous causes, such as tides, currents, rivers, and land-floods, is exerted with the fullest energy.

In order, therefore, to explain the present appearance of the surface, we must first go back to the time when the Sicilian formations were mere shoals at the bottom of the sea, in which the currents may have scooped out channels here and there. We must next suppose these shoals to have become small islands of which the cliffs were thrown down from time to time, as were those of Gian Greco, in Calabria, during the earthquake of 1783. The waves and currents would have continued their denuding action during the emergence of these islands, until at length, when the intervening channels were laid dry, and rivers began to flow, the deepening and widening of the valleys by rivers and land-floods would proceed in the same manner as in modern times in Calabria.†

Before a tract could be upraised to the height of several thousand feet above the level of the sea, the

* Vol. II. p. 224. † Ibid.

joint operation of running water and subterranean movements must greatly modify its physical geography; but when the action of the volcanic forces has been suspended, when a period of tranquillity succeeds, and the levels of the land remain fixed and stationary, the erosive power of water must soon be reduced to a state of comparative equilibrium. For this reason, a country that has been raised at a very remote period to a considerable height above the level of the sea may present nearly the same external configuration as one that has been more recently uplifted to the same height.

Migration of animals and plants. — The changes above described, which have been brought about by igneous and aqueous agency, cannot fail to strike the imagination, when we consider how recent in the calendar of nature is the epoch to which they are referred. But if we turn our thoughts to the organic world, we shall feel, perhaps, no less surprise at the great vicissitude which it has undergone during the same period.

We have seen that a large portion of Sicily has been converted from sea to land since the Mediterranean was peopled with the living species of testacea and zoophytes. The newly emerged surface, therefore, must, during this modern zoological epoch, have been inhabited for the first time by the terrestrial plants and animals which now abound in Sicily. It is fair to infer, that the existing terrestrial species are, for the most part, of as high antiquity as the marine; and if this be the case, a large proportion of the plants and animals, now found in the tertiary districts in Sicily, must have inhabited the earth before the newer Pliocene strata were raised above the waters. The

plants of the Flora of Sicily are common, almost without exception, to Italy or Africa, or some of the countries surrounding the Mediterranean *, so that we may suppose the greater part of them to have migrated from pre-existing lands, just as the plants and animals of the Phlegræan fields have colonized Monte Nuovo, since that mountain was thrown up in the sixteenth century.

We are brought, therefore, to admit the curious result, that the flora and fauna of the Val di Noto, and some other mountainous regions of Sicily, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters. Such conclusions throw a new light on the adaptation of the attributes and migratory habits of animals and plants, to the changes which are unceasingly in progress in the inanimate world. It is clear that the duration of species is so great, that they are destined to outlive many important revolutions in the physical geography of the earth; and hence those innumerable contrivances for enabling the subjects of the animal and vegetable creation to extend their range, the inhabitants of the land being often carried across the ocean, and the aquatic tribes over great continental spaces. † It is obviously expedient, that the terrestrial and fluviatile species should not only be fitted for the rivers, valleys, plains, and mountains which exist at the era of their creation, but for others

* Professor Viviani of Genoa informed me, that, considering the great extent of Sicily, it was remarkable that its flora produced scarcely any, *if any peculiar indigenous* species, whereas there are several in Corsica, and some other Mediterranean islands.

† See book iii. chaps. v. vi. and vii.

that are destined to be formed before the species shall become extinct; and, in like manner, the marine species are not only made for the deep or shallow regions of the ocean existing at the time when they are called into being, but for tracts that may be submerged or variously altered in depth during the time that is allotted for their continuance on the globe.

Recapitulation. — I may now briefly recapitulate some of the most striking results deduced from the investigation of a single district where the newer Pliocene strata are largely developed.

In the first place, we have seen reason to infer that a stratified mass of solid limestone, attaining sometimes a thickness of eight hundred feet and upwards, has been gradually deposited at the bottom of the sea, the imbedded fossil shells and corallines being almost all of recent species. Yet these fossils are frequently in the state of mere casts, so that in appearance they correspond very closely to organic remains found in limestones of very ancient date.

2dly. In some localities the limestone above mentioned alternates with volcanic rocks such as have been formed by submarine eruptions, recurring again and again at distant intervals of time.

3dly. Argillaceous and sandy deposits have also been produced during the same period, and their accumulation has also been accompanied by submarine eruptions. Masses of mixed sedimentary and igneous origin, at least two thousand feet in thickness, can thus be shown to have accumulated since the sea was peopled with the greater number of the aquatic species now living.

4thly. These masses of submarine origin have, since their formation, been raised to the height of two thou-

sand or three thousand feet above the level of the sea, and this elevation implies an extraordinary modification in the state of the earth's crust at some unknown depth beneath the tract so upheaved.

5thly. This modification may possibly correspond with the effects of what is usually called "plutonic action," or the agency of volcanic and other causes at considerable depths, in which case the newer Pliocene plutonic rocks, formed beneath Sicily, must be of great extent.

6thly. Considerable inequalities must have been caused on the surface of the new-raised lands during the emergence of the newer Pliocene strata, by the action of tides, currents, and rivers, combined with the disturbing and dislocating force of the elevatory movements.

7thly. There are no features in the forms of the valleys and sea-cliffs thus recently produced, which indicate the sudden rise of the strata to their present altitude, while there are some proofs of distinct and partial elevations at successive periods.

8thly. We may infer that the species of terrestrial and fluviatile animals and plants which now inhabit extensive districts, formed during the newer Pliocene era, were in existence not only before the new strata were raised, but before their materials were brought together at the bottom of the sea.

CHAPTER X.

NEWER PLIOCENE FORMATIONS — MARINE AND VOLCANIC.

Tertiary formations of Campania — Comparison of the recorded changes in this region with those commemorated by geological monuments — Dikes of Somma — Parallelism of their opposite sides — Age of the volcanic and associated rocks of Campania — Organic remains — No signs of diluvial waves — Marine newer Pliocene strata chiefly seen in countries of earthquakes — Illustrations from Chili — Peru — Parallel roads of Coquimbo — West Indies — East Indian archipelago — Red Sea.

Tertiary Formations of Campania.

Comparison of recorded changes with those commemorated by geological monuments. — In the second volume I traced the various changes which the volcanic region of Naples is known to have undergone during the last two thousand years; and, imperfect as are our historical records, the aggregate effect of igneous and aqueous agency, during that period, was shown to be far from insignificant. The rise of the modern cone of Vesuvius, since the year 79, was the most memorable event during those twenty centuries; but, in addition to this remarkable phenomenon, I enumerated the production of several new minor cones in Ischia, and of the Monte Nuovo, in the year 1538. The flowing also of lava currents upon the land and along the bottom of the sea was described, the showering down of volcanic sand, pumice, and scoriæ, in such abundance that whole cities were buried, — the filling up or shoaling of certain tracts of the sea, and the transportation of tufaceous sediment by rivers and

land floods. I also explained the evidence in proof of a permanent alteration of the relative levels of the land and sea in several localities, and of the same tract having, near Puzzuoli, been alternately upheaved and depressed to the amount of more than twenty feet. In connection with these convulsions, I pointed out that, on the shores of the Bay of Baiæ, there are recent tufaceous strata filled with fabricated articles, mingled with marine shells. It was also shown that the sea has been making gradual advances upon the coast, not only sweeping away the soft tuffs of the Bay of Baiæ, but excavating precipitous cliffs, where the hard Ischian and Vesuvian lavas have flowed down into the deep.

These events, it may be objected, although interesting, are the results of operations on a very inferior scale to those indicated by geological monuments. When we examine this same region, it will be said we find that the ancient cone of Vesuvius, called Somma, is larger than the modern cone, and is intersected by a greater number of dikes, — the hills of unknown antiquity, such as Astroni, the Solfatara, and Monte Barbaro, formed by separate eruptions, in different parts of the Phlegræan fields, far outnumber those of similar origin, which are recorded to have been thrown up within the historical era. In place of modern tuffs of slight thickness, and single flows of lava, we find, amongst the older formations, hills from five hundred to more than two thousand feet in height, composed of an immense series of tufaceous strata, alternating with distinct lava currents. We have evidence that in the lapse of past ages, districts, not merely a few miles square, were upraised to the height of twenty or thirty feet above their former

level, but that extensive and mountainous countries were uplifted to an elevation of more than one thousand feet, and at some points more than two thousand feet, above the level of the sea.

These and similar objections are made by those who compare the modern effects of igneous and aqueous causes, not with a part but with the whole results of the same agency in antecedent ages. Thus viewed in the aggregate, the leading geological features of each district must always appear to be on a colossal scale, just as a large edifice may seem an effort of superhuman power, until we reflect on the innumerable minute parts of which it is composed, and on the number of the persons who have contributed to raise it. A mountain mass, so long as the imagination is occupied in contemplating the gigantic whole, must appear the work of extraordinary causes; but when the separate portions of which it is made up are carefully studied, they are seen to have been formed successively, and the dimensions of each part, considered singly, are soon recognized to be comparatively insignificant, so that it appears no longer extravagant to liken them to the recorded effects of ordinary causes.

Difference in the Composition of Somma and Vesuvius.

As no traditional accounts have been handed down to us of the eruptions of the ancient Vesuvius, from the times of the earliest Greek colonists, the volcano must have been dormant for many centuries, perhaps for thousands of years, previous to the great eruption in the reign of Titus. But it will be shown hereafter that there are sufficient grounds for presuming this mountain, and the other igneous products of Cam-

pania, to have been produced during the newer Pliocene period.

We have seen * that the ancient and modern cones of Vesuvius were each a counterpart of the other in structure; and I may now remark that the principal point of difference consists in the greater abundance in the older cone of fragments of altered sedimentary rocks ejected during eruptions. We may easily conceive that the first explosions would act with the greatest violence, rending and shattering whatever solid masses obstructed the escape of lava and the accompanying gases, so that great heaps of ejected pieces of rock would naturally occur in the tufaceous breccias formed by the earliest eruptions. But when a passage had once been opened and an habitual vent established, the materials thrown out would consist of liquid lava, which would take the form of sand and scoriæ, or of angular fragments of such solid lavas as may have choked up the vent.

Among the fragments which abound in the tufaceous breccias of Somma, none are more common than a saccharoid dolomite, supposed to have been derived from an ordinary limestone altered by heat and volcanic vapours.

Carbonate of lime enters into the composition of so many of the simple minerals found in Somma, that M. Mitscherlich, with much probability, ascribes their great variety to the action of the volcanic heat on subjacent masses of limestone.

Dikes of Somma. — The dikes seen in the great escarpment which Somma presents towards the modern cone of Vesuvius are very numerous. They are

* Vol. II. p. 89.

for the most part vertical, and traverse at right angles the beds of lava, scoriæ, volcanic breccia, and sand, of which the ancient cone is composed. They project in relief several inches, or sometimes feet, from the face of the cliff, like the dikes of Etna already described (see wood-cut No. 70.), being, like them, extremely compact, and less destructible than the intersected tuffs and porous lavas. In vertical extent they vary from a few yards to five hundred feet, and in breadth from one to twelve feet. Many of them cut all the inclined beds in the escarpment of Somma from top to bottom, others stop short before they ascend above half way, and a few terminate at both ends, either in a point or abruptly. In mineral composition they scarcely differ from the lavas of Somma, the rock consisting of a base of leucite and augite, through which large crystals of augite and some of leucite are scattered.* Examples are not rare of one dike cutting through another, and in one instance a shift or fault is seen at the point of intersection. I observed before †, when speaking of the dikes of the modern cone of Vesuvius, that they must have been produced by the filling up of open fissures by liquid lava. In some examples, however, the rents seem to have been filled laterally.

The reader will remember our description of the manner in which the plain of Jerocarne, in Calabria, was fissured by the earthquake of 1783 ‡, so that the academicians compared it to the cracks in a broken

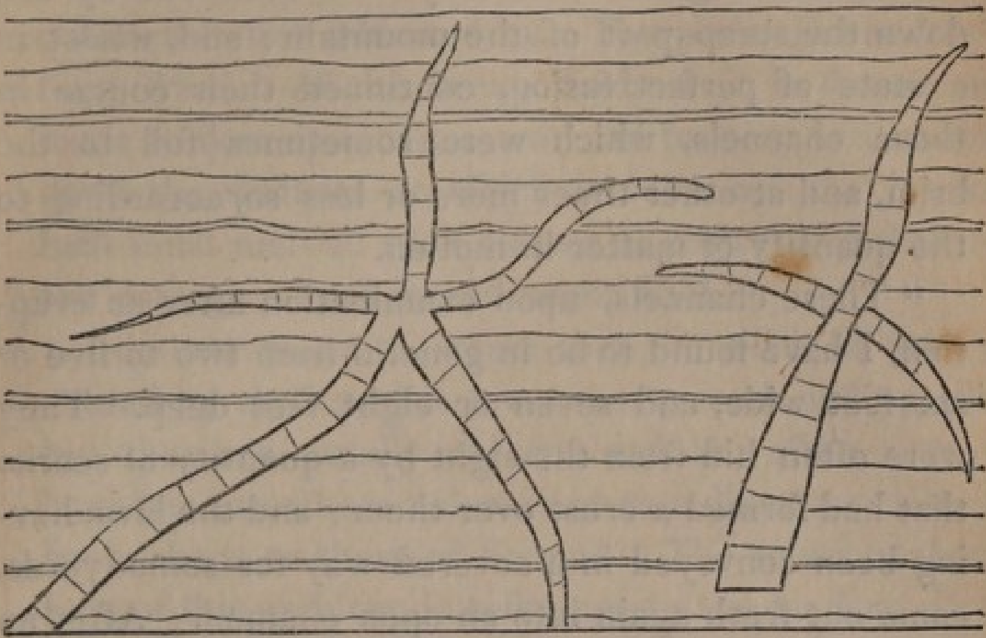
* Consult the valuable memoir of M. L. A. Necker, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tome ii. part i., Nov. 1822.

† Vol. II. p. 85.

‡ See Vol. II. p. 209., wood cut No. 28.

pane of glass. If we suppose the side walls of the ancient crater of Vesuvius to have been cracked in

No. 76.



Dikes or veins at the Punto del Nasone on Somma.

like manner, and the lava to have entered the rents and become consolidated, we can explain the singular form of the veins figured in the accompanying wood-cut.*

Parallelism of their opposite sides.—Nothing is more remarkable than the parallelism of the opposite sides of the dikes, which usually correspond with as much regularity as the two opposite faces of a wall of masonry. This character appears at first the more inexplicable, when we consider how jagged and uneven are the rents caused by earthquakes in masses of heterogeneous composition like those composing the cone of Somma; but M. Necker has offered an ingenious and, I think, satisfactory explanation of the phenomenon. He refers us to Sir W. Hamilton's account of an eruption of Vesuvius in the year 1779, who records the following facts:—" The lavas, when

* From a drawing of M. Necker, in Mém. before cited.

hey either boiled over the crater, or broke out from the conical parts of the volcano, constantly formed channels as regular as if they had been cut by art, down the steep part of the mountain; and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so, according to the quantity of matter in motion.

"These channels, upon examination after an eruption, I have found to be in general from two to five or six feet wide, and seven or eight feet deep. They were often hid from the sight by a quantity of scoriæ that had formed a crust over them; and the lava, having been conveyed in a covered way for some yards, came out fresh again into an open channel. After an eruption I have walked in some of those subterraneous or covered galleries, which were exceedingly curious, the sides, top, and bottom, *being worn perfectly smooth and even* in most parts, by the violence of the currents of the red-hot lavas, which they had conveyed for many weeks successively."

In another place, in the same memoir, he describes the liquid and red-hot matter as being received "into a regular channel, raised upon a sort of wall of scoriæ and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct."*

Now, if the lava in these instances had not run out from the covered channel, in consequence of the declivity whereon it was placed — if, instead of the space being left empty, the lava had been retained within until it cooled and consolidated, it would then have constituted a small dike with parallel sides. But the

* Phil. Trans., vol. lxx. 1780.

walls of a vertical fissure through which lava has ascended in its way to a volcanic vent, must have been exposed to the same erosion as the four sides of the channels before adverted to. The prolonged and uniform friction of the heavy fluid, as it is forced and made to flow upwards, cannot fail to wear and smooth down the surfaces on which it rubs, and the intense heat must melt all such masses as project and obstruct the passage of the incandescent fluid.

I do not mean to assert that the sides of fissures caused by earthquakes are never smooth and parallel, but they are usually uneven, and are often seen to have been so where volcanic or *trap* dikes are as regular in shape as those of Somma. The solution, therefore, of this problem, in reference to the modern dikes, is most interesting, as being of very general application in geology.

Varieties in their texture. — Having explained the origin of the parallelism of the sides of a dike, we have next to consider the difference of its texture at the edges and in the middle. Towards the centre, observes M. Necker, the rock is larger grained, the component elements being in a far more crystalline state, while at the edge the lava is sometimes vitreous, and always finer grained. A thin parting band, approaching in its character to pitchstone, occasionally intervenes on the contact of the vertical dike and intersected beds. M. Necker mentions one of these at the place called Primo Monte, in the Atrio del Cavallo; I saw three or four others in different parts of the great escarpment. These phenomena are in perfect harmony with the results of the experiments of Sir James Hall and Mr. Gregory Watt, which have shown that a glassy texture is the effect of sudden cooling, and that,

on the contrary, a crystalline grain is produced where fused minerals are allowed to consolidate slowly and tranquilly under high pressure.

It is evident that the central portion of the lava in a fissure would, during consolidation, part with its heat more slowly than the sides, although the contrast of circumstances would not be so great as when we compare the lava at the bottom and at the surface of a current flowing in the open air. In this case the uppermost part, where it has been in contact with the atmosphere, and where refrigeration has been most rapid, is always found to consist of scoriform, vitreous, and porous lava, while at a greater depth the mass assumes a more lithoidal structure, and then becomes more and more stony as we descend, until at length we are able to recognize with a magnifying glass the simple minerals of which the rock is composed. On penetrating still deeper, we can detect the constituent parts by the naked eye, and in the Vesuvian currents distinct crystals of augite and leucite become apparent.

The same phenomenon, observes M. Necker, may readily be exhibited on a smaller scale, if we detach a piece of liquid lava from a moving current. The fragment cools instantly, and we find the surface covered with a vitreous coat, while the interior, although extremely fine grained, has a more stony appearance.

It must, however, be observed, that although the lateral portions of the dikes are finer grained than the central, yet the vitreous parting layer before alluded to is extremely rare. This may, perhaps, be accounted for, as the above-mentioned author suggests, by the great heat which the walls of a fissure may acquire before the fluid mass begins to consolidate, in which case the lava, even at the sides, would cool very slowly. Some

fissures, also, may be filled from above; and in this case the refrigeration at the sides would be more rapid than when the melted matter flowed upwards from the volcanic foci, in an intensely heated state.

The rock composing the dikes of Somma is far more compact than that of ordinary lava, for the pressure of a column of melted matter in a fissure greatly exceeds that in an ordinary stream of lava; and pressure checks the expansion of those gases which give rise to vesicles in lava.

There is a tendency in almost all the Vesuvian dikes to divide into horizontal prisms, which are at right angles to the cooling surfaces *, a phenomenon in accordance with the formation of vertical columns in horizontal beds of lava.

Minor cones of the Phlegræan Fields. — In the volcanic district of Naples there are a great number of conical hills with craters on their summits, which have evidently been produced by one or more explosions, like that which threw up the Monte Nuovo in 1538. They are composed of trachytic tuff, which is loose and incoherent, both in the hills and, to a certain depth, in the plains around their base, but which is indurated below. It is suggested by Mr. Scrope, that this difference may be owing to the circumstance of the volcanic vents having burst out in a shallow sea, as was the case with Monte Nuovo, where there is a similar foundation of hard tuff, under a covering of loose lapilli. The subaqueous part may have become solid by an aggregative process like that which takes place in the setting of mortar, while the rest of the ejections, having accumulated on dry land when the

* See wood-cut, No. 76. p. 385.

cone was raised above the water, may have remained in a loose state.*

Age of the volcanic and associated rocks of Campania. — If we inquire into the evidence derivable from organic remains, respecting the age of the volcanic rocks of Campania, we find reason to conclude that such parts as do not belong to the Recent, are referrible to the newer Pliocene period. In the solid tuff quarried out of the hills immediately behind Naples, are found recent shells of the genera Ostrea, Cardium, Buccinum, and Patella, all referrible to species now living in the Mediterranean.† In the centre of Ischia the lofty hill called Epomeo or San Nichola, is composed of greenish indurated tuff of a prodigious thickness, interstratified in some parts with argillaceous marl, and here and there with great streams of indurated lava. Visconti ascertained by trigonometrical measurement that this mountain was 2605 feet above the level of the sea. In mineral composition and in form, as seen from many points of view, it resembles the hill to the north of Naples on the summit of which stands the convent of Camaldòli, which is 1643 feet in height. I collected in 1828 many recent marine shells from beds of clay and tuff, not far from the summit of Epomeo, about two thousand feet above the level of the sea, as also at another locality, about one hundred feet below the first, on the southern declivity of the mountain, and others still lower, not far above the town of Moropano. At Casamicciol, and several places near the sea-shore, shells have long been observed in stratified tuff and clay. From these various

* Geol. Trans., vol. ii. part iii. p. 351. Second Series.

† Scrope, ibid.

points I obtained, during a short excursion in Ischia, twenty-eight species of shells, all of which, with one exception, were identified by M. Deshayes with recent species.*

It is clear, therefore, that the great mass of Epomeo was not only raised to its present height above the level of the sea, but was also *formed*, since the Mediterranean was inhabited by the existing species of testacea.

In the Ischian tuffs we find pumice, lapilli, angular fragments of trachytic lava, and other products of igneous ejections, interstratified with some deposits of clay free from any intermixture of volcanic matter. These clays might have resulted from the decomposition of felspathic lava which abounds in Ischia, the materials having been transported by rivers and marine currents, and spread over the bottom of the sea where testacea were living. All these submarine tuffs, lavas, and clays of Campania, very much resemble those around the base of Etna, and in parts of the Val di Noto before described.

External configuration of the country how caused. — When once we have satisfied ourselves by inspection of the marine shells imbedded in tuffs at high elevations, that a mass of land like the island of Ischia has been raised from beneath the waters of the sea to its present height, we are prepared to find signs of the denuding action of the waves impressed upon the outward form of the island, especially if we conceive the upheaving force to have acted by successive movements. Let us suppose the low contiguous island of Procida to be raised by degrees until it attains the height of Ischia; we should in that case expect the

* See the list of these shells, Appendix II. first ed.

steep cliffs which now face Misenum to be carried upwards, and to become precipices near the summit of the central mountain. Such, perhaps, may have been the origin of those precipices which appear on the north and south sides of the ridge which forms the summit of Epomeo in Ischia. The northern escarpment is about one thousand feet in height, rising from the hollow called the Cavo delle Neve, above the village of Panella. The abrupt manner in which the horizontal tuffs are there cut off, in the face of the cliff, is such as the action of the sea, working on soft materials, might easily have produced, undermining and removing a great portion of the mass. A heap of shingle which lies at the base of a steep declivity on the flanks of Epomeo, between the Cavo delle Neve and Panella, may once, perhaps, have been a sea-beach, for it certainly could not have been brought to the spot by any existing torrents.

There is no difficulty in conceiving that if a large tract of the bed of the sea near Ischia should now be gradually upheaved during the continuance of volcanic agency, this newly raised land might present a counterpart to the Phlegræan fields before described. Masses of alternating lava and tuff, the products of submarine eruptions, might on their emergence become hills and islands; the level intervening plains might afterwards appear, covered partly by the ashes drifted and deposited by water, and partly by those which would fall after the laying dry of the tract. The last features imparted to the physical geography would be derived from such eruptions in the open air as those of Monte Nuovo and the minor cones of Ischia.

No signs of diluvial waves. — Such a conversion of a large tract of sea into land might possibly take place

while the surface of the contiguous country underwent but slight modification. No great wave was caused by the permanent rise of the coast near Puzzuoli in the year 1538, because the upheaving operation appears to have been effected by a succession of minor shocks.* A series of such movements, therefore, might produce an island like Ischia without throwing a diluvial rush of waters upon low parts of the neighbouring continent. The advocates of paroxysmal elevations may, perhaps, contend that the rise of Ischia must have been anterior to the birth of all the cones of loose scoriæ scattered over the Phlegræan Fields; for, according to them, the sudden rise of marine strata causes inundations which devastate adjoining continents. But the absence of any signs of such floods in the volcanic region of Campania does not appear to me to warrant the conclusion, either that Ischia was raised previously to the production of the volcanic cones, or that it may not have been rising during the whole period of their formation.

We learn from the study of the mutations now in progress, that one part of the earth's surface may, for an indefinite period, be the scene of continued change, while another, in the immediate vicinity, remains stationary. We need go no farther than our own country to illustrate this principle; for, reasoning from what has taken place in the last ten centuries, we must anticipate that in the course of the next four thousand or five thousand years, a long strip of land, skirting the line of our eastern coast, will be devoured by the ocean, while part of the interior, immediately adjacent, will remain at rest and entirely undisturbed. The

* See Vol. II. p. 256.

analogy holds true in regions where the volcanic fires are at work, for part of the Philosopher's Tower on Etna has stood for the last two thousand years, at the height of more than nine thousand feet above the sea, between the foot of the highest cone and the edge of the precipice which overhangs the Val del Bove, whilst large tracts of the surrounding district have been the scenes of tremendous convulsions. The great cone above has more than once been destroyed, and again renewed; the earth has sunk down in the neighbouring Cisterna *; the cones of 1811 and 1819 have been thrown up, on the ledge of rock below, pouring out of their craters two copious streams of lava; the watery deluge of 1755, descending from the desert region into the Val del Bove, has rolled vast heaps of rocky fragments towards the sea; fissures, several miles in length, have opened on the flanks of Etna; towns and villages have been laid in ruins by earthquakes, or buried under lava and ashes; — yet the tower has stood, as if placed there to commemorate the stability of one part of the earth's surface, while others in immediate proximity have been subject to most wonderful vicissitudes.

In concluding what I have to say of the marine and volcanic formations of the newer Pliocene period, I may notice the highly interesting fact, that the marine strata of this era have been found at great elevations, chiefly in those countries where earthquakes have occurred during the historical ages. On the other hand, it is a still more striking fact, that there is no example of any extensive maritime district, now habitually agitated by violent earthquakes, which has not, when carefully investigated, yielded traces of marine

* See above, p. 357.

strata, either of Recent or newer Pliocene eras, at a considerable height above the sea.

Chili — Conception Bay.—In illustration of the above remarks I may mention, that on the western coast of South America marine deposits occur, containing precisely the same shells as are now living in the Pacific. In Chili, for example, as before stated *, micaceous sand, containing the fossil remains of such species as now inhabit the Bay of Conception, are found at the height of from 1000 to 1500 feet above the level of the ocean. It is impossible to say how much of this rise may have taken place during the *Recent* period. One earthquake appears to have raised this part of the Chilian coast, in 1750, to the height of at least twenty-five feet above its former level. If we could suppose a series of such shocks to occur, one in every century, only 6000 years would be required to uplift the coast 1500 feet. But we have no data for inferring that so great a quantity of elevation has taken place in that space of time; and although there is no evidence that the micaceous sand may not belong to the Recent period, I think it more probable that it was deposited during the newer Pliocene period.

Peru. — I have been informed by Mr. A. Cruckshanks, a naturalist who resided for several years in South America, that in the valley of Lima, or Rimao, where the subterranean movements have been so violent in recent times, there are indications not only of a considerable rise of the land, but of that rise having resulted from *successive* movements. Distinct lines of ancient sea-cliffs have been observed at various heights, at the base of which the hard rocks of green-

* Vol. II. p. 244.

stone are hollowed out into precisely those forms which they now assume between high and low water mark on the shores of the Pacific. Immediately below these water-worn lines are ancient beaches strewed with rounded blocks. One of these cliffs appears in the hill behind Baños del Pujio, about seven hundred feet above the level of the sea, and two hundred above the contiguous valley. Another occurs at Amancaes, at the height of perhaps two hundred feet above the sea, and others at intermediate elevations.

Parallel roads of Coquimbo.— We can hardly doubt that the parallel roads of Coquimbo, in Chili, described by Captain Hall, owe their origin to similar causes. These roads, or shelves, occur in a valley six or seven miles wide, which descends from the Andes to the Pacific. Their general width is from twenty to fifty yards, but they are, at some places, half a mile broad. They are so disposed as to present exact counterparts of one another, at the same level, on opposite sides of the valley. There are three distinctly characterized sets; the upper one lies about three or four hundred feet above the level of the sea; the next twenty yards lower; and the lowest about ten yards still lower. Each resembles a shingle beach, being formed entirely of loose materials, principally water-worn, rounded stones, from the size of a nut to that of a man's head. The stones are principally granite and gneiss, with masses of schistus, whinstone, and quartz mixed indiscriminately, and all bearing marks of having been worn by attrition under water. *

The theory proposed by Captain Hall to explain these appearances is the same as that which had been

* Captain Hall's South America, vol. ii. p. 9.

adopted to account for the analogous parallel roads of Glen Roy in Scotland.* The valley is supposed to have been a lake, the waters of which stood, originally, at the level of the highest road, until a flat beach was produced. A portion of the barrier was then broken down, which allowed the lake to discharge part of its waters into the sea, and, consequently, to fall to the second level; and so on successively till the whole embankment was washed away, and the valley left as we now see it.

As I did not feel satisfied with this explanation, I applied to my friend Captain Hall for additional details, and he immediately sent me his original manuscript notes, requesting me to make free use of them. In them I find the following interesting passages, omitted in his printed account:—"The valley is completely open towards the sea; if the roads, therefore, are the beaches of an ancient lake, it is difficult to imagine a catastrophe sufficiently violent to carry away the barrier, which should not at the same time obliterate all traces of the beaches. I find it difficult also to account for the water-worn character of all the stones, for they have the appearance of having travelled over a great distance, being well rounded and dressed. They are in immense quantity too, and much more than one could expect to find on the beach of any lake, and *seem more properly to belong to the ocean.*"

I had entertained a strong suspicion, before reading these notes, that the beaches were formed by the waves of the Pacific, and not by the waters of a lake; in other words, that they bear testimony to the suc-

* See Sir T. D. Lauder, Ed. Roy. Soc. Trans., vol. ix.; and Dr. Macculloch, Geol. Trans., 1st Series, vol. iv. p. 314.

cessive rise of the land, not to the repeated fall of the waters of a lake. M. Boblaye has discovered four or five distinct ranges of ancient sea-cliffs, one above the other, at various heights, in the Morea, which attest that that country has been upheaved at as many successive periods. He found inland terraces or beaches, covered with shells, at the base of precipices worn like the modern sea-cliffs by the waves, and having, like them, many caverns and lithodomous perforations in the hard limestone.*

Near the northern gate of the town of St. Mihiel, south of Verdun, in France, I have examined a series of markings on the face of the limestone cliffs, much resembling some of those described by M. Boblaye. There are three and sometimes four distinct horizontal grooves, which have been scooped out of a white semicrystalline rock, or marble, of the oolitic period. This ancient cliff, which is near the right bank of the Meuse, is in part broken into a number of detached rocks, the upper parts of which present in some cases precipitous sides towards all points of the compass, round which the grooves pass in a circular course, just as if the summit of a rocky islet had been worn by the waves.†

* Journ. de Géol., No. x. Feb. 1831; Bull. de la Soc. Géol. de France, tom. ii. p. 236.

† I have no data for speculating on the period at which these cliffs may have emerged from the sea. I was directed to the spot, which I visited in June 1833, by M. Deshayes, and I stated in the second edition, on his authority, that the worn rocks were eaten into by marine lithodomous shells, but I was unable to discover any of these; and I believe that the fossils of the genus Saxicava, which M. Deshayes procured from this locality, were of the age of the corals of the limestone, not of the date of the excavation of the grooves. The fossil corals of this formation (coral rag) fre-

Captain Bayfield, in his survey of the coast of the Gulf of St Lawrence, traced in several places, especially in the Mingan Islands, a succession of shingle beaches, the most distant from the shore being sixty feet above the level of the highest tides. He also observed water-worn pillars of limestone accompanying these beaches, which bear evidence of having been worn and scooped out at different periods; the marks o the successive action of the water agreeing in level with the successive ridges of limestone shingle. The drawings of the pillars, made to illustrate his memoir, convince me that they are counterparts of the worn rocks which I have seen at St. Mihiel.*

If there exist lines of parallel upraised cliffs, we ought to find parallel lines of elevated beaches on those coasts where the rocks are of a nature to retain, for a length of time, the marks imprinted on their surface. We may expect such indications to be peculiarly manifest in countries where the subterranean force has been in activity within comparately modern times, and it is there that the hypothesis of paroxysmal elevations, and the instantaneous rise of mountain-chains, should first have been put to the test, before it was too hastily embraced and extended.

West Indian Archipelago.—According to the sketch given by Maclure of the geology of the Leeward Islands†, the western range consists in great part of formations of the most modern period. It will be remembered, that many parts of this region have been

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quently contain lithodomous shells, which seem to have pierced the zoophytes while they were still growing in the sea.

* Proceedings of Geol. Soc., No. 33. p. 5.

† Quart. Journ. of Sci., vol. v. p. 311.

subject to violent earthquakes; that in St. Vincent's and Guadaloupe there are active volcanos, and in some of the other islands boiling springs and solfataras. In St. Eustatia there is a marine deposit, estimated at fifteen hundred feet in thickness, consisting of coral limestone alternating with beds of shells, of which the species are, according to Maclure, the same as those now found in the sea. These strata dip to the south-west, at an angle of about 45°, and both rest upon, and are covered by, cinders, pumice, and volcanic substances. Part of the madreporic rock has been converted into silex and calcedony, and is, in some parts, associated with crystalline gypsum. Alternations of coralline formations with prismatic lava and different volcanic substances also occur in Dominica and St. Christopher's, and the American naturalist remarks, that as every lava-current which runs into the sea in this archipelago is liable to be covered with corals and shells, and these again with lava, we may suppose an indefinite repetition of such alternations to constitute the foundation of each isle.

I do not question the accuracy of the opinion, that the fossil shells and corals of these formations are of recent species, for there are specimens of limestone in the Museum of the Jardin du Roi at Paris, from the Antilles, in which the imbedded shells are all or nearly all identical with those now living. Part of this limestone is soft, but some of the specimens are very compact and crystalline, and contain only the casts of shells. Of thirty species examined by M. Deshayes from this rock, twenty-eight were decidedly recent.

Honduras.—Shells sent from some of the recent strata of Jamaica, and many from the nearest adjoining continent of the Honduras, may be seen in the British

Museum, and are identified with species now living in the West Indian seas.

East Indian Archipelago.— We have seen that the Indian ocean is one of the principal theatres of volcanic disturbance; it is to be expected, therefore, that future researches in this quarter of the globe will bring to light some of the most striking examples of marine strata upraised to great heights during comparatively modern periods.

From the observations of Dr. Jack, it appears that in the island of Pulo Nias, off the west coast of Sumatra, masses of corals of recent species can be traced from the level of the sea far into the interior, where they form considerable hills. Large shells of the Chama gigas (*Tridacna*, Lamk.) are scattered over the face of the country, just as they occur on the present reefs. These fossils are in such a state of preservation as to be collected by the inhabitants for the purpose of being cut into rings for the arms and wrists. *

Madeira.— The island of Madeira is placed between the Azores and Canaries, in both of which groups there are active volcanos, and Madeira itself was violently shaken by earthquakes during the last century. It consists in great part of volcanic tuffs and porous lava, intersected in some places, as at the Brazen Head, by vertical dikes of compact lava. † Some of the marine fossil shells, procured by Mr. Bowdich from this island, are referrible to recent species.

These examples may suffice for the present, and lead us to anticipate with confidence, that in almost all

* Geol. Trans., Second Series, vol. i. part ii. p. 397.

† MS. of Captain B. Hall.

countries where changes of level have taken place in our own times, the geologist will find monuments of a prolonged series of convulsions during the Recent and newer Pliocene periods. Exceptions may no doubt occur where a particular line of coast is sinking down, yet even here we may presume, from what we know of the irregular action of the subterranean forces, that some cases of partial elevation will have been caused by occasional oscillations of level, so that modern subaqueous formations will, here and there, have been brought up to view.

I shall conclude by enumerating some exceptions to the rule above illustrated, — instances of elevation where no great earthquakes have been recently experienced.

Grosœil, near Nice.—At a spot called Grosœil, near Nice, east of the Bay of Villefranche, in the peninsula of St. Hospice, a remarkable bed of fine sand occurs at an elevation of about fifty feet above the sea.* This sand rests on inclined secondary rocks, and is filled with the remains of marine species, all identical with those now inhabiting the neighbouring sea. No less than two hundred species of shells, and several crustacea and echini, have been obtained by M. Risso, in a high state of preservation, although mingled with broken shells. The winds have blown up large heaps of similar sand to considerable heights, upon ledges of the steep coast farther westward, but the position of the deposit at Grosœil cannot be referred to such agency, for among the shells may be seen the large Murex Triton, Linn., and a species of Cassis, weighing a pound and a half.

* I examined this locality, in company with Mr. Murchison, in 1828.

Uddevalla.—The ancient beaches of the Norwegian and Swedish coasts, described in the first volume*, in which the shells are of living species, afford evidence of a rise of two hundred feet or more of parts of those coasts during the newer Pliocene, if not the Recent epoch. These countries are far removed from any line of recent convulsions, but we have seen that many geologists are of opinion that Scandinavia is now the theatre of constant and unceasing changes in the relative level of the land and sea.

West of England.—The proofs lately brought to light of analogous elevations on our western shores, in Caernarvonshire and Lancashire, during some modern tertiary period, were before pointed out †; but the data are as yet exceedingly incomplete.

Western borders of the Red Sea.—Another exception may be alluded to, for which we are indebted to the researches of Mr. James Burton. On the western shores of the Arabian Gulf, about half way between Suez and Kosire, in the 28th degree of north latitude, a formation of white limestone and calcareous sand is seen, reaching the height of 200 feet above the sea. It is replete with fossil shells, all of recent species, which are in a beautiful state of preservation, many of them retaining their colour. ‡ The volcano of Gabel Tor, situate at the entrance of the Arabian Gulf, is the nearest volcanic region known to me at present.

Timor.—In the island of Timor, which approaches

* Vol. I. p. 338.

† See description of the Map, Vol. I. p. 209.

‡ These fossils are now in the museum of Mr. Greenough, in London, and duplicates, presented by him, in the cabinets of the Geological Society. A list of them was given in App. II., first

very near to the great volcanic band traced by Von Buch *, M. Péron mentions the occurrence of corals and marine shells, apparently of recent species †, and Dr. Fitton, in his account of Capt. King's collection of rocks from Australia, mentions a calcareous sandstone and breccia, at the height of several hundred feet above the sea, on many parts of the Australian coast. ‡ Future observations must decide whether these formations belong to the newest tertiary era, as conjectured.

Some of the above examples certainly afford proofs of elevation, since the commencement of the newer Pliocene period, to considerable heights, in countries far from the existing theatres of volcanic action; yet in these instances the upraised deposits containing recent shells appear in general to be confined to the coast, and not to enter largely, like those of Sicily, into the structure of mountains in the interior.

But the reader must not infer, from the facts above detailed, that marine strata of the newer Pliocene period have been produced almost exclusively in countries of earthquakes. If our illustrations have been drawn chiefly from modern volcanic regions, it is simply for this reason, that these formations have been made visible in those districts only where the conversion of sea into land has taken place in times comparatively modern. Other continents have, during the newer Pliocene period, suffered degradation, and rivers and currents have deposited sediment in other seas, but the new strata remain concealed wherever no subsequent alterations of level have taken place.

* See Map, Vol. II.

† Voy. découv. des Terres Australes, vol. ii. pp. 165. 183.

‡ App. to Captain P. King's Australia.

Yet to a certain limited extent the growth of new subaqueous deposits may have been greatest where igneous and aqueous causes have co-operated. It is there that the degradation of land is most rapid, and it is there only that materials ejected from below, by volcanic explosions, are added to the sediment transported by running water. *

* See book ii. part ii. chap. vii.; and book iii. chap. xviii.

CHAPTER XI.

NEWER PLIOCENE FORMATIONS. — FRESH-WATER AND ALLUVIAL.

Newer Pliocene fresh-water formations — Valley of the Elsa — Travertins of Rome — Loess of the Valley of the Rhine— Contains recent terrestrial and aquatic shells — Its origin — Osseous breccias of the newer Pliocene era — Fossil bones of Marsupial animals in Australian caves — Newer Pliocene alluviums — European alluviums chiefly tertiary — Erratic blocks of the Alps — Theory of their transportation by ice.

Fresh-water Formations.—In this chapter I shall treat of the fresh-water formations, and of the cave breccias and alluviums of the newer Pliocene period.

In regard to the first of these, they must have been formed, in greater or less quantity, in nearly all the existing lakes of the world; in those, at least, of which the basins were formed before the earth was tenanted by man. If the great lakes of North America originated before that era, the sedimentary strata deposited therein, in the ages immediately antecedent, would, according to the terms of our definition, belong to the newer Pliocene period.

Valley of the Elsa. — As an example of the strata of this age, which have been exposed to view in consequence of the drainage of a lake, I may mention those of the valley of the Elsa, in Tuscany, between Florence and Sienna, where we meet with fresh-water marls and travertins full of shells, belonging to species which now live in the lakes and rivers of Italy. Valleys several hundred feet deep have been excavated through the lacustrine beds, and the ancient town of Colle stands on a hill composed of them.

The subjacent formation consists of marine Subapennine beds, in which more than half the shells are of recent species. The fresh-water shells which I collected near Colle are in a very perfect state, and the colours of the Neritinæ are peculiarly brilliant. *

Travertins of Rome. — Many of the travertins and calcareous tufas which cap the hills of Rome may also belong to the same period. The terrestrial shells inclosed in these masses are of the same species as those now abounding in the gardens of Rome, and the accompanying aquatic shells are such as are found in the streams and lakes of the Campagna. On Mount Aventine, the Vatican, and the Capitol, we find abundance of vegetable matter, principally reeds encrusted with calcareous tufa, and intermixed with volcanic sand and pumice. The tusk of a mammoth has been procured from this formation, filled in the interior with solid travertin, wherein sparkling crystals of augite are interspersed, so that the bone has all the appearance of having been extracted from a hard crystalline rock. †

These Roman tufas and travertins repose partly on marine tertiary strata, belonging, perhaps, to the older Pliocene era, and partly on volcanic tuff of a still later date. They must have been formed in small lakes and marshes, which existed before the excavation of the valleys which divide the seven hills of Rome, and they must originally have occupied the lowest hollows of the country as it then existed;

* The following six species, all of which now inhabit Italy, were identified by M. Deshayes:— *Paludina impura*, *Neritina fluviatilis*, *Succinea amphibia*, *Limnea auricularis*, *L. pereger.*, and *Planorbis carinatus.*

† This fossil was shown me by Signor Riccioli at Rome.

whereas now we find them placed upon the summit of hills about two hundred feet above the alluvial plain of the Tiber. We know that this river has flowed nearly in its present channel ever since the building of Rome, and that scarcely any changes in the geographical features of the country have taken place since that era.

When the marine tertiary strata of this district were formed, those of Monte Mario for example, the Mediterranean was already inhabited by a large proportion of the existing species of testacea. At a subsequent period, volcanic eruptions occurred, and tuffs were superimposed. The marine formation then emerged from the deep, and supported lakes wherein the freshwater groups above described slowly accumulated, at a time when the mammoth inhabited the country. The valley of the Tiber was afterwards excavated, and the adjoining hills assumed their present shape, and then a long interval may, perhaps, have elapsed before the first human settlers arrived. Thus we have evidence of a chain of events, all regarded by the geologist as among the most recent, but which, nevertheless, may have preceded, for a long series of ages, a very remote era in the history of nations.

*Loess of the Valley of the Rhine.** — A remarkable

* Since the publication of the former edition of this volume, I have had opportunities of re-examining the loess in the country between Cologne and Heidelberg, especially near Andernach, and of studying it in several parts of Baden, Darmstadt, Wurtemberg, and Nassau. The details of these observations have been given in a memoir read to the Geological Society in May, 1834, when I explained at length my reasons for changing and modifying some opinions formerly expressed in regard to the origin of the Löss, and its relations to the volcanic formations of the Lower Eifel.

deposit of calcareous loam, containing land and fresh-water shells of recent species, occurs here and there, in detached patches, throughout the valley of the Rhine, between Basle and Cologne, and on the flanks of the hills bordering the great valley. This deposit is provincially termed "loess" by the Germans, and in Alsace, "lehm."

According to M. Leonhard, the loess at Heidelberg consists chiefly of argillaceous matter, combined with a sixth part of carbonate of lime, and a sixth of quartzose and micaceous sand. It may be described as a pulverulent loam, of a dirty yellowish-grey colour, often containing calcareous sandy concretions or nodules, rarely exceeding the size of a man's head. Its entire thickness, in some localities, amounts to between two hundred and three hundred feet; yet there are often no signs of stratification in the mass, except here and there at the bottom, where there is occasionally a slight intermixture of drifted materials derived from subjacent rocks.

I am informed by M. Studer, that the loess does not extend into Switzerland, but the Kaiserstuhl, a group of volcanic hills which stand almost in the middle of the plain of the Rhine, south of Strasburg, are covered with it to a great height; and I have seen it in large masses near the base of the Vosges, on the left side of the plain of the Rhine, near Strasburg, and on the right side, at the base of the mountains of the Black Forest. It extends also far into Wurtemberg, up the valley of the Neckar, and from Frankfort, up the valley of the Mayne, to above Dettelbach. In Nassau it is seen at Limburg, in the valley of the Lahn; and in Darmstadt, in the countries round Mayence, Oppenheim, and Worms.

It rises to a considerable height at Zeuten and Odenau, east of the Rhine, at a short distance from the Bergstrasse, between Wiesloch and Bruchsal, a locality first pointed out to me by Professor Bronn, where it is several hundred feet thick, and contains, both in the soft loam and in solid calcareous concretions, many shells, some of which retain occasionally their colour. The lower parts of this loess alternate with beds of alluvium derived from the degradation of the variegated sandstone and marl (bunter sandstein), of which the surrounding country is composed.

As the pure loess exhibits no divisions into strata, I at first imagined, with several other geologists, that this deposit was thrown down suddenly from the muddy waters of a transient flood, in the same manner as the moya of the Andes, or as the trass of the Rhine volcanos is generally believed to have been formed. But on re-examining the places where loess and alluvium, or loess and layers of volcanic matter alternate, I am compelled to renounce this view. In the deep gravel-pits without the Manheim gate of Heidelberg, loess is seen interstratified with gravel; and here more than one bed containing land and fresh-water shells rests upon, and is covered by, a stratum of gravel, showing the effects of successive accumulation. I observed the same fact in the valley of the Lahn, north of Limburg, near the village of Elz; and Professor Bronn informs me, that the calcareous concretions of the loess are sometimes arranged in horizontal layers, marking a difference in the carbonate of lime with which the sediment must have been charged at different periods.

Mammiferous remains are rare in the loess; but it is said that the bones of the mammoth, horse, and some

other quadrupeds, have been met with: but the most characteristic fossils are land-shells; and it will naturally be asked in what manner so prodigious a quantity of such shells could become buried at various depths in a subaqueous deposit. The answer is, that the Rhine, in our own times, bears down annually to the sea thousands of empty snail-shells, washed away during heavy rains, together with the floating shells of aquatic mollusca from streams, lakes, and stagnant pools. In the summer of 1833, I collected several hundred shells, which were exposed on the margin of the Rhine, on the fall of the waters, or had been cast ashore by large waves raised by the steam-boats; and on comparing them with a still larger collection obtained from the loess, the two groups proved to be referrible for the most part to identical species, and in both the terrestrial predominated numerically over the aquatic species. The genera most abundantly represented in each were Helix, Pupa, Limnea, Paludina, and Planorbis. But among the recent shells of the Rhine, the Unio and Neritina sometimes occurred; genera of which I never found any species in the loess.*

Now, it has been ascertained, that the waters of the Rhine, when evaporated, leave a residuum of calcareous loam, not distinguishable from loess†; so that, if

* In a former edition, I included in a list of loess shells (Appendix, p. 58.) Cyclas palustris, Drap., and C. lacustris, ib., but I have since ascertained that the shells in question had been brought to the field where I picked them up, in mud, used to fertilize the soil. The only bivalves I ever saw in loess were Cyclas fontinalis, Drap., at Odenau.

† See Mr. Horner, on the sediment of the Rhine, Proceedings of Geol. Soc., 1834.

these waters should enter a lake, they might give rise to a deposit, not only containing the same shells as the loess (with the exception of some fluviatile species), but having also the same mineral characters.

The loess is found reposing on every rock, from the granite near Heidelberg, to the gravel of the plains of the Rhine. It overlies almost all the volcanic products, even those between Neuwied and Bonn, which have the most modern aspect; and it has filled up, in part, the crater of the Roderberg; at the bottom of which a well was sunk, in 1833, through seventy feet of loess. Here, as elsewhere, it is a yellow loam with calcareous concretions, and has not the character of a local alluvium.

It is remarkable, indeed, that the loess is scarcely ever affected by the nature of the rocks which underlie or immediately surround its site, but wherever it occurs appears as if derived from one common source.

On revisiting the sections near Andernach, which have been appealed to by MM. Steininger, Hibbert, and others, as proving that some of the last eruptions of the Lower Eifel took place both during and since the deposition of the loess, I found it impossible not to come to the same conclusion. The loamy sediment may be seen in the Kirchweg, above Andernach, alternating with volcanic matter, over which is a mass of pure and unmixed loess, thirty feet and upwards in thickness, containing the usual shells; and over the whole are strewed layers of pumice, lapilli, and volcanic sand, from ten to fifteen feet thick, very much resembling the ejections under which Pompeii lies buried. There is no passage at this upper junction from the loess into the pumiceous superstratum; and this last follows the slope of the hill, just as it

would have done had it fallen in showers from the air on a declivity partly formed of loess.

The greatest known height attained by the loess is near Heilbronn, where it covers the slopes of some hills two or three hundred feet above the Neckar; that river being there about five hundred feet above the sea. Whatever theory we adopt to explain the position of such elevated masses, it must always be evident, that great geographical changes have taken place in the countries bordering the Rhine since some of the loess was formed, and, consequently, since the recent species of terrestrial and aquatic shells were in existence.

On the other hand, when we find the loess overlying the gravel of the Rhine near Strasburg, Bonn, and other places, we are compelled to admit that a great part of it was formed after the country had acquired nearly its present configuration. The first idea which has probably occurred to every one, after examining the loess between Mayence and Basle, is, to imagine that a great lake once extended throughout the valley of the Rhine between those places, which sent off large branches up the course of the Mayne, Neckar, and other tributary valleys. The barrier of such a lake might be placed somewhere in the narrow and picturesque gorge of the Rhine between Bingen and Bonn. But this theory is insufficient to explain the phenomena; for that gorge itself has once been filled with loess, which must have been tranquilly deposited in it, as also in the lateral valley of the Lahn, communicating with the gorge. The loess has also overspread the high adjoining platform near the village of Plaidt, above Andernach. Nay, on proceeding farther to the north, we discover that the hills

which skirt the valley between Bonn and Cologne have loess on their flanks, which also covers here and there the gravel of the plain as far as Cologne.

Instead of supposing one continuous lake of sufficient extent and depth to allow of the simultaneous accumulation of the loess at various heights, throughout the whole area where it now occurs, it might be a less violent hypothesis to assume, that the countries drained by the Rhine and its tributaries, after they had nearly acquired their actual form and leading geographical features, underwent great changes of level, by movements contemporaneous with the last series of volcanic eruptions of the Lower Eifel. Different parts of this region may have been alternately depressed and upraised in such a manner that they were each in their turn submerged beneath the waters of the Rhine, and covered with its sediment and floating shells. Gravel may have been intermingled in some places where the tributaries of the Rhine brought down coarser alluvium. After various tracts had thus been inundated in succession, covered with loess, and then laid dry, the larger portion of the loess must have been removed by denudation; a process which is still going on continually, as the particles of so fine a loam allow of their being washed away very readily by rain.

It is not, I think, impossible that some of the newly-formed lakes in the basin of Red River, in Louisiana, before described*, may have been occasioned by changes in the relative level of the lands there flooded; for the valley of the Mississippi is one of the modern theatres of earthquakes. Now, the

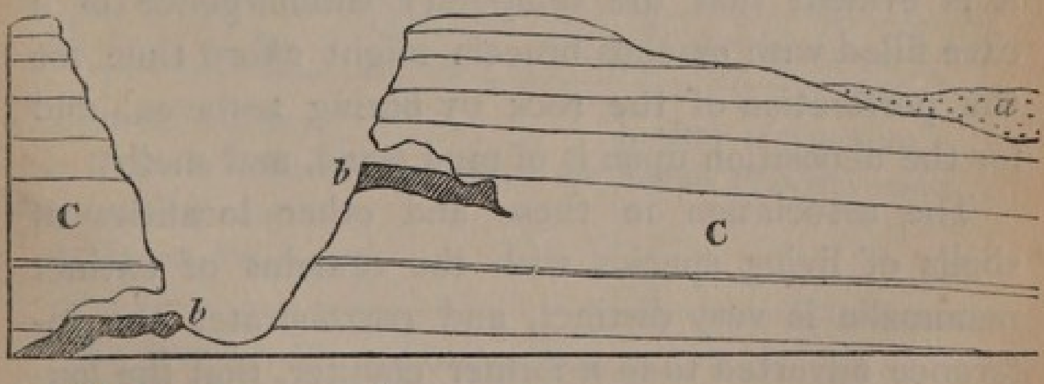
* Vol. I. p. 275.

course of Red River far exceeds in length, and is indeed nearly double, that of the Rhine; and whatever may be the causes which are giving rise to the successive submergence of its plains, they must also occasion the accumulation in many parts of that great valley of the red ochreous sediment so peculiar to Red River.

If the fluctuations in the relative levels of this great American valley should, in the course of ages, be so important as to produce elevations and subsidences to the amount of several hundred feet, the results, in regard to the superficial distribution of red fluviatile mud, might be very analogous to those observed in the position of the yellow loess in the valley of the Rhine above considered.*

Osseous Breccias — Sicily. — The breccias lately found in several caves in Sicily belong evidently to the period under consideration. I have shown, in the sixth chapter, that the cavernous limestone of the Val di Noto is of very modern date, as it contains a

No. 77.



a. Alluvium, } containing remains of *extinct* quadrupeds.
b, *b*. Deposits in caves, }
C. Limestone containing remains of *recent* shells.

* For particulars concerning the loess of the Rhine, consult the works of MM. Bronn, Leonhard, Boué, Voltz, Noeggerath, Steininger, Merian, Rozet, Von Meyer, and Hibbert.

great abundance of fossil shells of recent species; and if any breccias are found in the caverns of this rock, they must be of still later origin.

We are informed by M. Hoffmann, that the bones of the mammoth, and of an extinct species of hippopotamus, have been discovered in the stalactite of caves near Sortino, of which the situation is represented in the annexed diagram at *b*. The same author also describes a breccia, containing the bones of an extinct rhinoceros and hippopotamus, in a cave in the neighbourhood of Syracuse, where the country is composed entirely of the Val di Noto limestone. Some of the fragments in the breccia are perforated by lithodomi, and the whole mass is covered by a deposit of marine clay filled with recent shells.* These phenomena may, I think, be explained by supposing such oscillations of level as are known to occur on maritime coasts where earthquakes prevail — such, in fact, as have been witnessed on the shores of the Bay of Baiæ within the last three centuries.† For it is evident that the temporary submergence of a cave filled with osseous breccia might afford time for the perforation of the rock by boring testacea, and for the deposition upon it of mud, sand, and shells.

The association in these and other localities of shells of living species with the remains of extinct mammalia is very distinct, and corroborates the inference adverted to in a former chapter, that the longevity of *species* in the mammalia is, upon the whole, inferior to that of the testacea. I am by no means

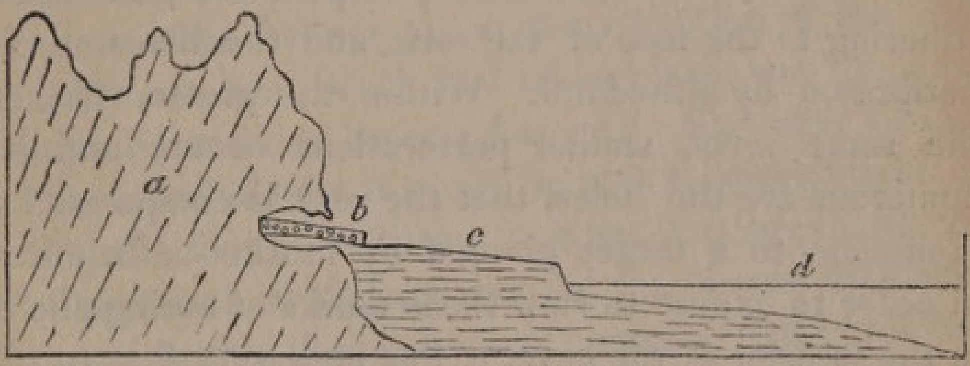
* Hoffmann, Archiv für Mineralogie, p. 393. Berlin, 1831. Dr. Christie, Proceedings of Geol. Soc., No. xxiii. p. 333.

† Vol. II. p. 255.

inclined to refer this circumstance to the intervention of man, and his power of extirpating the larger quadrupeds; for the succession of mammiferous species appears to have been in like manner comparatively rapid throughout the older tertiary periods. Their more limited duration depends, in all probability, on physiological laws, which render warm-blooded quadrupeds less capable, in general, of accommodating themselves to a great variety of circumstances, and, consequently, of surviving the vicissitudes to which the earth's surface is exposed in a great lapse of ages.*

Caves near Palermo.—The caves near Palermo exhibit appearances very analogous to those above described, and much curious information has been

No. 78.



a. Monte Grifone. *b.* Cave of San Ciro.

c. Plain of Palermo, in which are newer Pliocene strata of limestone and sand.

d. Bay of Palermo.†

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* See above, p. 48., and book i. chap. vi.

† This section is given by Dr. Christie, as of the Cave of San Ciro. Ed. New Phil. Journ., No. xxiii. Its geographical position and other characters agree so precisely with that of Mardolce, described by M. Hoffmann, that it may be another name for the same cave, or one immediately adjoining. An account has since appeared of the San Ciro cave, by Mr. S. P. Pratt, F.G.S.: see Proceedings of Geol. Soc. of London, No. xxxii. 1833.

lately published respecting them. According to Hoffmann, the grotto of Mardolce is distant about two miles from Palermo, and is twenty feet high and ten wide. It occurs in a secondary limestone, in the Monte Grifone, at the base of a rocky precipice about 180 feet above the sea. From the foot of this precipice an inclined plane, consisting of horizontal tertiary strata, of the newer Pliocene period, extends to the sea, a distance of about a mile.

The limestone escarpment was evidently once a sea-cliff, and the ancient beach still remains formed of pebbles of various rocks, many of which must have been brought from places far remote. Broken pieces of coral and shell, especially of oysters and pectens, are seen intermingled with the pebbles. Immediately above the level of this beach, serpulæ are still found adhering to the face of the rock, and the limestone is perforated by lithodomi. Within the grotto, also, at the same level, similar perforations occur; and so numerous are the holes, that the rock is compared by Hoffmann to a target pierced by musket-balls. But in order to expose to view these marks of boring-shells in the interior of the cave, it was necessary first to remove a mass of breccia, which consisted of numerous fragments of rock and an immense quantity of bones imbedded in a dark brown calcareous marl. Many of the bones were rolled as if partially subjected to the action of the waves. Below this breccia, which is about twenty feet thick, was found a bed of sand filled with sea-shells of recent species, and underneath the sand, again, is the secondary limestone of Monte Grifone. The state of the surface of the limestone in the cave above the level of the marine sand is very different from that below it. *Above*, the rock is jagged and

uneven, as is usual in the roofs and sides of limestone caverns; *below*, the surface is smooth and polished, as if by the attrition of the waves.

So enormous was the quantity of bones, that many ship-loads were exported in the years 1829 and 1830, in the hope of their retaining a sufficient quantity of gelatine to serve for refining sugar; for which, however, they proved useless. The bones belong chiefly to the mammoth (*E. primigenius*), and with them are those of an hippopotamus, distinct from the recent species, and smaller than that usually found fossil. Several species of deer, also, and, according to some accounts, the remains of a bear, were discovered.

It is easy to explain in what manner the cavern of Mardolce was in part filled with sea-sand, and how the surface of the limestone became perforated by lithodomi; but in what manner, when the elevation of the rocks and the ancient beach had taken place, was the superimposed osseous breccia formed? For want of more exact local details, it would be rash to speculate on this subject; but by referring to what was previously said of caverns near the sea-shore of the Morea, from which rivers escape, the reader may conceive that caves, after having been submerged and filled with sea-sand, may afterwards be upraised and flooded by the waters of engulphed rivers washing down animal remains from the land.*

Two other caverns are described by Dr. Christie as occurring in Mount Beliemi, about four miles west of Palermo, at a higher elevation than that of Mardolce, being more than three hundred feet above the level of the sea. In one of these places the bones are found only

* See p. 155.

in a talus at the outside of the cavern; in the other, they occur both within the cave and in the talus which slopes from it to the plain below. These caves appear to be situated much above the highest point attained by the tertiary deposits in this neighbourhood; nor is there the slightest appearance in the caves themselves of the sea having been there.*

Australian cave-breccias. — Ossiferous breccias have lately been discovered in fissured and cavernous limestone in Australia, and the remains of the fossil mammalia are found to be referrible to species now living in that country, mingled with some relics of extinct animals. Some of these caves have been examined by Major Mitchell, in the Wellington Valley, about 210 miles west of Sydney, on the river Bell, one of the principal sources of the Macquarie, and on the Macquarie itself.

The fissures and caverns appear to correspond closely with those which contain similar osseous breccias in Europe: they often branch off in different directions through the rock, widening and contracting their dimensions, the roofs and floors being covered with stalactite. The bones are often broken, but do not seem to be water-worn. In some caves and fissures they lie imbedded in loose earth, but usually they are included in a breccia, having a red ochreous cement as hard as limestone, and like that of the Mediterranean caves.

The remains found most abundantly are those of the kangaroo. Amongst others, those of the Wombat Dasyurus, Kaola, and Phalangista, have been recognized. The greater part of them belong to existing,

* Dr. T. Christie, on certain Newer Deposits in Sicily, &c. — Jameson, Ed. New Phil. Journ., No. xxiii. p. 1.

but some to extinct, species. One of the latter bones, of much greater size than the rest, is supposed, by Mr. Clift, to belong to an hippopotamus.*

In a collection of these bones sent to Paris, Mr. Pentland thought he could recognize a species of Halmaturus exceeding in size the largest living kangaroo.†

These facts are full of interest, for they prove that the peculiar type of organization which now characterizes the marsupial tribes has prevailed from a remote period in Australia, and that in that continent, as in Europe, North and South America, and India, some species of mammalia have become extinct. It also appears, although the evidence on this point is still incomplete, that among the extinct were land quadrupeds far exceeding in magnitude any of the wild animals now inhabiting New Holland.‡

Newer Pliocene Alluviums. — Some writers have attempted to introduce into their classification of geological periods an *alluvial epoch*, as if the transportation of loose matter from one part of the surface of the land to another had been the work of one particular period.

With equal propriety might they have endeavoured to institute a volcanic period, or a period of marine or fresh-water deposition; for alluvial formations must

* Mr. Clift, Ed. New Phil. Journ., No. xx. p. 394. Major Mitchell, Proceedings of Geol. Soc., 1831, p. 321.

† Journ. de Géologie, tome iii. p. 291. The bone mentioned as that of an *elephant*, by Mr. Pentland, was the same large bone alluded to by Mr. Clift.

‡ For remarks on the mode in which these caverns may have been filled with osseous breccias, see p. 152.

have originated in every age*, since the surface of the earth was first divided into land and sea, but most rapidly in any given district at those periods when land has been upheaved above, or depressed below, its former level.

If those geologists who speak of an "alluvial epoch" intend merely to say that a great part of the European alluviums are *tertiary*, there may undoubtedly be some truth in the opinion; for the larger part of the existing continent of Europe has emerged from beneath the waters during some one or other of the tertiary periods †; and it is probable, that even those districts which were land before the commencement of the tertiary epoch, may have shared in the subterranean convulsions by which the levels of adjoining countries have since been altered. During such subterranean movements new alluviums might be formed in great abundance, and those of more ancient date so modified as to retain scarcely any of their original distinguishing characters.

During the gradual rise of a large area, first from beneath the waters, and then to a great height above them, several kinds of superficial gravel must be formed and transported from one place to another. When the first islets begin to appear, and the breakers are foaming upon the new-raised reefs, many rocky fragments are torn off and rolled along the bottom of the sea.

Let the reader recall to mind the action of the tides and currents off the coast of Shetland ‡, where blocks of granite, gneiss, porphyry, and serpentine,

* See definition of alluvium, p. 146.

† See map, Vol. I. p. 209.

‡ See Vol. I. p. 383.

of enormous dimensions, are continually detached from wasting cliffs during storms, and carried in a few hours to a distance of many hundred yards from the parent rocks. Suppose the floor of the ocean, after being thus strewed over with detached blocks and pebbles, to be converted partially into land; the geologist might then, perhaps, search in vain for the masses from which the fragments were originally derived, since part of these may have been consumed by the waves, and the rest may remain submerged beneath them.

If this new land be then uplifted to a considerable height, the marine alluvium before alluded to would be raised up on the summits of the hills and on the surface of elevated platforms. It might still constitute the general covering of the country, being wanting only in such valleys and ravines as may have been caused by earthquakes, or excavated by the power of running water during the rise of the land; for the alluvium in those more modern valleys would consist partly of pebbles washed out of the older gravel before mentioned, but chiefly of fragments derived from the rocks which were removed during the erosion of the valleys themselves.

Erratic blocks.—Blocks of extraordinary magnitude have been observed at the foot of the Alps, and at a considerable height in some of the valleys of the Jura, exactly opposite the principal openings by which great rivers descend from the Alps. These fragments have been called "erratic," and many imaginary causes have been invented to account for their transportation. Some have talked of chasms opening in the ground immediately below, and of huge fragments having been cast out of them from the bowels of the

earth. Others have referred to the deluge, an agent in which a simple solution is so often found of every difficult problem exhibited by alluvial phenomena; and more recently, the sudden rise of mountain-chains has been introduced as a cause which may have given rise to diluvial waves, capable of devastating whole continents, and drifting huge blocks from one part of the earth's surface to another.

It seems necessary to suppose that the Jura once formed a prolongation of the Alps, and that large fragments of rock were, at a remote period, detached from the Alpine summits, and transported to lower hills or platforms, which were destined afterwards to be upraised and to form the independent chain now called the Jura. Ice, as has been often suggested, may have contributed its aid to the transfer of such blocks; for some of the masses are so enormous, that not even a flood like that in the valley of Bagnes, in 1818*, can be supposed to have conveyed them to considerable distances by the power of water alone.

That the Alps must have been moved and shaken by earthquakes at periods comparatively modern, is evident from the fact that they are skirted on their northern, southern, and eastern flanks by marine tertiary strata. When these were raised into their present position, to the height of many hundred feet above the sea, the whole of the older chain must have participated in the convulsions.

It is important, therefore, to consider what would now happen if regions like that of Mont Blanc were subjected to earthquakes. Large fragments of rock, detached by the action of rain and frost from the

* See Vol. I. p. 280.

peaks, or "needles," as they are called, of Chamouni, fall annually on the surface of the glaciers, and are gradually transported by ice to the distance of many leagues into the valleys below.* The shock of an earthquake would throw down a prodigious load of similar but far heavier masses, accompanied by avalanches of snow and ice, by which the moraine of the glacier would be greatly enlarged. If the shocks took place on the eve of a thaw in spring, when the accumulated snows of winter were beginning to melt, they would cause almost every where immense avalanches, by which many narrow gorges might be choked up, so that the valleys above such barriers of snow, ice, and rock would be converted into lakes. Portions of the rent glaciers, moreover, would at their lower extremities be covered with water, and might be floated off together with incumbent and included fragments of rock. At length, on the bursting of the temporary barrier, the whole mass of waters, together with huge rocks buoyed up by ice, would descend with tremendous violence into the lower country.

Sicily. — Assuming, then, that almost all the European alluviums are tertiary, we have next to inquire which of them are of newer Pliocene origin. It is clear that, when a district, like the Val di Noto, is composed of rocks of this age, all the alluvium upon the surface must necessarily belong either to the newer Pliocene or the Recent epoch. If, therefore, the elevation of the mountains of the Val di Noto was chiefly accomplished antecedently to the recent epoch, we must at once pronounce all alluviums, in

* See Vol. I. p. 255.

the position indicated at *a*, diagram No. 77. (p. 415.), to belong to the newer Pliocene era. I saw gravel so situated at Grammichele in Sicily, and was informed that it contained the bones of the mammoth.

END OF THE THIRD VOLUME.

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