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 varying—Causes which occasion this transference of the places of sedimentary deposition—Denudation augments the discordance in 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.

DIFFERENT CIRCUMSTANCES UNDER WHICH THE SECONDARY AND TERTIARY FORMATIONS MAY HAVE ORIGINATED.

We 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 described in the last chapter.

It is evident that large parts of Europe were simultaneously submerged beneath the sea when different portions of the secondary series were formed, because we find homogeneous mineral masses, including the remains of marine animals, referrible to the secondary period, extending over great areas; whereas the detached and isolated position of 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 subaqueous character in different parts of the vast area.

It is evident that, during such a state of a certain quarter of the globe, beds of 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 would 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; 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 strata distinguished by marked peculiarities of mineral composition. The organic remains would also be more varied, for in one locality fresh-water species would be imbedded, as in 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 Azof, 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, fresh-water, 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 great catastrophes, out of the ordinary course of nature, and sudden revolutions of the globe.

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 re-consider many of the topics treated of in our two former volumes, 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

largest 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, while the effects of vegetation have, as we have shown, only a conservative tendency, being very rarely instrumental in adding new masses of mineral matter to the surface of emerged lands; and when he also reflects 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, probably receives no new deposits whatever, being covered for ages with the clear blue waters uncharged with sediment. Here the relics of organic beings, lying in the ooze of the deep, may decompose like the leaves of the forest in autumn, and leave no wreck behind, but merely supply 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 we pointed out in the last volume, 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 we 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 more abrupt transition from one group to another; as, for example, in a gulf like that of the St. Lawrence, where 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 there are currents which 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 transverse 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 we 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 most frequent where subterranean movements alter, from time to time, the levels of land, and they must be immense 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.

We 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, 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 three hundred feet below the level of the ocean. The whole area might thus suddenly become the receptacle 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 contorted to any amount. If the movement entirely cease 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 immense 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 everywhere 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.

We endeavoured to show, in the last volume, 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 be found 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. Hence, from all the foregoing premises, it would follow, that the change of species would be in simultaneous operation everywhere 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 we 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 our idea of the working of this machinery, let us 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 after 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 two consecutive registers.

There are undoubtedly some other causes besides the mere quantity of time which may augment or diminish the amount of discrepancy. Thus, for example, at some periods a pestilential disease may lessen the average duration of human life, or a variety of circumstances may cause the births to be unusually numerous, and the population to multiply, or, a province may be suddenly colonized by persons migrating from surrounding districts.

We must also remind the reader, that we do not propose the above case as an exact parallel to those geological phenomena which we 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 frequent distinctness of the fossil remains, in formations immediately in contact, would be a necessary consequence of the existing laws of

sedimentary deposition, accompanied by the gradual birth and death of species.

We 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 forth, 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 over a wide area, the upper being undisturbed, there is usually a considerable discordance in the organic remains of the two groups; but this coincidence must not be ascribed to the agency of the disturbing forces, as if they had exterminated the living inhabitants of the surface. The immense *lapse of time* required for the development of so great a series of subterranean movements, has in these cases allowed the species also throughout the globe to vary, and hence the two phenomena are usually concomitant.

Although these inferences appear to us very obvious, we are aware that they are directly opposed to many popular theories respecting catastrophes; we shall, therefore, endeavour to place our views in a still clearer light before the reader. 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 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.*