CHAPTER IX.

Origin of the newer Pliocene strata of Sicily—Growth of submarine formations gradual—Rise of the same above the level of the sea probably caused by subterranean lava—Igneous newer Pliocene rocks, formed at great depths, exceed in volume the lavas of Etna—Probable structure of these recent subterranean rocks—Changes which they may have superinduced upon strata in contact—Alterations of the surface during and since the emergence of the newer Pliocene strata—Forms of the Sicilian valleys—Sea cliffs—Proofs of successive elevation—Why the valleys in the newer Pliocene districts correspond in form to those in regions of higher antiquity—Migrations of animals and plants since the emergence of the newer Pliocene strata—Some species older than the stations they inhabit—Recapitulation.

ORIGIN OF THE NEWER PLIOCENE STRATA OF SICILY.

HAVING in the last two chapters described the tertiary formations of the Val di Noto and Valdemone, both igneous and aqueous, we 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 shall inquire in what manner the submarine formations were accumulated beneath the waters; secondly, whether they emerged slowly or suddenly, and what modifications in the earth's crust, at considerable depths below the surface, may be indicated by their rise; 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 we have but few observations to make, for by reference to our former volumes, 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 therein. He will also understand how one sheet of lava, or 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 may 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, an immense 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 Bhooi. We have also seen *, that when the Monte Nuovo was thrown up, in the year 1538, a large fissure ap-

* Vol. i. chap. xix.

proached 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. We have shown 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 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.

Subterranean lava the upheaving cause.—The only feasible theory, indeed, that has yet been proposed, respecting the causes of the permanent rise of the bed of the sea, is that which refers the phenomenon to the generation of subterranean lava. We have stated, in the first volume, that the regions now habitually convulsed by earthquakes, include within them the site of all the active volcanos. We know that the expansive force of

* Vol. i. chap. xxv.

volcanic heat is sufficiently great to overcome the resistance of columns of lava, several miles or leagues in height, forcing them up from great depths, and causing the fluid matter to flow out upon the surface. To imagine, therefore, that this same power, which is so frequently exerted in different parts of the globe, should occasionally propel a column of lava to a considerable height, yet be unable to force it through the superincumbent rocks, is quite natural.

Whenever the superimposed masses happen to be of a yielding and elastic nature, they will bend, and instead of breaking, so as to afford an escape to the melted matter through a fissure, they will allow it to accumulate in large quantities beneath the surface, sometimes in amorphous masses, and sometimes in horizontal sheets. So long as such sheets of matter retain their fluidity, and communicate with the column of lava which is still urged upwards, they must exert an enormous hydrostatic pressure on the overlying mass, tending to elevate it, and an equal force on the subjacent beds pressing them down, and probably rendering them more compact. If we consider how great is the volume of lava that sometimes flows out on the surface from volcanic vents, we must expect that it will produce great changes of level so often as its escape is impeded.

Let us only reflect on the magnitude of Iceland, an island two hundred and sixty miles long by two hundred in breadth, and which rises, at some points, to the height of six thousand feet above the level of the sea. Nearly the entire mass is represented to be of volcanic origin; but even if we suppose some parts to consist of aqueous deposits, still that portion may be more than compensated by the great volume of lava which must have been poured out upon the bottom of the surrounding sea during the growth of the entire island; for we know that submarine eruptions have been considerable near the coast during the historical era. Now if the whole of this lava had been prevented from reaching the surface, by the weight and tenacity of certain overlying rocks, it might have given rise to the gradual elevation of a tract of land nearly as large as Iceland. We say *nearly*, because the lava which cooled down beneath the surface, and under considerable pressure, would be more compact than the same when poured out in the open air, or in a sea of moderate depth, or shot up into the atmosphere by the explosive force of elastic vapours, and thus converted into sand and scoriæ.

According to this theory, we must suppose the action of the upheaving power to be intermittent, and, like ordinary volcanic eruptions, to be reiterated again and again in the same region, at unequal intervals of time and with unequal degrees of force.

If we follow this train of induction, which appears so easy and natural, to what important conclusions are we led! The reader will bear in mind that the tertiary strata have attained in the central parts of Sicily, as at Castrogiovanni, for example, an elevation of about three thousand feet above the level of the sea, and a height of from fifty to two thousand feet in different parts of the Val di Noto. In this country, therefore, we must suppose a solid support of igneous rock to have been successively introduced into part of the earth's crust immediately subjacent, equal in volume to the upraised tract, and this generation of subterranean rock must have taken place during the latter part of the newer Pliocene period. The dimensions of the Etnean cone shrink into insignificance, in comparison to the volume of this subterranean lava; and, however staggering the inference might at first appear, that the oldest foundations of Etna were laid subsequently to the period when the Mediterranean became inhabited by the living species of testacea and zoophytes, yet we may be reconciled to such conclusions, when we find incontestable proofs of still greater revolutions beneath the surface within the same modern period.

Probable structure of the recent subterranean rocks of fusion.—Let us now inquire what form these unerupted newer Pliocene lavas of Sicily have assumed? For reasons already explained, we may infer that they cannot have been converted into tuffs and peperinos, nor can we imagine that, under enormous pressure, they could have become porous, since we observe, that the lava which has cooled down under a moderate degree of pressure, in the dikes of Etna and Vesuvius, has a compact and porphyritic texture, and is very rarely porous or cellular. No signs of volcanic sand, scoriæ, breccia, or conglomerate are to be looked for, nor any of stratification, for all these imply formation in the atmosphere, or by the agency of water. The only proofs that we can expect to find of the *successive* origin of different parts of the fused mass, will be confined to the occasional passage of veins through portions previously consolidated. This consolidation would take place with extreme slowness, when nearer the source of volcanic heat and under enormous pressure, so that we must anticipate a perfectly crystalline and compact texture in all these subterranean products.

Now geologists have discovered, as we before stated, great abundance of crystalline and unstratified rocks in various parts of the globe, and these masses are particularly laid open to our view in those mountainous districts where the crust of the earth has undergone the greatest derangement. These rocks vary considerably in composition, and have received many names, such as granite, syenite, porphyry, and others. That they must have been formed by igneous fusion, and at many distinct eras, is now admitted; and their highly crystalline texture is such as might result from cooling down slowly from an intensely-heated state. They answer, therefore, admirably to the conditions required by the above hypothesis, and we therefore deem it probable that similar rocks have originated in the nether regions below the island of Sicily, and have attained a thickness of from one thousand to three thousand feet, since the newer Pliocene strata were deposited.

It is, moreover, very probable, that these fused masses have come into contact with subaqueous deposits far below the surface, in which case they may, in the course of ages, have greatly altered their structure, just as dikes of lava render more crystalline the stratified masses which they traverse, and obliterate all traces of their organic remains.

Suppose some of these changes to have been superinduced upon subaqueous deposits underlying the tertiary formations of Sicily, it is important to reflect that in that case no geological proofs would remain of the era when the alterations had taken place; and if, at some future period, the whole island should be uplifted, and these rocks of fusion, together with the altered strata, should be brought up to the surface, it would not be apparent that they had assumed their crystalline texture in the newer Pliocene period. For aught that would then appear, they might have acquired their peculiar mineral texture at epochs long anterior, and might be supposed to have been formed before the planet was inhabited by living beings; instead of having originated at an era long subsequent to the introduction of the *existing species*.

CHANGES OF THE SURFACE DURING AND SINCE THE EMERGENCE OF THE NEWER PLIOCENE STRATA.

Valleys.—Geologists who are accustomed to attribute a great portion 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 many 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. 23). In the south of

No. 23.

Valley called Gozzo degli Martiri, below Melilli.

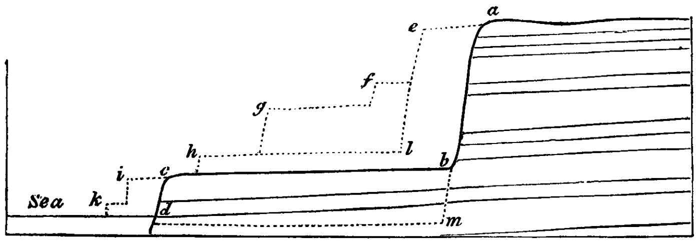
the island, as near Spaccaforno, Scicli and Modica, precipitous rocks of white limestone, ascending to the height of five hundred feet, have been carved out into the same form.

A careful examination of the mode of decomposition of the rock would be requisite, in order fully to explain this phenomenon. There is probably a tendency to a vertical fracture in this as in many other limestones, which, when exposed to the action of frost, scale off in small fragments at right angles to the plane of stratification. It might have been expected that, in this case, a talus composed of a breccia of the limestone would be found on each ledge, so that the slope would become gradual, but perhaps the fragments, instead of accumulating, may decompose and be washed away by the heavy rains.

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 before mentioned, terminates suddenly towards the sea in a lofty precipice, *a*, *b*, which varies in height from five

No. 24.



hundred to seven 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 must 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 fifty others, for the encroachment of the sea tends to obliterate all signs of a *succession* of cliffs.

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 had time to advance along the line *c, b*, all those ancient cliffs must then have been swept away one after the other, and reduced to the single precipice *a, b*. There may have been an antecedent period when the sea advanced along the line *h, l*, substituting the single cliff *e, l*, for the series *e, f, g*.

We may also imagine that the present cliffs may be the result of the union of several lines of smaller cliffs and terraces, which may once have been produced by a succession of elevatory movements. For example, the waves may have carried away the cliffs *k, i*, in advancing to *c, d*. In the same manner they may ultimately remove the mass *c, b, m, d*, and then the platform *c, b*, will disappear, and the precipice *a, m*, will be substituted for *a, b*.

We have stated, in the first volume, that the waves washed the base of the inland cliff near 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 an elevation 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 to resume its former position, when the terrace will be destroyed, and every trace of the *successive* rise of the land will be obliterated.

We 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 the hypothesis of the successive elevation of the country by the intermittent action of ordinary earthquakes *. On the other hand, we consider the magnitude of the valleys, and their correspondence in form with those of other parts of the globe, to lend countenance to the theory of the slow and gradual rise of subaqueous strata.

We have remarked in the first volume †, that the excavation of valleys must always proceed with the greatest rapidity when the levels of a country are undergoing alteration from time to time by earthquakes, and that 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 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 then continue 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 val-

* Since writing the above I have read the excellent memoir of M. Boblaye, on the alterations produced by the sea on calcareous rocks on the shores of Greece. By examining the line of littoral caverns worn by the waves in cliffs composed of the harder limestones, together with the modes of decomposition of the rock, acted upon by the spray and sea air, as well as lithodomous perforations, and other markings, he has proved that there are four or five distinct ranges of ancient sea cliffs, one above the other, at various elevations in the Morea, which attest as many *successive* elevations of the country. Journal de Géologie, No. 10. Feb. 1831.

† Chap. xxiv.

leys by rivers and land-floods would proceed in the same manner as in modern times in Calabria, according to our former description *.

Before a tract could be upraised to the height of several thousand feet above the level of the sea, the joint operation of running water and subterranean movements must greatly modify the 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.

In other words, the time required for the raising of a mass of land to the height of several hundred yards must usually be so enormous (assuming as we do that the operation is effected by ordinary volcanic forces), that the aqueous and igneous agents will have time before the elevation is completed to modify the surface, and imprint thereon the ordinary forms of hill and valley, by which our continents are diversified. But after the cessation of earthquakes these causes of change will remain dormant, or nearly so. The greater part, therefore, of the earth's surface will at each period be at rest, simply retaining the features already imparted to it, while smaller tracts will assume, as they rise successively from the deep, a configuration perfectly analogous to that by which the more ancient lands were previously distinguished.

Migration of animals and plants.—The changes which, according to the views already explained, have been brought about in the earth's crust by the agency of volcanic heat, cannot fail to strike the imagination, when we consider how recent in the calendar of nature is the epoch to which we refer them. But if we turn our thoughts to the organic world, we shall feel,

* Chap. xxiv.

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 with 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

* 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.

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 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 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.—We may now briefly recapitulate some of the most striking results which we have deduced from our investigation of a single district where the newer Pliocene strata are largely developed.

In the first place, we have seen 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 thousand or three

* See vol. ii., chapters v., vi., and vii.

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. The most probable hypothesis in regard to the nature of this change, is the successive generation and forcible intrusion into the inferior parts of the earth's crust of lava which, after cooling down, may have assumed the form of crystalline unstratified rock, such as is frequently exhibited in those mountainous parts of the globe where the greatest alterations of level have taken place.

6thly. Great 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 the whole or the greater part of their present altitude, while there are some proofs of distinct 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.