CHAPTER X.

Tertiary formations of Campania—Comparison of the recorded changes in this region with those commemorated by geological monuments—Differences in the composition of Somma and Vesuvius—Dikes of Somma, their origin—Cause of the parallelism of their opposite sides—Why coarser grained in the centre—Minor cones of the Phlegræan Fields—Age of the volcanic and associated rocks of Campania—Organic remains—External configuration of the country, how produced—No signs of diluvial waves—Marine Newer Pliocene strata visible only in countries of earthquakes—Illustrations from Chili—Peru—Parallel roads of Coquimbo—West-Indian archipelago—Honduras—East-Indian archipelago—Red Sea.

TERTIARY FORMATIONS OF CAMPANIA.

Comparison of recorded changes with those commemorated by geological monuments.—In the first volume we traced the various changes which the volcanic region of Naples is known to have undergone during the last 2000 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, we enumerated the production of several new minor cones in Ischia, and of the Monte Nuovo, in the year 1538. We described the flowing of lava-currents upon the land and along the bottom of the sea, 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. We 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 20 feet. In connexion with these convulsions, we 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, we shall be told, 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 500 to more than 2000 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 20 or 30 feet above their former level, but extensive and mountainous countries were uplifted to an elevation of more than 1000 feet, and at some points more than 2000 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 of striking architectural beauty seems an effort of superhuman power, until we reflect on the innumerable minute parts of which it is composed. 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, and 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 we shall afterwards show that there are sufficient grounds for presuming this mountain, and the other igneous products of Campania, to have been produced during the Newer Pliocene period.

We stated in the first volume *, that the ancient and modern cones of Vesuvius were each a counterpart of the other in structure; we may now remark that the principal point of difference consists in the greater abundance in the older cone of fragments of stratified 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 sedimentary 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 angular fragments of solid rock which abound in the tufaceous breccias of Somma, none are more common than a saccharoid dolomite, supposed to have been derived

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from an ordinary limestone altered by heat and volcanic vapours.

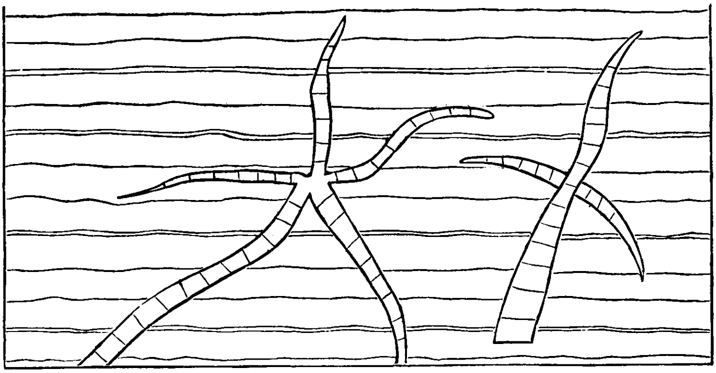
Carbonate of lime enters into the composition of so many of the simple minerals found in Somma, that M. Mitscherlich, with much probability, ascribes their great variety to the action of the volcanic heat on subjacent masses of limestone.

Dikes of Somma.—The dikes seen in the great escarpment which Somma presents towards the modern cone of Vesuvius are very numerous. They are 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 woodcut No. 19), being, like them, extremely compact, and less destructible than the intersected tuffs and porous lavas. In height they vary from a few yards to 500 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. We 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.

* 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. i. chap. xx.

No. 25.



Dikes or veins at the Punto del Nasone on Somma.

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 pane of glass. If we suppose the side walls of the ancient crater of Vesuvius to have been cracked in 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, we 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 they 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

* See vol. i. chap. xxiv., wood-cut No. 22.

† From a drawing of M. Necker, ibid.

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 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 flows 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.

We 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

* Phil. Trans., vol. lxx. 1780.

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 coarser 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 column of melted matter in a fissure greatly exceeds an ordinary stream of lava in weight, and the great 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

* See wood-cut No. 25.

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 cone was raised above the water, may have remained in a loose state *.

Age of the volcanic and associated rocks of Campania.—If we enquire 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 Ischia I collected marine shells in beds of clay and tuff, not far from the summit of Epomeo, or San Nichola, about 2000 feet above the level of the sea, as also at another locality, about 100 feet below, on the southern declivity of the mountain, and others 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 points I obtained, during a short excursion in Ischia, 28 species of shells, all of which, with one exception, were identified by M. Deshayes with recent species ‡.

As the highest parts of Epomeo are composed of regularly-stratified greenish tuff, and some beds near the summit contain the fossils above-mentioned, it is clear that that mountain 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 re-

* Geol. Trans., vol. ii. part iii. p. 351. Second Series.

† Scrope, ibid.

‡ See the list of these shells, Appendix II.

sulted 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. We may observe generally of these submarine tuffs, lavas, and clays, of Campania, that they strictly 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 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 1000 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 long 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 us 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 4000 or 5000 years, a long strip of land, skirting the line of our eastern

* See vol. i. p. 457, first edition; p. 527, second edition.

coast, will be devoured by the ocean, while part of the interior, immediately adjacent, will remain at rest and entirely undisturbed. The 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 2000 years, at the height of more than 9000 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 blown into the air, and again renewed; the earth has sunk down in the neighbouring Cisterna *; the cones of 1811 and 1819 have started up, on the ledge of rock below, pouring out of their craters two mighty streams of lava; the watery deluge of 1755 has rushed down from the steep desert region, into the Val del Bove, rolling along vast heaps of rocky fragments towards the sea; fissures, several miles in length, have opened on the flanks of Etna; cities and villages have been shattered by partial earthquakes, or buried under lava and ashes;—yet the tower has stood as if placed on the most perilous point in Europe, to commemorate the stability of one part of the earth's surface, while others in immediate proximity have been subject to most wonderful and terrific vicissitudes.

Marine Newer Pliocene strata only visible in countries of earthquakes.—In concluding what we have to say of the marine and volcanic formations of the newer Pliocene period, we may notice the highly interesting fact, that the marine strata of this era have hitherto been found at great elevations in those countries only where violent earthquakes have occurred during the historical ages. We do not deny that some *partial* deposits containing recent marine shells have been discovered at a considerable height in several maritime countries in Europe and elsewhere, far from the existing theatres of volcanic action; but stratified deposits of great extent and thickness, and replete with recent species, have only been observed to enter largely into the

* See above, p. 96.

structure of the interior, as in Sicily, Calabria, and the Morea, where subterranean movements are now violent. 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 great earthquakes, which has not, when carefully investigated, yielded traces of marine strata, either of the Recent or newer Pliocene eras, at considerable elevations.

Chili.—Conception Bay.—In illustration of the above remarks we 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 we 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. We have endeavoured to show that one earthquake raised this part of the Chilian coast, in 1750, to the height of at least 25 feet above its former level. If we could suppose a continued series of such shocks, 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 we cannot assume that the micaceous sand may not belong to the Recent period, we think it more probable that it was deposited during the newer Pliocene period.

Peru.—We are informed by Mr. A. Cruckshanks, 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 greenstone 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

* Vol. i. chap. xxv.

rounded blocks. One of these cliffs appears in the hill behind Baños del Pujio, about 700 feet above the level of the sea, and 200 above the contiguous valley. Another occurs at Amancaes, at the height of perhaps 200 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 20 to 50 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, and a lower one which is indistinct when approached, but when viewed from a distance is evidently of the same character with the others. 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 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

* Captain Hall's South America, vol. ii. p. 9.

† See Sir T. D. Lauder, Ed. Roy. Soc. Trans., vol. ix., and Dr. Macculloch, Geol. Trans., 1st Series, vol. iv. p. 314.

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.*'

We 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 successive rise of the land, not to the repeated fall of the waters of a lake. We have before cited the proofs adduced by M. Boblaye, that in the Morea there are four or five ranges of ancient sea-cliffs, one above the other, at various elevations, where limestone precipices exhibit lithodomous perforations and lines of ancient littoral caverns *. If we discover 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 comparatively 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 hastily embraced by a certain school of geologists.

West Indian Archipelago.—According to the sketch given by Maclure of the geology of the Leeward Islands †, the

* See above, p. 113. † Quart. Journ. of Sci., vol. v. p. 311.

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 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 1500 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.

We 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 30 species examined by M. Deshayes from this rock 28 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. We expect, 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 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.

We shall conclude by enumerating a few exceptions to the rule above illustrated—instances of elevation where no great earthquakes have been recently experienced.

* Geol. Trans., Second Series, vol. i. part ii. p. 397.

† MS. of Captain B. Hall.

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 50 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 200 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.

Uddevalla.—The ancient beaches of the Norwegian and Swedish coasts, described in the first volume †, in which the shells are of living species, present more marked exceptions as being farther removed from any line of recent convulsion. They afford evidence of a rise of 200 feet or more of parts of those coasts during the newer Pliocene, if not the Recent epoch.

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. I have been favoured with a list of

* I examined this locality in company with Mr. Murchison in 1828.

† Chap. xiii. ‡ See description of the map, vol. ii.

these shells, which will be found in Appendix II.* The volcano of Gabel Tor, situate at the entrance of the Arabian gulf, is the nearest volcanic region known to us at present.

We should guard the reader against inferring, from the facts above detailed, that marine strata of the newer Pliocene period have been produced exclusively in countries of earthquakes. If we have drawn our illustrations exclusively from modern volcanic regions, it is simply for this reason, that these formations have been made visible to us 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.

We believe, however, that to a certain limited extent the growth of new subaqueous deposits has been greatest where igneous and aqueous causes have co-operated. It is there, as we have explained in former chapters, 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 †.

* These fossils are now in the museum of Mr. Greenough, in London, and duplicates, presented by him, in the cabinets of the Geological Society.

† See vol. i. chap. xxiv.; and vol. ii. chap. xviii.