CHAPTER XXII.

Volcanic Archipelagos—The Canaries—Eruptions of the Peak of Teneriffe—Conesthrown up in Lancerote in 1730-36—Pretended distinction between ancient and modern lavas—Recent formation of oolitic travertine in Lancerote—Grecian Archipelago—Santorin and its contiguous isles—Von Buch's Theory of "Elevation Craters" considered—New islands thrown up in the Gulf of Santorin—Supposed "Crater of Elevation" in the Isle of Palma—Description of the Caldera of Palma—Barren island in the Bay of Bengal—Origin of the deep gorge on the side of "Elevation Craters"—Stratification of submarine volcanic products—Causes of the great size of the craters of submarine volcanos—Cone of Somma, formed in the same manner as that of Vesuvius—Mineral composition of volcanic products—Speculations respecting the nature of igneous rocks produced at great depths, by modern volcanic eruptions.

In our chronological sketch of the changes which have happened within the traditionary and historical period in the volcanic district round Naples, we described the renewal of the fires of a central and habitual crater, and the almost entire cessation of a series of irregular eruptions from minor and independent vents. Some volcanic archipelagos offer interesting examples of the converse of this phenomenon, the great habitual vent having become almost sealed up, and eruptions of great violence now proceeding, either from different points in the bed of the ocean, or from adjoining islands, where, as formerly in Ischia, new cones and craters are formed from time to time. Of this state of things the Canary Islands now afford an example.

The highest crater of the Peak of Teneriffe has been in the state of a solfatara ever since it has been known to Europeans; but several eruptions have taken place from the sides of the mountain, one in the year 1430, which formed a small hill, and another in 1704 and the two following years, accompanied with great earthquakes, when the lava overflowed a town and harbour. Another eruption happened in June, 1798, not far from the summit of the peak. But these lateral emissions of lava, at distant intervals, may be considered as of a subordinate

kind, and subsidiary to the great discharge which has taken place in the contiguous isles of Palma and Lancerote; and the occasional activity of the peak may be compared to the irregular eruptions before mentioned, of the Solfatara, of Arso in Ischia, and of Monte Nuovo, which have broken out since the renewal of the Vesuvian fires in 79.

We shall describe one of these insular eruptions in the Canaries, which happened in Lancerote, between the years 1730 and 1736, as the effects were remarkable; and Von Buch had an opportunity, when he visited that island in 1815, of comparing the accounts transmitted to us of the event, with the present state and geological appearances of the country*. On the 1st of September, 1730, the earth split open on a sudden two leagues from Yaira. In one night a considerable hill of ejected matter was thrown up, and a few days later, another vent opened and gave out a lava-stream, which overran Chinanfaya and other villages. It flowed first rapidly, like water, but became afterwards heavy and slow, like honey. On the 7th of September an immense rock was protruded from the bottom of the lava, with a noise like thunder, and the stream was forced to change its course, from N. to N.W., so that St. Catalina, and other villages, were overflowed. Whether this mass was protruded by an earthquake or was a mass of ancient lava, blown up like that before mentioned, in 1783, in Iceland, is not explained. On the 11th of September more lava flowed out and covered the village of Maso entirely, and, for the space of eight days, precipitated itself with a horrible roar into the sea. Dead fish floated on the waters in indescribable multitudes, or were thrown dying on the shore. After a brief interval of repose, three new openings broke forth, immediately from the site of the consumed St. Catalina, and sent out an enormous quantity of lapilli, sand, and ashes. On the 28th of October, the cattle throughout the whole country dropped lifeless to the ground, suffocated by putrid vapours, which condensed and fell down in drops. On the 1st of December, a lava-stream reached the sea, and formed an island, round which dead fish were strewed.

It is unnecessary here to give the details of the overwhelm-

* This account was principally derived by Von Buch from the MS. of Don Andrea Lorenzo Curbeto, Curate of Yaira, the point where the eruption began. Uber einen vulcanisch. Ausbruch auf der Insel Lanzerote.

ing of other places by fiery torrents, or of a storm which was equally new and terrifying to the inhabitants, as they had never known one in their country before. On the 10th of January, 1731, a high hill was thrown up, which, on the same day, precipitated itself back again into its own crater: fiery brooks of lava flowed from it to the sea. On the 3rd of February a new cone arose. Others were thrown up in March, and poured forth lava-streams. Numerous other volcanic cones were subsequently formed in succession, till at last their number amounted to about thirty. In June, 1731, during a renewal of the eruptions, all the banks and shores in the western part of the island were covered with dying fish, of different species, some of which had never before been seen. Smoke and flame arose from the sea, with loud detonations. These dreadful commotions lasted without interruption for *five successive years*, and a great emigration of the inhabitants became necessary.

As to the height of the new cones, Von Buch was assured that the formerly great and flourishing St. Catalina lay buried under hills 400 feet in height; and he observes, that the most elevated cone of the series rose 600 feet above its base, and 1378 feet above the sea, and that several others were nearly as high. The new vents were all arranged *in one line*, about two geographical miles long, and in a direction nearly east and west. If we admit the probability of Von Buch's conjecture, that these vents opened along the line of an open cleft, it seems necessary to suppose, that this subterranean fissure was only prolonged upwards to the surface by degrees, or that the rent was narrow at first, as is usually the case with fissures caused by earthquakes. Lava and elastic fluids might escape from some point on the rent where there was least resistance, till the first aperture becoming obstructed by ejections and the consolidation of lava, other orifices burst open in succession, along the line of the original fissure. Von Buch found that each crater was lowest on that side on which lava had issued; but some craters were not breached, and were without any lava-streams. In one of these were open fissures, out of which hot vapours rose, which in 1815 raised the thermometer to 145° Fahrenheit, and was probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour, yet they could not be pure steam, for the crevices were encrusted on

either side by siliceous sinter, (an opal-like hydrate of silica, of a white colour,) which extended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and how open fissures may be filled up laterally by mineral matter, sublimed from volcanic exhalations. The lavas of this eruption covered nearly a third of the whole island, often forming on slightly inclined planes great horizontal sheets several square leagues in area, resembling very much the basaltic plateaus of Auvergne.

One of the new lavas was observed to contain masses of olivine of an olive-green colour, resembling those which occur in one of the lavas of the Vivarais. Von Buch supposes the great crystals of olivine to have been derived from a previously existing basalt, melted up by the new volcanos, but sufficient data are not furnished for warranting such a conjecture. The older rocks of the island consist, in a great measure, of that kind of basaltic lava called dolerite, sometimes columnar, and of common basalt and amygdaloid. Some recent lavas assumed, on entering the sea, a prismatic form, and so much resembled the older lavas of the Canaries, that the only geological distinction which Von Buch appears to have been able to draw between them was, that they did not alternate with conglomerates, like the ancient basalts. Some modern writers have endeavoured to discover in the abundance of these conglomerates, a proof of the dissimilarity of the volcanic action in ancient and modern times; but this character is more probably attributable to the difference between submarine operations and those on the land. All the blocks and imperfectly rounded fragments of lava, transported, during the intervals of eruption by rivers and torrents, into the adjoining sea, or torn by the continued action of the waves from cliffs which are undermined, must accumulate in stratified breccias and conglomerates, and be covered again and again by other lavas. This is now taking place on the shores of Sicily, between Catania and Trezza, where the sea breaks down and covers the shore with blocks and pebbles of the modern lavas of Etna; and on parts of the coast of Ischia, where numerous currents of trachyte are in like manner undermined in lofty precipices. So often then as an island is raised in a volcanic

archipelago, by earthquakes from the deep, the fundamental and (relatively to all above) the oldest lavas will often be distinguishable from those formed by subsequent eruptions on dry land, by their alternation with beds of sandstone and fragmentary rocks. The supposed want of identity then between the volcanic phenomena of different epochs resolves itself into the marked difference between the operations simultaneously in progress, above and below the water. Such, indeed, is the source, as we stated in our fifth chapter, of many of our strongest theoretical prejudices in geology. No sooner do we study and endeavour to explain submarine appearances, than we feel, to use a common expression, *out of our element;* and unwilling to concede, that our extreme ignorance of processes now continually going on can be the cause of our perplexity, we take refuge in a "pre-existent order of nature."

Throughout a considerable part of Lancerote, the old lavas are covered by a thin stratum of limestone, from an inch to two feet in thickness. It is of a hard stalactitic nature, sometimes oolitic, like the Jura limestone, and contains fragments of lava and terrestrial shells, chiefly helices and spiral bulimi. Von Buch imagines, that this remarkable superstratum has been produced by the furious north-west storms, which in winter drive the spray of the sea in clouds over the whole island; from whence calcareous particles may be deposited stalactitically. If this explanation be correct, and it seems highly probable, the fact is interesting, as attesting the quantity of matter held in solution by the sea-water, and ready to precipitate itself in the form of solid rock. At the bottom of such a sea, impregnated, as in the neighbourhood of all active volcanos, with mineral matter in solution, lavas must be converted into calcareous amygdaloids, a form in which the igneous rocks so frequently appear in the older European formations. We may mention that recent crevices in the rocks of Trezza, one of the Cyclopian isles at the foot of Etna, are filled with a kind of travertine, as high as the spray of the sea reaches; and in this hard veinstone, fragments, and even entire specimens of recent shells thrown up by the waves, are sometimes included.

From the year 1736 to 1815, when Von Buch visited Lancerote, there had been no eruption; but, in August, 1824, a crater opened near the port of Rescif, and formed, by its ejec-

tions, in the space of twenty-four hours, a considerable hill. Violent earthquakes preceded and accompanied this eruption*.

Grecian Archipelago.—We shall next direct our inquiry to the island of Santorin, as it will afford us an opportunity of discussing the merits of a singular theory, which has obtained no small share of popularity in modern times, respecting "craters of elevation," (Erhebungs Cratere, Cratères de soulèvement,) as they have been termed. The three islands of Santorin, Therasia, and Aspronisi surround a gulf almost circular, and above six miles in diameter. They are chiefly composed of trachytic conglomerates and tuffs, covered with pumice; but in one part of Santorin clay-slate is seen to be the fundamental rock. The beds in all these isles

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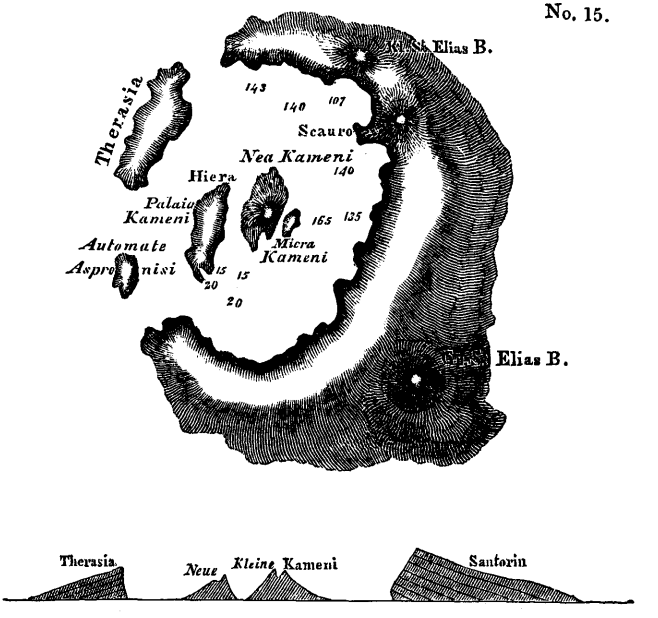


Chart and Section of Santorin and the contiguous islands in the Grecian Archipelago.

dip at a slight angle towards the exterior of the group, and lose themselves in the surrounding sea; whereas, on the con-

* Férussac, Bulletin des Sci. Nat., tome V., p. 45.—1825. The volcano was still burning when the account here cited was written.

trary, they present a high and steep escarpment towards the centre of the inclosed space. The gulf, therefore, is nearly on all sides environed by precipices; those of Santorin, which form two-thirds of the circumference, being two leagues in extent, and in some parts three hundred feet high. These rocky cliffs plunge at once into the sea, so that close to the shore soundings are only reached at a depth of eight hundred feet, and at a little distance farther at a depth of one thousand feet. In the middle of this gulf, the small isle of Hiera, now called Palaia Kameni, rose up, 144 years before the Christian era. In 1427 this isle received new accessions. In 1573 the Little Kameni was raised in the middle of the basin, its elevation being accompanied by the discharge of large quantities of pumice and a great disengagement of vapour. Lastly, in 1707 and 1709 the New Kameni was formed, which still exhales sulphureous vapours. These isles are formed of rocks of brown trachyte, which has a resinous lustre, and is full of crystals of glassy felspar. Although the birth of New Kameni was attended by an eruption, it is certain that it was upraised from a great depth by earthquakes, and was not a heap of volcanic ejections, nor of lava poured out on the spot. There were shells upon it when it first appeared; and beds of limestone and marine shells are described by several authors as entering, together with igneous rocks, into the structure of other parts of this group. In order, therefore, to explain the formation of such circular gulfs, which are common in other archipelagos, Von Buch supposes, and Humboldt adopts the same opinion, that the different beds of lava, pumice, and whatever else may be interstratified, were first horizontally disposed along the floor of the ocean. An expansive force from below then burst an opening through them, and, acting towards a central point, raised symmetrically on every side all which resisted its action, so that the uplifted strata were made to dip away on all sides from the centre outwards, as is usual in volcanic cones, while a deep hollow was left in the middle, resembling in all essential particulars an ordinary volcanic crater.

In the first instance we should inform the reader, that this theory is not founded on actual observations of analogous effects produced by the elevating forces of earthquakes, or the escape of elastic fluids in any part of the globe; for the infla-

tion from below, of the rocks in the plain of Malpais, during the eruption of Jorullo, was, as before stated, an hypothesis proposed, long after that eruption, to account for appearances which admit of a very different explanation. Besides, in the case of Jorullo, there was no great "crater of elevation" formed in the centre. All our modern analogies, therefore, being in favour of the origin of cones and craters exclusively by *eruptions*, we are entitled to scrutinize with no small severity the new hypothesis; and we have a right to demand demonstrative evidence, that known and ordinary causes are perfectly insufficient to produce the observed phenomena. Had Von Buch and Humboldt, for instance, in the course of those extensive travels which deservedly render their opinions, in regard to all volcanic operations, of high authority, discovered a single cone composed exclusively of marine or lacustrine strata, without a fragment of any igneous rock intermixed; and in the centre a great cavity, encircled by a precipitous escarpment; then we should have been compelled at once to concede, that the cone and crater-like configuration, whatever be its mode of formation, may sometimes have no reference whatever to ordinary volcanic eruptions.

But it is not pretended that, on the whole face of the globe, a single example of this kind can be pointed out. In Europe and North America thousands of square leagues of territory have been examined, composed of marine strata, which have been elevated to various heights, sometimes to more than ten thousand feet above the level of the sea, sometimes in horizontal tabular masses; in other cases with every degree of inclination, from the horizontal to the vertical. Some have been moved without great derangement, others have been rent, contorted, or shattered with the utmost violence. Sometimes large districts, at others small spaces, appear to have changed their position. Yet, amidst the innumerable accidents to which these rocks have been subject, never have they assumed that form, exactly representing a large truncated volcanic cone, with a great cavity in the centre. Are we then called upon to believe that whenever elastic fluids generated in the subterranean regions burst through horizontal strata, so as to upheave them in the peculiar manner before adverted to, they always select, as if from choice, those spots of comparatively insignifi-

cant area, where a certain quantity of volcanic matter happens to lie, while they carefully avoid purely lacustrine and marine strata, although they often lie immediately contiguous? Why on the southern borders of the Limagne d'Auvergne, where several eruptions burst through, and elevated the horizontal marls and limestones, did these freshwater beds never acquire in any instance a conical and crateriform disposition?

But let us proceed to examine some of the most celebrated examples adduced of craters of elevation. The most perfect type of this peculiar configuration is said to be afforded by the Isle of Palma; and while we controvert Von Buch's theoretical opinions, we ought not to forget how much geology is indebted to his talents and zeal, and amongst other works for his clear and accurate description of this isle *. In the middle of Palma rises a mountain to the height of four thousand feet, presenting the general form of a great cone, the upper part of which had been truncated and replaced by an enormous funnel-shaped cavity, about four thousand feet deep; and the surrounding borders of which attain, at their highest point, an elevation of seven thousand feet above the sea. The external flanks of this cone are gently inclined, and, in part, cultivated; but the bottom and the walls of the central cavity, called by the inhabitants the Caldera, present on all sides rugged and uncultivated rocks, almost completely devoid of vegetation.

No. 16.

View of the Isle of Palma, and of the Caldera in its centre.

So steep are the sides of the Caldera, that there is no path by which they can be descended; and the only entrance is by a great ravine, which, cutting through the rocks environing the

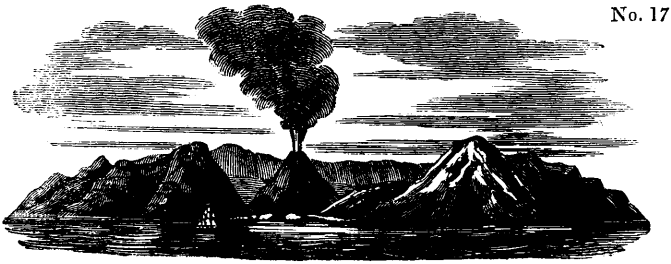
* Physical. Besch. der Canarischen Inseln. Berlin, 1825.

circus, runs down to the sea. The sides of this gorge are jagged, broken, and precipitous. In the mural escarpments surrounding the Caldera are seen nothing but beds of basalt, and conglomerates composed of broken fragments of basalt, which dip away with the greatest regularity, from the centre to the circumference of the cone. Now, according to the theory of "elevation craters," we are called upon to suppose that, in the first place, a series of horizontal beds of volcanic matter accumulated over each other, to the enormous depth of more than four thousand feet—a circumstance which alone would imply the proximity, at least, of a vent from which immense quantities of igneous rocks had proceeded. After the aggregation of the mass, the expansive force was directed on a given point with such extraordinary energy, as to lift up bodily the whole mass, so that it should rise to the height of seven thousand feet above the sea, leaving a great gulf or cavity in the middle. Yet, notwithstanding this prodigious effort of gaseous explosions, concentrated on so small a point, the beds, instead of being shattered, contorted, and thrown into the utmost disorder, have acquired that gentle inclination, and that regular and symmetrical arrangement, which characterize the flanks of a large cone of eruption, like Etna! We admit that earthquakes, when they act on extensive tracts of country, may elevate and depress them without deranging, considerably, the relative position of hills, valleys, and ravines. But is it possible to conceive that elastic fluids could break through a mere point as it were of the earth's crust, and that too where the beds were not composed of soft, yielding clay, or incoherent sand, but of solid basalt, thousands of feet thick, and that they could inflate them, as it were, in the manner of a bladder? Would not the rocks, on the contrary, be fractured, fissured, thrown into a vertical, and often into a reversed position; and, ere they attained the height of seven thousand feet, would they not be reduced to a mere confused and chaotic heap?

The Great Canary is an island of a circular form, analogous to that of Palma. Barren Island, also, in the Bay of Bengal, is proposed as a striking illustration of the same phenomenon; and here it is said we have the advantage of being able to contrast the ancient crater of elevation with a cone and crater of eruption in its centre. When seen from the ocean, this island

presents, on almost all sides, a surface of bare rocks, which rise up with a moderate declivity towards the interior; but at one point there is a narrow cleft, by which we can penetrate into the centre, and there discover that it is occupied by a great

No. 17.



Cone and Crater of Barren Island, in the Bay of Bengal.

circular basin, filled by the waters of the sea, bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The summit of this cone is 1690 French feet in height, corresponding to that of the circular border which incloses the basin; so that it can only be seen from the sea through the ravine, which precisely resembles the deep gorge by which we penetrate into the Caldera of the Isle of Palma, and of which an equivalent, more or less decided in its characters, is said to occur in all elevation craters.

The cone of the high peak of Teyda, in Teneriffe, is also represented as rising out of the middle of a crater of elevation, standing like a tower surrounded by its foss and bastion; the foss being the remains of the ancient gulf, and the bastion the escarpment of the circular inclosure. So that Teneriffe is an exact counterpart of Barren Island, except that one is raised to an immense height, while the other is still on a level with the sea, and in part concealed beneath its waters.

Now, without enumerating more examples, let us consider what form the products of submarine volcanos may naturally be expected to assume. There is every reason to conclude, from the few accounts which we possess of eruptions at the bottom of the sea, that they take place in the same manner there as on the open surface of a continent*. That the volcanic phenomena, if they are ever developed at unfathomable depths, may

* Scrope on Volcanos, p. 171.

be extremely different, is very possible; but when they have been witnessed by the crews of vessels casually passing, the explosions of aëriform fluids beneath the waters have closely resembled those of volcanos on the land. Rocky fragments, ignited scoriæ, and comminuted ashes, are thrown up, and in several cases conical islands have been formed, which afterwards disappeared; as when, in 1691 and 1720, small isles were thrown up off St. Michael in the Azores, or as Sabrina rose in 1811 near the same spot, and, in 1783, Nyöe, off the coast of Iceland. Where the cones have disappeared, they probably consisted of loose matters, easily reduced by the waves and currents to a submarine shoal. When islands have remained firm, as in the case of Hiera, and the New and Little Kameni in the Gulf of Santorin (see wood-cut No. 15), they have consisted in part of solid lava. Whatever doubts might have been entertained as to the action of volcanos entirely submarine, yet it must always have been clear, that in those numerous cases where they just raise their peaks above the waves, the ejected sand, scoriæ, and fragments of rock, must accumulate round the vent into a cone with a central crater, while the lighter will be borne to a distance by tides and currents, as by winds during eruptions in open air. The lava which issues from the crater spreads over the subaqueous bottom, seeking the lowest levels, or accumulating upon itself, according to its liquidity, volume, and rapidity of congelation; following, in short, the same laws as when flowing in the atmosphere *.

But we may next enquire, what characters may enable a geologist to distinguish between cones formed entirely, or in great part beneath the waters of the sea, and those formed on land. In the first place, large beds of shells and corals often grow on the sloping sides of submarine cones, particularly in the Pacific, and these often become interstratified with lavas. Instead of alluvions containing land-shells, like some of those which cover Herculaneum, great beds of tufaceous sand and conglomerate, mixed with marine remains, might be expected on such parts of the flanks of a volcano like Stromboli as are submerged beneath the waters. The pressure of a column of

* Scrope on Volcanos, p. 173.

water exceeding many times that of the atmosphere, must impede the escape of the elastic fluids and of lava, until the resistance is augmented in the same proportion; hence the explosions will be more violent, and when a cone is formed it will be liable to be blown up and truncated at a lower level than in shallower water or in the open air. Add to this, that when a submarine volcano has repaired its cone, it is liable to be destroyed again by the waves, as in several cases before adverted to. The vent will then become choked up with strata of sand and fragments of rock, swept in by the tides and currents. These materials are far more readily consolidated under water than in the air, especially as mineral matter is so copiously introduced by the springs which issue from the ground in all volcanic regions hitherto carefully investigated. Beds of solid travertin, also, and in hot countries coral reefs, must often, during long intervals of quiescence, obstruct the vent, and thus increase the repressive force and augment the violence of eruptions. The probabilities, therefore, in a submarine volcano, of the destruction of a larger part of the cone, and the formation of a more extensive crater, are obvious; nor can the dimensions of "craters of elevation," if referred to such operations, surprise us. During an eruption in 1444, accompanied by a tremendous earthquake, the summit of Etna was destroyed, and an enormous crater was left, from which lava flowed. The segment of that crater may still be seen near the Casa Inglese, and, when complete, it must have measured several miles in diameter. The cone was afterwards repaired; but this would not have happened so easily had Etna been placed like Stromboli in a deep sea, with its peak exposed to the fury of the waves. Let us suppose the Etnean crater of 1444 to have been filled up with beds of coral and conglomerate, and that during succeeding eruptions these were thrown out by violent explosions, so that the cone became truncated down to the upper margin of the woody region, a circular basin would then be formed thirty Italian miles in circumference, exceeding by five or six miles the circuit of the Gulf of Santorin. Yet we know by numerous sections that the strata of trachyte, basalt, and trachytic breccia, would, in that part of the great cone of Etna, dip on all sides off from the centre at a gentle angle to every point of the com-

pass, except where irregularities were occasioned, at points where the small buried cones before mentioned occurred. If this gulf were then again choked up, and the vent obstructed, so that new explosions of great violence should truncate the cone once more down to the inferior border of the forest zone of Etna, the circumference of the gulf would then be fifty Italian miles *. Yet even then the ruins of the cone of Etna might form a circular island entirely composed of volcanic rocks, sloping gently outwards on all sides at a very slight angle; and this island might be between seventy and eighty English miles in its exterior circuit, while the circular bay within might be between forty and fifty miles round. In fertility it would rival the Island of Palma; and the deep gorge which leads down from the Valley of Calanna to Zafarana, might well serve as an equivalent to the grand defile which leads into the Caldera.

It is most probable, then, that the exterior inclosure of Barren Island, *c d*, in the annexed diagram, is nothing more than the remains of the truncated cone *c a b d*, a great portion of which has been carried away, partly by the action of the

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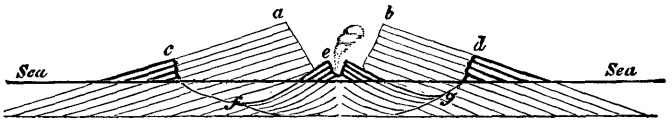

Supposed Section of Barren Island, in the Bay of Bengal.

waves, and partly by explosions which preceded the formation of the new interior cone, *f e g*. Whether the outer and larger cone has in this particular case, together with the bottom of the ocean on which it rests, been upheaved, or whether it originally projected in great part like Stromboli above the level of the sea, may, probably, be determined by geological investigations; for, in the former case, some beds replete with marine remains may be interstratified with volcanic ejections.

Some of the accounts transmitted to us by eye-witnesses, of the gradual manner in which New Kameni first rose covered with living shells in the Gulf of Santorin, appear, certainly,

* For the measurements of different parts of the cone of Etna, see Trattato dei boschi dell' Etna, Scuderi, Acti. dell' Acad. Gion. de Catan., vol. i.

to establish the possibility of the elevation of small masses from a depth of several hundred feet during an eruption, and during the emission of lava. But the protrusion of isolated masses, under such circumstances, affords no analogy to the supposed action of the expansive force in the formation of craters of elevation. It is hardly necessary, after the observations now made, to refer the reader again to our section of Somma and Vesuvius, and to say that we ascribed the formation of the ancient and the modern cone to operations precisely analogous.

M. Necker * long ago pointed out the correspondence of their structure, and explained most distinctly the origin of the form of Somma; and his views were afterwards confirmed by Mr. Scrope. But, notwithstanding the juxta-position of the entire and the ruined cone, the identity of the slope and quâquâ-versal dip of the beds, the similarity of their mineral composition, and the intersection of both cones by porphyritic dikes, the defenders of the "elevation" theory have declared that the lavas and breccias of Somma were once horizontal, and were afterwards raised into a conical mass, while they admit that those in Vesuvius have always been as highly inclined as they are now.

In controverting Von Buch's theory, we might have adduced as the most conclusive argument against it, that it would lead its advocates, if consistent with themselves, to the extravagant conclusion, that the two cones of Vesuvius had derived their form from very distinct causes. But as these geologists are not afraid to follow their system into all its consequences, and have even appealed to Somma as confirmatory of their views, it would be vain to hope, by pointing out the closest analogies between the effects of ordinary volcanic action and "craters of elevation," to induce them to abandon their hypothesis.

The marine shelly strata, interstratified with basalt, through which the great cone of Etna rises, are also said to have constituted an ancient crater of elevation; but when we allude more particularly to the geology of Sicily, it will appear that the strata in question do not dip so as to countenance in the least degree such an hypothesis. The nearest approach, perhaps, to the production of a conical mass by elevation from

* Mémoire sur le Mont Somma, Mém. de la Soc. de Phys. et d'Hist. Nat. de Genève, tom. ii., part I., p. 155.

below, is in the Cantal in Central France. The volcanic eruptions which produced at some remote period the volcanic mountain called the Plomb du Cantal, broke up through fresh-water strata, which must have been deposited originally in an horizontal position, on rocks of granitic schist. During the gradual formation of the great cone, beds of lava and tuff, thousands of feet in thickness, were thrown out from one or more central vents, so as to cover great part of the lacustrine strata, and these at the same time were traversed by dikes, and in parts lifted up together with the subjacent granitic rocks; so that if the igneous products could now be removed, and the marls, limestones, and fundamental schists, supported at their present elevation, they would form a kind of dome-shaped protuberance. But the outline of this shattered mass would be very unlike that of a regular cone, and the dip of the beds would be often horizontal, as near Aurillac, often vertical, often reversed, nor would there be in the centre any great cavity or crater of elevation*. On the other hand, the *volcanic* beds of the Plomb du Cantal are arranged in a conical form, like those of Etna, not by elevation from below, but because they flowed down during successive eruptions *from above*.

We may observe that the Fossa Grande on Vesuvius, a deep ravine washed out by the winter-torrents which descend from the Atrio del Cavallo, may represent, on a small scale, the Valley of Calanna, and its continuation, the Valley of St. Giacomo on Etna. In the Fossa Grande, a small body of water has cut through tuff, and in some parts solid beds of lava of considerable thickness; and the channel, although repeatedly blocked up by modern lavas, has always been re-excavated. It is natural that on one side of every large hollow, such as the crater of a truncated cone, there should be a channel to drain off the water; and this becoming in the course of ages a deep ravine, may have caused such gorges as exist in Palma and other isles of similar conformation.

Mineral Composition of Volcanic Products.—The mineral called felspar, forms in general more than half of the mass of

* See a Memoir by Messrs. Murchison and Lyell, Sur les Dépôts Lacustres Tertiaires du Cantal, &c., Ann. des Sci. Nat., October, 1829.

modern lavas. When it is in great excess, lavas are called trachytic; when augite (or pyroxene) predominates, they are termed basaltic. But lavas of composition, precisely intermediate, occur, and from their colour have been called greystones. A great abundance of quartz characterizes the granitic and other ancient rocks, now generally considered by geologists as of igneous origin, whereas that mineral, which is nothing more than silex crystallized, is rare in recent lavas, although silex enters largely into their composition. Hornblende, which is so common in ancient rocks, is rare in modern lava, nor does it enter largely into rocks of any age in which augite abounds. Mica occurs plentifully in some recent trachytes, but is rarely present where augite is in excess. We must beware, however, not to refer too hastily to a difference of era, characters which may, in truth, belong to the different circumstances under which the products of fire originate.

When we speak of the igneous rocks of our own times, we mean that small portion which happens in violent eruptions to be forced up by elastic fluids to the surface of the earth. We merely allude to the sand, scoriæ, and lava, which cool in the open air; but we cannot obtain access to that which is congealed under the pressure of many hundred, or many thousand atmospheres. We may, indeed, see in the dikes of Vesuvius rocks consolidated from a liquid state, under a pressure of perhaps a thousand feet of lava, and the rock so formed is more crystalline and of greater specific gravity than ordinary lavas. But the column of melted matter raised above the level of the sea during an eruption of Vesuvius must be more than three thousand feet in height, and more than ten thousand feet in Etna; and we know not how many miles deep may be the ducts which communicate between the mountain and those subterranean lakes or seas of burning matter which supply for thousands of years, without being exhausted, the same volcanic vents. The continual escape of hot vapours from many craters during the interval between eruptions, and the chemical changes which are going on for ages in the fumeroles of volcanos, prove that the volcanic foci retain their intense heat constantly, nor can we suppose it to be otherwise; for as lava-currents of moderate thickness require many years to cool down in the open air, we must suppose the great reservoirs of

melted matter at vast depths in the nether regions to preserve their high temperature and fluidity for thousands of years.

During the last century, about fifty eruptions are recorded of the five European volcanos, Vesuvius, Etna, Volcano, Santorin, and Iceland, but many beneath the sea in the Grecian Archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others on the contrary, like that of Skaptár Jokul in 1783, poured out melted matter for five or six years consecutively, which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate, that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there happen on the earth about two thousand eruptions in the course of a century, or about twenty every year.

However inconsiderable, therefore, may be the superficial rocks which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones must be as insignificant, when contrasted to the products of fire in the nether regions, as are the deposits formed in shallow estuaries when compared to submarine formations accumulating in the abysses of the ocean. In regard to the characters of these volcanic rocks, formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that the rocks are heavier and less porous than true lavas, and more crystalline, although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory, require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions; for this is seen to be the case in many lava-

currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic regions, and the fissures will be often injected with similar matter, so that dikes of crystalline rock will traverse masses of similar composition. It is also clear that no organic remains can be included in such masses, unless where sedimentary strata have subsided to great depths, and in this case the fossil substances will probably be so acted upon by heat, that all signs of organization will be obliterated. Lastly, these deep-seated igneous formations must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks either subjacent or included in the midst of them. If, by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may then, perhaps, study in some mountain chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.