GEOLOGICAL OBSERVATIONS

ON THE VOLCANIC ISLANDS AND PARTS OF SOUTH AMERICA VISITED DURING THE VOYAGE OF H. M. S. 'BEAGLE'

BY

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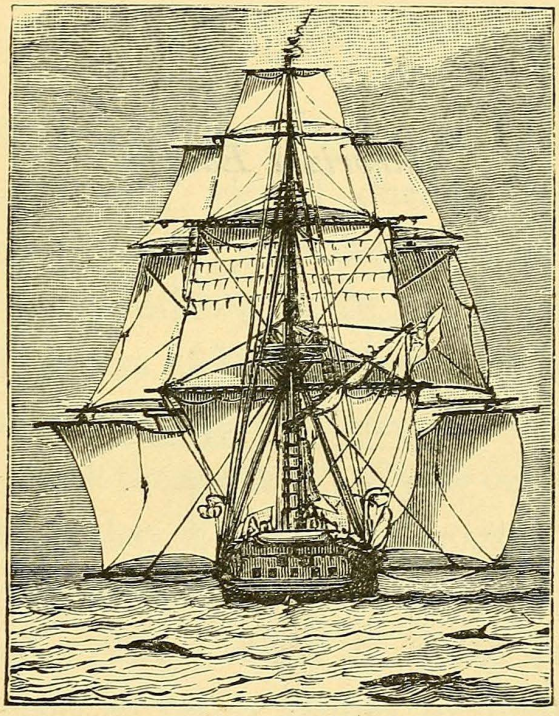

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CHAPTER IV.

ST. HELENA.

Lavas of the feldspathic, basaltic, and submarine series—Section Flagstaff Hill and of the Barn—Dikes—Turk's Cap and Prosperous Bays—Basaltic ring—Central crateriform ridge, with an internal ledge and a parapet—Cones of phonolite—Superficial beds of calcareous sandstone—Extinct land-shells—Beds of detritus—Elevation of the land—Denudation—Craters of elevation.

The whole island is of volcanic origin; its circumference, according to Beatson,[1] is about twenty-eight miles. The central and largest part consists of rocks of a feldspathic nature, generally decomposed to an extraordinary degree; and when in this state, presenting a singular assemblage of alternating, red, purple, brown, yellow, and white, soft, argillaceous beds. From the shortness of our visit, I did not examine these beds with care; some of them, especially those of the white, yellow, and brown shades, originally existed as streams of lava, but the greater number were probably ejected in the form of scoriæ and ashes: other beds of a purple tint, porphyritic with crystal-shaped patches of a white, soft substance, which are now unctuous, and yield, like wax, a polished streak to the nail, seem once to have existed as solid claystone-porphyries: the red argillaceous beds generally have a brecciated structure, and no doubt have been formed by the decomposition of

[1] Governor Beatson's 'Account of St. Helena.'

scoriæ. Several extensive streams, however, belonging to this series, retain their stony character; these are either of a blackish-green colour, with minute acicular crystals of feldspar, or of a very pale tint, and almost composed of minute, often scaly, crystals of feldspar, abounding with microscopical black specks; they are generally compact and laminated; others, however, of similar composition, are cellular and somewhat decomposed. None of these rocks contain large crystals of feldspar, or have the harsh fracture peculiar to trachyte. These feldspathic lavas and tuffs are the uppermost or those last erupted; innumerable dikes, however, and great masses of molten rock, have subsequently been injected into them. They converge, as they rise, towards the central curved ridge, of which one point attains the elevation of 2,700 feet. This ridge is the highest land in the island; and it once formed the northern rim of a great crater, whence the lavas of this series flowed: from its ruined condition, from the southern half having been removed, and from the violent dislocation which the whole island has undergone, its structure is rendered very obscure.

Basaltic series.—The margin of this island is formed by a rude circle of great, black, stratified, ramparts of basalt, dipping seaward, and worn into cliffs, which are often nearly perpendicular, and vary in height from a few hundred feet to two thousand. This circle, or rather horse-shoe shaped ring, is open to the south, and is breached by several other wide spaces. Its rim or summit generally projects little above the level of the adjoining inland country; and the more recent feldspathic lavas, sloping down from the central heights, generally abut against and overlap its inner margin; on the north-western side of the island, however, they appear (judging from a distance) to have

flowed over and concealed portions of it. In some parts, where the basaltic ring had been breached, and the black ramparts stand detached, the feldspathic lavas have passed between them, and now overhang the sea-coast in lofty cliffs. The basaltic rocks are of a black colour and thinly stratified; they are generally highly vesicular, but occasionally compact; some of them contain numerous crystals of glassy feldspar and octahedrons of titaniferous iron; others abound with crystals of augite and grains of olivine. The vesicles are frequently lined with minute crystals (of chabasie ?) and even become amygdaloidal with them. The streams are separated from each other by cindery matter, or by a bright red, friable, saliferous tuff, which is marked by successive lines like those of aqueous deposition; and sometimes it has an obscure, concretionary structure. The rocks of this basaltic series occur nowhere except near the coast. In most volcanic districts the trachytic lavas are of anterior origin to the basaltic; but here we see, that a great pile of rock, closely related in composition to the trachytic family, has been erupted subsequently to the basaltic strata: the number, however, of dikes, abounding with large crystals of augite, with which the feldspathic lavas have been injected, shows perhaps, some tendency to a return to the more usual order of superposition.

Basal submarine lavas.—The lavas of this basal series lie immediately beneath both the basaltic and feldspathic rocks. According to Mr. Seale,[1] they may be seen at intervals on the sea-beach round the entire island. In the sections which I examined, their nature varied much; some of the strata abound with crystals of

[1] 'Geognosy of the Island of St. Helena' Mr. Seale has constructed a gigantic model of St. Helena, well worth visiting, which is now deposited at Addiscombe College, in Surrey.

augite; others are of a brown colour, either laminated or in a rubbly condition; and many parts are highly amygdaloidal with calcareous matter. The successive sheets are either closely united together, or are separated from each other by beds of scoriaceous rock and of laminated tuff, frequently containing well-rounded fragments. The interstices of these beds are filled with gypsum and salt; the gypsum also sometimes occurring in thin layers. From the large quantity of these two substances, from the presence of rounded pebbles in the tuffs, and from the abundant amygdaloids, I cannot doubt that these basal volcanic strata flowed beneath the sea. This remark ought perhaps to be extended to a part of the superincumbent basaltic rocks; but on this point, I was not able to obtain clear evidence. The strata of the basal series, whenever I examined them, were intersected by an extraordinary number of dikes.

Flagstaff Hill and the Barn.—I will now describe some of the more remarkable sections, and will commence with these two hills, which form the principal external feature on the north-eastern side of the island. The square, angular outline, and black colour of the Barn, at once show that it belongs to the basaltic

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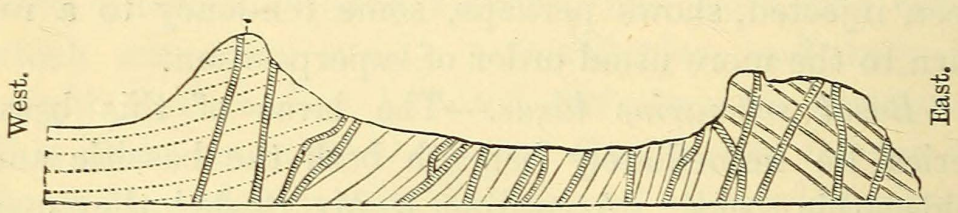

Flagstaff Hill. 2,272 feet high.

The Barn. 2,015 feet high.

The double lines represent the basaltic strata; the single, the basal submarine strata; the dotted, the upper feldspathic strata; the dikes are shaded transversely.

series; whilst the smooth, conical figure, and the varied bright tints of Flagstaff Hill, render it equally clear, that it is composed of the softened, feldspathic

rocks. These two lofty hills are connected (as is shown in the accompanying woodcut) by a sharp ridge, which is composed of the rubbly lavas of the basal series. The strata of this ridge dip westward, the inclination becoming less and less towards the Flagstaff; and the upper feldspathic strata of this hill can be seen, though with some difficulty, to dip conformably to the WSW. Close to the Barn, the strata of the ridge are nearly vertical, but are much obscured by innumerable dikes; under this hill, they probably change from being vertical into being inclined into an opposite direction; for the upper or basaltic strata, which are about 800 or 1,000 feet in thickness, are inclined north-eastward, at an angle between thirty and forty degrees.

This ridge, and likewise the Barn and Flagstaff Hills, are interlaced by dikes, many of which preserve a remarkable parallelism in a NNW. and SSE. direction. The dikes chiefly consist of a rock, porphyritic with large crystals of augite; others are formed of a fine-grained and brown-coloured trap. Most of these dikes are coated by a glossy layer,[1] from one to two-tenths of an inch in thickness, which, unlike true pitchstone, fuses into a black enamel; this layer is evidently analogous to the glossy superficial coating of many lava streams. The dikes can often be followed for great lengths both horizontally and vertically, and they seem to preserve a nearly uniform thickness:[2] Mr. Seale

[1] This circumstance has been observed (Lyell, 'Principles of Geology,' vol. iv. chap. x. p. 9) in the dikes of the Atrio del Cavallo, but apparently it is not of very common occurrence. Sir G. Mackenzie, however, states ('Travels in Iceland,' p. 372) that all the veins in Iceland have a 'black vitreous coating on their sides.' Capt. Carmichael, speaking of the dikes in Tristan D'Acunha, a volcanic island in the southern Atlantic, says ('Linnæan Transactions,' vol. xii. p. 485) that their sides, 'where they come in contact with the rocks, are invariably in a semi-vitrified state.'

[2] 'Geognosy of the Island of St. Helena,' plate 5.

states, that one near the Barn, in a height of 1,260 feet, decreases in width only four inches,—from nine feet at the bottom, to eight feet and eight inches, at the top. On the ridge, the dikes appear to have been guided in their course, to a considerable degree, by the alternating soft and hard strata: they are often firmly united to the harder strata, and they preserve their parallelism for such great lengths, that in very many instances it was impossible to conjecture, which of the beds were dikes, and which streams of lava. The dikes, though so numerous on this ridge, are even more numerous in the valleys a little south of it, and to a degree I never saw equalled anywhere else: in these valleys they extend in less regular lines, covering the ground with a network, like a spider's web, and with some parts of the surface even appearing to consist wholly of dikes, interlaced by other dikes.

From the complexity produced by the dikes, from the high inclination and anticlinal dip of the strata of the basal series, which are overlaid, at the opposite ends of the short ridge, by two great masses of different ages and of different composition, I am not surprised that this singular section has been misunderstood. It has even been supposed to form part of a crater; but so far is this from having been the case, that the summit of Flagstaff Hill once formed the lower extremity of a sheet of lava and ashes, which were erupted from the central, crateriform ridge. Judging from the slope of the contemporaneous streams in an adjoining and undisturbed part of the island, the strata of the Flagstaff Hill must have been upturned at least twelve hundred feet, and probably much more, for the great truncated dikes on its summit show that it has been largely denuded. The summit of this hill now nearly equals in height the crateriform ridge; and before having

been denuded, it was probably higher than this ridge, from which it is separated by a broad and much lower tract of country; we here, therefore, see that the lower extremity of a set of lava-streams have been tilted up to as great a height as, or perhaps greater height than, the crater, down the flanks of which they originally flowed. I believe that dislocations on so grand a scale are extremely rare[1] in volcanic districts. The formation of such numbers of dikes in this part of the island shows that the surface must here have been stretched to a quite extraordinary degree: this stretching, on the ridge between Flagstaff and Barn Hills, probably took place subsequently (though perhaps immediately so) to the strata being tilted; for had the strata at that time extended horizontally, they would in all probability have been fissured and injected transversely, instead of in the planes of their stratification. Although the space between the Barn and Flagstaff Hill presents a distinct anticlinal line extending north and south, and though most of the dikes range with much regularity in the same line, nevertheless, at only a mile due south of the ridge the strata lie undisturbed. Hence the disturbing force seems to have acted under a point, rather than along a line. The manner in which it has acted, is probably explained by the structure of Little Stony-top, a mountain 2,000 feet high, situated a few miles southward of the Barn; we there see, even from a distance, a dark-coloured, sharp, wedge of compact columnar rock, with the bright-coloured feldspathic strata, sloping away on each side from its uncovered apex. This wedge, from which it derives its name of Stony-top, consists of a body of rock, which has been

[1] M. Constant Prevost ('Mém. de la Soc. Géolog.' tom. ii.) observes, that 'les produits volcaniques n'ont que localement et rarement même dérangé le sol, à travers lequel ils se sont fait jour.'

injected whilst liquefied into the overlying strata; and if we may suppose that a similar body of rock lies injected, beneath the ridge connecting the Barn and Flagstaff, the structure there exhibited would be explained.

Turk's Cap and Prosperous Bays. — Prosperous Hill is a great, black, precipitous mountain, situated two miles and a half south of the Barn, and composed, like it, of basaltic strata. These rest, in one part, on the brown-coloured, porphyritic beds of the basal series, and in another part, on a fissured mass of highly scoriaceous and amygdaloidal rock, which seems to have formed a small point of eruption beneath the sea, contemporaneously with the basal series. Prosperous Hill, like the Barn, is traversed by many dikes, of which the greater number range north and south, and its strata dip, at an angle of about 20°, rather obliquely from the island towards the sea. The space between Prosperous Hill and the Barn, as represented in this woodcut, consists of lofty cliffs, composed of the lavas of the upper

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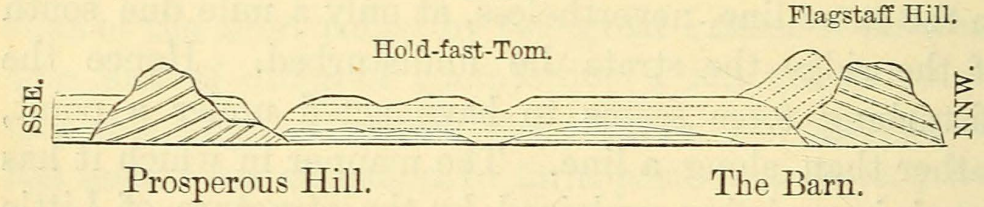

The double lines represent the basaltic strata; the single, the basal submarine strata; the dotted, the upper feldspathic strata.

or feldspathic series, which rest, though unconformably, on the basal submarine strata, as we have seen that they do at Flagstaff Hill. But differently from what occurs in that hill, these upper strata are nearly horizontal, gently rising towards the interior of the island; they are also composed of greenish-black, or more commonly, pale brown, compact lavas, instead of softened and highly coloured matter. These brown-coloured, compact lavas, consist almost entirely of small

glimmering scales, or of minute acicular crystals, of feldspar, placed close by the side of each other, and abounding with minute black specks, apparently of hornblende. The basaltic strata of Prosperous Hill project only a little above the level of the gently-sloping, feldspathic streams, which wind round and abut against their upturned edges. The inclination of the basaltic strata seems to be too great, to have been caused by their having flowed down a slope, and they must have been tilted into their present position before the eruption of the feldspathic streams.

Basaltic ring.—Proceeding round the island, the lavas of the upper series, southward of Prosperous Hill, overhang the sea in lofty precipices. Further on, the headland, called Great Stony-top, is composed, as I believe, of basalt; as is Long Range Point, on the inland side of which, the coloured beds abut. On the southern side of the island, we see the basaltic strata of the South Barn, dipping obliquely seaward at a considerable angle; this headland, also, stands a little above the level of the more modern, feldspathic lavas. Further on, a large space of coast, on each side of Sandy Bay, has been much denuded, and there seems to be left only the basal wreck of the great, central crater. The basaltic strata reappear, with their seaward dip, at the foot of the hill called Man-and-Horse; and thence they are continued along the whole north-western coast to Sugar-Loaf Hill, situated near to the Flagstaff; and they everywhere have the same seaward inclination, and rest, in some parts at least, on the lavas of the basal series. We thus see that the circumference of the island is formed by a much-broken ring, or rather a horse-shoe, of basalt, open to the south, and interrupted on the eastern side by many wide breaches. The breadth of this marginal fringe on the north-western

side, where alone it is at all perfect, appears to vary from a mile to a mile and a half. The basaltic strata, as well as those of the subjacent basal series, dip, with a moderate inclination, where they have not been subsequently disturbed, towards the sea. The more broken state of the basaltic ring round the eastern half, compared with the western half of the island, is evidently due to the much greater denuding power of the waves on the eastern or windward side, as is shown by the greater height of the cliffs on that side, than to leeward. Whether the margin of basalt was breached, before or after the eruption of the lavas of the upper series, is doubtful; but as separate portions of the basaltic ring appear to have been tilted before that event, and from other reasons, it is more probable, that some at least of the breaches were first formed. Reconstructing in imagination, as far as is possible, the ring of basalt, the internal space or hollow, which has since been filled up with the matter erupted from the great central crater, appears to have been of an oval figure, eight or nine miles in length by about four miles in breadth, and with its axis directed in a NE. and SW. line, coincident with the present longest axis of the island.

The central curved ridge.—This ridge consists, as before remarked, of gray feldspathic lavas, and of red, brecciated, argillaceous tuffs, like the beds of the upper coloured series. The gray lavas contain numerous, minute, black, easily fusible specks; and but very few large crystals of feldspar. They are generally much softened; with the exception of this character, and of being in many parts highly cellular, they are quite similar to those great sheets of lava which overhang the coast at Prosperous Bay. Considerable intervals of time appear to have elapsed, judging from the marks of denudation, between the formation of the

successive beds, of which this ridge is composed. On the steep northern slope, I observed in several sections a much worn undulating surface of red tuff, covered by gray, decomposed, feldspathic lavas, with only a thin earthy layer interposed between them. In an adjoining part, I noticed a trap-dike, four feet wide, cut off and covered up by the feldspathic lava, as is represented in the woodcut. The ridge ends on the

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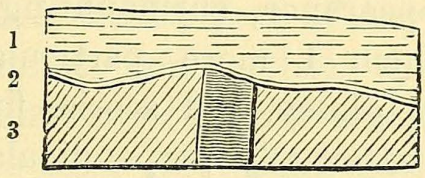

DIKE.

1—Gray feldspathic lava.
2—A layer, one inch in thickness, of a reddish earthy matter.
3—Brecciated, red, argillaceous tuff.

eastern side in a hook, which is not represented clearly enough in any map which I have seen; towards the western end, it gradually slopes down and divides into several subordinate ridges. The best defined portion between Diana's Peak and Nest Lodge, which supports the highest pinnacles in the island varying from 2,000 to 2,700 feet, is rather less than three miles long in a straight line. Throughout this space the ridge has a uniform appearance and structure; its curvature resembles that of the coast-line of a great bay, being made up of many smaller curves, all open to the south. The northern and outer side is supported by narrow ridges or buttresses, which slope down to the adjoining country. The inside is much steeper, and is almost precipitous; it is formed of the basset edges of the strata, which gently decline outwards. Along some parts of the inner side, a little way beneath the summit, a flat ledge extends, which imitates in outline the smaller curvatures of the crest. Ledges of this kind occur

not unfrequently within volcanic craters, and their formation seems to be due to the sinking down of a level sheet of hardened lava, the edges of which remain (like the ice round a pool, from which the water has been drained) adhering to the sides.[1]

In some parts, the ridge is surmounted by a wall or parapet, perpendicular on both sides. Near Diana's Peak this wall is extremely narrow. At the Galapagos Archipelago I observed parapets, having a quite similar structure and appearance, surmounting several of the craters; one, which I more particularly examined, was composed of glossy, red scoriæ firmly connected together; being externally perpendicular, and extending round nearly the whole circumference of the crater, it rendered it almost inaccessible. The Peak of Teneriffe and Cotopaxi, according to Humboldt, are similarly constructed; he states[2] that 'at their summits a circular wall surrounds the crater, which wall, at a distance, has the appearance of a small cylinder placed on a truncated cone. On Cotopaxi[3] this peculiar structure is visible to the naked eye at more than 2,000 toises' distance; and no person has ever reached its crater. On the Peak of Teneriffe, the parapet is so high, that it would be impossible to reach the *caldera*, if on the eastern side there did not exist a breach.' The origin of these circular parapets is probably due to the heat or vapours from the crater, penetrating and hardening the sides to a nearly equal depth, and afterwards to the mountain being slowly acted on by the weather, which would leave the hardened part,

[1] A most remarkable instance of this structure is described in Ellis's 'Polynesian Researches' (second edit.), where an admirable drawing is given of the successive ledges or terraces, on the borders of the immense crater at Hawaii, in the Sandwich Islands.

[2] 'Personal Narrative,' vol. i. p. 171.

[3] Humboldt's 'Picturesque Atlas,' folio, pl. 10.

projecting in the form of a cylinder or circular parapet.

From the points of structure in the central ridge, now enumerated,—namely, from the convergence towards it of the beds of the upper series,—from the lavas there becoming highly cellular,—from the flat ledge, extending along its inner and precipitous side, like that within some still active craters,—from the parapet-like wall on its summit,—and lastly, from its peculiar curvature, unlike that of any common line of elevation, I cannot doubt that this curved ridge forms the last remnant of a great crater. In endeavouring, however, to trace its former outline, one is soon baffled; its western extremity gradually slopes down, and, branching into other ridges, extends to the sea-coast; the eastern end is more curved, but it is only a little better defined. Some appearances lead me to suppose that the southern wall of the crater joined the present ridge near Nest Lodge; in this case the crater must have been nearly three miles long, and about a mile and a half in breadth. Had the denudation of the ridge and the decomposition of its constituent rocks proceeded a few steps farther, and had this ridge, like several other parts of the island, been broken up by great dikes and masses of injected matter, we should in vain have endeavoured to discover its true nature. Even now we have seen that at Flagstaff Hill the lower extremity and most distant portion of one sheet of the erupted matter has been upheaved to as great a height as the crater down which it flowed, and probably even to a greater height. It is interesting thus to trace the steps by which the structure of a volcanic district becomes obscured, and finally obliterated: so near to this last stage is St. Helena, that I believe no one has hitherto suspected that the central ridge or

axis of the island, is the last wreck of the crater, whence the most modern volcanic streams were poured forth.

The great hollow space or valley southward of the central curved ridge, across which the half of the crater must once have extended, is formed of bare, water-worn hillocks and ridges of red, yellow, and brown rocks, mingled together in chaos-like confusion, interlaced by dikes, and without any regular stratification. The chief part consists of red decomposing scoriæ, associated with various kinds of tuff and yellow argillaceous beds, full of broken crystals, those of augite being particularly large. Here and there masses of highly cellular and amygdaloidal lavas protrude. From one of the ridges in the midst of the valley, a conical precipitous hill, called Lot, boldly stands up, and forms a most singular and conspicuous object. It is composed of phonolite, divided in one part into great curved laminæ, in another, into angular concretionary balls, and in a third part into outwardly radiating columns. At its base the strata of lava, tuff, and scoriæ, dip away on all sides:[1] the uncovered portion is 197[2] feet in height, and its horizontal section gives an oval figure. The phonolite is of a greenish-gray colour, and is full of minute acicular crystals of feldspar; in most parts it has a conchoidal fracture, and is sonorous, yet it is crenulated with minute air-cavities. In a SW. direction from Lot, there are some other remarkable columnar pinnacles, but of a

[1] Abich, in his 'Views of Vesuvius' (plate vi.), has shown the manner in which beds, under nearly similar circumstances, are tilted up. The upper beds are more turned up than the lower; and he accounts for this, by showing that the lava insinuates itself horizontally between the lower beds.

[2] This height is given by Mr. Seale, in his Geognosy of the island. The height of the summit above the level of the sea, is said to be 1,444 feet.

less regular shape, namely, Lot's Wife, and the Asses Ears, composed of allied kinds of rock. From their flattened shape, and their relative position to each other, they are evidently connected on the same line of fissure. It is, moreover, remarkable that this same NE. and SW. line, joining Lot and Lot's Wife, if prolonged, would intersect Flagstaff Hill, which, as before stated, is crossed by numerous dikes running in this direction, and which has a disturbed structure, rendering it probable that a great body of once fluid rock lies injected beneath it.

In this same great valley there are several other conical masses of injected rock (one, I observed, was composed of compact greenstone), some of which are not connected, as far as is apparent, with any line of dike; whilst others are obviously thus connected. Of these dikes, three or four great lines stretch across the valley in a NE. and SW. direction, parallel to that one connecting the Asses' Ears, Lot's Wife, and probably Lot. The number of these masses of injected rock is a remarkable feature in the geology of St. Helena. Besides those just mentioned, and the hypothetical one beneath Flagstaff Hill, there is Little Stony-top and others, as I have reason to believe, at the Man-and-Horse, and at High Hill. Most of these masses, if not all of them, have been injected subsequently to the last volcanic eruptions from the central crater. The formation of conical bosses of rock on lines of fissure, the walls of which are in most cases parallel, may probably be attributed to inequalities in the tension, causing small transverse fissures; and at these points of intersection the edges of the strata would naturally yield, and be easily turned upwards. Finally, I may remark, that hills of phonolite every-

where are apt[1] to assume singular and even grotesque shapes, like that of Lot: the peak at Fernando Noronha offers an instance; at St. Jago, however, the cones of phonolite, though tapering, have a regular form. Supposing, as seems probable, that all such hillocks or obelisks have originally been injected, whilst liquefied, into a mould formed by yielding strata, as certainly has been the case with Lot, how are we to account for the frequent abruptness and singularity of their outlines, compared with similarly injected masses of greenstone and basalt? Can it be due to a less perfect degree of fluidity, which is generally supposed to be characteristic of the allied trachytic lavas?

Superficial deposits. — Soft calcareous sandstone occurs in extensive, though thin, superficial beds, both on the northern and southern shores of the island. It consists of very minute, equal-sized, rounded particles of shells, and other organic bodies, which partially retain their yellow, brown, and pink colours, and occasionally, though very rarely, present an obscure trace of their original external forms. I in vain endeavoured to find a single unrolled fragment of a shell. The colour of the particles is the most obvious character by which their origin can be recognised, the tints being affected (and an odour produced) by a moderate heat, in the same manner as in fresh shells. The particles are cemented together, and are mingled with some earthy matter: the purest masses, according to Beatson, contain 70 per cent. of carbonate of lime. The beds, varying in thickness from two or three feet to fifteen feet, coat the surface of the ground; they generally lie on that side of the valley which is protected from the wind, and they occur at the height

[1] D'Aubuisson, in his 'Traité de Géognosie' (tom. ii. p. 540) particularly remarks that this is the case.

of several hundred feet above the level of the sea. Their position is the same, which sand, if now drifted by the trade-wind, would occupy; and no doubt they thus originated, which explains the equal size and minuteness of the particles, and likewise the entire absence of whole shells, or even of moderately-sized fragments. It is remarkable that at the present day there are no shelly beaches on any part of the coast, whence calcareous dust could be drifted and winnowed; we must, therefore, look back to a former period when before the land was worn into the present great precipices, a shelving coast, like that of Ascension, was favourable to the accumulation of shelly detritus. Some of the beds of this limestone are between 600 and 700 feet above the sea; but part of this height may possibly be due to an elevation of the land, subsequent to the accumulation of the calcareous sand.

The percolation of rain-water has consolidated parts of these beds into a solid rock, and has formed masses of dark brown, stalagmitic limestone. At the Sugar-Loaf quarry, fragments of rock on the adjoining slopes,[1] have been thickly coated by successive fine layers of calcareous matter. It is singular, that many of these pebbles have their entire surfaces coated, without any point of contact having been left uncovered; hence, these pebbles must have been lifted up by the slow deposition between them of the successive films of carbonate of lime. Masses of white, finely oolitic rock are attached to the outside of some of these coated pebbles.

[1] In the earthy detritus on several parts of this hill, irregular masses of very impure, crystallised sulphate of lime occur As this substance is now being abundantly deposited by the surf at Ascension, it is possible that these masses may thus have originated; but if so, it must have been at a period when the land stood at a much lower level. This earthy selenite is now found at a height of between 600 and 700 feet.

Von Buch has described a compact limestone at Lanzarote, which seems perfectly to resemble the stalagmitic deposition just mentioned: it coats pebbles, and in parts is finely oolitic: it forms a far-extended layer, from one inch to two or three feet in thickness, and it occurs at the height of 800 feet above the sea, but only on that side of the island exposed to the violent north-western winds. Von Buch remarks,[1] that it is not found in hollows, but only on the unbroken and inclined surfaces of the mountain. He believes, that it has been deposited by the spray which is borne over the whole island by these violent winds. It appears, however, to me much more probable that it has been formed, as at St. Helena, by the percolation of water through finely comminuted shells: for when sand is blown on a much exposed coast, it always tends to accumulate on broad, even surfaces, which offer a uniform resistance to the winds. At the neighbouring island, moreover, of Fuerteventura,[2] there is an earthy limestone, which, according to Von Buch, is quite similar to specimens which he has seen from St. Helena, and which he believes to have been formed by the drifting of shelly detritus.

The upper beds of the limestone, at the above-mentioned quarry on the Sugar-Loaf Hill, are softer, finer-grained and less pure, than the lower beds. They abound with fragments of land-shells, and with some perfect ones; they contain, also, the bones of birds, and the large eggs,[3] apparently of water-fowl. It is probable that these upper beds remained long in an uncon-

[1] 'Description des Isles Canaries,' p. 293.

[2] Idem, pp. 314 and 374.

[3] Colonel Wilkes, in a catalogue presented with some specimens to the Geological Society, states that as many as ten eggs were found by one person. Dr. Buckland has remarked ('Geolog. Trans.' vol. v. p. 474) on these eggs.

solidated form, during which time, these terrestrial productions were embedded. Mr. G. R. Sowerby has kindly examined three species of land-shells, which I procured from this bed, and his descriptions are given in the Appendix. One of them is a Succinea, identical with a species now living abundantly on the island: the two others, namely, *Cochlogena fossilis* and *Helix biplicata*, are not known in a recent state: the latter species was also found in another and different locality, associated with a species of Cochlogena which is undoubtedly extinct.

Beds of extinct land-shells.—Land-shells, all of which appear to be species now extinct, occur embedded in earth, in several parts of the island. The greater number have been found at a considerable height on Flagstaff Hill. On the NW. side of this hill, a rain-channel exposes a section of about twenty feet in thickness, of which the upper part consists of black vegetable mould, evidently washed down from the heights above, and the lower part of less black earth, abounding with young and old shells, and with their fragments: part of this earth is slightly consolidated by calcareous matter, apparently due to the partial decomposition of some of the shells. Mr. Seale, an intelligent resident, who first called attention to these shells, gave me a large collection from another locality, where the shells appear to have been embedded in very black earth. Mr. G. R. Sowerby has examined these shells, and has described them in the Appendix. There are seven species, namely, one Cochlogena, two species of the genus Cochlicopa, and four of Helix: none of these are known in a recent state, or have been found in any other country. The smaller species were picked out of the inside of the large shells of the *Cochlogena auris-vulpina*. This last-mentioned species is in many

respects a very singular one; it was classed, even by Lamarck, in a marine genus, and having thus been mistaken for a sea-shell, and the smaller accompanying species having been overlooked, the exact localities where it was found have been measured, and the elevation of this island thus deduced! It is very remarkable that all the shells of this species found by me in one spot, form a distinct variety, as described by Mr. Sowerby, from those procured from another locality by Mr. Seale. As this Cochlogena is a large and conspicuous shell, I particularly enquired from several intelligent countrymen whether they had ever seen it alive; they all assured me that they had not, and they would not even believe that it was a land animal: Mr. Seale, moreover, who was a collector of shells all his life at St. Helena, never met with it alive. Possibly some of the smaller species may turn out to be yet living kinds; but, on the other hand, the two land-shells which are now living on the island in great numbers, do not occur embedded, as far as it is yet known, with the extinct species. I have shown in my Journal,[1] that the extinction of these land-shells possibly may not be an ancient event; as a great change took place in the state of the island about 120 years ago, when the old trees died, and were not replaced by young ones, these being destroyed by the goats and hogs, which had run wild in numbers, from the year 1502. Mr. Seale states, that on Flagstaff Hill, where we have seen that the embedded land-shells are especially numerous, traces are everywhere discoverable, which plainly indicate that it was once thickly clothed with trees; at present not even a bush grows there. The thick bed of black vegetable mould which covers the shell-bed, on the

[1] 'Journal of Researches,' 1845, p. 489.

flanks of this hill, was probably washed down from the upper part, as soon as the trees perished, and the shelter afforded by them was lost.

Elevation of the land.—Seeing that the lavas of the basal series, which are of submarine origin, are raised above the level of the sea, and at some places to the height of many hundred feet, I looked out for superficial signs of the elevation of the land. The bottoms of some of the gorges, which descend to the coast, are filled up to the depth of about a hundred feet, by rudely divided layers of sand, muddy clay, and fragmentary masses; in these beds, Mr. Seale has found the bones of the tropic-bird and of the albatross; the former now rarely, and the latter never visiting the island. From the difference between these layers, and the sloping piles of detritus which rest on them, I suspect that they were deposited, when the gorges stood beneath the sea. Mr. Seale, moreover, has shown that some of the fissure-like gorges,[1] become, with a concave outline, gradually rather wider at the bottom than at the top; and this peculiar structure was probably caused by the wearing action of the sea, when it entered the lower part of these gorges. At greater heights, the evidence of the rise of the land is even less clear: nevertheless, in a bay-like depression on the table-land behind Prosperous Bay, at the height of about 1,000 feet, there are flat-topped masses of rock, which it is scarcely conceivable, could have been insulated from the surrounding and similar strata, by any other agency than the denuding action of a sea-beach. Much denudation, indeed, has been effected at great elevations, which it would not be easy to explain by any other means: thus, the flat summit of the Barn, which is

[1] A fissure-like gorge, near Stony-top, is said by Mr. Seale to be 840 feet deep, and only 115 feet in width.

2,000 feet high, presents, according to Mr. Seale, a perfect network of truncated dikes; on hills like the Flagstaff, formed of soft rock, we might suppose that the dikes had been worn down and cut off by meteoric agency, but we can hardly suppose this possible with the hard, basaltic strata of the Barn.

Coast denudation.—The enormous cliffs, in many parts between 1,000 and 2,000 feet in height, with which this prison-like island is surrounded, with the exception of only a few places, where narrow valleys descend to the coast, is the most striking feature in its scenery. We have seen that portions of the basaltic ring, two or three miles in length by one or two miles in breadth, and from one to two thousand feet in height, have been wholly removed. There are, also, ledges and banks of rock, rising out of profoundly deep water, and distant from the present coast between three and four miles, which, according to Mr. Seale, can be traced to the shore, and are found to be the continuations of certain well-known great dikes. The swell of the Atlantic Ocean has obviously been the active power in forming these cliffs; and it is interesting to observe that the lesser, though still great, height of the cliffs on the leeward and partially protected side of the island, (extending from the Sugar-Loaf Hill to South West Point,) corresponds with the lesser degree of exposure. When reflecting on the comparatively low coasts of many volcanic islands, which also stand exposed in the open ocean, and are apparently of considerable antiquity, the mind recoils from an attempt to grasp the number of centuries of exposure, necessary to have ground into mud and to have dispersed the enormous cubic mass of hard rock which has been pared off the circumference of this island. The contrast in the superficial state of St. Helena, compared with the

nearest island, namely, Ascension, is very striking. At Ascension, the surfaces of the lava-streams are glossy, as if just poured forth, their boundaries are well defined, and they can often be traced to perfect craters, whence they were erupted; in the course of many long walks, I did not observe a single dike; and the coast round nearly the entire circumference is low, and has been eaten back (though too much stress must not be placed on this fact, as the island may have been subsiding) into a little wall only from ten to thirty feet high. Yet during the 340 years, since Ascension has been known, not even the feeblest signs of volcanic action have been recorded.[1] On the other hand, at St. Helena, the course of no one stream of lava can be traced, either by the state of its boundaries or of its superficies; the mere wreck of one great crater is left; not the valleys only, but the surface of some of the highest hills, are interlaced by worn-down dikes, and, in many places, the denuded summits of great cones of injected rock stand exposed and naked; lastly, as we have seen, the entire circuit of the island has been deeply worn back into the grandest precipices.

Craters of Elevation.

There is much resemblance in structure and in geological history between St. Helena, St. Jago, and Mauritius. All three islands are bounded (at least in

[1] In the 'Nautical Magazine' for 1835, p. 642, and for 1838, p. 361, and in the 'Comptes Rendus,' April, 1838, accounts are given of a series of volcanic phenomena—earthquakes—troubled water—floating scoriæ and columns of smoke—which have been observed at intervals since the middle of the last century, in a space of open sea between longitudes 20° and 22° west, about half a degree south of the equator. These facts seem to show, that an island or an archipelago is in process of formation in the middle of the Atlantic: a line joining St. Helena and Ascension, prolonged, intersects this slowly nascent focus of volcanic action.

the parts which I was able to examine) by a ring of basaltic mountains, now much broken, but evidently once continuous. These mountains have, or apparently once had, their escarpements steep towards the interior of the island, and their strata dip outwards. I was able to ascertain, only in a few cases, the inclination of the beds; nor was this easy, for the stratification was generally obscure, except when viewed from a distance. I feel, however, little doubt that, according to the researches of M. Elie de Beaumont, their average inclination is greater than that which they could have acquired, considering their thickness and compactness, by flowing down a sloping surface. At St. Helena, and at St. Jago, the basaltic strata rest on older and probably submarine beds of different composition. At all three islands, deluges of more recent lavas have flowed from the centre of the island, towards and between the basaltic mountains; and at St. Helena the central platform has been filled up by them. All three islands have been raised in mass. At Mauritius the sea, within a late geological period, must have reached to the foot of the basaltic mountains, as it now does at St. Helena; and at St. Jago it is cutting back the intermediate plain towards them. In these three islands, but especially at St. Jago and at Mauritius, when, standing on the summit of one of the old basaltic mountains, one looks in vain towards the centre of the island,—the point towards which the strata beneath one's feet, and of the mountains on each side, rudely converge,—for a source whence these strata could have been erupted; but one sees only a vast hollow platform stretched beneath, or piles of matter of more recent origin.

These basaltic mountains come, I presume, into the class of Craters of elevation: it is immaterial

whether the rings were ever completely formed, for the portions which now exist have so uniform a structure, that, if they do not form fragments of true craters, they cannot be classed with ordinary lines of elevation. With respect to their origin, after having read the works of Mr. Lyell,[1] and of MM. C. Prevost and Virlet, I cannot believe that the great central hollows have been formed by a simple dome-shaped elevation, and the consequent arching of the strata. On the other hand, I have very great difficulty in admitting that these basaltic mountains are merely the basal fragments of great volcanos, of which the summits have either been blown off, or more probably swallowed up by subsidence. These rings are, in some instances, so immense, as at St. Jago and at Mauritius, and their occurrence is so frequent, that I can hardly persuade myself to adopt this explanation. Moreover, I suspect that the following circumstances, from their frequent concurrence, are someway connected together,—a connection not implied in either of the above views: namely, first, the broken state of the ring, showing that the now detached portions have been exposed to great denudation, and in some cases, perhaps, rendering it probable that the ring never was entire; secondly, the great amount of matter erupted from the central area after or during the formation of the ring; and thirdly, the elevation of the district in mass. As far as relates to the inclination of the strata being greater than that which the basal fragments of ordinary volcanos would naturally possess, I can readily believe that this inclination might have been slowly acquired by that amount of elevation, of which, according to M. Elie de Beaumont, the numerous upfilled fissures or

[1] 'Principles of Geology' (fifth edit.), vol. ii. p. 171.

dikes are the evidence and the measure,—a view equally novel and important, which we owe to the researches of that geologist on Mount Etna.

A conjecture, including the above circumstances, occurred to me, when,—with my mind fully convinced, from the phenomena of 1835 in South America,[1] that the forces which eject matter from volcanic orifices and raise continents in mass are identical,—I viewed that part of the coast of St. Jago, where the horizontally upraised, calcareous stratum dips into the sea, directly beneath a cone of subsequently erupted lava. The conjecture is that, during the slow elevation of a volcanic district or island, in the centre of which one or more orifices continue open, and thus relieve the subterranean forces, the borders are elevated more than the central area; and that the portions thus upraised do not slope gently into the central, less elevated area, as does the calcareous stratum under the cone at St. Jago, and as does a large part of the circumference of Iceland,[2] but that they are separated from it by curved

[1] I have given a detailed account of these phenomena, in a paper read before the Geological Society in March, 1838. At the instant of time, when an immense area was convulsed and a large tract elevated, the districts immediately surrounding several of the great vents in the Cordillera remained quiescent; the subterranean forces being apparently relieved by the eruptions, which then recommenced with great violence. An event of somewhat the same kind, but on an infinitely smaller scale, appears to have taken place, according to Abich ('Views of Vesuvius,' plates i. and ix.), within the great crater of Vesuvius, where a platform on one side of a fissure was raised in mass twenty feet, whilst on the other side, a train of small volcanos burst forth in eruption.

[2] It appears, from information communicated to me in the most obliging manner by M. E. Robert, that the circumferential parts of Iceland, which are composed of ancient basaltic strata alternating with tuff, dip inland, thus forming a gigantic saucer. M. Robert found that this was the case, with a few and quite local exceptions, for a space of coast several hundred miles in length. I find this statement corroborated, as far as regards one place, by Mackenzie, in his 'Travels' (p. 377), and in another place by some MS. notes kindly lent me by Dr. Holland. The coast is deeply indented by creeks, at the head of which the land is generally low. M. Robert

faults. We might expect, from what we see along ordinary faults, that the strata on the upraised side, already dipping outwards from their original formation as lava-streams, would be tilted from the line of fault, and thus have their inclination increased. According to this hypothesis, which I am tempted to extend only to some few cases, it is not probable that the ring would ever be formed quite perfect; and from the elevation being slow, the upraised portions would generally be exposed to much denudation, and hence the ring become broken; we might also expect to find occasional inequalities in the dip of the upraised masses, as is the case at St. Jago. By this hypothesis the elevation of the districts in mass, and the flowing of deluges of lava from the central platforms, are likewise connected together. On this view the marginal basaltic mountains of the three foregoing islands might still be considered as forming 'Craters of elevation;' the kind of elevation implied having been slow, and the central hollow or platform having been formed, not by the arching of the surface, but simply by that part having been upraised to a less height.

informs me, that the inwardly dipping strata appear to extend as far as this line, and that their inclination usually corresponds with the slope of the surface, from the high coast-mountains to the low land at the head of these creeks. In the section described by Sir G. Mackenzie, the dip is 12°. The interior parts of the island chiefly consist, as far as is known, of recently erupted matter. The great size, however, of Iceland, equalling the bulkiest part of England, ought perhaps to exclude it from the class of islands we have been considering; but I cannot avoid suspecting that if the coast-mountains, instead of gently sloping into the less elevated central area, had been separated from it by irregularly curved faults, the strata would have been tilted seaward, and a 'Crater of elevation,' like that of St. Jago or that of Mauritius, but of much vaster dimensions, would have been formed. I will only further remark, that the frequent occurrence of extensive lakes at the foot of large volcanos, and the frequent association of volcanic and fresh-water strata, seem to indicate that the areas around volcanos are apt to be depressed beneath the general level of the adjoining country, either from having been less elevated, or from the effects of subsidence.