## LI. *Notices respecting New Books.*

*Geological Observations on the Volcanic Islands, visited during the voyage of H.M.S. Beagle, together with some brief notices on the Geology of Australia and the Cape of Good Hope. Being the second part of the Geology of the Voyage of the Beagle, under the command of* Captain Fitzroy, *R.N., during the years* 1832 *to* 1836. *By* CHARLES DARWIN, M.A., F.R.S., Vice-President of the Geological Society, and Naturalist to the Expedition. *Published with the approval of the Lords Commissioners of Her Majesty's Treasury.* London, 1844, 8vo. pp. 175. With a Plan of the Island of Ascension, and numerous wood-cuts.

WE are presented in the work now before us with a further portion of the results of the geological researches made by Mr. Darwin, during the expedition in which, with so much zeal and success, he gave his valuable and disinterested services as naturalist.

Almost every branch of natural knowledge has profited from the voyage of the Beagle;—zoology in nearly all its departments, palæontology, physical geography, meteorology, hydrography, mineralogy and geology. And if the present continuation of Mr. Darwin's labours does not present us with those striking and salient points of scientific interest which are within the scope of every lover of nature and of science,—if it does not call up again the extinct gigantic quadrupeds, which in South America, as in so many other parts of the world, almost immediately preceded the existing animals of the same types,—or, if it does not depict the stupendous phænomena attending the simultaneous outburst of volcanic fires along lines thousands of miles in extent;—it supplies the philosophical naturalist with minute information on a multitude of the constituent elements, as it were, of these greater phænomena, essential to their successful investigation, and with the details of physical structure of many volcanic islands and groups hitherto undescribed, and of others respecting which we were before deficient in exact knowledge. Mr. Darwin unites to a bold facility of comprehending the mutual relations of the greater features exhibited by the physical phænomena which have come under his observation, a happy and perspicacious power of recognizing a peculiar order of geological dynamic agents, which, though certainly not the first to notice—for many of them are matters of common and daily observation—he has yet been the first to develope in the before unsuspected greatness of their continual operation, and the first broadly to exhibit as causes—as *veræ causæ*—of geological phænomena. In his works, the agency of the winds, of the chemical elements dissolved in the waves which they impel, of the dust which they raise and diffuse, of the depositions of rivers on the rocks over which they flow, of the matter resulting from the action of the elements on collections of animal excretions and exuviæ, of the earth-worm as a labourer in geological dynamics, of the compound-polyp which, separating lime from sea-water, secretes its carbonate in the form of coral, have been developed and portrayed for the first time in their genuine tenour and importance. With respect to coral reefs and islands, much, indeed, had previously been effected, in part by English naturalists, in part by foreign voyagers; but the true interpretation, we conceive, of many of their observations, has been first given by Mr. Darwin, together with numerous other facts which belong exclusively to himself.

In these geological observations on the volcanic islands visited during the voyage of the Beagle, we have the effects of both the qualities of facile and accurate induction we have just attributed to their author. Unlike some of his former works, they are not adapted to gratify the general reader, or even to please the popular scientist, but they will supply inestimable materials for the elucidation of volcanic geology, in the hands of the profound investigator of nature, to whom they will also be suggestive of some of the deepest questions of geological causation.

We have not before had a suitable opportunity of acknowledging as it deserves the value of Mr. Darwin's contributions to science, and were unwilling to omit such an acknowledgement when directing our readers' attention to a work in which some of them are recorded. We will now proceed to a brief analytical view of these "Observations," and to extract from them certain portions, which we deem peculiarly characteristic of their author's modes of thought and description.

The title of the work states explicitly its contents. The first 130 pages relate almost exclusively to the volcanic islands and their constitution, under the heads of St. Jago, in the Cape de Verde Archipelago, Fernando Noronha, Terceira, Tahiti, Mauritius, Ascension, St. Helena, the Galapagos Archipelago, Trachyte and Basalt, Distribution of Volcanic Isles. The remainder of the volume consists of observations chiefly on the geology of New South Wales, Van Diemen's Land, New Zealand, King George's Sound, and the Cape of Good Hope; and an appendix contains descriptions of fossil shells from a tertiary deposit at St. Jago, of extinct land-shells from St. Helena, and of shells from the palæozoic formation of Van Diemen's Land, all by Mr. G. B. Sowerby; together with descriptions of fossil corals from the same formation by Mr. Lonsdale, who, we are thus happy to see, continues to aid the geologist by his valuable labours in invertebral palæontology.

Of the manner in which the information imparted respecting these localities is distributed, as well as of its nature, the following "contents" of the first and last chapters will give a sufficient notion.

"Chap. I.—*St. Jago, in the Cape de Verde Archipelago.*—Rocks of the lowest series—A calcareous sedimentary deposit, with recent shells, altered by the contact of superincumbent lava, its horizontality and extent—Subsequent volcanic eruptions, associated with calcareous matter in an earthy and fibrous form, and often enclosed within the separate cells of the scoriæ—Ancient and obliterated orifices of eruption of small size—Difficulty of tracing over a bare plain recent streams of lava—Inland hills of more ancient volcanic rock—Decomposed olivine in large masses—Felspathic rocks beneath the upper crystalline basaltic strata—Uniform structure and form of the more ancient volcanic hills—Form of the valleys near the coast—Conglomerate now forming on the sea beach.

"Chap. VII.—New South Wales—Sandstone formation—Imbedded pseudo-fragments of shale—Stratification—Current-cleavage—Great valleys—Van Diemen's Land—Palæozoic formation—Newer formation with volcanic rocks—Travertin with leaves of extinct plants—Elevation of the land—New Zealand—King George's Sound—Superficial ferruginous beds—Superficial calcareous deposit, with casts of branches; its origin from drifted particles of shells and corals; its extent—Cape of Good Hope—Junction of the granite and clay-slate—Sandstone formation."

From the second chapter* we extract the subjoined description of the island called St. Paul's Rocks, including that of a glossy incrustation coating extensive portions of those rocks, which affords an example of the particular class of geological dynamic agents, which Mr. Darwin, as we have observed, has been so happy in recognising in their full importance.

"*St. Paul's Rocks.*—This small island is situated in the Atlantic Ocean, nearly one degree north of the equator, and 540 miles distant from South America, in 29° 15′ west longitude. Its highest point is scarcely fifty feet above the level of the sea; its outline is irregular, and its entire circumference barely three-quarters of a mile. This little point of rock rises abruptly out of the ocean; and except on its western side, soundings were not obtained, even at the short distance of a quarter of a mile from its shore. It is not of volcanic origin; and this circumstance, which is the most remarkable point in its history (as will hereafter be referred to†), properly ought to exclude it from the present volume. It is composed of rocks unlike any which I have met with, and which I cannot characterize by any name, and must therefore describe.

"The simplest, and one of the most abundant kinds, is a very compact, heavy, greenish-black rock, having an angular, irregular fracture, with some points just hard enough to scratch glass, and infusible. This variety passes into others of paler green tints, less hard, but with a more crystalline fracture, and translucent on their edges; and these are fusible into a green

* A portion of this chapter relates to the effects of steam on the volcanic rocks of Terceira in the Azores, in which the author observed small aggregations of hyalite that had been deposited by the steam. Dr. Daubeny had previously observed the same fact in Hungary, and a similar one in Ischia, as noticed in his work on volcanos, pp. 100, 182.

† This island is afterwards pointed out, p. 125, as one of the very few exceptions to the rule, that all the islands scattered throughout the Atlantic (as well as the Pacific and Indian oceans), are composed either of volcanic or of modern coral-rocks.

enamel. Several other varieties are chiefly characterized, by containing innumerable threads of dark-green serpentine, and by having calcareous matter in their interstices. These rocks have an obscure, concretionary structure, and are full of variously-coloured angular pseudo-fragments. These angular pseudo-fragments consist of the first-described dark green rock, of a brown softer kind, of serpentine, and of a yellowish harsh stone, which, perhaps, is related to serpentine rock. There are other vesicular, calcareo-ferruginous soft stones. There is no distinct stratification, but parts are imperfectly laminated; and the whole abounds with innumerable veins, and vein-like masses, both small and large. Of these vein-like masses, some calcareous ones, which contain minute fragments of shells, are clearly of subsequent origin to the others.

" *A glossy incrustation.*—Extensive portions of these rocks are coated by a layer of a glossy polished substance, with a pearly lustre and of a grayish-white colour; it follows all the inequalities of the surface, to which it is firmly attached. When examined with a lens, it is found to consist of numerous exceedingly thin layers, their aggregate thickness being about the tenth of an inch. It is considerably harder than calcareous spar, but can be scratched with a knife; under the blow-pipe it scales off, decrepitates, slightly blackens, emits a fetid odour, and becomes strongly alkaline: it does not effervesce in acids*. I presume this substance has been deposited by water draining from the birds' dung, with which the rocks are covered. At Ascension, near a cavity in the rocks, which was filled with a laminated mass of infiltrated birds' dung, I found some irregularly-formed, stalactitical masses of apparently the same nature. These masses when broken had an earthy texture, but on their outsides, and especially at their extremities, they were formed of a pearly substance, generally in little globules, like the enamel of teeth, but more translucent, and so hard as just to scratch plate-glass. This substance slightly blackens under the blow-pipe, emits a bad smell, then becomes quite white, swelling a little, and fuses into a dull white enamel; it does not become alkaline; nor does it effervesce in acids. The whole mass had a collapsed appearance, as if in the formation of the hard glossy crust, the whole had shrunk much. At the Abrolhos Islands, on the coast of Brazil, where also there is much birds' dung, I found a great quantity of a brown, arborescent substance adhering to some trap-rock. In its arborescent form, this substance singularly resembles some of the branched species of Nullipora. Under the blow-pipe, it behaves like the specimens from Ascension; but it is less hard and glossy, and the surface has not the shrunk appearance."

In the third chapter, allotted to Ascension, we have an interesting notice of the volcanic bombs which are so numerous in that island, and which are probably connected in their origin with the explosions of aëriform matter that have covered the flanks of Green Mountain and the surrounding country with a mass some hundred feet in thickness, of loose fragments, consisting chiefly of tuffs and pumiceous breccia†. Here the author found bombs, the internal structure of

* "In my Journal I have described this substance; I then believed that it was an impure phosphate of lime."

† On the northern side of Green Mountain a thin seam of compact oxide of iron extends over a considerable area, lying in the lower part of the mass of fragments. "This seam of compact stone," it is remarked, p. 39, "by intercepting the little rain-water which falls on the island, gives rise to a small dripping spring, first discovered by Dampier. It is the only fresh-water on the island, so that the possibility of its being inhabited has entirely depended on the occurrence of this ferruginous layer."

which presented a symmetrical and very curious appearance, of which he gives a figure and the subjoined description:—

"The whole interior is coarsely cellular; the cells averaging in diameter about the tenth of an inch; but nearer the outside they gradually decrease in size. This part is succeeded by a well-defined shell of compact lava, having a nearly uniform thickness of about the third of an inch; and the shell is overlaid by a somewhat thicker coating of finely cellular lava (the cells varying from the fiftieth to the hundredth of an inch in diameter), which forms the external surface: the line separating the shell of compact lava from the outer scoriaceous crust is distinctly defined. This structure is very simply explained, if we suppose a mass of viscid scoriaceous matter to be projected with a rapid, rotatory motion through the air; for whilst the external crust, from cooling, became solidified (in the state we now see it), the centrifugal force, by relieving the pressure in the interior parts of the bomb, would allow the heated vapours to expand their cells; but these being driven by the same force against the already-hardened crust, would become, the nearer they were to this part, smaller and smaller or less expanded, until they became packed into a solid, concentric shell. As we know that chips from a grindstone* can be flirted off, when made to revolve with sufficient velocity, we need not doubt that the centrifugal force would have power to modify the structure of a softened bomb, in the manner here supposed. Geologists have remarked, that the external form of a bomb at once bespeaks the history of its aërial course, and we now see that the internal structure can speak, with almost equal plainness, of its rotatory movement."

M. Beudant has described in his Travels in Hungary, some singular little oval balls of obsidian, found strewed on the surface of the ground, their surface regularly marked with concentric ridges and furrows, all of which on the same ball are at right angles to one axis; and he supposes that these were produced by masses of lava, which when soft were shot into the air with a rotatory movement round the same axis. This leads Mr. Darwin to describe and figure a volcanic bomb of obsidian from Australia, which exhibits the external structure described by M. Beudant, and the internal cellular condition of the bombs from Ascension, described in the preceding extract. In this case, from certain parts of the existing structure, one is forced to suppose, as the author remarks, that the bomb burst during its rotatory course, before being quite solidified, and that the axis of rotation then changed.

The following observations relating also to some of the rocks of Ascension are important, as involving the history of a process partly related to that by which siliceous petrifactions have been produced, a subject as yet enveloped in total obscurity:—

"*Siliceous sinter and jasper.*—The siliceous sinter is either quite white, of little specific gravity, and with a somewhat pearly fracture, passing into pinkish pearly quartz; or it is yellowish-white, with a harsh fracture, and it then contains an earthy powder in small cavities. Both varieties occur, either in large irregular masses in the altered trachyte, or in seams included in broad, vertical, tortuous, irregular veins of a compact, harsh stone of a dull red colour appearing like a sandstone. This stone, however, is only altered trachyte; and a nearly similar variety, but often honeycombed,

* "Nichol's Architecture of the Heavens."

sometimes adheres to the projecting plate-like veins, described in the last paragraph. The jasper is of an ochre-yellow or red colour; it occurs in large irregular masses, and sometimes in veins, both in the altered trachyte and in an associated mass of scoriaceous basalt. The cells of the scoriaceous basalt are lined or filled with fine, concentric layers of chalcedony, coated and studded with bright-red oxide of iron. In this rock, especially in the rather more compact parts, irregular angular patches of the red jasper are included, the edges of which insensibly blend into the surrounding mass; other patches occur having an intermediate character between perfect jasper and the ferruginous, decomposed basaltic base. In these patches, and likewise in the large vein-like masses of jasper, there occur little rounded cavities, of exactly the same size and form with the air-cells, which in the scoriaceous basalt are filled and lined with layers of chalcedony. Small fragments of the jasper, examined under the microscope, seem to resemble the chalcedony with its colouring matter not separated into layers, but mingled in the siliceous paste, together with some impurities. I can understand these facts,—namely, the blending of the jasper into the semi-decomposed basalt,—its occurrence in angular patches, which clearly do not occupy pre-existing hollows in the rock,—and its containing little vesicles filled with chalcedony, like those in the scoriaceous lava,—only on the supposition that a fluid, probably the same fluid which deposited the chalcedony in the air-cells, removed in those parts where there were no cavities, the ingredients of the basaltic rock, and left in their place silica and iron, and thus produced the jasper. In some specimens of silicified wood, I have observed, that in the same manner as in the basalt, the solid parts were converted into a dark-coloured homogeneous stone, whereas the cavities formed by the larger sap-vessels (which may be compared with the air-vesicles in the basaltic lava) and other irregular hollows, apparently produced by decay, were filled with concentric layers of chalcedony; in this case there can be little doubt that the same fluid deposited the homogeneous base and the chalcedonic layers. After these considerations, I cannot doubt but that the jasper of Ascension may be viewed as a volcanic rock silicified, in precisely the same sense as this term is applied to wood when silicified: we are equally ignorant of the means by which every atom of wood, whilst in a perfect state, is removed and replaced by atoms of silica, as we are of the means by which the constituent parts of a volcanic rock could be thus acted on*. I was led to the careful examination of these rocks, and to the conclusion here given, from having heard the Rev. Professor Henslow express a similar opinion regarding the origin in trap-rocks of many chalcedonies and agates. Siliceous deposits seem to be very general, if not of universal occurrence, in partially decomposed trachytic tuffs†;

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* "Beudant (*Voyage en Hongrie*, tom. iii. p. 502, 504) describes kidney-shaped masses of jasper-opal, which either blend into the surrounding trachytic conglomerate, or are imbedded in it like chalk-flints; and he compares them with the fragments of opalized wood, which are abundant in this same formation. Beudant, however, appears to have viewed the process of their formation, rather as one of simple infiltration, than of molecular exchange; but the presence of a concretion, wholly different from the surrounding matter, if not formed in a pre-existing hollow, clearly seems to me to require, either a molecular or mechanical displacement of the atoms, which occupied the space afterwards filled by it. The jasper-opal of Hungary passes into chalcedony, and therefore in this case, as in that of Ascension, jasper seems to be intimately related in origin with chalcedony."

† "Beudant (*Voyage Min.* tom. iii. p. 507) enumerates cases in Hungary, Germany, Central France, Italy, Greece, and Mexico."

and as these hills, according to the view above given, consist of trachyte softened and altered *in situ*, the presence of free silica in this case may be added as one more instance to the list."

Mr. Darwin truly observes, as above, that we are ignorant of the means by which, in the silicification of wood, every atom of wood, whilst in a perfect state, is removed and replaced by atoms of silica. The recent discovery by Ebelmen, as noticed in our last Volume, p. 397, of the production of silicic æthers, by the substitution of silica in equivalent proportions for the water which in alcohol is united to the oxide of a certain hydro-carbon, induces us to offer a suggestion on this subject. Hydro-carbons, combinations of hydrogen and carbon, in various proportions, are the results, as Liebig has shown by a comprehensive induction from facts previously investigated by other chemists, of eremacausis, and of other changes, which either spontaneously occur or are readily induced, in natural operations, in ligneous and other vegetable matter, and some of them, as the turpentines, are the actual products of vegetable life. Now silicic æther, it is found, is soluble in all proportions, in alcohol and æther, which involves the fact of *the practical indefinite solubility of silica in the oxide and the hydrated oxide of that peculiar hydro-carbon which has been called by modern chemists, ethyl.* But if these products of vegetable matter have this kind of loose affinity for silica, causing them thus to unite with it in large proportions, from which it is again readily separable, is it not in the highest degree probable that other (natural) products of vegetation, other hydro-carbons or their oxides, may have a similar power of dissolving silica, readily to part with it again? If so, we have an indication of the line of research by which we may hope to solve the problem of the silicification of wood. A most interesting and extensive field for experiment and investigation, chemical, botanical, mineralogical and geological, is thus presented, and will be entered upon, we hope, by some competent inquirer. An accomplished man of science would be required to devote himself to the task, necessarily an arduous one, but its successful performance would gain or even enhance the highest reputation.

To return however to Mr. Darwin's researches. In the annexed account of the formation of calcareous rocks on the coast of Ascension, and in that of a peculiar incrustation on certain rocks of that island which immediately succeeds it, we have further examples of that particular class of existing causes in geology which have opened to him so fertile a field of inquiry.

"*Formation of calcareous rocks on the sea-coast.*—On several of the sea-beaches, there are immense accumulations of small, well-rounded particles of shells and corals, of white, yellowish and pink colours, interspersed with a few volcanic particles. At the depth of a few feet, these are found cemented together into stone, of which the softer varieties are used for building; there are other varieties, both coarse and fine-grained, too hard for this purpose: and I saw one mass, divided into even layers half an inch in thickness, which were so compact, that when struck with a hammer they rang like flint. It is believed by the inhabitants that the particles become united in the course of a single year. The union is effected by calcareous matter; and in the most compact varieties, each rounded particle of shell and volcanic rock can be distinctly seen to be enveloped in a husk of pellucid carbonate of lime. Extremely few perfect shells are imbedded in these agglutinated masses; and I have examined even a large fragment under a microscope, without being able to discover the least vestige of striæ or other marks of external form: this shows how long each particle must have been rolled about, before its turn came to be imbedded and cemented*. One of the most compact varieties, when placed in acid, was entirely dissolved, with the exception of some flocculent animal matter; its specific gravity was 2·63. The specific gravity of ordinary limestone varies from 2·6 to 2·75; pure Carrara marble was found by Sir H. De la Beche† to be 2·7. It is remarkable that these rocks of Ascension, formed close to the surface, should be nearly as compact as marble, which has undergone the action of heat and pressure in the plutonic regions.

"The great accumulation of loose calcareous particles, lying on the beach near the Settlement, commences in the month of October, moving towards the S.W., which, as I was informed by Lieut. Evans, is caused by a change in the prevailing direction of the currents. At this period the tidal rocks, at the S.W. end of the beach, where the calcareous sand is accumulating, and round which the currents sweep, become gradually coated with a calcareous incrustation, half an inch in thickness. It is quite white, compact, with some parts slightly spathose, and is firmly attached to the rock. After a short time it gradually disappears, being either redissolved, when the water is less charged with lime, or more probably is mechanically abraded. Lieut. Evans has observed these facts during the six years he has resided at Ascension. The incrustation varies in thickness in different years: in 1831 it was unusually thick. When I was there in July, there was no remnant of the incrustation; but on a point of basalt, from which the quarrymen had lately removed a mass of the calcareous freestone, the incrustation was perfectly preserved. Considering the position of the tidal rocks, and the period at which they become coated, there can be no doubt that the movement and disturbance of the vast accumulation of calcareous particles, many of them being partially agglutinated together, causes the waves of the sea to be so highly charged with carbonate of lime, that they deposit it on the first objects against which they impinge. I have been informed by Lieut. Holland, R.N., that this incrustation is formed on many parts of the coast, on most of which, I believe, there are likewise great masses of comminuted shells."

This is succeeded, as intimated above, by a minute description illustrated by a figure, of a frondescent incrustation of calcareous and animal matter, coating throughout the year the tidal volcanic rocks at Ascension, that project from the beaches composed of broken shells; the origin of this he shows, is due to the solution and subsequent deposition of matter derived from the rounded particles of corals and shells, which form the nuclei of the fronds or discs of which the incrustation is composed, mingled with minute lamellæ of selenite derived from the sea-water; and it is an interesting circumstance, he remarks, thus to find the waves of the ocean sufficiently charged with sulphate of lime, to deposit it on the rocks, against which they dash every tide. When the incrustation now described

* "The eggs of the turtle being buried by the parent, sometimes become enclosed in the solid rock. Mr. Lyell has given a figure (Principles of Geology, book iii. ch. 17) of some eggs, containing the bones of young turtles, found thus entombed."

† "Researches in Theoretical Geology," p. 12.

has been deposited on the underside of ledges of rocks or in fissures, it appears always to be of a pale pearly-gray colour, whereas, in other situations, it has a dark gray or even a jet-black colour. This induces the author to suppose

"that an abundance of light is necessary to the development of the dark colour, in the same manner as seems to be the case with the upper and exposed surfaces of the shells of living mollusca, which are always dark, compared with their under surfaces and with the parts habitually covered by the mantle of the animal. In this circumstance,—in the immediate loss of colour and in the odour emitted under the blow-pipe,—in the degree of hardness and translucency of the edges,—and in the beautiful polish of the surface, rivalling when in a fresh state that of the finest Oliva, there is a striking analogy between this inorganic incrustation and the shells of living molluscous animals*. This appears to me to be an interesting physiological fact."

In continuation of the geological history of Ascension are described some singular laminated beds, alternating with and passing into obsidian. These consist,—1, of a pale gray, irregularly and coarsely laminated harsh-feeling rock, resembling clay-slate which has been in contact with a trap-dike, and easily fusing, like the following varieties, into a pale glass; 2, a bluish-gray or pale brown, compact, heavy, apparently homogeneous stone, in which, however, under a lens, a crystalline fracture and even separate minerals can be observed; 3, a stone resembling the last, but streaked with crystalline white hairs of quartz and green transparent needles of diopside; 4, a compact crystalline rock banded with innumerable layers seeming to be composed chiefly of felspar, and containing numerous perfect crystals of glassy felspar placed lengthways, minute black specks of hornblende or augite, and red specks of oxide of iron; 5, a compact heavy rock, not laminated, with an irregular, angular, highly crystalline fracture, abounding with distinct crystals of glassy felspar, and having the crystalline felspathic base mottled with a black mineral, and the entire rock strikingly resembling, in aspect, a primitive greenstone.

We have been thus particular in describing after our author the characters of these rocks, because the knowledge of those characters is essential to the accurate comprehension of the history of their passage into obsidian, which, with its accompaniments, we deem one of the most instructive and suggestive portions of the work, and which, therefore, we will extract entire.

The five varieties of rock just described,

"with many intermediate ones, pass and repass into each other. As the compact varieties are quite subordinate to the others, the whole may be considered as laminated or striped. The laminæ, to sum up their characteristics, are either quite straight, or slightly tortuous, or convoluted; they are all parallel to each other, and to the intercalating strata of obsidian; they

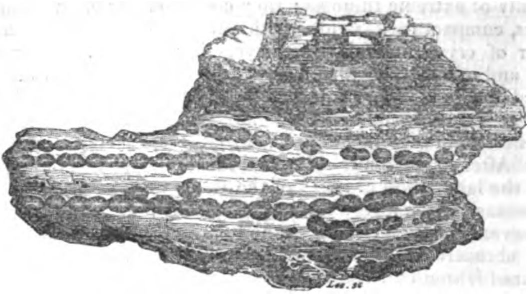
* "In the section descriptive of St. Paul's Rocks, I have described a glossy, pearly substance which coats the rocks, and an allied stalactitical incrustation from Ascension, the crust of which resembles the enamel of teeth, but is hard enough to scratch plate glass. Both these substances contain animal matter, and seem to have been derived from water infiltering through birds' dung."

are generally of extreme thinness; they consist either of an apparently homogeneous, compact rock, striped with different shades of gray and brown colours, or of crystalline felspathic layers in a more or less perfect state of purity, and of different thicknesses, with distinct crystals of glassy felspar placed lengthways, or of very thin layers chiefly composed of minute crystals of quartz and augite, or composed of black and red specks of an augitic mineral and of an oxide of iron, either not crystallized or imperfectly so. After having fully described the obsidian, I shall return to the subject of the lamination of rocks of the trachytic series.

"The passage of the foregoing beds into the strata of glassy obsidian is effected in several ways; first, angulo-nodular masses of obsidian, both large and small, abruptly appear disseminated in a slaty, or in an amorphous, pale-coloured felspathic rock, with a somewhat pearly fracture. Secondly, small irregular nodules of the obsidian, either standing separately, or united into thin layers, seldom more than the tenth of an inch in thickness, alternate repeatedly with very thin layers of a felspathic rock, which is striped with the finest parallel zones of colour, like an agate, and which sometimes passes into the nature of pitchstone; the interstices between the nodules of obsidian are generally filled by soft white matter, resembling pumiceous ashes. Thirdly, the whole substance of the bounding rock suddenly passes into an angulo-concretionary mass of obsidian. Such masses (as well as the small nodules) of obsidian are of a pale green colour, and are generally streaked with different shades of colour, parallel to the laminæ of the surrounding rock; they likewise generally contain minute white sphærulites, of which half is sometimes imbedded in a zone of one shade of colour, and half in a zone of another shade. The obsidian assumes its jet black colour and perfectly conchoidal fracture, only when in large masses; but even in these, on careful examination and on holding the specimens in different lights, I could generally distinguish parallel streaks of different shades of darkness.

"One of the commonest transitional rocks deserves in several respects a further description. It is of a very complicated nature, and consists of numerous thin, slightly tortuous layers of a pale-coloured felspathic stone, often passing into an imperfect pitchstone, alternating with layers formed of numberless little globules of two varieties of obsidian, and of two kinds of sphærulites, imbedded in a soft or in a hard pearly base. The sphærulites are either white and translucent, or dark brown and opake; the former are quite spherical, of small size, and distinctly radiated from their centre. The dark brown sphærulites are less perfectly round, and vary in diameter from the $\frac{1}{20}$ to $\frac{1}{30}$ of an inch; when broken they exhibit towards their centres, which are whitish, an obscure radiating structure; two of them, when united, sometimes have only one central point of radiation; there is occasionally a trace of a hollow or crevice in their centres. They stand either separately, or are united two or three or many together into irregular groups, or more commonly into layers, parallel to the stratification of the mass. This union in many cases is so perfect, that the two sides of the layer thus formed are quite even; and these layers, as they become less brown and opake, cannot be distinguished from the alternating layers of the pale-coloured felspathic stone. The sphærulites, when not united, are generally compressed in the plane of the lamination of the mass; and in this same plane they are often marked internally by zones of different shades of colour, and externally by small ridges and furrows. In the upper part of the accompanying woodcut, the sphærulites with the parallel ridges and furrows are represented on an enlarged scale, but they are not well executed; and in the lower part their usual manner of grouping is shown. In another specimen, a thin layer formed of the brown sphærulites closely

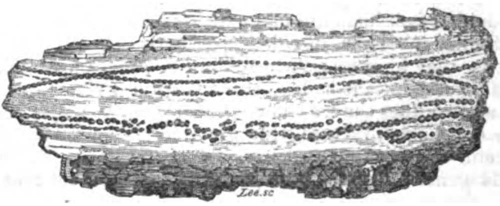
No. 6.



Opake brown sphærulites, drawn on an enlarged scale. The upper ones are externally marked with parallel ridges. The internal radiating structure of the lower ones is much too plainly represented.

united together, intersects, as represented in the woodcut, No. 7, a layer of similar composition; and after running for a short space in a slightly curved line, again intersects it, and likewise a second layer lying a little way beneath that first intersected. The small nodules also of obsidian are some-

No. 7.



A layer formed by the union of minute brown sphærulites, intersecting two other similar layers; the whole represented of nearly the natural size.

times externally marked with ridges and furrows, parallel to the lamination of the mass, but always less plainly than the sphærulites. These obsidian nodules are generally angular, with their edges blunted; they are often impressed with the form of the adjoining sphærulites, than which they are always larger; the separate nodules seldom appear to have drawn each other out by exerting a mutual attractive force. Had I not found in some cases a distinct centre of attraction in these nodules of obsidian, I should have been led to have considered them as residuary matter, left during the formation of the pearlstone, in which they are imbedded, and of the sphærulitic globules.

"The sphærulites and the little nodules of obsidian in these rocks so closely resemble in general form and structure concretions in sedimentary deposits, that one is at once tempted to attribute to them an analogous origin. They resemble ordinary concretions in the following respects,—in their external form,—in the union of two or three, or of several, into an irregular mass, or into an even-sided layer,—in the occasional intersection of one such layer by another, as in the case of chalk-flints,—in the presence of two or three kinds of nodules, often close together, in the same basis,—in their fibrous, radiating structure, with occasional hollows in their centres,—in the coexistence of a laminary, concretionary, and radiating structure, as is so well developed in the concretions of magnesian limestone described by Professor Sedgwick *. Concretions in sedimentary deposits, it is known, are due to

* "Geological Transactions, vol. iii. part i. p. 37."

the separation from the surrounding mass of the whole or part of some mineral substance, and its aggregation round certain points of attraction. Guided by this fact, I have endeavoured to discover whether obsidian and the sphærulites (to which may be added marekanite and pearlstone, both of them occurring in nodular concretions in the trachytic series) differ in their constituent parts from the minerals generally composing trachytic rocks. It appears from three analyses, that obsidian contains on an average 76 per cent. of silica; from one analysis, that sphærulites contain 79·12; from two, that marekanite contains 79·25; and from two other analyses, that pearlstone contains 75·62 of silica*. Now, the constituent parts of trachyte, as far as they can be distinguished, consist of felspar, containing 65·21 of silica; or of albite, containing 69·09; of hornblende, containing 55·27†, and of oxide of iron: so that the foregoing glassy concretionary substance all contain a larger proportion of silica than that occurring in ordinary felspathic or trachytic rocks. D'Aubuisson‡, also, has remarked on the large proportion of silica compared with alumina, in six analyses of obsidian and pearlstone given in Brongniart's Mineralogy. Hence I conclude, that the foregoing concretions have been formed by a process of aggregation, strictly analogous to that which takes place in aqueous deposits, acting chiefly on the silica, but likewise on some of the other elements of the surrounding mass, and thus producing the different concretionary varieties. From the well-known effects of rapid cooling§ in giving glassiness of texture, it is probably necessary that the entire mass, in cases like that of Ascension, should have cooled at a certain rate; but considering the repeated and complicated alternations, of nodules and thin layers of a glassy texture with other layers quite stony or crystalline, all within the space of a few feet or even inches, it is hardly possible that they could have cooled at different rates, and thus have acquired their different textures.

"The natural sphærulites in these rocks‖, very closely resemble those produced in glass when slowly cooled. In some fine specimens of partially devitrified glass, in the possession of Mr. Stokes, the sphærulites are united into straight layers with even sides, parallel to each other, and to one of the outer surfaces, exactly as in the obsidian. These layers sometimes interbranch and form loops; but I did not see any case of actual intersection. They form the passage from the perfectly glassy portions, to those nearly homogeneous and stony, with only an obscure concretionary

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* "The foregoing analyses are taken from Beudant, *Traité de Minéralogie*, tom. ii. p. 113; and one analysis of obsidian, from Phillips's Mineralogy."

† "These analyses are taken from Von Kobell's *Grundzüge der Mineralogie*, 1838."

‡ "*Traité de Géogn.* tom. ii. p. 535."

§ "This is seen in the manufactory of common glass, and in Gregory Watts's experiments on molten trap; also on the natural surfaces of lava-streams, and on the side-walls of dikes."

‖ "I do not know whether it is generally known, that bodies having exactly the same appearance as sphærulites sometimes occur in agates. Mr. Robert Brown showed me in an agate, formed within a cavity in a piece of silicified wood, some little specks, which were only just visible to the naked eye: these specks, when placed by him under a lens of high power, presented a beautiful appearance: they were perfectly circular, and consisted of the finest fibres of a brown colour, radiating with great exactness from a common centre. These little radiating stars are occasionally intersected, and portions are quite cut off by the fine, ribbon-like zones of colour in the agate. In the obsidian of Ascension, the halves of a sphærulite often lie in different zones of colour, but they are not cut off by them as in the agate."

structure. In the same specimen, also, sphærulites differing slightly in colour and in structure occur imbedded close together. Considering these facts, it is some confirmation of the view above given of the concretionary origin of the obsidian and natural sphærulites, to find that M. Dartigues*, in his curious paper on this subject, attributes the production of sphærulites in glass to the different ingredients obeying their own laws of attraction and becoming aggregated. He is led to believe that this takes place, from the difficulty in remelting sphærulitic glass, without the whole be first thoroughly pounded and mixed together; and likewise from the fact, that the change takes place most readily in glass composed of many ingredients. In confirmation of M. Dartigues' view, I may remark, that M. Fleuriau de Bellevue† found that the sphærulitic portions of devitrified glass were acted on both by nitric acid and under the blow-pipe, in a different manner from the compact paste in which they were imbedded."

The author next points out how closely the description of the obsidian rocks of Hungary given by Beudant, that by Humboldt of the same formation in Mexico and Peru, and likewise the descriptions given by Scrope, Dolomieu, and D'Aubuisson, of the trachytic regions in the Italian Islands, agree with his own observations at Ascension. Many passages, he remarks, might have been transferred without alteration from the works of those authors, and would have been applicable to this island. He then proceeds to investigate the lamination of volcanic rocks of the trachytic series, and after referring to the frequently zoned structure of obsidian itself, and to the observations of the geologists named above, and the theoretical views on the subject enunciated by some of them, he finds, guided by Professor Forbes's clear description of the zoned structure of glacier ice, that

"far the most probable explanation of the laminated structure of these felspathic rocks appears to be, that they have been stretched whilst slowly flowing onwards in a pasty condition‡, in precisely the same manner as Professor Forbes believes that the ice of moving glaciers is stretched and fissured. In both cases, the zones may be compared to those in the finest agates; in both, they extend in the direction in which the mass has flowed, and those exposed on the surface are generally vertical: in the ice, the porous laminæ are rendered distinct by the subsequent congelation of infiltrated water, in the stony felspathic lavas, by subsequent crystalline and concretionary action. The fragment of glassy obsidian in Mr. Stokes' collection, which is zoned with minute air-cells, must strikingly resemble, judging from Professor Forbes' descriptions, a fragment of the zoned ice;

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* "*Journ. de Physique*, tom. lix. (1804), pp. 10, 12."

† "*Ibid.* tom. lx. (1805), p. 418."

‡ "I presume that this is nearly the same explanation which Mr. Scrope had in his mind, when he speaks (Geol. Trans. vol. ii. second series, p. 228) of the ribboned structure of his trachytic rocks having arisen from 'a linear extension of the mass, while in a state of imperfect liquidity, coupled with a concretionary process.'"—[On this subject we may refer for additional illustration to the observations by Professors Forbes and L. Gordon in our last Number, p. 206, on the motion of flowing pitch, as confirming the viscous theory of glaciers. Those who are familiar with the aspect of masses of glass, whether natural or artificial, which have retained their original surface, will immediately recognise its identity with that of flowing pitch, as represented in the lithograph illustrating the observations.]

and if the rate of cooling and nature of the mass had been favourable to its crystallization or to concretionary action, we should here have had the finest parallel zones of different composition and texture. In glaciers, the lines of porous ice and of minute crevices seem to be due to an incipient stretching, caused by the central parts of the frozen stream moving faster than the sides and bottom, which are retarded by friction: hence, in glaciers of certain forms and towards the lower end of most glaciers, the zones become horizontal. May we venture to suppose that in the felspathic lavas with horizontal laminæ we see an analogous case? All geologists who have examined trachytic regions have come to the conclusion, that the lavas of this series have possessed an exceedingly imperfect fluidity; and as it is evident that only matter thus characterized would be subject to become fissured and to be formed into zones of different tensions, in the manner here supposed, we probably see the reason why augitic lavas, which appear generally to have possessed a high degree of fluidity, are not*, like the felspathic lavas, divided into laminæ of different composition and texture. Moreover, in the augitic series, there never appears to be any tendency to concretionary action, which we have seen plays an important part in the lamination of rocks of the trachytic series, or at least in rendering that structure apparent."

In the fourth chapter, relating to St. Helena, we have by far the most definite and explicit account of the structure of that island which has yet been made public, and from which, if studied in conjunction with the views and local descriptions given in Seale's "Geognosy" of the island, the geologist may acquire positive and satisfactory notions of the phænomena it presents, such as will be comparable with those which he possesses of the volcanic regions of Naples or Central France. We would gladly follow our author in this place, but our limits warn us to conclude; and simply referring to the account, p. 87, of certain beds of soft calcareous sandstone in St. Helena, the particles composing which have been drifted into their present position by the wind, and subsequently consolidated by the percolation of rain-water, we pass to the end of the chapter, from which we extract the following instructive considerations on a difficult and much-debated subject.

"*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 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 escarpments 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

* "Basaltic lavas, and many other rocks, are not unfrequently divided into thick laminæ or plates of the same composition, which are either straight or curved; these being crossed by vertical lines of fissure, sometimes become united into columns. This structure seems related in its origin to that by which many rocks, both igneous and sedimentary, become traversed by parallel systems of fissures."

and 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* 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 connexion 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 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 phænomena of 1835 in South America†, that the forces which eject matter from volcanic orifices and

* "Principles of Geology (fifth edition), vol. ii. p. 171."

† "I have given a detailed account of these phænomena, in a paper read before the Geological Society in March 1838. [See Phil. Mag. S. 3. vol. xii. p. 584.] 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."

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*, but that they are separated from it by curved 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."

Other subjects scarcely inferior in interest are discussed in the chapter on the Galapagos Archipelago, as the fluidity of different

* "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 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 freshwater 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."

lavas, craters of tuff*, direction of the fissures of eruption; and also in the sixth chapter, on trachyte and basalt†, the origin of trap-dikes (p. 123), and the distribution of volcanic vents. The subject of the last chapter we have already stated in detail, and we will here terminate this article, commending this "Second Part of the Geology of the Voyage of the Beagle" to the attention of every student of geology and philosophical mineralogy, and hoping that the publication of the Third Part, which will be devoted, we find, exclusively to South America, will follow at no distant period.