PETROLOGY.

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The numerous specimens illustrating the rock formations of the Isle of Rodriguez, collected by Mr. I. Bayley Balfour from different localities, need only a cursory inspection to attest the volcanic character of the whole mass of the island.

Rodriguez, in fact, consists of Doleritic lavas that appear to have been poured out at a considerable number of volcanic orifices at successive periods. It would be difficult, without more minute description of the physical geography of the island than is accessible, to assign any precise date or duration to these volcanic eruptions, or to trace with any certainty the degree to which and the mode in which subsequent denudation has helped in giving the island its present remarkable aspect.

But the fact of that denudation and the degree to which alteration has proceeded in affecting the minerals composing rocks that by their position must have been among the later of the out-poured lavas, would point to a remote date, possibly to one contemporary with the tertiary period, as that of the volcanic activity of Rodriguez.

A central ridge, lofty for an island of only about 13 miles in length by 5 in width, divides the north from the south, except that a break occurs at about two-thirds of the distance from east to west. A succession of peaks on this ridge range from the Mount Quatre-vents, which forms the western bastion, 1,120 feet high, of the central mass of the island, to the Grande Montagne, which is 1,140 feet in height, and looks into the steep valleys of the rivers Grévier, Palmiste, de l'Est, and Bouteille, that lead down from it in a semicircle to the sea around the eastern end of the island.

Between these points, or in positions a little in advance of the general line of mountains, Mount Limon, 1,300 feet, Le Pitou, 1,160 feet, and another height between it and Mount Limon, 1,240 feet, are among the peaks that crown this volcanic mass of mountain. The steep flanks of these high lava ridges assume in some cases columnar forms, the basaltic columns of the cliffs, at Mount Tonnerre for instance, rising to 200 perpendicular feet.

It would seem, however, from the contour of the island and from the nature of the rock composing it, that the steep valleys which groove the sides of the chief mountain mass have been mainly engineered by the brooks that find their way to the sea, and meet the innumerable little bays and inlets that indent its shores on every side.

It is especially on the east and round the eastern end that the mountain range is steepest, for there the coral reef comes nearly close to the shore, and the island would seem to rise rather abruptly from the depths of the ocean.

The rock specimens which Mr. Balfour collected appear to have been brought together with a naturalist's discrimination as regards their variety, and with considerable care as regards their representation of the different localities.

The petrological study of them brings out the fact that, while externally they differ considerably in their mechanical texture and appearance, they all, as has been above stated, belong to the doleritic and basaltic group of rocks, and especially to a variety of these rich in Olivine, and free from any appreciable amount of glassy ground-mass.

The coarser grained and more strictly doleritic varieties of this rock (strictly, perhaps, they should be called Anamesite) are illustrated by various specimens taken from Mount Grenade, from the summit of Mount Pitou, from the summit and also from a valley south of the Grande Montagne; likewise in some of the carefully collected specimens, of which further mention will be made, from the Cascade valley, a valley carved out by a stream which, rising between Mount Pitou and Mount Limon, almost exactly in the centre of the island, enters the sea at the back of the little town of Mathurin, on the northern shore. The cliff at the back of this town, the valley running up from the east of English Bay Point, a hill overhanging the mouth of the point and bay of Banane, and a steep ridge above the Anse (or bay of) Bouteille, are other localities taken in topographical order from W. to E., from which the coarser-grained lavas were collected.

These coarser or more doleritic kinds vary in tint, but are generally of light grey colour, the larger grained kinds tending to a somewhat violet grey, the finer to a bluer and more slaty hue. They are by no means hard in texture; some of them are compact, others more or less vesicular, and occasionally carry zeolitic minerals, or aragonite.

Viewed microscopically, the white felspar is seen to be mottled with dark grey minerals, among which conspicuous crystals of orange-yellow Olivine stand out, and are generally decomposed to a considerable degree, and here and there small grains of magnetite can be recognised.

In thin sections these dolerites of coarser grain present in the microscope a beautiful assemblage of interlaced felspar crystals, which in polarised light exhibit the twinned and ribboned stripes that characterise the anorthic felspars. This felspar is in fact Labradorite. That it is so is confirmed by the analysis of the crystals picked with great care from the crushed rock; a specimen quite characteristic in its felspar being selected from those from the river Palmiste.

In some of these dolerites, as in that from Mount Grenade and from Pitou, the crystals of felspar are long and blade-like in form, while in those from some of the other localities the crystals are comparatively short in proportion to their length;

they do not, however, appear to belong to different varieties, for they pass through intermediate stages. The felspar in most of the rocks becomes prominent in individual crystals, and imparts a micro-porphyritic character to the rock, independently of the Olivine. Of ground-mass, strictly speaking, these dolerites are devoid. The mass of the rock is made up of the interlaced felspar crystals, the interstices being filled with a brown, and in finer grained varieties a nearly opaque, mineral, which sometimes crystallises in distinct forms, and in its less distinct variety is only to be recognised as crystalline by examination with a high power between crossed tourmalines. It is undoubtedly Augite. In some instances the Augite is to be recognised in quite distinct and transparent short pale greenish brown crystals, quite unattacked by decomposition.

The Olivine which often porphyrises the rock by its abundance and distinctness of crystallisation rises into an important ingredient of these dolerites. Some of them might indeed be termed Olivine dolerites, from the abundance of this mineral.

The Olivine belongs to a variety rich in iron, and has undergone the usual characteristic decomposition; the crystals being encrusted by, and sometimes entirely converted into, a dark reddish brown mineral, which has also penetrated the crystals wherever fissures have afforded lines of entrance by which acid or thermal waters could attack them. In one or two of the rocks of finer grain a mineral closely resembling Chlorophæite can be recognised.

Minute grains of magnetite, the rectangular or nearly rectangular sections of which can often be recognised, are abundant in some specimens of the rock, and are seen very evenly distributed in the microscopic sections.

A very characteristic accompaniment of the felspar is Apatite, a mineral which presents itself in long transparent needles and microlites. The presence in some little abundance of phosphoric acid is attested by treating a solution of the mineral, freed from its Silica, in nitric acid by Ammonium Molybdate, confirmatory of the anticipations formed with the microscope.

The Mount Grenade Dolerite is highly vesicular, and like that from the east side of English Bay contains more Augite than that from Pitou, or from what would seem to be the older lavas from the bottom of the Cascade Valley.

Passing to the other extreme of the rock series, that, namely, in which the grain is finest and the texture most dense, we have a few specimens which, as regards these characters, may be classed as somewhat coarse basalt, or as fine-grained anamesite. Their colour is generally dark in contrast with the coarser grained lavas. The eye detects no distinguishable minerals when aided by an ordinary lens, except that a few crystals of felspar and numerous crystals of olivine are to be seen enclosed in the formless mass, and that in one dense rock from the Tonnerre Cliff a certain silky sheen can be detected in the fractured surface, which is due to a stream-like distribution of the felspar crystals.

In the microscope the appearance of those finer rocks is quite similar to that of

the dolerites. The Tonnerre Cliff rock, dark grey in hue, is under the microscope a beautiful congeries of minute blades of Labradorite streaming in directions that run along and round the large crystals of Olivine, and a great number of very small black points of magnetite mingled with some pale yellowish green Augite.

These basalts, which are at once the finest in grain and hardest in texture of all the Rodriguez rocks, seem to form the material of the columnar masses of the island, though not confined to these. The localities noted by Mr. Balfour on some of the more characteristic of them are, besides Tonnerre Cliff, the locality of the finest columns in the island; Beline high fall, the rock in the bed of the cascade brook, a columnar mass in the Cascade Valley, and the valley on the E. side of English Bay Point.

The banks of the river Poursuite yield also a fine basaltic rock; sometimes vesicular and charged with Aragonite, a Magnesian Lime-carbonate and Chlorophæite in fissures, and Zeolites, among which striated little crystals of Chabazite are distinctly recognisable.

The felspar in this basalt offers indications of commencing decomposition.

And similar minerals occur in other vesicular varieties, chiefly of the finer-grained rocks.

A curious feature of some of the Rodriguez rocks (and among those collected it is confined to the Anamesites and fine-grained and more strictly basaltic varieties) is seen in the tendency of the rock to break into unevenly rounded fragments; this variety of rock possessing but little tenacity, and being without difficulty separated into knob-like pieces. This nodular texture is traceable in the more pronounced cases to a great number of curved fissures traversing the mass, which are perhaps the result of the conditions under which it cooled. Not improbably they may be due to an imperfect development of a kind of pyromerid structure, in the production of which the felspar may have been the formative ingredient.

Another peculiarity of certain of these Rodriguez Anamesites is probably due to, and in part only a differently developed effect of, a similar cause. These show a spotted or variolitic surface, in which very light spots are seen on the darker slaty gray ground. Usually they are about an eighth to a quarter of an inch in diameter, and are rarely confluent. Microscopically examined the rock is seen at the spots to be nearly devoid of Olivine, whereas this mineral is very plentiful in the other parts: while microscopical inspection reveals in some of the spots a peculiar structure in the felspar, which is here and there grouped with some of its crystals rudely tangential to a circle, at some distance from a larger crystal or crystals of the same mineral, which forms as it were the centre or nucleus of the spot. It would seem that here also the spot is due to the tendency of the felspar to originate an orbicular rock structure, analogous to, but by no means resembling, in the grouping of its crystals, that of the orbicular corsite. It is to be noted also, as bearing on this point, that the spots in the true variolite seem to be due to a peculiar segregation of

Labradorite. The variolitic structure is especially noticeable in a rock from the Grenade Bay.

A variety of the basalt from the bed of the torrent in the Cascade Valley is remarkable for a peculiarity converse to that just described. Here the base of the rock presents the pale grey hue of that of the spots in the rock from the Grenade Bay, but is flecked with tortuous stripes, and with spots of darker hue. At these parts it is seen in a microscopic section that the felspar is less, and the augite more abundant in the dark spots and stripes than in the paler ground. The felspar is here in somewhat larger crystals than in that of the Tonnerre basalt, but presents a similar stream structure.

There remain for consideration certain substances varying greatly in colour from a dull brick red to a liver-brown, and presenting the features of earthy clays, of which Mr. Balfour collected a very complete assortment.

It would seem that they form intermediate beds, intervening between two layers of regular basalt; as in the case of the Cascade Valley, where the most complete series of them was made. The overlying basalt has evidently exercised on the upper layers of this stratum the colouring action to be expected from a molten lava acting on a clay bed; it has given the clay a brick-red colour, and so far hardened it. The lowest bed is of a brown hue, and appears unchanged by heat. The intermediate beds vary in hue from reddish yellow and grey to a deep chocolate or burnt sienna brown.

That these clay strata are the result of the action of water on the rocks of the island seems borne out by their composition, which is shown by a qualitative-analysis to be that of a ferric-aluminous silicate, almost entirely free from calcium or magnesium compounds; a residue, in short, left after these earthy and the alkaline bases had been removed by the action of carbonated waters. In this respect they no doubt correspond to the red earth of Mauritius, the history of which would appear from the scanty notices (Mauritius, by Rev. F. Flemyng, pp. 18 and 19) of it, to be that of a disintegration of the volcanic rocks of that island; though, from the description, it would seem that it has a more pisolitic structure, and is richer in iron oxide than the corresponding earth in Rodriguez. Remotely, too, it may be compared with some kinds of laterite.

Mr. Bayley Balfour made some careful observations on this earth with a view to establish its petrological relations and history; and the following extract from his journal will show the sort of evidence which he derived on the spot in favour of its being a product of the alteration of the lava-rock of the island:—

"This red bed, as I call it, is evidently the same as the one which I noticed further down, about a mile from the town, and on the opposite side of the valley. I could trace that one a good way up the valley; but eventually it became hidden by the boulders and scrub, but its presence was indicated by the fragments at the side of the burn below. This bed, at the point where these specimens were taken,

is about a foot thick, and is well seen on both sides of the valley, the intervening mass which has been washed away being seen on the face of the Fall Cliff, the distance being about 30 yards. It is to this soft bed that the fall is due, as it lies below a harder rock, of which 64 is a specimen. My specimens show more or less of a gradation from normal basalt to this clay. This clay may be the same as the Terre rouge of Mauritius, but as I have not seen the latter, I cannot say whether it be so or no. It is evidently decomposed lava, the contained crystals of minerals being numerous; but I have not yet analyzed them. I cannot think of any cause for this decomposition. I observed at the place about a mile from Mathurin, where I first picked this red clay, a spring of water rising just at the top of this red bed, and coming along a tunnel of about 4 inches diameter out of the side of the hill. The opening being about 3 feet above the burn level, and about 4 feet from the water as it then was; but in wet seasons the burn must rise fully a long way above its opening. However, the water of the burn was good to drink, and beyond the usual earthy taste, possessed more or less by all the water here, it had no taste; but this spring water was abominable, warm and brackish, specially noticeable on contrasting it with the burn water. It may be that this spring, containing as it clearly does some chemical substances in solution, in addition to the usual constituents of water, may have some influence and should; as it seems probable from facts I have learnt from inhabitants, as also from observation, that many such exist. We may have here a cause of the rapid disintegration. At the Cascade itself, on the E. side, where I picked my specimens, I noticed a hole in the rock just above the red bed similar in form to that through which, below, the spring water emerged, but there was no sign of any moisture—contrarily, the rocks here were very dry."

That it is the result of water-worked disintegration of the basalts and dolerites, the analysis renders more than probable. But whether it does not in fact mark an epoch of pause in the volcanic activity of the island, or at least in the N.E. end of it, during which a long process of denudation and water action supervened over a then submerged area, would need a more minute and extensive topographical study of the district than has yet been given to it. There are veins of a white waxy Aluminium silicate traversing the brown or yellowish brown clays, which probably fill fissures produced by the drying of the original mass, which in some cases, as in that of certain specimens of the red baked upper layer, seems to have assumed a quasi-columnar structure.