III. *On some Specimens of Lava from Old Providence Island.*

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SOME months since I received from J. G. Grenfell, Esq., of Clifton College, a few small specimens of igneous rock which he had collected in the year 1880 on Old Providence Island. This is an island in the Caribbean Sea about 90 miles off the Mosquito Coast, in lat. 13°26′ N, long. 81°18 W. It is oval in shape, 4½ miles long from N to S, and 2¼ miles wide. Barely separated from it on the North is a little island named Sta. Catalina. Mr. Grenfell describes the main island as mountainous, with three chief peaks, the highest of which rises to 1,190 ft. Spurs from these terminate on the shore in peaked hills from 300 to 700 feet high. The materials of both islands, as far as seen, were volcanic—lavas, tuffs and agglomerates; but the fragmental materials on Split Hill exhibited a more uniform stratification than we should have expected in débris simply ejected from a volcano. The rocks numbered (*d*) and (*e*) come from a cave near Morgan's Head on the west coast of Sta. Catalina, the others represent the ordinary igneous rock of Old Providence. The specimens consist of bits of dull reddish scoria, of a rather decomposed pale purplish-red or reddish-lavender porphyritic rock and a nearly black minutely porphyritic rock. All appeared to belong to a group of rather basic lavas; and on the first glance at the last named I was at once struck with its resemblance to those compact black lavas variously named augite-andesites, pitchstone porphyrites, &c., which have recently attracted so much attention as containing a rhombic pyroxene, possibly hypersthene. I selected five of the more promising varieties for microscopic examination, and append the following description:—

(*a*). A brown-black rock, almost as dark as many basalts, fracture rather irregular with a slight rather resinous lustre, structure compact, numerous brownish-grey crystals of felspar from about $\frac{1}{20}''$ to $\frac{1}{10}''$ long, rather square in outline, also very small crystals of a black pyroxenic mineral, outer surface not decomposed and slightly pitted. Under the microscope the rock exhibits a brown glassy base of minutely granulated aspect; this is due to its being rather thickly studded with very minute crystallites and granules of felspar, pyroxene and opacite. In this are scattered, fairly

thickly, larger grains of opacite and crystals of felspar and a pyroxenic mineral. The felspar is rather variable in form, but the crystals are generally approximately oblong in outline, the breadth being not seldom about half the length. Most if not all are obviously plagioclase; some show zonal banding, many polysynthetic twinning, though a 'Carlsbad' habit is not unfrequent. The extinction angle between successive lamellæ commonly varies from 20° to 30°, and sometimes exceeds the latter amount, and the least angle made with a vibration plane of one of the Nicols by the edge of a crystal is about 10°. I have little doubt that these crystals are either anorthite or labradorite, possibly both. Some of the crystals are almost clear, but the majority contain inclusions. Many of these are brown glass, which is sometimes quite clean, but at others contains opacite and other crystallites; for these enclosures I cannot make out any rule, they are not restricted to the larger crystals. Granules of a pyroxenic mineral are often included. Here and there a crystal appears to become fused into the adjacent base by being crowded with crystallites. In short these felspars exhibit the usual features of crystals which occur in rocks of this nature. There may also be some cavities, but I do not detect any bubbles. The pyroxenic constituent is fairly abundant. It has a rather fibrous look, is slightly dichroic; the prisms extinguish as nearly as possible parallel to their edges. In cross section the pinacoidal planes are best developed, the prismatic cleavages are the more prominent and constant, and the plane of the optic axes appears to be parallel with a pinacoidal face. The green tint is most marked in a longitudinal section when its axis is parallel with the vibration plane of the polariser (alone), the red when transverse. In two parts of the slide the felspar crystals are grouped so as to enclose a portion of the base. This, however, differs from that outside in being a clear brown glass with only a few granules of opacite, and in one case two or three small crystals of the rhombic pyroxene.

(*b*). A rock generally similar to the above, but slightly browner, and a shade rougher in fracture, and less lustrous. Under the microscope the ground-mass has not quite such a glassy aspect, as the included crystallites (doubtless of felspar) are rather larger and give to the slide more of a 'felted' look. The larger crystals of felspar are similar to the above, but with fewer glass enclosures. There is some of the rhombic pyroxene, but certain other crystals appear to be normal augite, well marked octagonal prisms being fairly abundant; there are larger grains of iron peroxide.

(*c*). Differs but little from the above, macroscopically or microscopically, but is in all respects, especially as regards the matrix, a little nearer to (*a*). The description of that will apply to the larger crystals of this, word for word.

(*d*). A compact purplish-grey moderately dark rock, clouded here and there with a dull red, with small dead-white crystals of felspar scattered about. It weathers to a pale lavender-grey, and was selected as the most hopeful example of the more decomposed specimens. Under the microscope we see that, allowing for its condition, it has a general resemblance to the above described, being perhaps nearest to (*b*); the larger crystals are less numerous, but a decomposed plagioclastic felspar and a grain or two of a black bordered brown pyroxenic mineral can be recognised. Several dark brown globulitic spots and grains of iron oxide are scattered about.

(*e*). A purplish-red rock, with sundry small vesicles on the outer surface having a decidedly scoriaceous aspect. Minute crystals of a decomposed felspar and a darker mineral are visible. Under the microscope it presents a general resemblance to the above described, but is rather decomposed, and the base is more variable in colour, having a dingy muddled look. The felspar is much decomposed, and has often broken away in the grinding of the slide; the pyroxenic constituent is generally bordered with opacite and darkened, and is thus difficult to determine.

I am indebted to my friend J. J. H. Teall, Esq., M.A., F.G.S. for the following notes on the chemical composition of one of these dark lavas, that from which the slide was prepared from Old Providence Island.

I. "1·0530 gramme of the substance dried at 110°C and fused with the mixed carbonates of soda and potash gave ·6436 gr. of silica, ·1868 gr. of alumina, ·0628 gr. of ferric oxide, ·0574 gr. of lime, and ·0706 gr. of magnesium pyro-phosphate.

II. "1·0846 gramme heated in a sealed tube with hydrofluoric and sulphuric acids required 4·75c.c. of permanganate of potash solution (1 c.c. = ·00551 gr. of Fe.) to convert the ferrous into ferric oxide.

III. "1·1006 gramme, dried at 110 and treated according to Lawrence Smith's method, gave ·0994 gr. of the chlorides of sodium and potassium, and ·1192 gr. of the double chloride of platinum and potassium.

IV. "1·0578 gr. dried at 110° and heated to redness in a current of air yielded ·0269 gr. of water.

Whence it follows that the rock contains :—

SiO_2	... ...	61·12 per cent.
Al_2O_3	... ...	17·78 ,,
Fe_2O_3	... ...	2·52 ,,
FeO	... ...	3·10 ,,
CaO	... ...	5·45 ,,
MgO	... ...	2·39 ,,
Na_2O	... ...	3·01 ,,
K_2O	... ...	2·09 ,,
H_2O	... ...	2·54 ,,
		99·95

Specific gravity of specimen analysed 2·582.

"The loss on ignition was 2·31 per cent., a result which is seen to agree very well with the direct determination of water when we remember that the ferrous iron would take up oxygen during ignition.

"The evaporations were all performed in platinum vessels, so that no excess in the analysis, due to the corrosion of glass vessels, is to be expected."

I am also indebted to the same gentleman for the annexed series of analyses for comparison with the above; from which it will be seen not only that they form a well marked group of closely allied rocks, but also that the difference of the last of these (No. VI.) from the rest and from this Old Providence rock is extremely small. Yet that is a porphyrite from the Cheviots of Old Red Sandstone age, while all the others are later Tertiary or recent. When to this we add the microscopic resemblance noted below, it becomes difficult to maintain the distinction so often, and in my opinion so wrongly asserted to exist between Pre-Tertiary and subsequent igneous rocks.

	I.	II.	III.	IV.
SiO_2 ...	61·37	60·71	61·64	62·76
Al_2O_3 ...	15·76	16·00	17·44	18·10
Fe_2O_3 ...	4·06	2·09	0·82	5·14
FeO ...	2·94	3·87	3·99	—
MgO ...	2·86	3·07	3·05	2·59
CaO ...	7·27	5·17	5·86	6·03
Na_2O ...	3·04	2·74	3·45	3.45
K_2O ...	0·71	3·78	1·15	1·35
H_2O ...	2·64	1·48	2·64	—
	100·65	99·92	100·04	99·42

			V.	VI.
SiO_2	...	...	62·00	63·0
Al_2O_3	...	...	17·84	14·9
Fe_2O_3	...	...	—	4·7
FeO	...	...	4·40	—
MgO	...	...	2·64	2·8
CaO	...	...	5·37	4·8
Na_2O	...	...	4·29	4·0
K_2O	...	...	1·47	1·9
H_2O	...	...	1·66	4·0 (Loss).
			99·67*	100·1

I. Hypersthene Andesite—St. Egidi, Steierwartz. Niedzwiedski, Min. Mitth. 1872, p. 255. This rock macroscopically bears the closest resemblance to the Old Providence Lava and the Cheviot Andesite.

II. "Augite Andesite"—White Rock, Cedar Mountains, Utah. King, Geol. Expl. of the 40th Parallel, 1877. II. 466.

III. "Augite Andesite"—Cortez Range, Wagon Canon, Nevada. King, Expl. 40th Parallel, 1877, II. 582.

IV. Andesite from the Volcano of Rincon de la Viega (Andes). Dr. O. Proeless. Beiträge zur Kenntniss der Trachyte. Neues Jahrbuch 1866, p. 652.

V. Pumice of a Hypersthene-andesite from Mount Shasta. A. Hague and J. P. Iddings, American Journal of Science, 1883, p. 230.

VI. Andesite with Rhombic Pyroxene, Cheviot. Teall, Geol. Mag. March 1883.

Nos. I., II., and III. are quoted from Roth's Beiträge zur Petrographie der plutonische Gesteine.

From the above description it is evident that we have in these specimens from Old Providence Island representatives of the group of Augite Andesites, which contain a rhombic pyroxene, probably hypersthene. This group, as is well known, has recently attracted much attention, and I may refer readers for further particulars and for references on the subject to the excellent Papers of Mr. Teall and Mr. Waller in the *Geological Magazine* (Dec. II. Vol. x. pp. 100, 252, 290). To the former gentleman I am indebted for the opportunity of comparing these Old Providence specimens with several slides obtained from various localities. The resemblance is in some cases very striking; the Old Providence specimens (especially *a*, *b*, *c*) closely resemble in their microscopic structure an

* With $TiO_2 = 0·17$. P_2O_5 0·29 total in all 100·13. There was a trace of MnO.

'augite andesite' from Bagonya, and another from Dolny Tured, Kremnitz, also anorthite trachytes from Lorinczi, from Aphroessa (Santorin), (1866), and "Kleiner Eliasberg" Thera. They present also considerable resemblance to his slides of "Pitchstone porphyrite" from the Cheviots, especially from Carl Croft, Blindburn, Fernhaugh, Windyhaugh, Cognet, and Alvin; and to one of the same rock (though less close) from a foreign locality, Vethalm. I also note a resemblance to an anorthite-trachyte from Matra, and from Borac (S. Servia) in my own collection. There are also resemblances macroscopic and microscopic to some specimens brought me by Mr. Whymper from Antisana, Pichincha, and Chimborazo (Andes) and macroscopic to specimens in my collection from Kremnitz.

A paper has recently been published by Messrs. A. Hague and J. P. Iddings (Notes on the Volcanoes of Northern California, Oregon, and Washington Territory*), to which Mr. Teall and Prof. Judd have both called my attention, giving a very full description of the andesites of Lassens Peak, Mount Hood, Mount Shasta, and Mount Ranier, extinct volcanoes, now forming lofty peaks in the chain of the Sierra Nevada. These observers were successful in isolating a sufficient quantity of the rhombic pyroxene for chemical analysis, with the following result:—

SiO_2	50·33
Al_2O_3	0·97
FeO	22·0
CaO	1·88
MgO	23·29
MnO	0·64
	99·11

Optical examination of isolated crystals also confirmed its orthorhombic character: so there can be little doubt that the mineral is a true hypersthene. The authors also call attention to the fact that "hypersthene is the substitute for olivine in rocks, differing from basalt in a somewhat higher silica percentage, the former mineral being as it is simply the bisilicate of the same Fe Mg elements." It is however noteworthy that the most frequent associate of olivine in the peridotites is not hypersthene but some variety of the closely allied mineral enstatite, usually bronzite. (Compare with this the occurrence of diallage in gabbro, the peridotites appearing to be generally deep-seated rocks.)

* *Amer. Jour. Scien.* Vol. xxvi. p. 222.

The investigations of these gentlemen fully confirm those of Mr. W. Cross and Prof. Fouqué, so that we need not hesitate to admit this rhombic pyroxene to be a true hypersthene, and recognise a rather extensive and wide-spread group of rocks characterised by its presence, to which belong these lavas of Old Providence island. It will perhaps hardly be necessary to form a distinct species for them, or mark them off more strongly from the normal augite-andesites than, in the case of basalts, we should separate one from which olivine is absent, from one in which it is rather abundant. Examination of the peridotites shows us that the presence of enstatite (bronzite), augite, or hornblende, has hardly more than a varietal value, but we may conveniently form a sub-group, hypersthene-augite—andesites which will be related to the normal augite-andesites, much as olivine-basalts are to normal basalts.