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Petrographical Notes on the Rock-Specimens collected in the Little Island of Trinidad, S. Atlantic, by the Antarctic Expedition of 1839-43, under Sir James Clark Ross.

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THE Little Island of Trinidad, as it is called to distinguish it from the larger island in the West Indies, is situated in the South Atlantic Ocean, about 700 miles off the coast of Brazil, in lat. 20°31' S. and long. 29°19' W.

According to Ross,¹ who in 1839 effected a landing on the N.W. coast, the island is a mass of volcanic matter, the rocks of which it is composed assuming the most extraordinary shapes. The most remarkable of these are the Sugar Loaf Hill on the southern and the Nine-Pin Rock on the north-western coast. The latter is described as consisting of "greenstone" (phonolite, see below), and rising to a height of 850 ft. almost perpendicularly from the sea in the form of a beautifully proportioned column. It is attached on the land side to a ridge of hills, two or three hundred feet high, also composed of "greenstone," like the perpendicular

¹ *A Voyage of Discovery and Research in the Southern and Antarctic Regions during the years 1839-43.* London, John Murray, 1849.

cliffs which opposed an insuperable barrier between the beach on which the landing was effected and the interior of the island.

Further details concerning the extraordinary physical features of this desolate volcanic island are given by E. F. Knight,¹ who conducted an expedition there in search of a treasure supposed to have been hidden by pirates. According to Knight, Trinidad is a precipitous mass of barren volcanic rock studded with sharp, needle-like peaks, the highest of which is about 3,000 ft. above sea-level. It is about 15 miles in circumference, and is surrounded by sharp coral reefs. The conical hill on the S.E. known as the Sugar Loaf is about 1,500 ft. high. It is described by Knight as "apparently of grey granite," but, like the Nine-Pin Rock it most probably consists of phonolite.²

The rock close to it, called from its peculiar shape "Noah's Ark," is 800 ft. high, and is referred to as "probably a crater." Certainly, in East Bay, in the neighbourhood of these rocks, the signs of volcanic activity were more evident than elsewhere, in a succession of streams of black basaltic lava, ledges of which extend far out to sea. A peculiarity of the island insisted on by Knight is that it is nowhere solid, but rotten throughout. The lower slopes on the western side are composed of *débris*, with loose stones of every size easily dislodged, and even the columns of basalt forming precipitous walls rising hundreds of feet high above this *débris* are described as rotten and crumbling away under the tread, so that the ascent to the grass-covered plateaux in the centre of the island was a work of great difficulty.

The rock-specimens collected by Ross serve to illustrate these descriptions of the island. With the exception of two rolled pebbles (probably from the beach) of radiolarian chert and coralline limestone, they are all of volcanic material. They are mostly of phonolite, but comprise also examples of basaltic rocks, including nephelinite and limburgite, and of tuffs and agglomerates made up of fragments of both phonolites and basalts.

Phonolites.

The phonolites in appearance and structure are of various types, although in general characterised by the size and great number of the abundant phenocrysts of nepheline, as well as by the large amount of

¹ *The Cruise of the "Falcon."* London, Sampson Low, &c., 1887. *The Cruise of the "Alert."* London, Longmans, Green & Co., 1890.

² The phonolite Peak of Fernando Noronha was originally described as of granite (*Quart. Journ. Geol. Soc.* xlii, 1872, p. 43).

the pyroxenic constituent ægirine-augite. They are therefore somewhat darker and more strikingly porphyritic than the ordinary type of phonolite, and some, by decrease in the felspathic constituent and gradual replacement of the grass-green ægirine-augite by purplish augite, approach to nephelinites.

As already mentioned, the "greenstone" of the Nine-Pin Rock in Ross's account is probably phonolite and not basalt. Dr. McCormick, the surgeon on board the *Erebus*, in his book, *Voyages of Discovery in the Arctic and Antarctic Seas, &c.* (London, Sampson Low, 1884) describes on one side of the Nine-Pin Rock a dyke of "basalt," and on the other a larger one of "greenstone," thus distinguishing between the two. The large dyke of "greenstone" is stated to exhibit on its surface a singular mammiform appearance.

One of the specimens of phonolite (75355) in the collection answers precisely to this description. It is a dark greenish-brown rock with greasy lustre and splintery fracture, with a weathered surface covered with warty mammiform protuberances as described by McCormick.

Under the microscope are seen large porphyritic nephelines with small ægirine-augites and, very sparingly, sanidine and sphene in a fine-grained base of lath-shaped feldspars, ægirine-augite and nepheline.

The nepheline phenocrysts are in very sharply-defined hexagonal (showing in convergent light a negative uniaxial figure) and rectangular sections: they are clear and unaltered, and include small crystals of ægirine-augite, sphene and magnetite. In one hexagonal section stages of growth are marked by a series of lines of dark inclusions parallel to the outer edges.

Sanidine is only represented amongst the phenocrysts by one or two Carlsbad twins.

The ægirine-augite is in large amount in small well-defined prismatic crystals, showing pleochroism a=grass-green; b=dull-green; c=bright brownish yellow with a tinge of red. The maximum extinction in prismatic sections does not exceed 30°. Some of the larger phenocrysts have purple centres.

Hornblende is represented by a few corroded deep brownish-red sections with the pleochroism of barkevicite or basaltic hornblende. These show signs of being partly re-absorbed, and have borders of magnetite grains, in one or two cases fringed with ægirine-augite. Small rounded patches of an aggregate of magnetite grains and reddish-brown hornblende, surrounded by a zone of ægirine-augite, are in all probability pseudomorphs after hornblende crystals.

The sphene is in sharply-defined colourless characteristic lozenge-shaped crystals.

One or two altered hexagonal sections are probably to be referred to nosean.

The groundmass, showing well-marked flow-structure, consists of felspar laths with straight extinction, needles of ægirine-augite, and nepheline in rectangular and hexagonal sections. It is rendered rather dense by dusty brown interstitial matter.

A pale green rock (No. 75349), with greasy lustre, markedly porphyritic, with large crystals (up to 5 mm. in length) of sanidine and nepheline, is in appearance more like an ordinary phonolite. It contains the same minerals as the preceding, but is much more porphyritic, the phenocrysts being more numerous, and in the case of the ægirine-augite larger, and the groundmass much finer-grained and showing no flow structure.

The pyroxenic constituent is in large amount, both as small prismatic crystals in the base and as sharply-defined phenocrysts. It consists for the most part of grass-green to yellow ægirine-augite, but some of the sections are pleochroic (purplish brown to yellow) augite, while others show purple centres with green borders, and one has a green centre and border with a purple zone between.

The section shows a coarse-grained patch of orthoclase and nepheline with prismatic ægirine-augite. Similar patches have been recorded in phonolites from Fernando Noronha, and have been regarded as fragments of the nepheline-syenite magma.¹

A still more porphyritic type (No. 75353) shows large phenocrysts of sharply-defined nephelines and rounded, partially re-absorbed, sanidines, with smaller augites (both purple and grass-green), noseans (showing six-rayed stars of inclusion) and sphenes, in a pale brown very fine-grained base crowded with minute ægirine-augite microliths. Some of the felspar phenocrysts show very fine twin striations suggestive of anorthoclase. A phonolite from Leao, Fernando Noronha, presents very similar characters.

A specimen (No. 75348) of a somewhat camptonitic type is a pale greenish-grey rock with small vesicular cavities filled with zeolites, showing no porphyritic nepheline or felspar, but only long prismatic augites with a few larger hornblendes. Under the microscope the porphyritic augites are seen to be mainly of the purplish titaniferous kind,

¹ *Am. J. Sci.* XXXVII, 1889, p. 185.

and the hornblendes, in almost as large amount as the augites, are of the same type as in the preceding rocks, and have generally a mantle of green augite with magnetite. Nepheline is present in a few small rectangular sections much altered. Sphene and altered noseans are fairly plentiful. Apatite occurs in small hexagonal sections enclosed in the hornblende and augite. Only one phenocryst of sanidine was observed in the slide. The fine-grained groundmass consists of inter-lacing minute lath-shaped feldspars with altered nosean and some granular augite: some clear isotropic patches are probably analcime.

This slide also contains a coarse-grained patch (about 4 mm. square) of nepheline and lath-shaped Carlsbad twins of feldspar, with a little ægirine-augite.

A specimen (No. 75358) approaching more closely in structure the ordinary type of phonolite than any of the preceding, is a greenish-brown somewhat altered rock showing to the lens only small prismatic phenocrysts of sanidine. In the section besides these sanidines (in Carlsbad and Baveno twins) are one or two large altered nephelines and a little ægirine-augite. The groundmass consists of lath-shaped feldspars with trachytic flow structure and much ægirine in small prismatic crystals, showing approximately straight extinction and compensating with the quartz wedge along their length (α -axis of indicatrix nearly coincident with the crystallographic axis c).

Phonolite-Nephelinites.

A dark greenish grey to black very compact rock (No. 75346), showing porphyritic nephelines and an occasional large sanidine, has characters intermediate between a phonolite and a nephelinite. It consists of phenocrysts of purplish-green augite in large amount, a little basaltic hornblende similar to that in the preceding rocks, and a few large nephelines with sphene and apatite in a base composed of altered nephelines with small prismatic ægirine-augites and some feldspar laths. The nephelines, unlike those in the phonolites previously described, are for the most part corroded and rounded (in some cases presenting perfectly circular outlines), and are often crowded with gas-pores.

Hornblende, mostly nearly re-absorbed, is not present in large amount, but the section contains dark patches (in one case over $\frac{1}{2}$ -in. square), consisting of an aggregate of purplish and green augite, deep brownish-red pleochroic hornblende, much opaque iron-ore (magnetite?), with apatite and sphene, which may represent original hornblende crystals

one of these patches had a roughly crystalline outline with two faces meeting at an angle of about 124° .

A specimen (No. 75341) of a dark-grey to deep reddish-brown compact rock showing porphyritic crystals of augite and hornblende, generally small, but in the case of the hornblende sometimes reaching 5 mm. in length, shows a closer approximation to a nephelinite. It consists of a base of nepheline in large plates and indefinite crystals with only a little feldspar, forming a sort of paste in which are distributed augites in large amount, hornblendes, sphene and apatite, with some magnetite and ilmenite. The augites and hornblendes have similar characters to those of the preceding rock. The pleochroism of the hornblende was similar to that of barkevicite, viz. α =pale yellowish brown; β =deep reddish-brown; γ =deep brown, nearly opaque. Prismatic sections showing only one cleavage gave extinctions as high as 13° , and octagonal sections showed the two cleavages inclined at an angle of about 124° . The apatite was so crowded with gas-pores as to be nearly opaque.

Limburqites.

These dense black basaltic-looking rocks (Nos. 75352 and 75333) are seen under the microscope to consist of small porphyritic augites, and in smaller amount of olivine, with magnetite, in a dense brownish-red glass, containing microliths of augite. The augite phenocrysts are very pale purple, generally with a green centre. One or two of the larger crystals had a centre consisting of an aggregate of magnetite grains and a deep brown hornblende, and are the result probably of the re-absorption of an original hornblende crystal. One or two rounded grains of reddish-brown basaltic hornblende are present in the slide. The augite and hornblende phenocrysts are therefore somewhat similar in character to those in the preceding nephelinites.

The olivine is clear and fresh, and occurs generally in long prismatic crystals. One or two corroded grains and irregular crystals of olivine have attachments of augite and hornblende on the corners and filling up cracks.

A patch of grass-green ægirine-augite grains with sphene has probably been derived from the phonolites.

Another specimen (No. 75364) of dense black basaltic rock, with a rough glassy surface, shows in section the passage (from the surface inwards) from a brown glass, with augite microliths, in which are distributed crystals of clear fresh olivine in large amount, to a rock consisting of porphyritic olivines in a dense base almost opaque from separation of

magnetite and crowded with radiating groups of small pale purple augites. In the intermediate part the augite microliths are surrounded by deep halos of magnetite, and the intervening glass is a clear pale yellow.

Volcanic Agglomerate.

A specimen of volcanic agglomerate (No. 75360) contains, besides fragments of nepheline, felspar, ægirine-augite, and phonolite, also fragments of more basic rocks, some of them showing long prismatic crystals of basaltic hornblende, and presenting a structure very similar to that of the dyke rocks from Fernando Noronha, which were described by the author (*Min. Mag.* XI, 1897, 171) as related to the monchiquites of Rosenbusch.

The only specimens not of volcanic origin were fragments, probably from the beach, of *coralline limestone* containing pebbles of phonolite, and a rounded pebble of *radiolarian chert*.

The characters of these rocks, as well as many of the geological features of the island, such as the remarkable peaks of phonolite associated with basaltic lavas, suggest analogies between Trinidad and the island of Fernando Noronha off the coast of Brazil, a thousand miles to the north, so that it appears possible that the two islands owe their origin to a very similar, if not contemporaneous, volcanic outbreak.

In Fernando Noronha, as Branner¹ states, the original lofty central portion has been denuded away until only the great Peak and its smaller companions remain to suggest the former elevation of the group. In Trinidad the disintegrating agents have not effected so radical a change. The lofty inaccessible peaks of the central portion still remain, but Knight's account suggests that the time when these will have been levelled cannot be very far distant, for denudation appears to be going on at a very rapid rate, and enormous landslips are of frequent occurrence.

¹ *Am. J. Sci.* XXXVII, 1889, p. 146.