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ORIGINAL ARTICLES.

I.—A NOTE ON THE GEOLOGY OF SOCOTRA AND ABD-EL-KURI.

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THE first account of the geology of Socotra we owe to Lieutenant J. R. Wellsted,¹ who compiled the Admiralty chart and map, and in 1835 described the island in a detailed memoir, in which he showed that it consists of a mass of granite capped by limestones. Nothing material was added to this description until 1883, when Professor Bonney published his account² of the extensive rock collection made by Professor J. B. Balfour during a six weeks' visit to the island in February and March, 1879. Professor Bonney's study of the rock specimens enables him to prove that Socotra consists of a block of Archean rocks covered in places by massive limestones, which, on the evidence of their foraminifera, Professor T. R. Jones suggested were probably of Miocene age. It was further shown that both the Archean series and the Cainozoic limestones are cut through by dykes of trachyte and basalt, associated with a series of rhyolitic lavas. Professor Balfour's expedition not only proved that the foundations of Socotra are built of old materials, but that the island is of considerable antiquity, as is indicated by its rich endemic flora.³

In 1880 Socotra was visited by Emil Riebeck, who collected some rock specimens containing the mineral which was described in 1888 by Sauer under the name of Riebeckite.⁴ Further details regarding the Archean and volcanic rocks were given in the same year in a paper by Miss Raisin.⁵

¹ J. R. Wellsted, "Memoir on the Island of Socotra": Journ. Roy. Geogr. Soc., vol. v (1835), pp. 129–229, and map.

² T. G. Bonney, "On a Collection of Rock Specimens from the Island of Socotra": Phil. Trans., vol. 174 (1883), pp. 273–294, pls. vi and vii. Some preliminary remarks on the geology of the island were included in Professor Balfour's report, "On the Island of Socotra": Rep. Brit. Assoc., 1881, p. 486.

³ According to Balfour ("Botany of Socotra": Trans. Roy. Soc. Edinb., vol. xxxi, 1888, p. lxxv) the island has been a land area since the Permo-Carboniferous, and "an island certainly from Tertiary times."

⁴ Sauer, "Ueber Riebeckit, ein neues Glied der Hornblendegruppe": Zeit. deut. geol. Ges., vol. xl (1888), pp. 138–146.

⁵ C. A. Raisin, "Rock Specimens from Socotra": GEOL. MAG., Dec. III, Vol. V (1888), pp. 504–7.

During last winter Socotra and the neighbouring island of Abd-el-Kuri were visited by Dr. H. O. Forbes and Mr. Ogilvie Grant, who made a collection of rocks, upon which I have been asked to report. Dr. Forbes has given me an account of the mode of occurrence and distribution of the principal rocks. At about the same time both islands were visited by the Austrian South Arabian Expedition in the "Gottfried," and a note on their geology has been published by Dr. F. Kossmat, in which he remarks the occurrence of Cenomanian and Eocene limestones.¹

GEOLOGICAL SKETCH MAP OF NORTH-CENTRAL SOCOTRA.

The present collection does not necessitate any modification in the geological history of Socotra, as deciphered by Professor Bonney from the materials available in 1883. But the collection adds to the knowledge of the distribution of the different rocks in the island.

1. SOCOTRA.

The rock collection from Socotra contains representatives of three groups of rocks—a basal Archean series, some massive limestones, and some comparatively recent volcanic rocks.

The largest part of the collection consists of Archean rocks and some associated granites. As a rule the gneiss is more granitoid

¹ F. Kossmat: Sitz. math. nat. Cl. k. Akad. Wiss. Wien, 1899, No. ix, pp. 73-82.

than the rock which forms the main mass of the East African Archean plateau; but a specimen from Thlutid, at the height of 900 feet, corresponds with the typical gneiss of the mainland. With the granitoid gneiss there is a coarse pink granite which forms the summit of Gebel Haggier, the highest peak in Socotra; it occurs also at Adho Dimellus, and at the height of 1500 feet at Fadehen.

The second group of the Archean series consists of dark-green amphibolite schists, of the type that forms such a conspicuous feature in the East African gneiss series. This rock was collected by Dr. Forbes in the Hadibo Plain near Tamrida.

The Archean rocks of Socotra therefore resemble those of the East African Nyika series, and the island is simply an outlier of the East African plateau.

Overlying the gneisses is a compact, massive limestone which has been sometimes rendered coarsely crystalline, probably by contact metamorphism. This limestone forms the extensive plateau at the eastern end of the island, and according to Dr. Forbes sections cut by the Goahal river show that the limestone there rests directly on the Archean series. South of the Goahal river the limestone forms a plateau, the southern end of which is continued westward round the southern flanks of the central highlands. From the Hamadari plateau a belt of limestone extends westward to beyond Tamrida; the rivers have cut through it, showing that it rests on the Archean series.

The collection gives no evidence as to the age of the limestones, but fortunately Herr Kossmat has obtained from it a number of mollusca and echinids, which enabled him to determine it as Eocene. Kossmat also records an underlying Cenomanian sandstone with *Janira quinquecostata*.

The last group of rocks represented in the collection is a series of recent volcanic rocks, of types already described from Socotra by Professor Bonney and Miss Raisin.

The volcanic rocks include rhyolites, quartz-felsites, and basalt. Most of the specimens are dyke rocks, but one lava is included in the collection. It is a rhyolite with well-marked fluxion structure and containing many angular fragments; it was collected on the edge of the plateau, south of the Goahal river. A similar rock has been described and figured by Professor Bonney¹ from Azorah, and according to Dr. Forbes the rounded hill in the Ghariah Plain near Kamakanu consists of the same rhyolite.

Quartz-felsites were collected from dykes intrusive in the Archean series at Homhil and Adho Dimellus. The felsites at both localities are intensely altered by decomposition; the abundant iron-ores have been altered to leucoxene, and the matrix is stained bright red. The only unaltered minerals are the large phenocrysts of quartz; and they are deeply corroded, as illustrated by Velain² from the quartz-trachytes of Aden, and by Miss Raisin³ in a quartz-felsite from Socotra.

¹ Bonney: op. cit., p. 287, pl. vii, fig. 5.

² Ch. Velain: "Descript. géol. presqu'île d'Aden," 1878, p. 18, fig. 2.

³ Raisin: op. cit., p. 505, fig. 1.

In one case the quartz shows a zonal arrangement of the inclusions, a feature unusual in volcanic quartz crystals; but the identification of the mineral was confirmed by the use of convergent polarized light. The felsite from Adho Dimellus has numerous, somewhat ill-defined spherulites; in that from Homhil some of the smaller patches of secondary quartz are traversed by faint lines like cleavages, suggesting that the quartz has been formed by the alteration of tridymite aggregates.

The last member of the rhyolite-felsite series is an altered, fine-grained trachyte from the Ghariah Plain. It is similar in character to the trachyte figured by Professor Bonney¹ from the Azorah district.

A dyke of a fairly fresh basalt was found by Dr. Forbes at Thlutid, on the north-west slope of the granite mass of Adho Dimellus.

The most interesting feature in the trachyte and felsite is that the rocks resemble those of the Aden volcanic series rather than those of the East African volcanic group. For opportunities of examining some of the Aden rocks I am indebted to Mr. G. T. Prior.

Hence Socotra appears to be an outlier of the Somali plateau, which has been involved in the movements which formed the Gulf of Aden, and has been the scene of the eruption of volcanic rocks of the Aden series.

2. ABD-EL-KURI.

West of Socotra is the small island of Abd-el-Kuri, where a larger rock collection was made by Messrs. Forbes and Grant. It was also visited by Dr. Kossmat, who has described it as composed of amphibolites, penetrated by a network of granites and camptonite dykes, and capped by a limestone which he suggests to be of Turonian age. The only previous geological account of the island known to me is by H. J. Carter,² who in his memoir on the geology of the south-east coast of Arabia described Abd-el-Kuri as composed of a mass of granite and diorite, capped by a limestone which reaches to the summit at the level of 1600 feet above the sea.

The collection from Abd-el-Kuri is composed mainly of rocks belonging to the Archean series. They include a series of amphibolite schists, a syenitic gneiss, some specimens of which have a considerable development of epidote, and a white gneiss with hornblende aggregations: the last rock is strikingly like one which is common in the Ulu Mountains of Ukambani in British East Africa. This series of foliated rocks is cut through by pegmatite dykes, which are almost as coarse in grain as those of Somaliland: in one specimen collected the muscovite occurs in crystals from two to three inches in diameter.

The Archean rocks are covered by limestones which occur at different levels from 40 feet above the sea to the summits of Gebel

¹ Bonney: *op. cit.*, p. 287, pl. vii, fig. 6.

² "Geol. Papers on Western India," 1857, p. 620. On p. 621 of the same work Carter describes 'The Brothers,' the islets between Socotra and Abd-el-Kuri, as also formed of granite and diorite capped by limestone.

Saleh and Gebel Somali, the highest peaks in the island. The limestones appear to be very fossiliferous, and one specimen is crowded with shell fragments; but the only specimen generically determinable is a *Nerinea* in a block of limestone collected by Dr. Forbes at the height of 700 feet. The limestone at that point is therefore no doubt Cretaceous.

On the lower parts of the island a reef limestone occurs up to a height of 40 feet above sea-level. As it contains well-preserved specimens of *Goniastrea retiformis*, it is no doubt of Pleistocene age.

II.—NOTES ON SOME HARDANGER LAKES.

By HORACE W. MONCKTON, F.L.S., F.G.S.

IN many places in Western Norway we find a lake separated from a fjord by a mile or so of sand and gravel. Looking from the fjord, we see in such a case a series of step terraces, with possibly a high mound at the back, forming a dam at the end of the lake.

Several examples of this arrangement were mentioned by Amund Helland in a paper published by the Geological Society in 1877,¹ and he adopts the explanation suggested by S. A. Sexe,² that the dam at the end of the lake is a moraine formed when a glacier filled the space now occupied by the lake; in short, that it is the terminal moraine of a glacier which must have halted for some time at the point during the retreat of the ice, and consequently these mounds and terraces were formed at the close of or after the Glacial Period, for any advance of the ice beyond their site in the valleys would have carried them away to a greater or less extent.

During visits to Norway in 1896, 1898, and 1899, I have explored several of the valleys in which these moraines occur, and I think the following notes may be of interest.

I will first describe a side valley which branches off south from the great valley of the Hardanger Fjord, between 80 and 90 miles from the open sea. It is a deep channel carved out of gneiss, and the sides have in many places been scored and smoothed by ice, and these smoothed rock-sides pass behind all the deposits in the valley, showing that it is older than them all; in this it differs from many of our English valleys, that of the Thames for instance, where we believe that the valley is more recent than the drift around it and that the gravels in the valley mark stages in its excavation.

The mouth of the branch of the Hardanger Fjord valley of which I am speaking is at Vik i Eidfjord, and it has been filled up with gravel, sand, etc., almost to the edge of the main valley, so that there is but a small bay or indent in the fjord at its mouth.

From the fjord one sees a series of step terraces rising one above the other, the highest being on the east side with a flat top and of considerable extent.

If we follow the river up from its mouth we find that it has cut a channel through all the terraces, which look like great railway

¹ Quart. Journ. Geol. Soc., vol. xxxiii, p. 142.

² "Mærker often en listid"; 4to; Christiania, 1866.