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*Barkevikite from Lugar, Ayrshire.*

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IN recent years a number of alkali-rich rocks have been described, containing barkevikite or 'barkevikitic hornblende.' So far as I am aware, however, no detailed examination has been made of the mineral since Brögger's work<sup>1</sup> on the original material from Barkevik in Norway, with the exception of the investigation by Michel Lévy and Lacroix.<sup>2</sup> Hence, when a rock was found amongst the Permo-Carboniferous rocks of Ayrshire, with comparatively large crystals of barkevikite, it was decided to examine it in some detail. The rock, which has been designated lugarite by Tyrrell,<sup>3</sup> occurs as thin veins and dykes intrusive into the picrite of the Lugar sill and as 'Schlieren' and irregular patches in the theralite of Barshaw, near Paisley. It has close affinities to the ijolites of Madagascar, and consists essentially of phenocrysts of barkevikite, titanaugite, and labradorite in a groundmass of analcite and nepheline, the two last-named minerals comprising about 50 per cent. of the whole.

The barkevikite occurs as black, lustrous, prismatic crystals, elongated parallel to the *c*-axis and up to three inches in length, the maximum thickness being about  $\frac{3}{16}$  inch. The forms recognizable in the prism-zone are *b* (010) and *m* (110), while the terminal faces, which are much less regularly developed, include *c* (001) and a low pyramid which is probably *r* ( $\bar{1}11$ ). Crystals twinned on *a* (100) are fairly common. The cleavage parallel to the prism *m* (110) is highly perfect, and cleavage fragments gave excellent signals on the goniometer. The mean value of

<sup>1</sup> W. C. Brögger, *Geol. För. Förh. Stockholm*, 1887, vol. ix, p. 269; *Zeits. Kryst. Min.*, 1890, vol. xvi, pp. 412-415.

<sup>2</sup> A. M. Lévy and A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1888, vol. cvi, p. 778; and 'Les Minéraux des Roches,' 1888, p. 148. Compare C. Hintze, 'Handbuch der Mineralogie,' 1894, vol. i, pp. 1254, 1257.

<sup>3</sup> G. W. Tyrrell, *Geol. Mag.*, 1912, dec. 5, vol. ix, pp. 77-80.

eight measurements was  $55^{\circ} 36'$ , the limits being  $55^{\circ} 32'$  and  $55^{\circ} 41'$ . This is fairly close to the value obtained by Brögger, namely  $55^{\circ} 44\frac{1}{2}'$ . There are also traces of a cleavage parallel to  $b$  (010).

The plane of the optic axes is the symmetry-plane and  $b = \bar{b}$ . The extinction-angles were measured on a number of sections, approximately parallel to  $b$  (010), of twinned crystals. The maximum value obtained was  $c:\bar{c} = 11\frac{1}{2}^{\circ}$ , while several crystals gave values of  $11^{\circ}$ . Attempts were made to prepare prisms for the determination of the refractive indices, but these failed, as the refracting edge always broke up as it became thin, owing to the perfect cleavages. The strong absorption prevented the use of cleavage-flakes as prisms, the angle being too high for the images to be measurable. The mean refractive index was determined by immersing sections in mixtures of methylene iodide and  $\alpha$ -monobromonaphthalene, and was found to be approximately 1.690. The lowest value obtained was 1.680 and the highest 1.701. The maximum double refraction observed in any one section was 0.018, but the true value of  $\gamma - \alpha$  is probably a little above 0.02. The optical sign is negative.

The optic axial angle was measured by means of the Fedorov stage, but the results obtained were only approximate, as the only sections available were those occurring in thin sections of the rock, the brushes being fairly broad and somewhat indistinct on account of the strong absorption. The value of  $2H_a$  obtained from seven measurements varied from  $58^{\circ}$  to  $66^{\circ}$ , with a mean value of  $62^{\circ}$ . As the refractive index of the glass hemisphere used was 1.524, the value of  $2V_a$  is  $52^{\circ}$ . The dispersion, both of the bisectrices and of the optic axes, is slight. The pleochroism is very intense and is the most prominent characteristic of the mineral under the microscope. The absorption is greatest for  $\epsilon$  and least for  $a$ , the scheme being  $\epsilon$  very dark brown,  $b$  reddish-brown,  $a$  light yellow.

This scheme for the pleochroism is in agreement with that described by Brögger,<sup>1</sup> but differs from that of Michel Lévy and Lacroix,<sup>2</sup> who found that there was a similar absorption for  $a$  and  $b$ , instead of  $b$  and  $\epsilon$ , as in the present case. The values of the refractive indices obtained by the latter authors were slightly higher than those given above, being  $\alpha = 1.687$  and  $\gamma = 1.708$ , but the amount of double refraction was practically the same. The only previous determination of the optic axial angle is one given by Rosenbusch,<sup>3</sup> who obtained the value  $2E_a = 54^{\circ} 18'$  by means of the Mallard method.

<sup>1</sup> W. C. Brögger, loc. cit.

<sup>2</sup> A. M. Lévy and A. Lacroix, loc. cit.

<sup>3</sup> H. Rosenbusch, 'Mikroskopische Physiographie,' 1906, vol. i (2), p. 236.

In general the optical properties of the Lugar mineral are in agreement with those of the barkevikite of Barkevik and Madagascar. The greenish-brown colour which appears in some sections of the mineral from Pouzac (Hautes-Pyrénées)<sup>1</sup> and Madagascar,<sup>2</sup> however, has not been observed in this case.

In order to obtain material for analysis, the rock was broken into coarse fragments, and the barkevikite picked out under a lens. This was then ground to a fine powder, and immersed in methylene iodide in order to eliminate apatite, which is the only important inclusion. The separated material was then washed with benzene and finally dried at 140° C. Column I in the following table gives the percentages by weight and column II the molecular percentages. Column III gives the analysis, by weight, of the Barkevik mineral.

		I.	II.	III.	IV.
SiO <sub>2</sub>	...	42.48	46.81	42.46	38.41
TiO <sub>2</sub>	...	2.90	2.38	—	—
Al <sub>2</sub> O <sub>3</sub>	...	8.58	5.55	11.45	17.65
Fe <sub>2</sub> O <sub>3</sub>	...	6.81	2.84	6.18	3.75
FeO	...	15.62	14.34	19.93	21.75
MnO	...	0.39	0.39	0.75	0.15
MgO	...	2.78	4.62	1.11	2.54
CaO	...	13.45	15.87	10.24	10.52
Na <sub>2</sub> O	...	6.32	6.74	6.08	2.95
K <sub>2</sub> O	...	0.60	0.46	1.44	1.95
H <sub>2</sub> O	...	0.25	—	—	0.24
		100.18	100.00	99.64	99.91

I. Barkevikite from Lugar, Ayrshire. Sp. gr. 3.298.

II. ditto, molecular percentages.

III. Barkevikite from Barkevik, Norway. Analysed by G. Flink.

IV. Hornblende from sodalite-syenite from Square Butte, Montana. Analysed by W. H. Melville.

The agreement between I and III is fairly close, particularly with regard to silica, ferric oxide, and the alkalis. The Lugar mineral, however, has a noticeably lower content in ferrous oxide and a complementary excess of lime and magnesia. Brögger states that the silica

<sup>1</sup> A. Lacroix, Bull. Soc. Géol. France, 1890, sér. 3, vol. xviii, pp. 513-514; 'Minéralogie de la France,' 1893, vol. i, p. 665.

<sup>2</sup> A. Lacroix, 'Les roches alcalines caractérisant la province pétrographique d'Ampasindava.' Nouv. Arch. Mus. Hist. Nat. Paris, 1902, sér. 4, vol. i, p. 16.

in Flink's analysis contains the titanium dioxide. It seems much more probable that most of the latter is with the alumina. Hillebrand<sup>1</sup> is of the opinion that the residue left after volatilizing the silica with a mixture of sulphuric and hydrofluoric acids, may contain one-third of the total amount of titanium dioxide, but that it generally has less than this. As the earlier analyses of Plantamour and Rammelsberg<sup>2</sup> showed the 'Hornblende von Brevik' to have between one and two per cent. of oxide of titanium, this, if deducted from the alumina, would make the amounts of the latter more nearly alike.

Column IV gives the composition of a 'hornblende near barkevikite from a sodalite-syenite described by Lindgren.'<sup>3</sup> It shows considerable similarity to the other analyses in the relative amounts of ferrous oxide and lime, but differs from them in its higher content of alumina and smaller amount of alkalis.

An examination of the rock in which the barkevikite occurs, gives some indication of the conditions under which this mineral was formed. The crystals are exceedingly well developed and have obviously formed later than the titanite and labradorite, since euhedral crystals of the latter penetrate the barkevikite. The occurrence of the rock in veins and 'Schlieren' shows that, to some extent, it is a magmatic residuum and therefore comparable to the pegmatites in which the Barkevik mineral is found. The comparative rarity of the mineral, in general, is probably to be explained by the fact that it only forms in soda-rich rocks and through a limited temperature range, which seems to be fairly low. The Lugarite magma must have remained mobile to a low temperature owing to its richness in water, and it is probably on this account, coupled with the composition, that the residual ferromagnesian material crystallized as barkevikite.

With regard to its position in the amphibole group, it seems to be intermediate between the basaltic hornblendes which characterize not only basalts but also such subalkalic rocks as tephrites, &c., and the titanamphibole which is typical of foyaitic and theralitic rocks. Barkevikite has a smaller content in sesquioxides and a greater amount of soda than the former, while it differs from the latter in containing less titanium dioxide and magnesia. In its richness in soda, it is related, not only to the titanamphiboles but also to arfvedsonite, with which it shows many similarities in composition and differs only in having less

<sup>1</sup> W. F. Hillebrand, Bull. U. S. Geol. Surv., 1910, No. 422, p. 96.

<sup>2</sup> Quoted by Brögger, loc. cit.

<sup>3</sup> W. Lindgren, Amer. Journ. Sci., 1893, ser. 3, vol. xlv, pp. 286-297.

ferrous oxide and soda. Optically, it is distinguished from arfvedsonite and the related katoforite,<sup>1</sup> by its much smaller extinction-angle and the absence of the characteristic blue-green colour. It therefore possesses sufficient characteristics, both chemical and optical, to justify its position as a separate species.

In conclusion, I wish to express my indebtedness to the Carnegie Trustees, as this work was done during the tenure of a Carnegie Research Scholarship.

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<sup>1</sup> W. C. Brögger, 'Die Eruptivgesteine des Kristianiagebiets,' 1894, vol. i, p. 27.

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