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Boehmite in syenite from New Zealand

UNUSUALLY large crystals of boehmite have been found associated with analcime in syenite from the Mandamus igneous complex in New Zealand, and are probably a replacement product of feldspar. The crystals are sufficiently large to allow measurement of 2V with the universal stage; a second cleavage {100} reported by de Lapparent (1930), but not since observed, is well developed. The identification of boehmite is confirmed by X-ray data, and the mineral has been analysed using an electron microprobe.

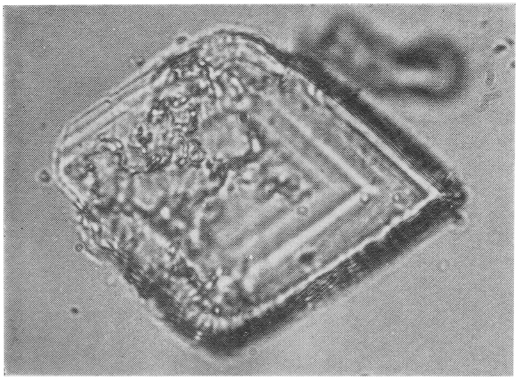
The Mandamus igneous complex is Cretaceous in age and comprises a variety of alkali-syenites, diorites, and gabbros with associated trachyte and igneous breccias. It intrudes complexly folded Torlesse supergroup sediments of probable Triassic age, and is overlain (on an erosional surface) by a sequence of uppermost Cretaceous–Tertiary sediments. The general petrology of the complex has been described by Mason (1951) and Reid (1972). The boehmite-bearing syenite occurs 150 m from a volcanic vent and to the south-west of Hurunui Peak (NZMS 1: Sheet S61, Culverden, grid ref. 971474, 20 km west of Culverden and 80 km north of Christchurch). The syenite is made of interlocking subhedral crystals up to 5 mm length of perthitic alkali-feldspar (approx. 80 %), prismatic crystals of complexly zoned amphibole (probably hastingsite/ferro-hastingsite overgrown by arfvedsonite), aegirine, and biotite. Extensive areas of analcime up to several millimetres across appear to be in part interstitial to the feldspars and in part a replacement product of them. Reid (1972) reports analcime replacing nepheline in some adjacent syenites.

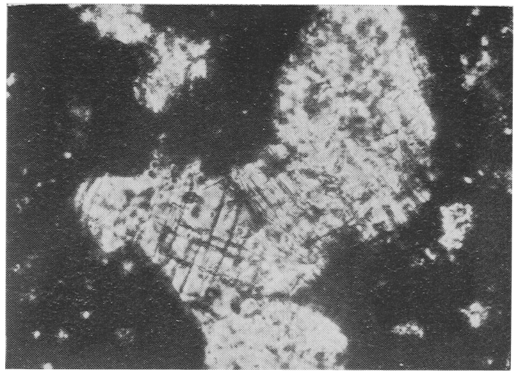
The boehmite is everywhere embedded in the analcime and commonly associated with calcite; it is therefore probably a hydrothermal alteration product of feldspar, or possibly in part of nepheline. Boehmite replacing feldspar and nepheline has been reported in the literature (e.g. Wyart *et al.*, 1963; Deer *et al.*, 1962).

The boehmite crystals vary in size up to 0·2 mm, are colourless, and euhedral to anhedral. Anhedral grain boundaries are often concave. Euhedral grains have well-developed {101} faces, as described also by de Lapparent (1930—his {110}) and Sahama *et al.* (1973), so that (010) sections and cleavage fragments (fig. 1) are rhomb-shaped; the interfacial angle (101):(10$\bar{1}$) is approximately 104°, agreeing with previous measurements. Euhedral compositional zone-boundaries in (010) sections (fig. 1) are marked by slight changes in relief and birefringence. The perfect {010} cleavage described by Sahama *et al.* (1973) and previous workers is present, but in addition there is a good {100} cleavage, so that the two are seen at right angles to each other in (001) sections (fig. 2). The {100} cleavage was observed by de Lapparent (1930) but not by Sahama *et al.* (1973), and it is not reported by Deer *et al.* (1962). Refractive indices, measured in sodium light, are $\alpha = 1{\cdot}640$, $\parallel$ [001], and $\gamma = 1{\cdot}660$, $\parallel$ [100], (both $\pm 0{\cdot}002$). Several measurements of the optic axial angle with the U-stage (orthoscopic illumination) give the value $2V_\gamma = 86$ to 88°.

A sample of the mineral was separated for an X-ray diffraction powder photograph from a concentrate (mainly of amphibole and epidote) with a specific gravity range of 2·9 to 3·3. Cu-$K\alpha$ radiation on four silt-size grains in a 115-mm camera for 16 hours gave sharp lines with the spacings and estimated intensities shown in Table I. They correspond well with those of boehmite in the JCPDS index (21.1307).

Considerable difficulty was experienced using the microprobe to analyse the boehmite. A very wide beam of 13 to 15 microns was necessary to minimize the loss of water during analysis





FIGS. 1 and 2: FIG. 1 (left). (010) cleavage fragment of boehmite illustrating well-developed {101} faces and compositional zones. Grain, immersed in oil, measures 0·1 mm along long diagonal. Plane polarized light. FIG. 2 (right). Anhedral boehmite grains in thin section. Lower-left grain displays {010} and {100} cleavages at right angles to each other. Isotropic background is analcime. Field of view measures 0·23×0·17 mm. Crossed polarized light.

TABLE I. *Estimated intensities, interplanar spacings, and analysis* (average of three grains) for boehmite from syenite*

I	*d*	*I*	*d*	*I*	*d*	SiO_2	0.76	*Cations on*	
						Al_2O_3	83.84	*basis of 2 (O, OH)*	
100	6.11	5	1.766	5	1.381	TiO_2	0.03		
60	3.15	10	1.661	15	1.308	∮Fe_2O_3	0.53	Si	0.008
60	2.347	5	1.528	5	1.173	MgO	0.02	Al	0.985
5	1.979	10	1.448	5	1.160	CaO	0.08	Fe^{3+}	0.004
20	1.862	10	1.431	5	1.134	†Na_2O	trace	Ca	0.001
20	1.850	5	1.394			H_2O+(calc.)	15.05	OH	1.000
							100.31		1.998

* The mineral analysis was made up with a JEOL JXA-5A electron microproble at 15kv, using a specimen current of 0.013 microamps. The beam was defocused to 13-15 microns.

∮ Total Fe as FeO recalculated as Fe_2O_3.

† Na_2O found in traces in other grains. Not analysed for in these three grains.

Erratum: Line 5 from end, *for* microproble *read* microprobe

and, even then, the best results (Table I) were obtained by analysing only for the main elements (Al, Si, Fe), thus minimizing exposure of the crystal to the beam. Although the wide beam size made it impossible to study the fine compositional zoning, a possible cause is the silica content since in all analyses this varied in the range 0·31–1·14 %. Water variation is less likely since the X-ray lines are quite sharp.

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3T muscovite from a staurolite-zone south-alpine gneiss, Cermeledo, Italy

SYSTEMATIC studies of the white micas of the metamorphic rocks of the south-alpine complex of Valtellina, central Alps, Italy, showed in places occurrences of the 3T polymorph coexisting with the ubiquitous 2M form. The 3T mica has the chemical and X-ray characteristics of muscovite. It was found to be dominant in a specimen collected at Cermeledo, near Dazio, and this rock was therefore chosen for detailed examination. The rock is 'Morbegno Gneiss' (Bonsignore *et al.*, 1971) and was metamorphosed under amphibolite facies conditions (staurolite–almandine subfacies, B 2.1, Winkler, 1967). The main mineral constituents of the sample are K-feldspar, quartz, plagioclase, biotite, muscovite, and garnet. The chemical compositions, cell parameters, and optical properties of the white micas are given in Table I, where they are compared with the well-known 3T muscovite from Sultan Basin (Güven and Burnham, 1967) and with muscovite from the Sanbagawa metamorphic belt (Kihara *et al.*, 1975).