Porphyroblastic adularia from Shimabala, Zambia

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Summary. An unusual occurrence of adularia as a porphyroblastic mineral in an Upper Pre-Cambrian marble from Zambia is described, and optical and chemical data given. The presence of good cleavages oblique to the crystal faces indicates that the latter are hemi-orthodomes and high index pyramids, although the crystals are of simple form.

ADULARIA is commonly regarded as the low-temperature member of the orthoclase family, distinguished from orthoclase itself mainly on the basis of its morphology and mode of occurrence. The original and characteristic examples came from Alpine-type veins and drusy cavities produced by low-temperature hydrothermal activity. It also occurs as a more widely dispersed hydrothermal mineral (Geffroy and Kraut, 1952) and as an authigenic mineral in sediments (Tester and Atwater, 1934).

The purpose of the present communication is to record an unusual occurrence of adularia as a porphyroblastic mineral in a metamorphosed Katangan (Upper Pre-Cambrian) limestone from Shimabala quarries in the Central Province of Zambia (Grid Reference 35LPN330702, Map Sheet 1528 C1).

The marble quarried at Shimabala, for use in cement manufacture, occurs a little above the base of a thick carbonate formation. It is a grey and white banded calcitic rock in which the main impurities are thin, plicated seams of carbonaceous 'dust' with a little muscovite and pyrite. These mark the original bedding. The specimens with adularia were collected from the north-east corner of the main quarry in September, 1961. The basal members of the same formation are more variable and consist of both calcitic and dolomitic marbles with intercalated semi-pelitic schists. The marbles contain large and abundant porphyroblasts of scapolite, albite, and microcline, and more rarely biotite, muscovite, and tremolite.

The Shimabala quarries are situated five miles north-west of the mantled gneiss dome of the Mpande hills and three and a half miles outside the garnet isograd in the pelitic schists below the carbonate

formation The basal marbles directly overlie non-chloritic muscovite–biotite schists.

The Shimabala adularias are, without exception, nucleated on the carbonaceous bands, the latter being preserved within the feldspars (fig. 1*a*). The crystals are normally situated so that there are approximately equal amounts above and below the carbonaceous bands. The adularias generally have a maximum dimension of more than 1 mm and reach a recorded maximum size of $2{\cdot}5 \times 4 \times 1$ mm. The crystals appear almost monoclinic and consist of two large rhombic faces joined by four short rectangular ones, with a symmetry plane crossing the short diagonal of the rhomb. They are thus morphologically similar to the potash feldspars of adularia habit described by Baskin (1956), which consist of rhombic (001) faces and short prisms {110}. In the Shimabala adularias, however, the cleavages do not lie parallel to the crystal faces; one set are normal to the rhombic faces and parallel to the short diagonal of the rhomb (fig. 1*a*), and another parallel to the long diagonal and intersecting the rhombic faces at approximately 33° (fig. 1*c*).

If it is accepted that the cleavages are more fundamental to the feldspar structure than is the morphology of the crystals, then the first cleavage, parallel to the symmetry plane, is parallel to (010) and the second is parallel to (001). In this case the faces present are two rhombic hemiorthodomes, (304) and $(\bar{3}0\bar{4})$ and four high-index pyramids (the orthodome indices were calculated using the axial ratio 0·6616:1:0·5534, derived from data on six adularia-like potash feldspars given by Baskin (1956, p. 144)).

Though closely approaching euhedral form, the faces are very rough and somewhat bevelled and embayed by the corroding matrix calcite, so that the angular relationships cannot be measured accurately. Large embayments are common at the obtuse angle of the rhombic faces, particularly when this is close to the carbonaceous bands (fig. 1*b*), and may result from incomplete growth of twinned adularia, for the black bands continue undisturbed from calcite into feldspar. This contrasts with replacement rims of calcite, which cut across the black bands. In exceptional cases all that remains of the original feldspar is a pseudomorph in clear crystalline calcite. Very fine quadrille twinning in four quadrants is apparent in sections cut parallel to or near to the rhombic faces (fig. 1*b*), but not in other sections. Similar twinning was recorded in adularia by Mallard (1876, figure reproduced in Chaisson, 1950).

The optic axial plane is inclined at an angle of 4° to the (001) cleavage and $2V_\alpha = 69\frac{1}{2} \pm 1\frac{1}{2}°$. On rhombic sections the extinction is undulose

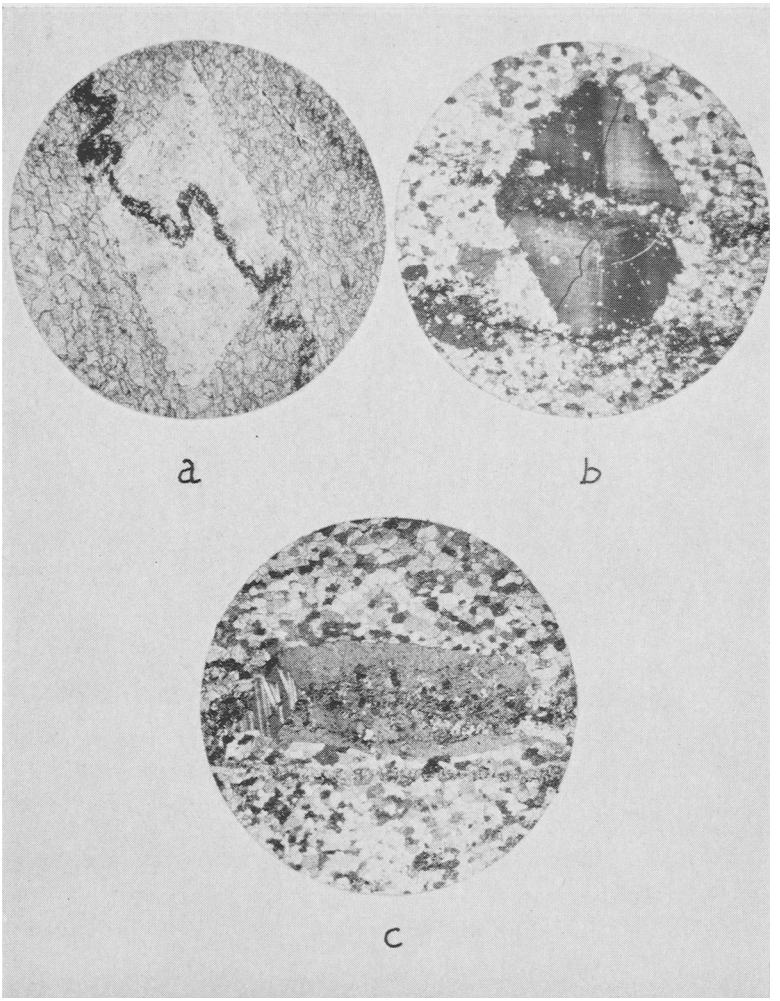

FIG. 1. Photomicrographs of Shimabala adularia. *a*. Rhombic section with contorted carbonaceous band and (010) cleavage. Ordinary light, ×23. *b*. Rhombic section with quadrille twinning in four segments. Crossed nicols, ×21. *c*. (010) section with (001) cleavage intersecting the rhombic faces. Crossed nicols, ×21.

across the quadrille twinning so that γ:[010] ranges from 1° to 10°. The optical data have been plotted on a stereogram (fig. 2) to show the small degree of triclinicity of the Shimabala adularia, and to allow direct comparison with similar stereograms constructed by Chaisson (1950).

In more than half the crystals examined, clear overgrowths were present, mainly on the prism faces. The thickness of the overgrowth on a particular face may be uniform or wedge-shaped, the base of the wedge being furthest away from the carbonaceous band. In rhombic sections the overgrowths have straight extinction $\gamma = [010]$ and therefore appear to be monoclinic.

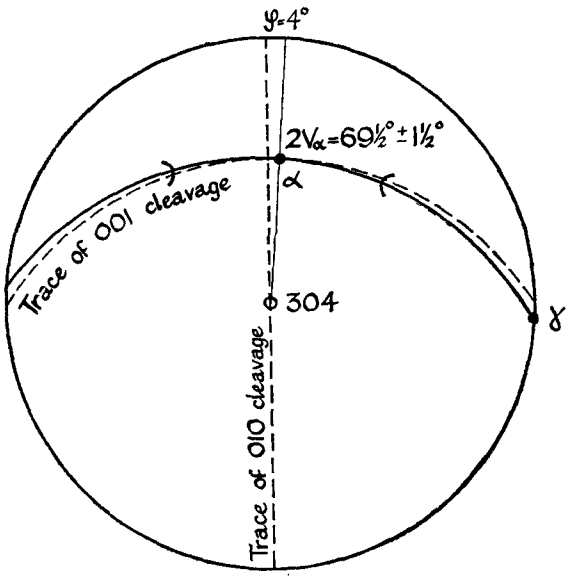

FIG. 2. Optical orientation of the Shimabala adularia.

Chemistry. Partial analysis of the Shimabala adularia (alkalies by flame photometer and alkaline earths by X-ray spectrograph) gave the results shown in table I. The adularia invariably contains small amounts of carbon, muscovite, and pyrite and consequently the oxide percentages obtained are probably too low. The feldspar molecules have been recalculated to 100 %.

When barium is assumed to substitute for potassium and calcium for sodium, the total (Or+Cels) content becomes 90·7 and (Ab+An) 9·3. A feldspar with composition $Or_{90\cdot7}Ab_{9\cdot3}$ and $2V_\alpha = 69\frac{1}{2}\pm1\frac{1}{2}°$ falls close to the field of the adularias plotted by Tuttle (1952). Earlier, Spencer (1937) used the optic axial angle as a basis of subdivision of the potash feldspars and regarded $2V_\alpha = 70°$ as the upper limit for adularia. Marfunin (1961) on the other hand recognized nine separate potash

feldspars with some overlap of 2V values; in particular, he showed that adularias have $2V_\alpha = 36–63°$ and barium feldspars $2V_\alpha = 57–73°$. The high 2V of the Shimabala adularia may be due to the relatively high barium content.

TABLE I. Partial analysis of adularia from Shimabala, Zambia (G. Hornung, anal.), compared with the range of 51 partial and 10 complete analyses from the literature

	1	2		1a
K_2O	13·8	13·08–16·0	Or	86·2
Na_2O	0·64	0·32–2·80	Ab	5·7
CaO	0·65	0·01–1·50	An	3·4
BaO	1·75	0·07–3·2	Cn	4·5
SrO	0·05	0·041–0·31	Sf	0·2
Rb_2O	—	0·07–0·17		[100·0]

1. Analysis of the Shimabala adularia.
2. Range of adularia analyses from the literature.

1a. Anal. 1 calculated in terms of the standard end-members (Sf = $SrAl_2Si_2O_8$) and then recalculated to 100 %; the sum of the standard end-members as calculated from the partial analysis was 94·7 %.

In comparing the Shimabala analysis with a number in the literature it was found that the sum of the standard end-members $(K,Na)AlSi_3O_8$ and $(Ca,Ba,Sr)Al_2Si_2O_8$ almost invariably falls short of 100 %. This suggests that further, silica-rich end-members such as $(Ca,Ba,Sr)_{0.5}AlSi_3O_8$ may be necessary to express the composition of many feldspars (assuming that the analyses are full and correct, and the material free of impurities). In nine of the ten complete analyses of adularia the alumina is in excess of the alkalies and alkaline earths, but, as Deer, Howie, and Zussman (1963) stressed, the excess may be more apparent than real if no account is taken of small amounts of ions substituting for K, Na, and Ca.

An error occurs in the calculations of Kozu and Endo (1920); 14·70 % K_2O, 1·12 % Na_2O, and 0·35 % CaO yields $Or_{88.66}$ $Ab_{9.56}$ $An_{1.77}$ (not $An_{2.4}$ as quoted).

The powder *X-ray diffraction pattern* of the Shimabala feldspar is indistinguishable from those of adularia and microcline. In spite of the close similarity in the diffraction patterns of adularia and microcline there are striking differences in optical properties, notably the marked triclinicity of microcline. This may be due, as Chaisson suggested, to small changes of internal structure, barely discernable by X-rays.

Origin. The mode of occurrence of the Shimabala adularia leaves no doubt that it is a truly porphyroblastic mineral. The authigenic feldspars described by Grandjean (1909) and Reynolds (1929) have a form very similar to that of the Shimabala adularia, i.e. a combination of rhombic {001} with short prism faces {110}. Both writers noted internal zones with cross-hatch twinning and external zones with straight extinction. Grandjean considered this to indicate microcline cores with orthoclase rims, whereas Reynolds postulated a member of the

anorthoclase–microcline group as the core. The similarities with the Shimabala feldspar, however, are so striking that the possibility of their being triclinic adularias with monoclinic overgrowths must be considered. These authigenic feldspars are considerably smaller than the Shimabala adularias and the latter must be considered to be the product of the low grade metamorphism that produced the wide range of porphyroblastic minerals in associated marbles.

Adularia is generally regarded as a monoclinic variety of orthoclase. Mallard (1876), however, noted the quadration and quadrille twinning and concluded that it was triclinic and transitional between orthoclase and microcline. Barth (1928) reached a similar conclusion after observing albite, pericline, and acline-B twins. His X-ray work, however, revealed a divergence of only 10′ from monoclinic symmetry. Chaisson's detailed optical work, coupled with Laves' (1950) X-ray determinations, confirmed the existence of both triclinic and monoclinic adularia. They also showed that as adularia assumed a small degree of triclinicity the optical orientation and axial angle became closer to sanidine rather than to microcline. Chaisson records considerable variation in $2V_\alpha(22–64°)$ and in the orientation of the optical axial plane (from $\parallel$ [010] to $\perp$ [010]). She also records monoclinic cores with triclinic margins—the latter being regarded as the result of partial reversion from an original metastable monoclinic form. Their optical and X-ray work led Chaisson and Laves to believe that all adularia crystallizes in a monoclinic form and reverts to a disordered triclinic form at temperatures too low to allow complete ordering to triclinic microcline. Since microcline is a constituent of associated rocks, the implication is that the Shimabala adularia is a late product of the metamorphism, having been produced at temperatures too low to allow reversion to microcline. Subsequent to the production of slightly triclinic adularia, monoclinic overgrowths were formed before partial replacement of the feldspar by matrix calcite.

Unlike the microclines in associated limestones, the adularias are all nucleated on the carbonaceous bands, suggesting a genetic connexion between the two. Initial nucleation may have been located by the concentration of alkalies in the argillaceous impurities in the carbonaceous bands.

The common occurrence of feldspars in limestones is readily explained by the work of Königsberger and Müller (1920), who showed that the presence of CO_2 greatly facilitated the precipitation of the feldspars. They mixed $KAlO_2$, $Al(OH)_3$, and potassium silicate and obtained leucite, but, on addition of CO_2, obtained a more siliceous mineral,

orthoclase. Gruner (1936) showed that adularia could be produced synthetically from a mixture of montmorillonite + H_2O + $KHCO_3$ by heating at 300° C for one week or 245° C for six weeks.

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