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Reverse zoning between myrmekite and albite in a quartzofeldspathic gneiss from Broken Hill, New South Wales

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SUMMARY. Grain boundary migration and the exsolution of albite from alkali feldspar, followed by the precipitation of myrmekite from the same source on to adjacent plagioclase grains, will explain the reversed zoning of these phases in contrast to the normal zoning seen in igneous rocks.

DETAILED studies on myrmekite have revealed some correlation between rock type and the morphology and spatial distribution of these quartz–plagioclase intergrowths, e.g. the bulbous habit occurring around megacrysts in deformed quartzofeldspathic rocks (Edelman, 1949; Phillips and Carr, 1973) or rim myrmekite, which characterizes most even-grained undeformed 'granites' in which plagioclase abuts against alkali feldspar (Phillips, 1964; Hubbard, 1967). Little significance, however, appears to have been attached to the zonation that may occur between myrmekite and the albite that is commonly involved with it. In igneous rocks where zoning can be established the usual development of the rim type is from a core of primary plagioclase to a layer of myrmekite (An_{20-15}) that passes out to a margin of quartz-free albite set next to potash feldspar (fig. 1) (Phillips, 1964; Watt, 1965). Even the intergranular blebs occurring between adjacent alkali feldspar crystals change from myrmekite at the original grain boundary to an outer rim of albite. Solid-state exsolution will explain such an arrangement (Ransom and Phillips, 1969; Hubbard, 1969).

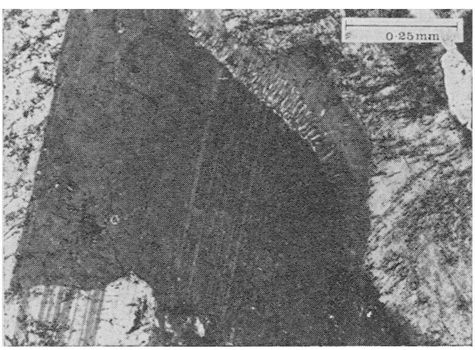

FIG. 1. Plagioclase from a granite partially rimmed by myrmekite, which zones out to albite free from quartz vermicules (right-top). The adjacent crystal to the right of the photograph is alkali feldspar. Crossed nicols.

Recently, however, Byerly and Vogel (1973, p. 194) have drawn attention to grain boundary phenomena in which plagioclase crystals are partially surrounded by a zone of albite, which in turn is rimmed by Ca-enriched myrmekite. A similar texture has been seen in the 'lower granitic gneiss' outcropping for some 2 to 10 km north-east of Broken Hill (Carruthers and Pratten, 1961).

Descriptions. The lower granitic gneiss has a foliated structure and is composed essentially of xenoblastic quartz, plagioclase, microperthitic microcline ($2V\alpha$ 58 to 75°), and biotite (Vernon, 1969, p. 30). A division into two varieties has been made on the basis of the morphology of the perthite: in one the plagioclase phase forms coarse 'beads' of sodic oligoclase associated with fine films; in the other regular, sparsely repeated film perthite is developed almost exclusively. Because the lower granitic gneiss outcrops just south-east of the boundary between Binns's (1964) metamorphic zones B and C, it would appear to lie in the amphibolite–granulite transitional facies of Turner (1968, p. 325).

In the gneiss with the regular film perthite, unzoned 'primary' plagioclase cores (An_{24}) generally pass abruptly outwards through a 'smooth' contact surface to a narrow zone of almost parallel-sided albite (An_{0-5}). The albite changes abruptly to a well-developed outer rim of myrmekite (An_{15-17}) (fig. 2). Rim and intergranular albite, without myrmekite, are present in the type with the coarser bead perthite. Certain additional features may be noted in the rock with the regular film perthite and reverse zoning: rimming is almost totally restricted to areas of contact with microcline; some rims are of albite with no myrmekite present; locally minute quartz stems may be seen in albite immediately adjacent to core plagioclase, thus suggesting a second generation of poorly developed myrmekite; both albite and myrmekite are optically continuous with the plagioclase core; a myrmekite rim may have developed next to only one particular microcline whereas other nearby microcline crystals have no neighbouring myrmekite; and intergranular myrmekite and albite have formed between adjacent microclines.

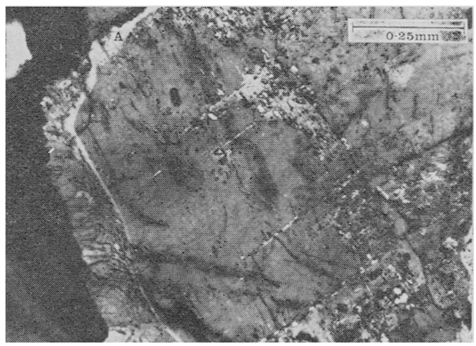

FIG. 2. Plagioclase from the lower granitic gneiss with regular film perthite development. The unzoned core (An_{24}) passes out through a partial narrow zone of albite to a rim of myrmekite set next to a microcline crystal almost at extinction. Note that at area A the albite passes directly into microcline (a different crystal from the microcline at extinction). The grain to the right is a plagioclase and no grain boundary phenomena can be seen between this and the central plagioclase crystal. Crossed nicols.

Discussion. In their discussion of nonstoichiometry and the presence of impurities within a *plagioclase* feldspar lattice, Byerly and Vogel (1973, p. 199) suggested that under conditions of the amphibolite facies Ca was expelled from plagioclase to its grain boundaries. They also proposed that adjustment in the plagioclase Al:Si ratio released Si to form the quartz in myrmekitic intergrowths. Their explanation was that as vacancy-linked Ca (Schwantke's molecule, $Ca(AlSi_3O_8)_2$) was expelled from albite rims to the boundary, a more calcic and myrmekitic outer rim formed as the vacancies were neutralized. The questions of the plausibility of nonstoichiometry within the alkali feldspars and the effects of exsolution have still not been resolved (Orville, 1972; Phillips, 1972) and the extension of such notions to the plagioclase feldspars is even more problematical.

It seems that in the Broken Hill lower granitic gneiss the microcline, rather than the albitic plagioclase, is the source of both the myrmekite and albite rims because: (i) The rims are found at grain boundaries between microcline and plagioclase; if the rims were derived from the plagioclase little reason exists for their restriction to contacts with alkali feldspars and they should occur at grain boundaries with other minerals. (ii) Myrmekite forms by far the thicker part of the rim (fig. 2) and it is difficult to believe that the vermicular quartz and the plagioclase of myrmekite were '. . . expelled from the albite rims to the boundary . . .' (Byerly and Vogel, 1973, p. 201); it might be expected rather that the source material remained in greater amount than the product. (iii) Albite rims are more persistent than myrmekite rims; at some microcline–plagioclase boundaries albite occurs alone, and in others only one particular microcline among three or four crystals bordering a single plagioclase grain has an associated myrmekite rim attached to the albite. If the albite were the source of the myrmekite all adjacent microclines should be associated with myrmekite.

Thus we believe that both the albite and the myrmekite were derived from the microcline—an explanation supported by many workers for other similar phenomena found elsewhere (e.g. Tuttle, 1952; Ramberg, 1962; Barth, 1969). Exsolution of an albitic phase from the alkali feldspar grains will account for the pure albite rims and a similar process will explain the more selective deposition of the associated albite and myrmekite layers. The problems are to explain how the reversal between the myrmekite and albite zones (as contrasted with igneous rocks) came about and why only certain parts of an albite zone, adjacent to a particular microcline, has a myrmekite rim.

Our explanation is that two distinct phases of rim development, reflecting a complex metamorphic history, occurred. Rocks with the coarser bead perthite (which holds a considerable volume of plagioclase) represent the stage in which albite alone was exsolved from alkali feldspar to feldspar–feldspar grain boundaries. The gneisses with the regular sparse film perthite experienced a later, more thorough expulsion of the plagioclase and quartz components (held as Schwantke's molecule) from the alkali feldspar leading to myrmekite development (see also Hubbard, 1966, p. 771). Another suggestion is that the albite rims are relict, having formed during an earlier igneous event and it has been proposed (Vernon, 1969, p. 27) that the granitic gneisses are in fact metamorphosed granites. The precipitation of the myrmekite may have occurred after the granite was subjected to regional metamorphism.

The selective deposition of myrmekite adjacent to one particular microcline may be explained by non-coherent relationships. Deposition of myrmekite may have been restricted by energy considerations to the most non-coherent grain boundary, thus leaving other albite rims myrmekite-free.

The evidence that we have gathered for this study leads us to the suggestion that grain-boundary phenomena associated with adjacent feldspar crystals may still be explained in terms of exsolution of a sodic plagioclase phase from an originally high-temperature alkali feldspar.

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