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Myrmekites from the Haast Schists, New Zealand

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Abstract

Myrmekitic oligoclase grains in the garnet and oligoclase-zone schists of the Haast River differ from common myrmekites in two main ways: (1) they occur in rocks generally devoid of K-feldspar; (2) they are not grain-boundary features but form mosaics often constituting a major component of thick rock masses. The intergrowths are found in the quartzofeldspathic folia and are associated with ordinary poikiloblastic and non-poikiloblastic oligoclases of the same age. Textural gradations between myrmekite and ordinary poikiloblastic oligoclases indicate that the myrmekite represents inclusion of *recrystallizing* quartz in blastic oligoclase. This, and various other hypotheses of myrmekite formation, are briefly discussed.

Introduction

The Haast Schist Group, which comprises the Otago, Alpine, and Marlborough Schists (Suggate, 1961), covers extensive areas of the South Island of New Zealand. Turner (1933, 1938), Reed (1958), and Mason (1962) have established chlorite, biotite, garnet, and oligoclase zones. More recently, the schists have been described in the context of the Cretaceous paired metamorphic belts of the Pacific Region (Landis and Coombs, 1967).

The specimens discussed in this paper come from the section along the Haast River, South Westland (Fig. 1), where a sequence from chlorite to oligoclase-zone schist is exposed. Along this section, as elsewhere in the Haast Schists, the predominant rocks exposed form a monotonous sequence of chloritic and/or micaceous quartzo-feldspathic schists. The Haast River area has recently been mapped in detail (Cooper, 1970). Oligoclase occurs with albite in the garnet-zone schists, and the oligoclase-zone boundary is marked by the absence of albite.

Unlike the common myrmekites of granitic rocks, the Haast Schist myrmekites are (1) not generally restricted to grain boundaries but instead are exceedingly abundant throughout thick rock masses, and (2) are not associated with K-feldspar. This latter fact makes their study particularly relevant to a general understanding of myrmekite formation since two of the principal hypotheses (Becke, 1908; Schwantke, 1909) require the presence of K-feldspar.

Throughout this paper the term foliation (and hence folia) is used in the sense of Harker (1932) to mean mineral banding as distinct from the 'fissility' or schistosity of the rock; this is consistent with normal New Zealand usage.

Description and Occurrence of the Myrmekitic Schists

Figure 1 shows the location of myrmekitic and non-myrmekitic specimens with respect to the mineralogical zone boundaries along the type Haast River section. Specimen numbers are those referred to in the text. In addition, other specimens in the University of Canterbury collection have been examined during the course of this work. The intergrowths only occur in schists of the high garnet or low oligoclase zones (Fig. 1). These schists generally have quartz-oligoclase folia 1 or 2 mm (but up to 5 mm) thick that are separated by somewhat thinner folia rich in biotite and oligoclase.

The schists are heterogeneous by nature; hence their composition is not suited to simple quantitative description. In general, their quartzofeldspathic folia are made up of quartz and oligoclase (and very minor albite in high garnet zone). The proportions vary within a single specimen from pure quartz to folia with roughly equal amounts of quartz and oligoclase. Most commonly there is a quartz-to-oligoclase ratio of 2 or 3 to 1. Both quartz and feldspar characteristically form roughly equant grains, which are slightly strained, and have triple point junctions. However, grain boundaries are highly irregular and blocky, resembling those produced during syntectonic recrystallization of

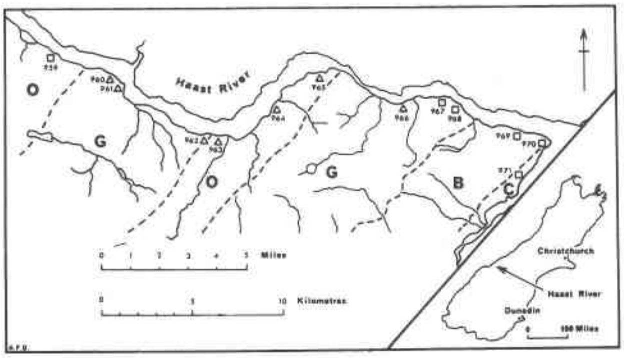

FIG. 1. Map showing location of myrmekitic (triangles) and non-myrmekitic (squares) specimens of Haast Schist in relation to the metamorphic mineralogical zones. C—Chlorite Zone, B—Biotite Zone, G—Garnet Zone, O—Oligoclase Zone. Zone boundaries from Cooper (1971).

quartz (Hobbs, 1968, Plates VI & VII). Texturally, the oligoclase may be (1) non-poikiloblastic, (2) poikiloblastic with quartz inclusions, or (3) myrmekitic with rods of quartz. The percentage of each textural type in specimens 960–965 inclusive are: 90,5,5; 20,60,20; 5,25,70; 10,30,60; 20,50,30; 40,50,10. These figures are necessarily somewhat arbitrary since each textural type grades into the other, as described in a later section.

The biotite-rich folia consist principally of biotite, the orientation of which defines the schistosity, and of oligoclase grains somewhat elongate parallel to the schistosity. The biotite and oligoclase are usually present in approximately equal quantities. There are lesser quantities of fine opaque minerals, muscovite, and epidote or clinozoisite. The oligoclase of these folia is often poikiloblastic but seldom myrmekitic.

Specimen 966 has a different overall texture from the others in that it is not foliated, and contains a coarse aggregate of poikiloblastic plagioclase, much of which is myrmekitic. The ratio of non-poikiloblastic to poikiloblastic to myrmekitic plagioclase is approximately 5:55:40.

Anorthite contents (determined optically using the curves of Slemmons (1962)) of plagioclase in specimens 960–966 are as follows: 22–25; 20–23; 19–22; 20–24; 20–23; 25–33; 29–35.

Description of the Oligoclases with Inclusions

Myrmekitic, normal-poikiloblastic, and non-poikiloblastic oligoclases commonly occur alongside each other, and all appear to have developed during the same period of metamorphism. Brief descriptions of the main types seem appropriate, in order to set the general context in which the myrmekite can be properly discussed.

Oligoclase with included trails

The oligoclase grains in the biotite-rich folia frequently enclose trails of other minerals, in particular of biotite and fine opaques (Fig. 2A). Generally, the trails are parallel to the exterior schistosity, but sometimes they have a folded form that is only imperfectly, if at all, represented in the surrounding simpler schistosity. This, together with the fact that the grain-size of the biotite and opaques is always finer when included in oligoclase, makes it clear that the trails represent an earlier schistosity or an early stage of the present schistosity. A few quartz grains, strongly elongate parallel to the trails, are also included in some of the oligoclases, this feature being most common in the biotite-rich folia.

Oligoclases with trails occur in all of the specimens, myrmekitic and non-myrmekitic. Albite in some of the lower grade rocks includes similar trails.

Oligoclase with non-vermicular quartz inclusions

In the quartzofeldspathic folia, much of the oligoclase contains quartz inclusions which are irregularly shaped blebs (Fig. 2B). The blebs are usually separated from one another, each having a different optical orientation. Their grain-size is finer than the mosaic quartz surrounding the oligoclases. Two or more blebs are sometimes joined together in mosaic form (Fig. 2B), and it appears that the included blebs represent relics of an earlier and finer-grained metamorphic mosaic. Indeed, it is not always possible to draw a clear boundary between blebs enclosed near the margins of oligoclase grains and the surrounding coarser quartz mosaic (Fig. 2B). It would appear that the growth of large quartz grains lagged in time behind the growth of large feldspar crystals.

Myrmekitic oligoclase

Oligoclase grains intergrown with branching rods of quartz occur in the same specimens as the ordinary poikiloblastic textures described above. The grain size of the feldspar is of the same order in both myrmekitic and non-myrmekitic grains. These intergrowths (Fig. 2C) look very much like the common myrmekite of granitic rocks, but with four important differences. First, there is no K-feldspar at all in four of the myrmekitic schists (962, 963, 965, 966), and extremely little in the three others

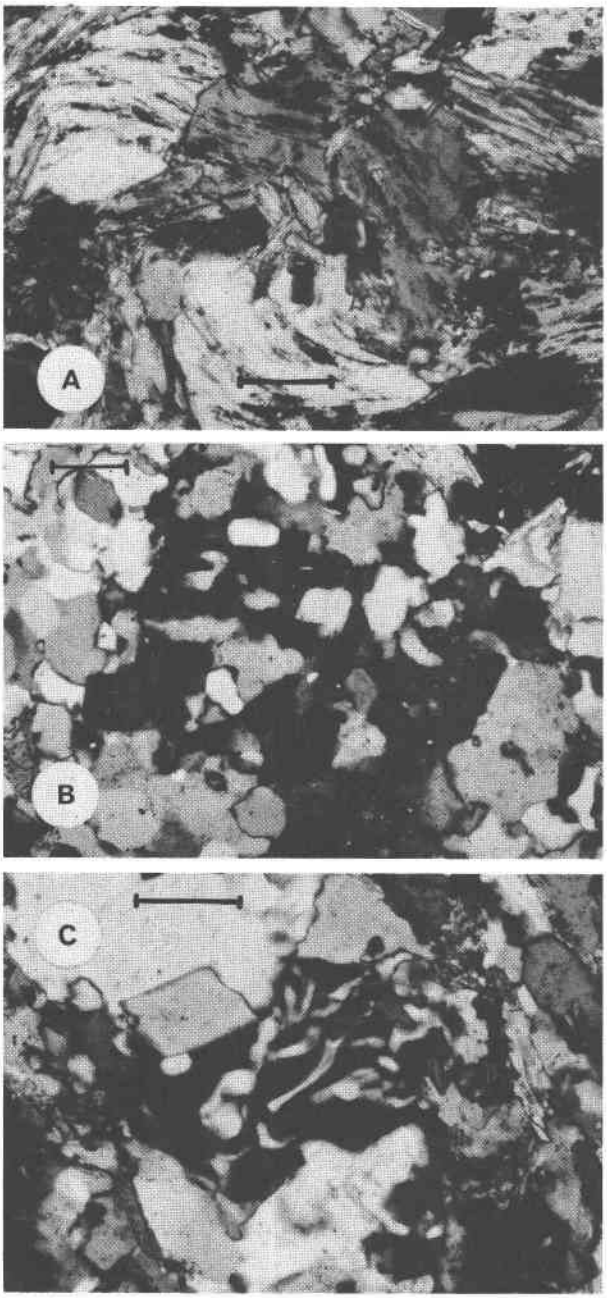

FIG. 2. Three varieties of inclusions in the Haast Schist oligoclases. Scale marks represent 0.1 mm. (A) Opaque minerals and biotite trails in specimen 961. (B) Centered in photograph from specimen 964 is an almost extinct plagioclase approximately 0.5 × 0.3 mm with very fine twin-lamellae visible running across but slightly down towards the right of the grain. The plagioclase includes irregular quartz blebs (not extinguished) and mosaics which merge outwards with the surrounding quartz mosaic. The tiny bright specks in the plagioclase are mainly sericite inclusions. (C) Rods of quartz branching towards the top right corner in the extinguished oligoclase grain at center of photograph from specimen 962.

(960, 961, 964) and then as very small grains not apparently associated in space with the myrmekite; it is quite clear that thick rock masses lack K-feldspar but contain abundant myrmekite. Second, the rods are coarser than is generally the case in granitic examples. Third, the Haast myrmekites are an intrinsic part of the metamorphic mosaic and are not grain-boundary features as in granites. Fourth, the simple fan-like arrangements of rods in common myrmekite is not generally developed. As judged from an examination of oriented sections both perpendicular and parallel to the schistosity, the rods in the Haast myrmekites tend to be oriented at right angles to the schistosity. For example, Figures 2C, 3A, 3C, 5A, 5B, 6A, and 6B all show rods at a high angle to the cleavage of adjacent biotite grains. Nevertheless, growth directions are not simple, and rods commonly branch and then join together again (Fig. 3A). As with common myrmekite, all the rods in one grain frequently have the same optical orientation, but sometimes several groupings of rods occur with separate orientations within the same oligoclase grain. Rods of quartz of the same orientations occasionally extend from the boundary of two oligoclase grains into both, and presumably the nucleation of both grains was based at this one place.

Examples with poorly developed rods and numerous separate orientations of quartz (Fig. 3B) exist as gradations between the normal blebby poikiloblastic oligoclase (Fig. 2B) and the good specimens of myrmekite (Figs. 2C and 3A). Blebs or elongate quartz trails sometimes grade out within a single oligoclase grain into quartz rods (Fig. 3C); such examples also commonly occur with granitic myrmekites (*e.g.* Shelley, 1964, Figures 7 and 8). All these types may occur together within a single specimen, the oligoclase of each having the same general grain-size and overall texture in relation to the rock as a whole. Furthermore, some oligoclases may contain mineral trails and vermicular quartz in the same grain (see Figure 5A and 5B).

The ratio of quartz to oligoclase varies widely, whereas the oligoclase composition is relatively restricted (*ca*, $An_{19} - An_{35}$). The relative volumes of quartz and oligoclase are difficult to measure since the rods have irregular shapes and distributions, and are finer than the thin sections are thick. However, it is estimated that the ratio varies continuously between 40:60 and 0:100. Except for omissions of an oligoclase with no quartz, Figure 4 illustrates this variation plus an example in which rods developed only in restricted parts of the oligoclase.

Specimen 966 is different from the others in that it contains coarse poikiloblastic plagioclases of the order of 2mm grain-size. Aggregates of the grains are set in an anastomosing mosaic of biotite, quartz and plagioclase with approximate grain-size 0.5mm. Garnet, opaque minerals, and clinozoisite up to 0.2mm in size occur throughout. The poikiloblastic plagioclase includes quartz, garnet, and opaque minerals, as well as aligned crystals of clinozoisite and biotite (approximately 0.1-0.2mm long, and always very much finer than the surrounding biotite). Clearly, the plagioclase has overgrown a pre-existing finer-grained metamorphic fabric. The quartz inclusions vary considerably in shape, but may be placed in three main groups: first, quartz grains elongate parallel to the aligned biotite inclusions; second, irregular blebs or patches of quartz mosaics of a fine grain-size; third, rods of quartz producing a myrmekitic texture (Figs. 5A and 5B). All these types occur within a single thin section and transitions from one to another occur within single grains.

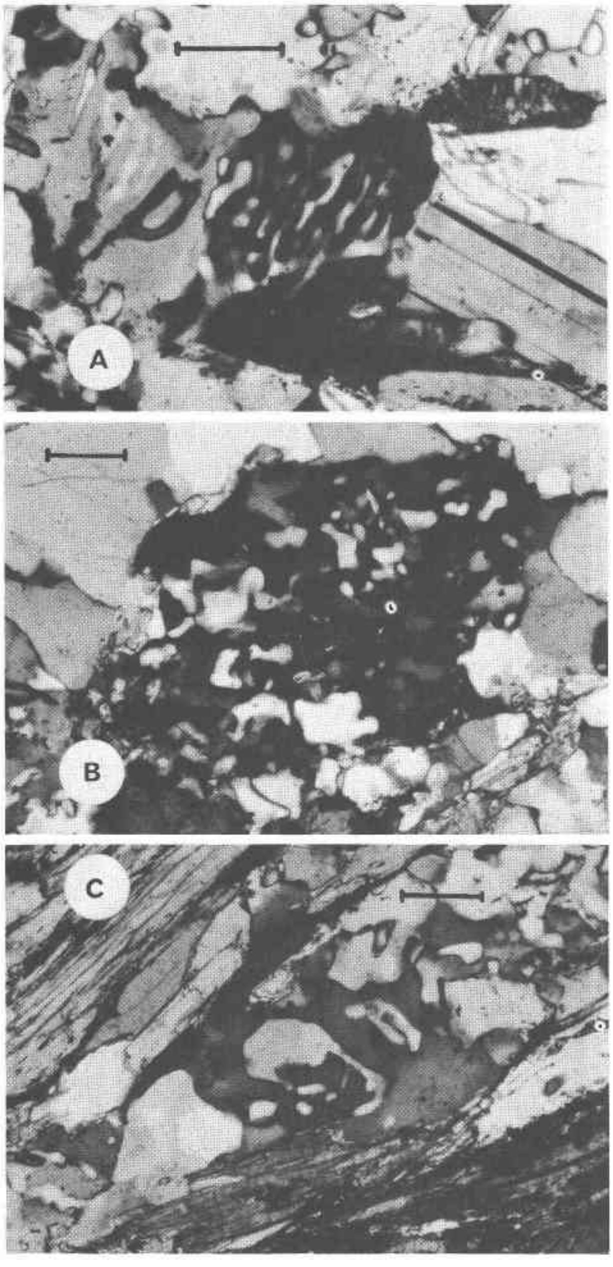

FIG. 3. Textures observed in specimen 963, each scale mark representing 0.1 mm. (A) Myrmekite with quartz rods branching, then joining together again at center of photograph. (B) Several groups of sub-vermicular quartz grains in one oligoclase crystal (in extinction). This is an intermediate stage between textures shown in Figure 2B and 2C. (C) Centered in photograph is a quartz bleb grading outwards into quartz rods within an (almost extinct) oligoclase crystal.

Conclusions

Neither Schwantke's (1909) hypothesis, in which myrmekite is formed from Schwantke's molecule [$Ca(AlSi_3O_8)_2$] on exsolution from a K-feldspar, nor Becke's (1908) hypothesis, in which myrmekite is formed as the result of the replacement of K-feldspar by plagioclase, can explain the Haast myrmekites. Phillips *et al.* (1972) have suggested that myrmekites in rocks with no K-feldspar (as described by Shelley, 1970) may have developed by complete replacement of K-feldspar by plagioclase, quartz and muscovite. However, in the Haast schists there is no evidence for the former presence of widespread K-feldspar, very little or no muscovite occurs in the myrmekitic rocks, and it is never in any clear way associated with the myrmekites.

Cooper (1970, 1972) noted the obvious difficulties with Schwantke's and Becke's hypotheses. The occurrence of myrmekite in the upper garnet and lower oligoclase zones led him to suggest that

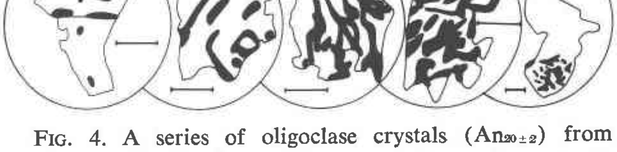

FIG. 4. A series of oligoclase crystals ($An_{20\pm2}$) from specimen 962 showing varying proportions of quartz to oligoclase, and in the last, an irregular distribution of quartz rods in oligoclase. Scale marks represent 0.1 mm.

it forms during progressive metamorphism from the greenschist to amphibolite facies. Cooper suggested the following reaction had occurred:

$$2\ NaAlSi_3O_8 + 2\ Ca_2Al_3Si_3O_{12}(OH)\ [\text{clinozoisite}]$$
$$= 4\ CaAl_2Si_2O_8 + 4SiO_2 + Na_2O + H_2O$$

However, I believe the following facts argue against this or similar reactions. (1) Clinozoisite occurs with myrmekite in several specimens, and is included in the intergrowths of specimen 966 with no evidence of reaction. (2) The first appearance of oligoclase in the specimens I have collected (albite and oligoclase occur together in 967) is not accompanied by myrmekite formation. (3) Oligoclase with no quartz occurs alongside myrmekitic intergrowths (*e.g.* Fig. 3A). (4) There is no consistent volumetric ratio of quartz to oligoclase in the myrmekites of any of the specimens (Fig. 4). (5) The degree of development of rod-forms and their abundance varies within wide limits in single grains (Fig. 4). The argument is not valid that the intergrowth is due to reaction because it appears restricted to a particular metamorphic zone. The texture and fabric of a rock will also change progressively with increasing metamorphism, and it is already a well established practice in New Zealand to separate mineralogical from textural zones. For example, Bishop (1972) also shows that over large areas textural zones do not precisely parallel mineralogical zones.

The preceding descriptions show that poikiloblastic oligoclase growth has preserved the relics of an earlier, finer-grained foliated schist, these relics including fine-grained quartz in the quartzofeldspathic folia. The arguments against a reaction origin for myrmekite plus the transitions that exist between myrmekite and normal poikiloblastic oligoclase indicate the intergrowths to be a special type of poikiloblastic texture. The oligoclases—whether non-poikiloblastic, normal-poikiloblastic, or myrmekitic—do not appear to differ in age and the variations in inclusion type must therefore reflect the local growth-site characteristics. In the case of myrmekite, the growth-site was probably an unstable one of recrystallizing quartz; as the quartz was included by the oligoclase, the recrystallization enabled it to take on shapes reflecting the growth directions of the feldspar, but at the same time maintaining a relatively small surface area for volume (circular cross-section rods).

Discussion

The origin suggested above is essentially the same as one of the hypotheses for common myrmekite (Shelley, 1964), except that here the plagioclase is not derived from K-feldspar by exsolution. The hypothesis that myrmekite is a special type of poikiloblastic texture is a very versatile one, being readily adapted to the wide variety of myrmekite-like intergrowths involving other mineral pairs (Shelley, 1970).

In considering hypotheses for myrmekite formation, Becke (1908), Phillips and Ransom (1968), and Barker (1970) all cite increasing quartz content with anorthite content of the plagioclase, which is as predicted by both Becke's and Schwantke's hypotheses. On the other hand, a lack of proportionality has been reported by Sederholm (1916),

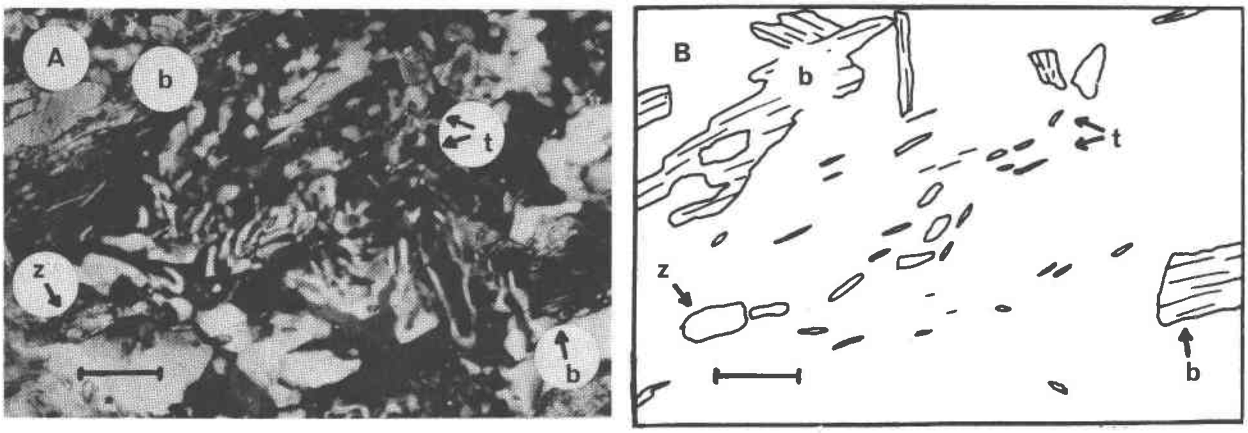

FIG. 5. (A) Myrmekitic plagioclase in specimen 966 with most quartz rods branching upwards and slightly to the left. Trails of biotite and clinozoisite within the myrmekite are just visible on the photograph (t) and are represented for clarity on the tracing (B). Other grains of biotite (b) and clinozoisite (z) at the boundary of the myrmekite are also shown. Scale mark represents 0.1 mm.

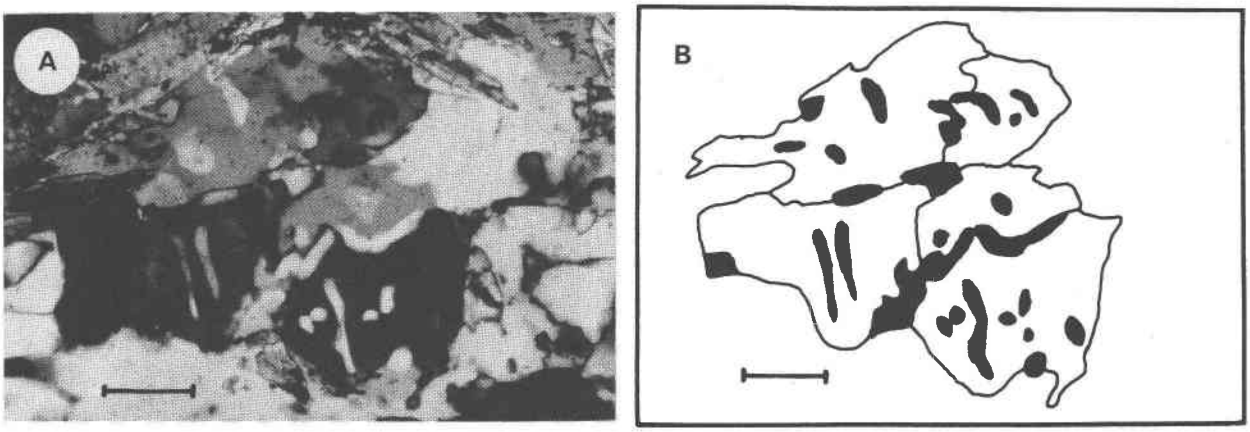

FIG. 6. (A) Five myrmekitic grains in specimen 964 with quartz along the oligoclase grain-boundaries. (B) is a tracing from (A) to show clearly the five grains and the position of the quartz (blacked in).

Shelley (1969, 1970, and this paper) and Phillips *et al.* (1972). It is not usual to quantify negative evidence, especially when it is visually self-evident (Shelley, 1969 and this paper; Phillips *et al.*, 1972). Because of this natural tendency to quantify positive but not negative evidence (well illustrated by contrasting the 1968 paper of Phillips and Ransom with the 1972 paper of Phillips *et al.*), the representativeness of data plotted on graphs such a Barker's (1970) must be in doubt. If myrmekite is polygenetic, as Phillips *et al.* (1972) suggest, then the plotting of only those ratios that are in agreement with a particular hypothesis can not be taken as *primary* evidence for that hypothesis.

Phillips *et al.* (1972) point out that if common myrmekite grows by including intergranular quartz (as illustrated in Shelley, 1970, Fig. 2), myrmekites with excess quartz at their margins should occur. A related problem that can be raised here is that plagioclase growth on common myrmekites appears to cease once the intergranular quartz is used up. These problems do not apply to the Haast myrmekites since they frequently have quartz rods that end before the plagioclase boundary is reached. (*e.g.* Figs 3A, 6A, and 6B), and quartz is often found along their margins (Figs. 6A and 6B). On the other hand, for some granitic myrmekites these problems do exist, and no solution immediately presents itself. However, it is well known with eutectic crystallization that the spacing of rods is controlled by diffusion rates and other energy factors. Could it be that some such factors lead to the nicely spaced out quartz rods that commonly occur in myrmekite? Unfortunately, this is the sort of question that is difficult to answer, even when studying experimentally produced crystal growth structures. A process that may be important in halting myrmekite growths when intergranular quartz is used up is the "poisoning" of the crystal boundaries by concentrating impurities between myrmekite and K-feldspar; this is a factor well known in impeding or preventing growth at grain boundaries of metals.

Clearly, there are problems in applying any hypothesis to myrmekite in general. However, there are obvious dangers in resorting too frequently to the answer that myrmekite is therefore polygenetic, since this may often mean nothing but special pleading; if myrmekite is polygenetic, then great care must be exercised in providing sufficient criteria for recognizing each type.

Acknowledgments

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