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MYRMEKITE IN THE AMBELA GRANITIC COMPLEX, N. PAKISTAN: A PRODUCT OF DEFORMATION AND REPLACEMENT IN THE FELDSPAR

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ABSTRACT

The Ambela Granitic Complex in N. Pakistan is locally intersected by strike-slip and thrust faults, which have resulted in the development of relatively sheared granites. A characteristic feature of the deformed granites is the occurrence of myrmekite in the K-feldspar porphyroclasts, which is otherwise absent in the complex. A detailed petrographic study shows that the myrmekites are localised along those margins of the porphyroclasts which are most strained and which are adjacent to the trails of secondary muscovite. A comparison with the established examples of strain-related myrmekites suggests that though the deformation may be important in the genesis of the Ambela myrmekite, there may be a greater role of metasomatic replacement accompanying deformation.

INTRODUCTION

A corroded feldspar with vermicules within an orthoclase grain was first described by Michel-Levy in 1875, and later on such intergrowths were named as myrmekite by Sederholm (1899). Details of the early work on myrmekite were summarised in Sederholm (1916) and Drescher-Kaden (1948). Phillips (1974, 1980) reviewed the various hypothesis for the genesis of myrmekite and presented a modern supplement to the work of Sederholm (1916) and Drescher-Kaden (1948).

The role of deformation in the replacement of K-feldspar by myrmekite, particularly in acidic plutonic rocks, was first recognised by Futherer (1894). Several later workers (e.g., Eskola, 1914; Spencer, 1945; Sarma and Raja, 1959; Shelly, 1964; Bhattacharyya, 1971; Phillips and Carr, 1973) pointed out the significance of deformation in the origin of myrmekite. Indeed deformation is considered to be an effective mean of driving replacement reactions (Wintsch and Knipe, 1983; Tullis, 1983; Vernon et al., 1983; Hibbard, 1987; La Tour and Barnett, 1987). Another mechanism which is considered to be responsible for the formation of some of the naturally occurring myrmekites is solid-state diffusion and exsolution (Schwantke, 1909; Phillips, 1974), which is considered to be more effective during deformation (White, 1975; Simpson, 1985) than under normal conditions.

In this paper we present examples of myrmekites occurring in strained K-feldspar porphyroclasts in sheared granites from the Ambela Granitic Complex (AGC), and explain their growth in terms of a collective role of solid-state diffusion and reaction replacement under directed stresses.

PETROGRAPHY OF THE MYRMEKITE-BEARING DEFORMED GRANITES

Petrography, geochemistry, and petrogenesis of the granites from the AGC have been described in detail by Rafiq (1987) and Rafiq and Jan (1988). Whereas the bulk of the complex is undeformed, there are strike-slip and thrust faults in the north eastern part of the complex, which contain heterogeneously sheared granites (Rafiq, 1987). A peculiar feature is the occurrence of myrmekite in these granites, which is apparently formed in the feldspar grains due to a complex interplay of deformation and replacement.

The myrmekite-bearing deformed granites, in the Ambela Granitic Complex, resemble closely with the S–C mylonites of Berthe et al. (1979), consisting of alternating zones of high (C planes) and low strain (S planes) (Fig. 1A). Whereas the C planes are narrow and are defined by trails of dynamically recrystallised quartz and fine-grained muscovite, the S planes are marked by recrystallised quartz ribbons oriented obliquely to the C planes. Recrystallised biotite and muscovite, with their (001) planes parallel to the quartz ribbons are also present in the S planes. An important component of the S planes is the K-feldspar porphyroclasts (Fig. 1A,B), which occur more or less parallel to the quartz ribbons, often surrounded by trails of recrystallised muscovite and biotite. Myrmekite, the subject of this study, occurs in these K-feldspar porphyroclasts (Fig. 1B). In the following we present a brief petrography of K-feldspar and other constituent minerals of the S–C granitic mylonites from the AGC.

The K-feldspar in the deformed granites is usually turbid to cloudy in appearance. It is tabular to ovoid, locally augen-like in shape, commonly showing recrystallised tails parallel to the quartz ribbons. It is more or less perthitic with mostly microcline structural characteristics (M. Rafiq, unpublished XRD data). It contains anhedral to very irregular forms of perthitic albite of metasomatic origin (Rafiq, 1987). This perthite has inclusions of blebby quartz which may or may not display a preferred orientation. En-echelon perthite and micaceous alterations along oriented cracks are also present (Fig. 1C). En-echelon veins of quartz and feldspar, oriented subperpendicular to S planes and probably filling tension cracks are common in deformed K-feldspar grains (Fig. 1C,D). Also found are inclusions of biotite and, rarely, apatite and ore.

Quartz occurs in dynamically recrystallised extremely fine grains in the C planes. In the case of the S planes, either it occurs in aggregates of a lenticular ribbon shape consisting of recrystallised polygonal grains, or as porphyroclasts with strong undulose extinction and tails of subgrains.

Plagioclase grains are commonly homogeneous but some show a weak marginal zoning from An_{22} to An_4. Microprobe and optical data suggest an average composition of An12. Plagioclase is mostly undeformed, but some rocks contain grains with internal fractures and cracked margins. Twinning is according to the albite twin law. The twin morphology in some sections is mechanical (kinking and bending) and resembles the deformation twining. (cf. White, 1975). Recrystallisation in plagioclase is negligible.

Biotite forms clusters and schlieren of fine flakes to medium-sized tabular grains. The grain boundaries are often serrated and show aggregates of fine epidote, opaque oxide (also

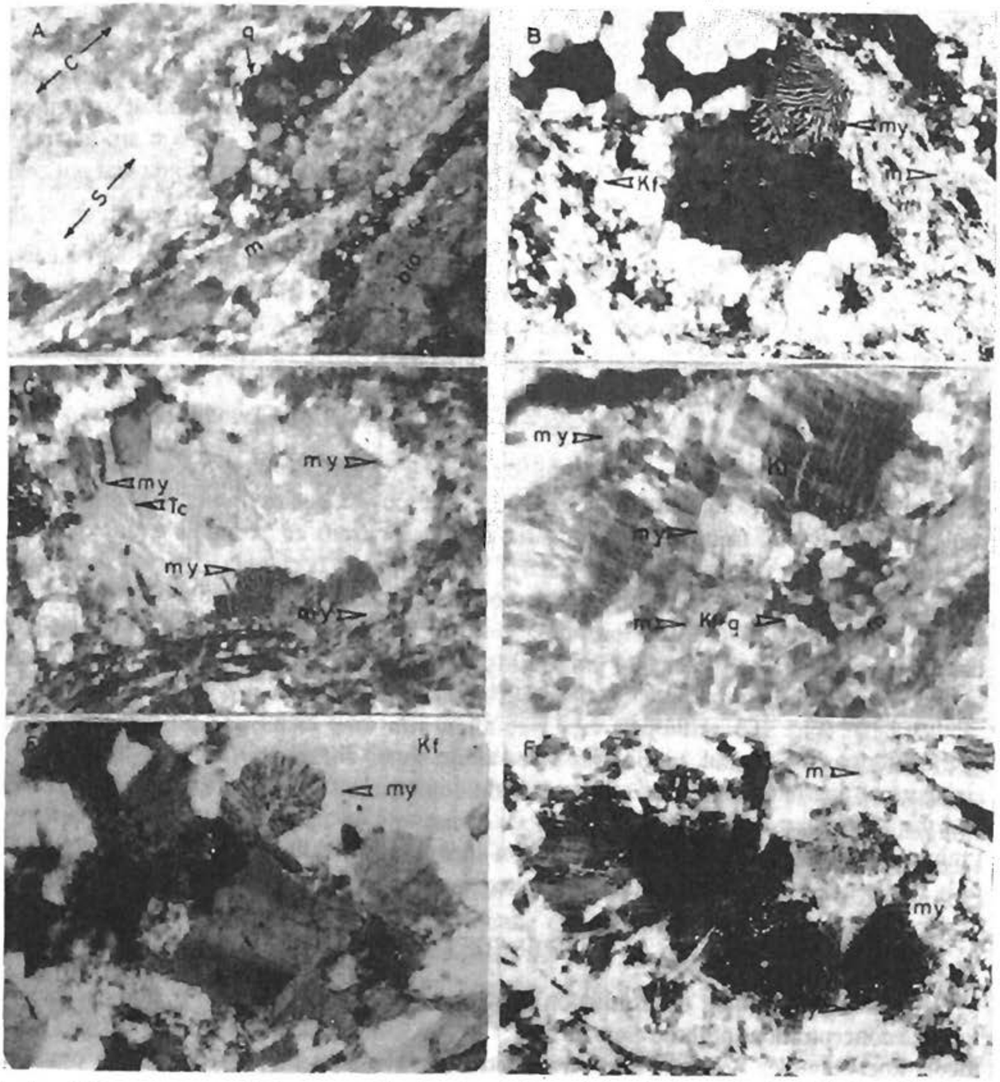

Fig. 1: Microstructures of the myrmekite-bearing deformed granite from the Ambela Granitic Complex. A) Geometrical relationship between the C and S foliation planes. Note the occurrence of K-feldspar porphyroclasts in the S-planes, together with the quartz (q) ribbons and muscovite (m) trails. B) A closer view of an S-foliation in the AGC mylonites. Note the strained porphyroclast of K-feldspar (Kf), with recrystallised trails. A bulbous myrmekite (my), rooted in a muscovite trail invades the porphyroclast at its margin facing the finite shortening. C) A large porphyroclast of K-feldspar, with fractures and tension cracks (Tc) at right angle to the S-foliation. Angular and bulbous myrmekites are present at the margins of the K-feldspar porphyroclast. D) A perthetised K-feldspar porphyroclast in S-plane, with planar and bulbous myrmekites at margins parallel to S-planes. E) A typical bulb-shaped myrmekite cutting across a K-feldspar porphyroclast. F) Angular myrmekite, apparently developed along tension gashes in the K-feldspar porphyroclast at high angles to the S planes.

along cleavages), sphene, leucoxene and sometimes, rutile. Alteration to chlorite is rare. Ilmenite inclusions are generally rimmed by sphene, and can be attributed to deformation in these rocks (see Vernon et al., 1983). Secondary biotite forms fine droplets to fine-grained anhedral patches. Biotite grains vary from undeformed, gently bent with undulose extinction. to those intensely deformed. Responsible for this inhomogeneous deformation are microshear planes (both C and S), which in a dynamically recrystallised matrix of quartz and muscovite contain elongated biotite crystals.

Muscovite is closely associated with all its topocrystalline and structural habits to biotite. It is mostly seen in close association with myrmekite. Secondary sericite is initiated genetically as blebs and flakes with opaque dust in the K-feldspar grains and along the foliation planes, which locally grades into well developed crystals.

MYRMEKITE MORPHOLOGY AND STRUCTURAL POSITION

The S-foliation in rocks under discussion is clearly defined by narrow ribbons of recrystallised quartz, elongated biotite, secondary muscovite, and asymmetric feldspar porphyroclasts (Fig. 1A,B). Commonly the quartz ribbons or trails of secondary muscovite wrap around the feldspar porphyroclasts (Fig. 1B). The myrmekite is characteristically developed in the marginal zones of the K-feldspar porphyroclasts, particularly where the porphyroclast is in contact with a trail of fine-grained muscovite (Fig. 1B). Apparently it is rooted along the muscovite trails and protrudes into the K-feldspar porphyroclast. In most cases, the protruding myrmekite is blebby or bulbous (Fig. 1B,D,E) but in a few cases, it is angular (Fig. 1F), and rarely planar (Fig. 1C). Although very fine albite rim may locally be present, this bulbous myrmekite has, in general, no distinct outer albite zone. The worm-like elongated drops and stringers of quartz project more or less at right angle to the interface between the myrmekite and the K-feldspar. Mushroom-shaped lobes of myrmekite embay the margins of K-feldspar grains. The K-feldspar porphyroclasts do not contain myrmekite in all its marginal parts, but only in those, which face the maximum finite shortening direction.

DISCUSSION

Models explaining the formation of myrmekite mostly advocate readjustments in the relative concentrations of three elements Na, Ca, and K in K-feldspar grains or in some parts of them. For example, Becke (1908) suggested that myrmekites are essentially a product of replacement reactions whereby Na and Ca are introduced and K removed along grain boundaries, resulting in the development of a sodic plagioclase and release of silica as vermicular quartz. Phillips (1980) noted that introduction of water to the system may result in the dissolution of alkali feldspar in myrmekites together with a development of muscovite. Schwantke (1909) accepted the readjustment in the relative proportions of Na, Ca and K in parts of the alkali feldspar grains for the origin of myrmekites, but favoured the mechanism of solid-state diffusion rather than metasomatic replacement. Recently, Simpson (1983, 1985) has described myrmekites from high-grade mylonites from the eastern Peninsular Ranges granitoids. These myrmekites are essentially strain-related and were explained to have formed in response to an enhanced solid-state diffusion of Na, under the influence of non-hydrostatic stresses (cf. White, 1975). This model is supported by the position of myrmekites typically at those margins of the K-feldspar porphyroclast which face the maximum shortening direction.

As concluded by Phillips (1980), there is every possibility that myrmekites in nature form due to an interaction of metasomatic replacement and solid-state diffusion-exsolution. It is the petrography which would decide about the dominance of the mechanism responsible for myrmekites in a particular set of rocks. The myrmekites in the AGC are characterised by textures which suggest a role of deformation, solid-state diffusion, and reaction replacement. As stated in the previous section, the myrmekite in the AGC is typically found in the K-feldspar porphyroclasts which are strained, and within them it is always located at the margins which face the maximum shortening direction. The composition of the myrmekite is more albitic than the discrete plagioclase present in the rock, suggesting that they developed locally and subsequent to primary crystallisation. The existence of planner to gently curved boundaries of the myrmekites against the host K-feldspar porphyroclasts lends further support for the strain-related origin of the myrmekites in the AGC (cf. Simpson, 1985). There are however, some differences in the microstructures of the K-feldspar porphyroclasts in the AGC relative to those of the high-grade myrmekite-bearing mylonites reported by Simpson (1985). In the latter, the deformation is essentially ductile and there is no evidence of the existence of a fluid phase during deformation as shown by the absence of secondary hydrous minerals like muscovite and sericite. In the case of the AGC, the porphyroclasts display tension gashes and fractures oriented at right angels to the S foliation planes (Fig. 1C,D,F). This suggests that the deformation is generally brittle, although limited recrystallisation has taken place in their tails (Fig. 1B). Additionally, there is a close textural relationship between the trails of muscovite and the myrmekites; the latter being commonly rooted in the muscovite trails. The presence of a fluid phase accompanying deformation has previously been suggested to be responsible for the development of fibrous silliminite in the AGC shear zones (Rafiq and Jan, 1987). The loss of K relative to Na and Ca at the K-feldspar porphyroclast margins may partially be associated with the activity of fluids which crystallised muscovite in the adjacent shear planes. The common occurrence of the myrmekites in a bulbous shape with invasive appearance, and the presence of quartz vermicules extending up to the myrmekite-feldspar interface is considered by Phillips (980) and Simpson (1985) to be an evidence for the role of metasomatic replacement. Thus, although there is little doubt that the myrmekite in the AGC is formed under a direct role of deformation, the mechanism involved was an interplay of both solid-state diffusion and exsolution and reaction replacement in the presence of fluids.

CONCLUSIONS

The characteristic position of the myrmekites at the margins of the K-feldspar porphyroclasts facing shortening direction indicates some relationship between the formation of myrmekite and deformation. The presence of muscovite along foliation planes, and their close association with the myrmekites suggest an open system, in which fluids facilitated free ionic movement in the replacement reaction. Shear strain was localised along biotite and muscovite-bearing foliation planes anastomosing around K-feldspar grains, which polygonised (or recrystallised) quartz, and strained and partly recrystallised K-feldspar. Solid-state diffusion of Na and Ca to the sites of high strain at the porphyroclast margins might have been partially responsible for the origin of myrmekites. There is, however, a stronger evidence for the role of reaction-replacement in their genesis. Brittle-ductile deformation together with an activity of circulating fluid phases caused dissolution of K-feldspar porphyroclasts in their relatively strained parts depleting them in K relative to Ca and Na, which resulted in the formation of myrmekites in close association with muscovite.

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