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1. ORIGIN OF MYRMEKITE AND METASOMATIC GRANITE

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Two different generally-accepted hypotheses for the origin of myrmekite are examined in seven different photomicrographs.

First Hypothesis

Myrmekite, the vermicular intergrowth of quartz in plagioclase, is considered by some geologists to form by replacement of K-feldspar by Ca- and Na-bearing fluids.

$KAlSi_3O_8 + Na^{+1} = NaAlSi_3O_8 + K^{+1}$
$2KAlSi_3O_8 + Ca^{+2} = CaAl_2Si_2O_8 + 4SiO_2 + 2K^{+1}$
potassium feldspar   myrmekite

This hypothesis seems logical, particularly when the K-feldspar crystal is relatively large (>1 cm) and when the myrmekite is tiny (less than 0.5 mm) and forms wartlike projections into the K-feldspar margins (as seen later in Figs. 2-5). But is the K-feldspar primary and is the myrmekite a secondary alteration? *Does the above mass-for-mass equation actually represent the reaction in a rock where it is clear that the K-feldspar is primary and replaced by Na and Ca to form secondary plagioclase?* Let's look at textures in a rock from Ausable Forks, New York (USA) (Fig. 1a and Fig. 1b).

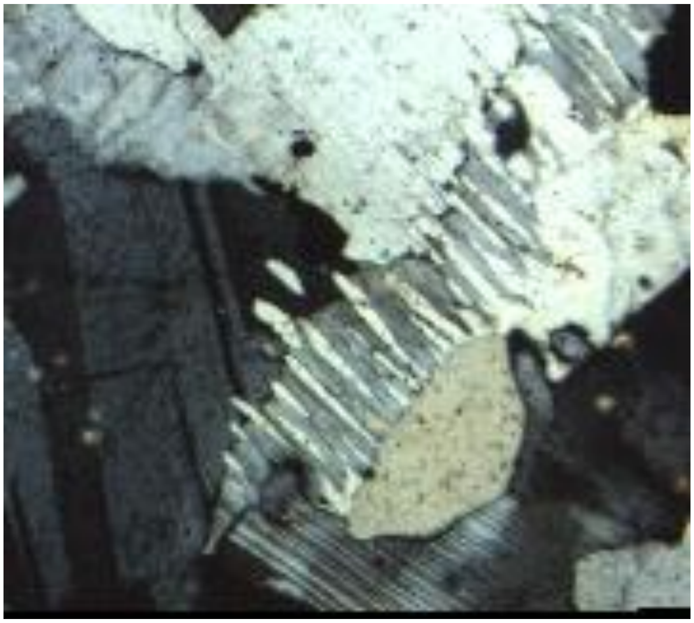

Fig. 1a.

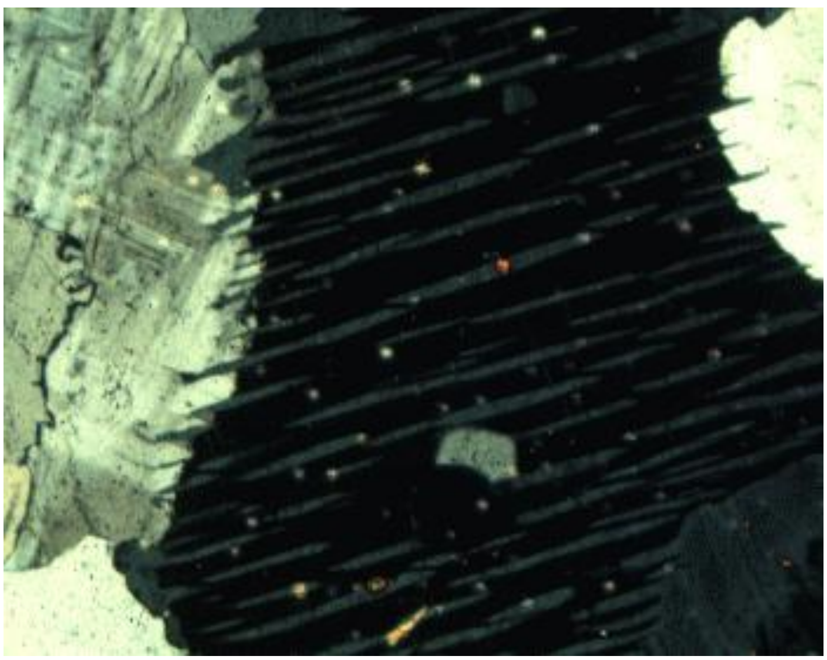

Fig. 1b

Figs. 1a and 1b. These photomicrographs show magmatic granite that contains coarse mesoperthite and clinopyroxene in a granulite facies. Where the granite is slightly-deformed, secondary albite-twinned plagioclase An_{20} has replaced the K-feldspar of the perthite leaving plagioclase lamellae sticking out like teeth of a comb into the secondary plagioclase. Note remnant plagioclase lamellae (creamyellow) in secondary plagioclase (upper left) and remnant plagioclase lamellae (black) projecting into secondary plagioclase (light gray, lower right). Primary, unreplaced microcline enclosing the lamellae is either light gray or very dark gray.

Discussion

If replacement of K-feldspar by plagioclase were mass-for-mass, as in the above balanced equations, tiny quartz vermicules should have formed in the secondary plagioclase in Fig. 1a and Fig. 1b, but none is present. Therefore, the replacement is not mass-for-mass but volume-for-volume. In the latter case, the greater density of secondary plagioclase (2.63) relative to the lesser density of K-feldspar (2.56) requires that silica cannot be released but is consumed in forming the secondary plagioclase that fills the space once occupied by the K-feldspar. Thus, although the balanced mass-for-mass equations appear to be quite logical, they cannot be used to explain the origin of myrmekite, at least in some rocks.

As further evidence that Ca- and Na-replacements of K-feldspar are not valid is shown by four different granites (Figs. 2-5), which have characteristics that make mass-for-mass reactions unlikely. If myrmekite in these granites were formed by Ca- and Na-bearing fluids that replaced K-feldspar, then the myrmekite in each host granite should be most abundant near fault zones, should be concentrated along fractures in K-feldspar crystals, and should totally replace the K-feldspar in some places, and none of these characteristics is found in the following examples. An exception that fulfills the aforesaid characteristics is illustrated in http://www.csun.edu/~vcgeo005/Nr4CaMyrm.pdf.

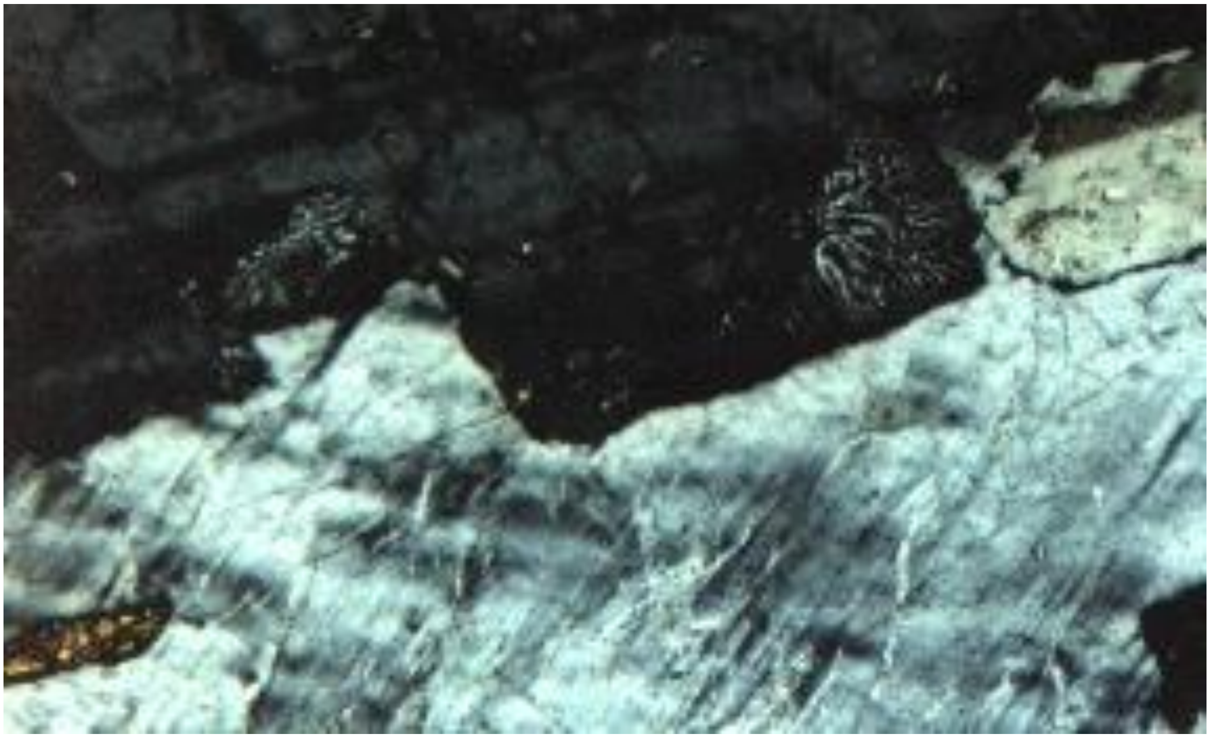

Fig. 2. This photomicrograph shows myrmekite in the S-type Cottonwood Creek granite pluton in Australia.

Similar myrmekite occurs in the S-type Cooma pluton, also in Australia. Metasedimentary wall rocks of the latter pluton contain plagioclase, averaging about An24. Myrmekite is in two places: top center of albite-twinned plagioclase (dark) against K-feldspar (light gray, top). Quartz vermicules are tiny and barely visible.

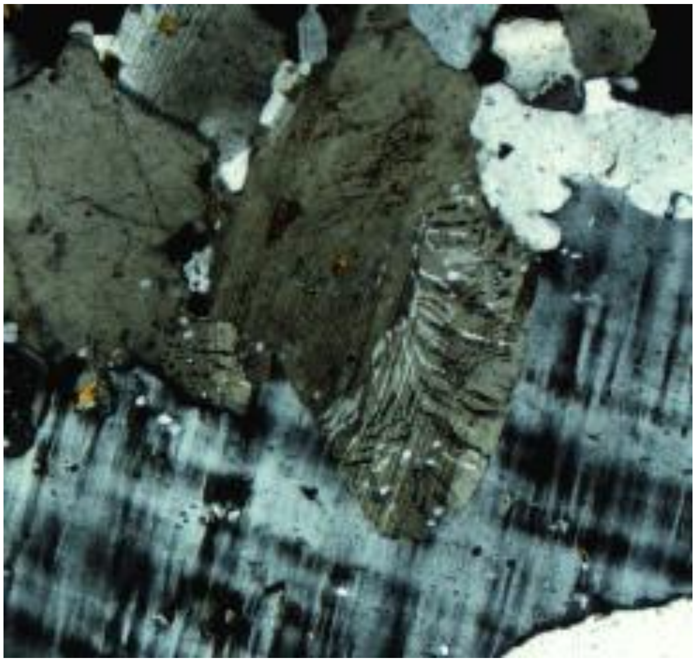

Fig. 3. This photomicrograph shows wartlike myrmekite (center) from granite near Temecula, California.

Zoned plagioclase in the wall rock (biotite-hornblende diorite) has an average composition of about An_{30}. Note that the unzoned, albite-twinned plagioclase An_{15} has tiny quartz vermicules in myrmekite that are slightly coarser than in Figure 1 and that myrmekite occurs where it is enclosed by the K-feldspar (microcline, grid-twinning, top). Plagioclase is quartz free where it is not enclosed by K-feldspar. Quartz (clear, white or gray) and biotite (brown) are coexisting grains. Keep this photo in mind because it shows the end-product of a replacement sequence described in http://www.csun.edu/~vcgeo005/Nr43Temecula.pdf.

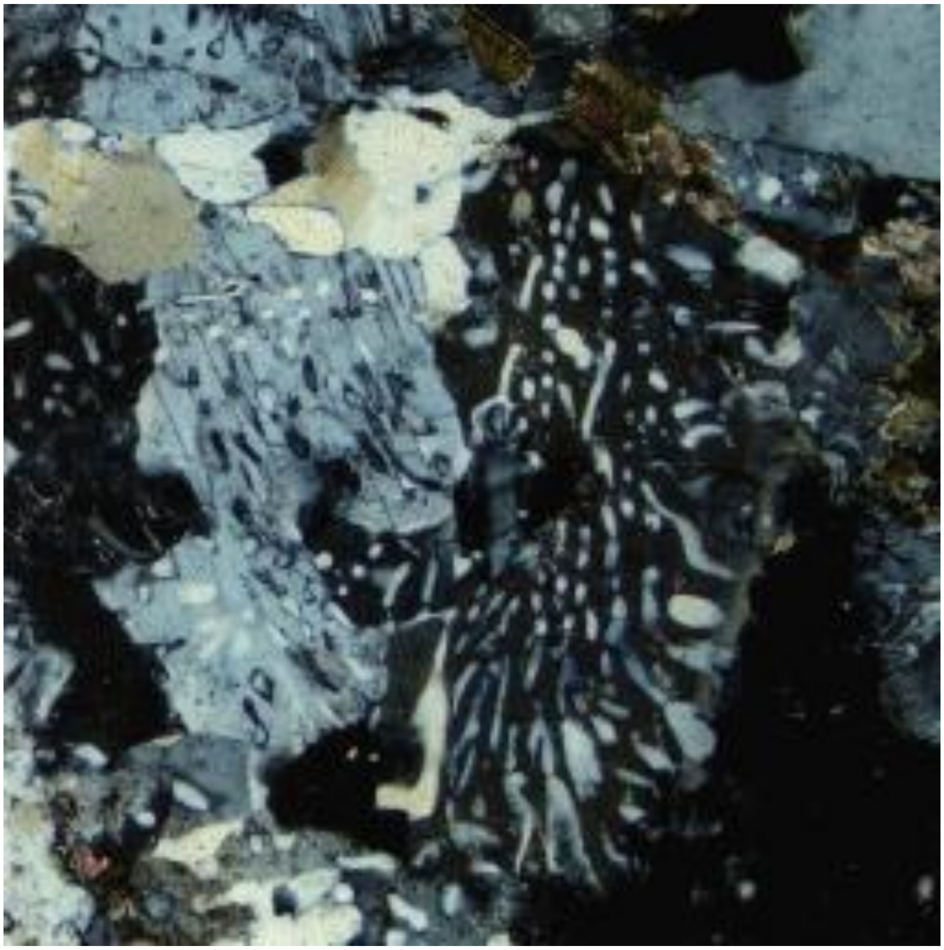

Fig. 4. This photomicrograph is from granite in the Cargo Muchacho Mountains in southeastern California.

The plagioclase in the wall rock diorite has an average composition of about An_{45}. The maximum thickness of the quartz vermicules is now much larger than in the granite at Temecula (Fig. 3). Sphene (brown) and epidote (red, green) occur at left side of photo.

Fig. 5. This photomicrograph is from peraluminous two-mica granite near Niles Lake, Washington.

It shows wartlike myrmekite projecting into microcline (grid-twinning) in which the maximum sizes of quartz vermicules are also relatively thick. Bright colored grains are muscovite; biotite is brown; quartz is clear white and gray. Calcic diorite and gabbro, containing plagioclase An_{45-60}, occur adjacent to the granite, but I did not observe their contacts with the granite.

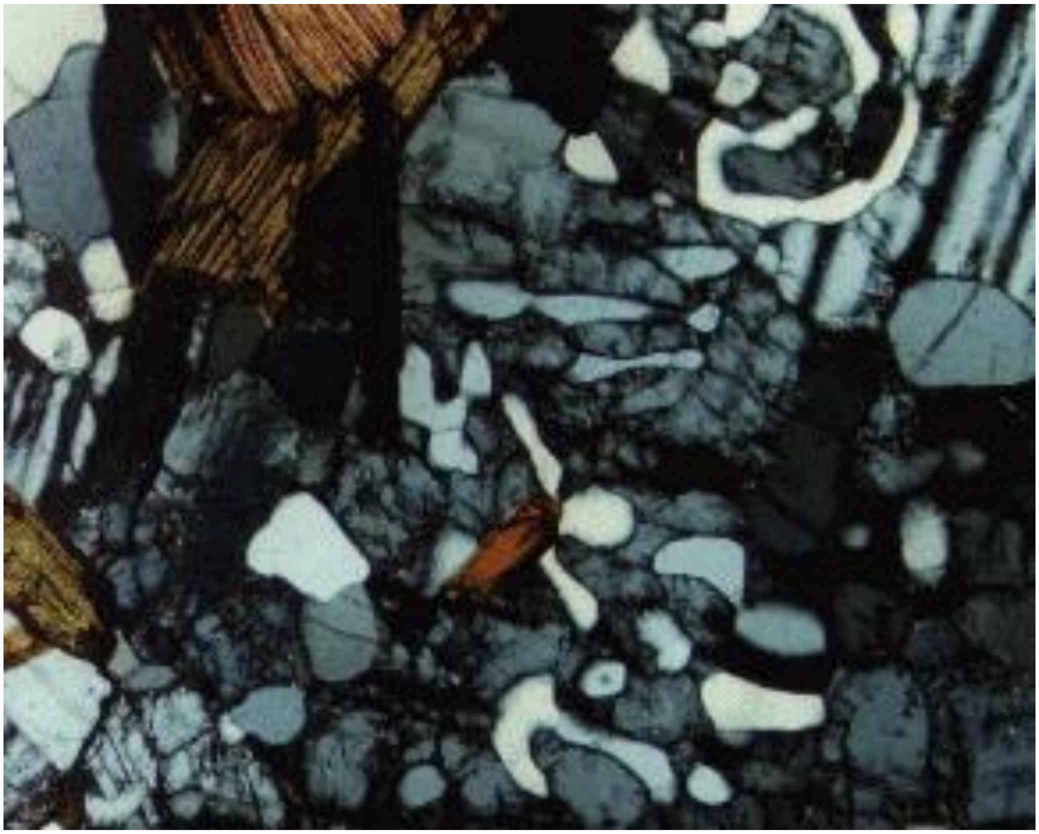

Fig. 6. This photomicrograph is from a deformed biotite-orthopyroxene gabbro layer (30-50 mm wide and 20 km long) near Split Rock Pond northeast of Dover, New Jersey.

The gabbro gradationally becomes sillimanite-garnet-muscovite-biotite gneiss along strike where planar deformation of the former gabbro is greatest. Reddish titaniferous biotite occurs in the photo. Plagioclase composition in the gabbro is An_{80}, but in the sillimanite gneiss is An_{40}. Maximum sizes of quartz vermicules in myrmekite shown in this transition rock are thick where K-feldspar is absent and less thick in the sillimanite gneiss where K-feldspar is present, but still quite thick.

Second Hypothesis

A second hypothesis that is commonly used to explain the origin of wartlike myrmekite is to suggest that the K-feldspar is primary --- a high-temperature orthoclase, containing dissolved Na and Ca. At low temperatures the orthoclase, under stress, inverts to microcline and supposedly exsolves the Na and Ca to the margin of the crystal to form myrmekite. As above, balanced mass-for-mass equations are used to explain what happens. Because calcic plagioclase requires less silica in its lattice than in K-feldspar or sodic plagioclase, silica is left over to form quartz vermicules in the myrmekite proportional to the Ca-content.

$KALSi_3O_8$ = $KAlSi_3O_8$ + $NaAlSi_3O_8$ + $2SiO_2$
$NaAlSi_3O_8$ $CaAl_2Si_2O_8$
$CA(AlSi_3O_8)_2$
H-T K-feldspar K-feldspar myrmekite

Examples of photomicrographs of myrmekite with increasing sizes of quartz vermicules include Fig. 2, Fig. 3, Fig. 4, Fig. 5, and Fig. 6.

Discussion

The examples in Figs. 2-5 have been purposefully selected to show textures in granites adjacent to wall rocks containing plagioclase having a range of An-contents from sodic to calcic. Other investigators have assumed that the K-feldspar in these granites is primary, formed at high temperatures, and that the myrmekite is a secondary alteration product, formed by exsolution. But if all these granites have essentially the same modal compositions or nearly so, then one has to ask: "*Why do myrmekitic textures look so different for granites of the same modal composition?*" Moreover, if the granite is an intrusive magmatic body, coming from some unknown source at depth, and the K-feldspar crystallized from this magma, how is it possible that the maximum sizes of quartz vermicules in the coexisting myrmekite in each granite correlate with increasing Ca-contents of the plagioclase in the adjacent wall rocks? Should not the composition of the K-feldspar in the granite be nearly independent of the wall rock? How would an intruding magma know what the wall rock composition is going to be?

In the granites illustrated in Fig. 2 (Cooma pluton but not the Cottonwood Creek pluton) and Fig. 3 and Fig. 5, I have observed all mineralogical changes between undeformed wall rocks through increasing degrees of deformation toward the associated granite. In early stages the first appearances of K-feldspar and myrmekite occur in the deformed wall rocks. Where the rocks are first deformed and where K-feldspar and myrmekite appear for the first time, the volume of myrmekite commonly far exceeds the volume of adjacent K-feldspar. The larger volume of myrmekite makes it impossible for the myrmekite to have formed by exsolution from the adjacent smaller K-feldspar crystal. Moreover, where the deformed parent rock is calcic diorite or gabbro, the Ca-content of the plagioclase in the myrmekite is greater than could have been possibly contained in the volume of the adjacent high-temperature orthoclase. Therefore, these relationships suggest that myrmekite is not formed by exsolution but by some other process.

The occurrences of muscovite in the two-mica granite (Fig. 5) and of other aluminous minerals (sillimanite, garnet, epidote, and cordierite) in other granites give further support to the possible origin of such rocks by K-replacement processes, provided that the granites are myrmekite-bearing. If these peraluminous granites have formed by replacement of wall rocks that contain plagioclase An_{45-100} in diorite or gabbro, this plagioclase is also relatively Al-rich in comparison to K-feldspar. Because displaced Al has low mobility, it tends to remain behind in metasomatic granite to make it peraluminous.

Moreover, if calcic diorite and gabbro are the source rocks and they are strongly deformed in planar shear zones, then garnet, garnet-sillimanite, and garnet-sillimanite-cordierite gneisses could form instead of peraluminous granites, and such rocks would be improperly identified as metapelites.

If the former gabbro contains plagioclase near An_{100}, as occurs in some places near Central City, Colorado, then the gneisses may have recrystallized products that are unrecognized as myrmekite. The quartz vermicules would be so thick that they would appear to be just large quartz grains in the ground mass.

Finally, it is quite apparent that reversing the direction of the two, aforesaid, balanced, mass-for-mass equations consumes quartz instead of producing it, so that myrmekite could not form in such a reaction. This obvious fact provides the logic for ridiculing any hypothesis which proposes that myrmekite forms by K-replacement of plagioclase. The wartlike projection of myrmekite into large K-feldspar grains (Figs. 2-5) further makes such a hypothesis seem silly. However, in http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf I show that secondary K-feldspar replaces primary plagioclase volume-for-volume and that myrmekite is formed simultaneously in the same process.

In http://www.csun.edu/~vcgeo005/Nr3Myrm.pdf I show additional photos of field and microscopic relationships of myrmekite-bearing granitic rocks.

In a supplement, I provide 16 more photomicrographs to illustrate replacement textures in the Temecula, California site.
http://www.csun.edu/~vcgeo005/Nr43Temecula.pdf