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3. MICROSCOPIC AND MEGASCOPIC RELATIONSHIPS FOR MYRMEKITE-BEARING GRANITIC ROCKS FORMED BY K- METASOMATISM

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The following nine illustrations in this presentation include three photomicrographs and seven field photos to show relationships that support the formation of myrmekite-bearing granites by K-metasomatism. Before looking at these photos, see two additional presentations.
http://www.csun.edu/~vcgeo005/Nr1Mrym.pdf
http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf.

Kernville diorite-gabbro, California

Fig. 1. This photo suggests a possible origin for ghost stratigraphy and oriented enclaves in some granites that are formed by replacement processes.

Fig. 1shows banded, myrmekite-bearing gneiss in the Kernville diorite-gabbro pluton north of Lake Isabella in the southern Sierra Nevada, California. In some places the rock is more uniformly banded, and such rocks might be interpreted as (1) metasediments, (2) as rocks in which partial melting has occurred to form pods of granite, or (3) as metasediments which have been injected by granite magma in lit-par-lit fashion.

Along and across strike, however, all gneissic rocks in the picture grade into massive undeformed biotite-hornblende diorite. The implication is that prior to deformation and replacement, these gneissic rocks were all diorite. Their present diversity in appearance is a function of the local degree of shearing and replacement. At this site, some layers are remnant unaltered islands of diorite.

From massive diorite toward these banded rocks, biotite and hornblende are progressively replaced by quartz, and in some places hornblende is totally replaced by quartz. As replacement progresses zoned plagioclase is replaced by microcline and myrmekite as other altered plagioclase grains recrystallize as more sodic species. K-feldspar in the felsic and pegmatitic pods are myrmekite-bearing.

In some terranes gneissic rocks, like these, fade into wispy feathers (ghost stratigraphy) in massive myrmekite-bearing granite. In still other places, myrmekite-bearing granite may contain lenticular, parallel-oriented enclaves of mafic igneous rocks. Such enclaves could be island remnants of former diorite that did not get sheared enough to permit fluids to cause them to be replaced.

Kinsman granodiorite

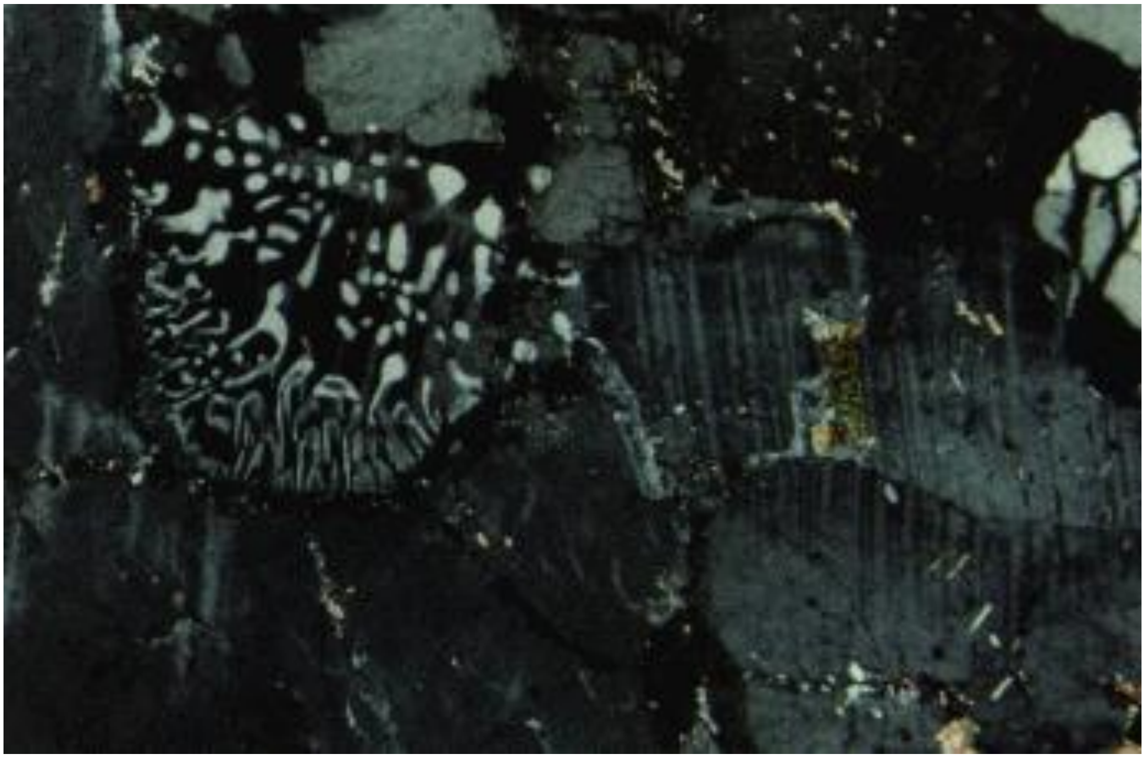

Fig. 2. This photomicrograph shows a portion of a microcline megacryst (black, left side) with irregular, non-uniformly distributed albite lamellae in perthitic intergrowths (light gray) in Kinsman granodiorite in New Hampshire (USA). Coarseness of quartz vermicules in bordering myrmekite suggests that the K-feldspar replaced a former diorite. Note that vertical albite twins in plagioclase are bent and broken (dark gray, right side), and locally K-feldspar (light gray) has replaced the plagioclase along a fracture. Field relationships support a magmatic origin for the Kinsman pluton because dikes from this pluton extend into the country rock. The maximum size of quartz vermicules in the myrmekite suggests, however, that this pluton was a former magmatic intrusive diorite that was later

deformed and replaced by K-bearing fluids to create the K-feldspar megacrysts (as much as 4 cm long).

In other plutons in final stages of solidification, minor deformation allows fluids to bring in only small amounts of K to cause metasomatism. In such plutons the degree of replacement is so minuscule that it is almost isochemical and may be called deuteric alteration. The K-feldspar is interstitial and generally less than 5 percent of the rock, and zoned plagioclase grains may be bordered by rim myrmekite.

Perrault Falls, Ontario, Canada

Fig. 3. This photograph shows megacrysts of pink microcline in a road cut along highway 105 south of Perrault Falls in western Ontario, Canada. Most geologists would consider the megacrysts to be primary and crystallized from magma. These large K-feldspar crystals are bordered by myrmekite, however, and this granitic rock grades into adjacent, sheared and recrystallized, biotite-rich, diorite and gabbro. Potentially, these K-feldspar crystals could become rapakivi-type, if concentrations of myrmekite along borders were recrystallized as rims of sodic plagioclase and the quartz vermicules leaked outward to become quartz grains in the ground mass.

Cape Ann granite, Hamilton, Massachusetts

Fig. 4a. This photo shows a cut and polished drill-core sample from South Hamilton, Massachusetts (USA) where the contact between the Salem diorite and the Cape Ann granite can be seen. In this image, the diorite is at the left side (black) and gradational to the granite. The core was donated by Peter Britton. White is empty space surrounding the core.

Fig. 4b. This photo also shows a cut and polished drill-core sample from South Hamilton, Massachusetts (USA). (White area is empty space surrounding the core.)

In these cores the contact is gradational in one core (Fig. 4a) and seemingly sharp in the second (Fig. 4b). In Fig. 4b, however, the diorite becomes blacker toward the left away from the granite. See also Fig. 7, Fig. 8, and Fig. 9 in http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf. Two centimeters from the granite, hornblende and plagioclase in the diorite show no apparent alteration. But in the black diorite adjacent to the granite many hornblende crystals are replaced in their interiors by quartz in a sieve texture; see next illustration, Fig. 5. In this same interval plagioclase is progressively replaced by K-feldspar and wartlike myrmekite in which the maximum thickness of quartz vermicules is what would be expected for the Ca-content of the plagioclase in the diorite. In the adjacent granite remnant hornblende with quartz sieve textures looks exactly like that in the nearby diorite, and large pink K-feldspar crystals have myrmekite that has the same appearance as that in the adjacent black diorite.

Fig. 5. This is a photomicrograph of the Salem diorite (black portion adjacent to granite in Fig. 4b), showing some hornblende crystals (dark brown to black) being replaced by quartz (center, white) in a sieve texture while other hornblende crystals still remain unreplaced. Microcline (gray, grid twinning) has also been introduced here, but is absent farther into the diorite.

According to Peter Britton, some geologists have interpreted the diorite to be younger than the granite, but the myrmekite and other replacement textures indicate that the granite has replaced the diorite.

A good example that provides evidence that microcline has replaced plagioclase can be seen in Fig. 6.

Fig. 6. This photomicrograph shows a remnant zoned plagioclase crystal in the massive, pink, Cape Ann granite several meters from the contact with the Salem diorite. The plagioclase is Carlsbad-twinned and has a weathered, sericitized calcic core. This crystal is similar in size and shape to Carlsbad-twinned plagioclase crystals in the diorite. At the right end of the plagioclase crystal, its calcic core is truncated and replaced by K-feldspar whose Carlsbad twinning is inherited from the former plagioclase lattice that once filled this space. In other places the Carlsbad-twinned plagioclase crystals are deformed and replaced progressively by microcline and wartlike myrmekite.

In this particular photomicrograph, the microcline replaces one end (right side) of a Carlsbad-twinned plagioclase crystal (black, speckled, and light gray, left side). During replacement, the calcic core was truncated by the microcline (black and gray, right side) so that the rounded-part of the plagioclase core at the right end is missing, but the Carlsbad twin plane is continuous between the two feldspars. This is strong evidence that the microcline (and the granite) did not form by crystallization from magma but resulted from replacement of the former diorite.

Josephine Mountain pluton, California

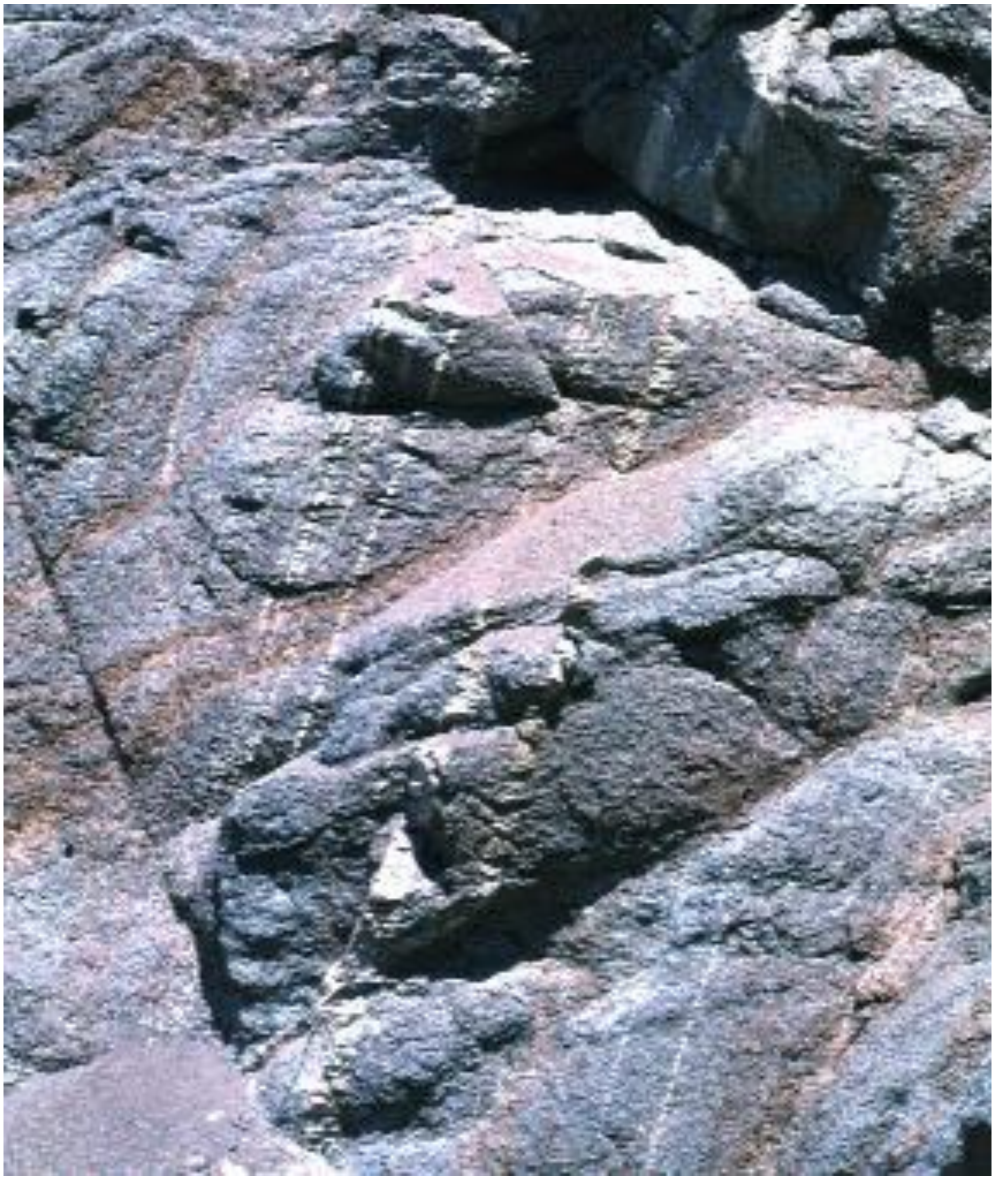

Fig. 7. In this photo of a road-cut exposure, a mafic facies of the Josephine Mountain pluton can be seen in the San Gabriel Mountains, north of Pasadena, California (USA). In the center of the photo several narrow bands (0.5 to 4 cm wide) of pink granite extend up-slope parallel to each other. If these narrow bands were pure quartz, most geologists would probably agree that the quartz was not

deposited there by a magma consisting of 100% silica. The viscosity would be too great. Instead, most geologists would agree that the silica in the quartz vein was brought in by hydrous fluids and deposited there. The pink granite is not 100% silica but is at least 72%, and, therefore, it also would be unlikely to be injected as magma in such narrow channels (0.5 cm wide). These pink bands consist predominantly of microcline, quartz, myrmekite, and albite. On the basis of the myrmekite and other replacement textures, I interpret these narrow bands to be formed by K-metasomatism where hydrous fluids moved through parallel cataclastic shear zones.

Fig. 8. In this photo can be seen a massive, pink, granite facies of the Josephine pluton. Pink K-feldspar crystals are 1 cm long. This granite has exactly the same textures, including myrmekite, as occur in the narrow "dikes" that are observed in Fig. 7, but now this rock is part of a pluton more than one km wide. Is not the myrmekite in both places evidence that K-metasomatism can create granite bodies on a plutonic scale with a uniform composition and massive appearance?

Perrault Falls, Ontario, Canada

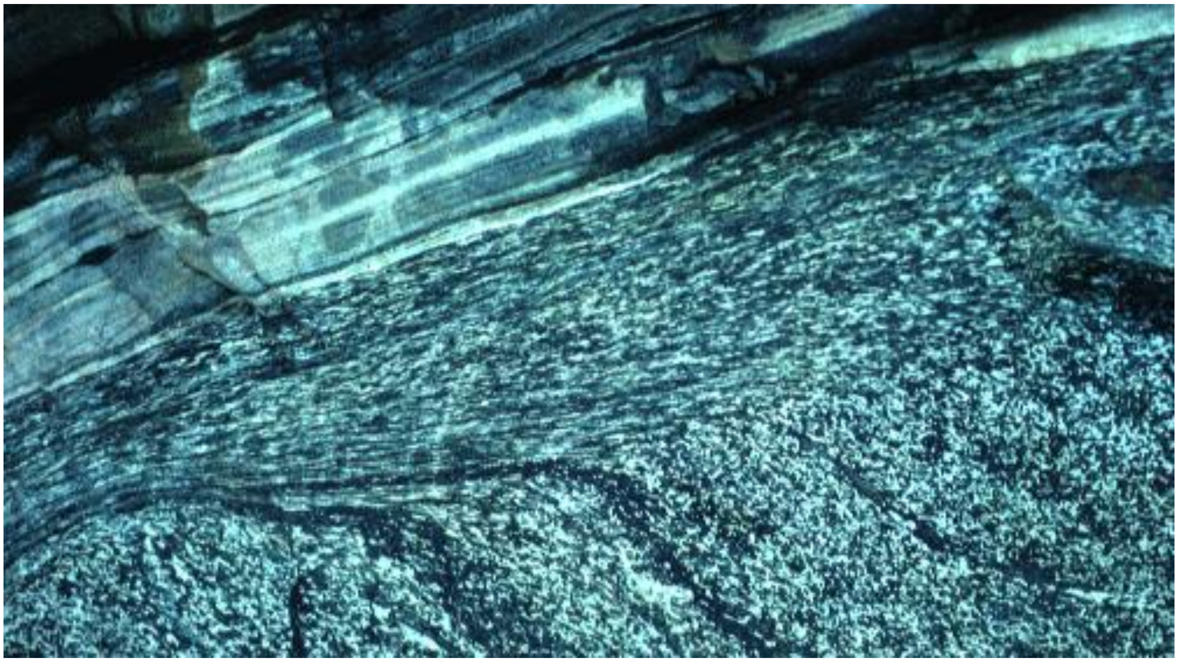

Fig. 9. In this photo, taken along highway 105 south of Perrault Falls, Canada, a massive, coarse-grained, mafic, igneous rock can be seen which is increasingly deformed toward the top of the photo. The dark deformed rock abruptly changes into a strongly-foliated, light-pink, felsic rock with narrow streaks of mafic minerals. Does this photo show a contact between deformed magmatic granite and the mafic igneous rock or is the felsic rock a product of K-replacement of the mafic rock where the deformation has permitted fluids to enter and cause metasomatism? How could you tell? See also: Myers (1978) for pictures of similar deformed rocks.

Discussion

Tuttle and Bowen (1958) reached the conclusion that all granites (on a plutonic scale) must be formed by magmatic differentiation processes. Their arguments are seemingly logical and are generally accepted by most petrologists. But their experimental work on granites in closed systems does not eliminate the possibility that some granites can be formed by metasomatism on a plutonic scale. For example, the massive, uniform appearance of the metasomatic Josephine pluton, Fig. 8, can be achieved by starting with a solid, mafic, igneous rock, crystallized from magma, which is uniform in composition and fabric. If this rock is deformed so that fluids can enter and cause metasomatism at temperatures below melting conditions, a granite with uniform appearance can be the final product. This can happen because about half the original primary plagioclase in the original mafic rock could be replaced by K-feldspar while the other half is recrystallized as sodic plagioclase as the K displaces the Na. Because most of the ferromagnesian silicates are replaced by quartz, the final product is granite whose composition lies on or near the eutectic minimum. In magmatic or metasomatic granites, the mineral assemblages are the same and stable at the same P-T conditions.

Broad dikes extend from the Josephine granite facies into anorthosite and other wall rocks, but those dikes need not be evidence that the Josephine granite is magmatic because hot plastic solids can also intrude fractures as can also sandstones and coal. Moreover, the dikes could have been an intrusive magmatic diorite now replaced by granite.

It is true that most granites have probably crystallized from magmas, but for the above reasons, such granites need not originate by magmatic differentiation. They could arrive at their felsic compositions by K- and Si-metasomatism prior to melting. Experimental, theoretical, and field examples of K- and Si-metasomatism in deformed rocks are provided by Dipple and Ferry (1992).

Of course, if metasomatism on a large scale is possible, it raises the issues again of the source of water, energy, Si, and K needed to convert mafic rocks into granite, and of explaining where the displaced elements Ca, Mg, Fe, and Al have gone.

Could silane (SiH_4), originating in the mantle as a liquid or gas at high temperature, be the source of Si? Silane is a highly reactive substance and is unlikely to reach the Earth's surface or upper crust because it spontaneously reacts with free oxygen or water. Nevertheless, such reactions would generate heat and more water (steam) which could bring in the silica for the metasomatic processes; see Hunt et al., (1992).

Potassium is an incompatible element in the mantle and largely escaped from there in Precambrian times. Could K still be coming up in some places after Precambrian times as an on-going process? (See Larin, 1993).

Could petroleum hydrocarbons, hydrogen, and carbon dioxide, emerging from the mantle be agents to promote the metasomatism? (See Porfir'yev, 1974)

Do lamprophyre dikes and appinites that are common in granite terranes represent the sites where some of the displaced mafic elements have gone? (see Collins in press)

Could deep planetary faults (subduction zones) provide avenues for outgassing of necessary fluids?

Do ancient impacts from large bolides cause deep cataclasis that permits K to rise and cause metasomatism?

Does the expanding-Earth model permit deep lateral deformation (horizontal faults and shear zones) to allow K- and Si-metasomatism to occur in outer ductile and brittle rocks in the upper granitic crust?

In Greenland and Scandinavia, are some rapakivi granites magmatic and others formed by K-metasomatism?

Does the pink color of K-feldspar crystals in some places result from the ambient fluids being saturated with iron released from ferromagnesian silicates replaced by quartz?

Do zoned plutons with central granite cores in Ireland, Scotland, and the Sierra Nevada result from K-metasomatism instead of magmatic differentiation?

Would K-metasomatism help solve some parts of the room problem?

Are the magmatic Donegal "granites" in northwest Ireland modified by late-stage K-metasomatism?

Would not K-metasomatism of plagioclase and Si metasomatism of biotite disrupt the Rb-Sr systematics?

Would not quartz-replacements of ferromagnesian silicates release trace Zr, U, and Th and cause overgrowths on zircons to create some discordant zircon populations for isotopic age-dating methods?

Research opportunities are there waiting for all of you to get busy and find answers to these questions.

For other discussions of myrmekite, see Collins (1988ab, 1996), Hunt et al. (1992), and http://www.polarpublishing.com for publishing company information.

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