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13. MYRMEKITE IN THE RUBIDOUX MOUNTAIN LEUCOGRANITE - A REPLACEMENT PLUTON

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Introduction

The Rubidoux Mountain leucogranite is one of many granitic plutons that occur in the eastern part of the Southern California batholith in the Peninsular Range province (Larsen, 1948; Banks, 1963). Scattered outcrops of this leucogranite in and around Riverside, California (USA), suggest that this pluton covers an area of at least 32 square kilometers (Fig. 1). Myrmekite in leucogranite on Mount Rubidoux (northwest of Riverside) has been studied in detail by electron-microprobe, scanning electron microscopy, and cathodoluminescence methods (Hopson and Ramseyer, 1990ab). These investigators reached conclusions that the myrmekite was formed by multi-replacement processes. In my studies I examined thin sections of the leucogranite in all of its scattered locations as well as thin sections of the Bonsall tonalite west of Mount Rubidoux, south and east of Quarry Hill, and on the east side of the pluton, north of Arlington Avenue (Fig. 1).

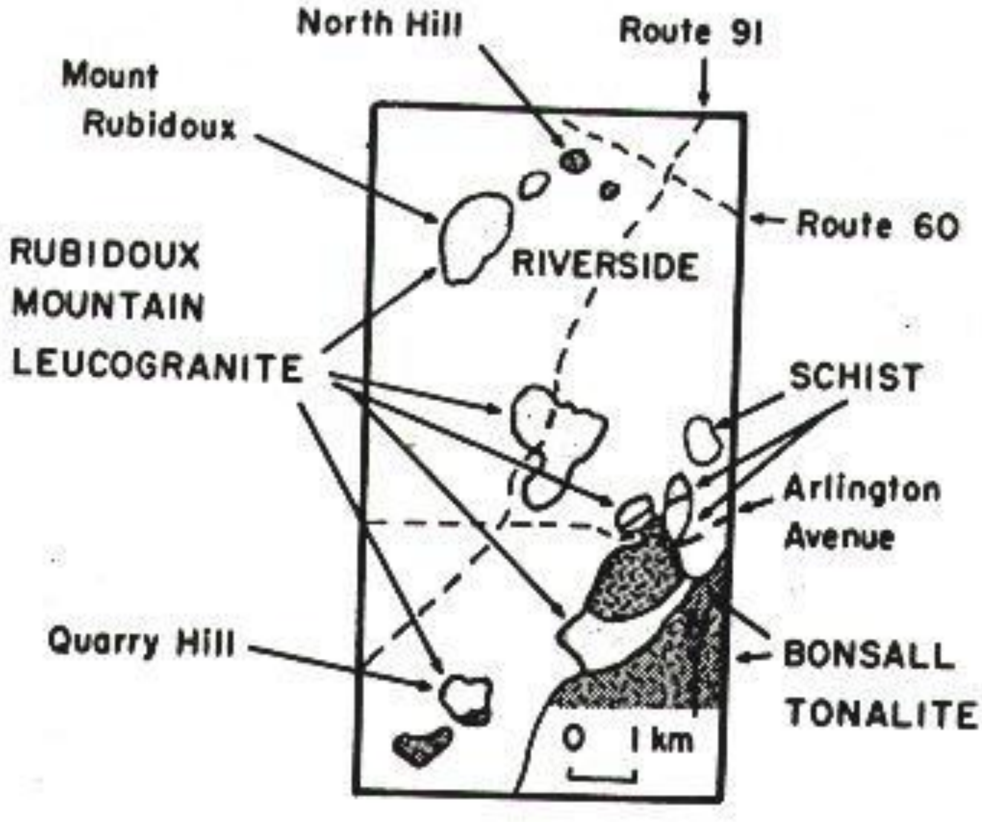

Fig. 1. Map showing location of the Rubidoux Mountain leucogranite near Riverside, California (USA) and associated wall rocks of Bonsall tonalite and Julian schist.

The purpose of this presentation is to look at the evidence presented by Hopson and Ramseyer (1990ab) and to point out where I agree and disagree with their hypotheses. Space was not available to do this adequately in my one-page "*Comment*" article (Collins, 1990). The same observed textures are analyzed, but additional information, not considered by Hopson and Ramseyer (1990a), is incorporated. Their cathodoluminescence images (some of which are unpublished) and chemical data obtained by scanning electron microscopy and electron microprobe studies are relied upon, for which I give grateful credit.

Petrography and geologic setting of the Rubidoux Mountain leucogranite

1. *Leucogranite*.

In most of the area (Fig. 1), both coarse- and fine-grained facies of the leucogranite occur in which the dominant minerals are microcline (27-36 vol. %), quartz (33-40 vol. %), and normally zoned plagioclase (An_{18-39}, 22-31 vol. %). The dominant ferromagnesian silicate is biotite (2.0-2.5 vol. %), but hornblende (trace to 1.4 vol. %) and trace amounts of iron oxides, hypersthene, and fayalite olivine, mostly altered to iddingsite, also occur (Banks, 1963).

2. ***Wall rocks*.**

The wall rocks of the leucogranite (at Arlington Avenue) consist of Julian schist (fine-grained, biotite-hypersthene-bearing metasedimentary rock) and Bonsall tonalite, containing biotite (12-19 vol. %), hypersthene (8-29 vol. %), plagioclase (64-66 vol. %), quartz (1-14 vol. %), and minor iron oxides. Some facies of the Bonsall tonalite lack hypersthene and contain biotite and hornblende as the dominant ferromagnesian silicates (west contact with leucogranite at Mount Rubidoux and south and east of Quarry Hill). No olivine was found in any Bonsall tonalite facies.

Observations and hypotheses presented by Hopson and Ramseyer

Among many ideas presented by Hopson and Ramseyer (1990ab) are:

1. Several different types of myrmekite are reported which the authors grouped into three categories: rim, wartlike, and isolated myrmekite. At least three different origins are suggested for the myrmekite types.

2. Wartlike myrmekite is formed by Ca- and Na-metasomatism of primary K-feldspar during a first stage of metasomatism and rim myrmekite by a similar second stage.

3. Plagioclase in wartlike myrmekite hosting quartz vermicules is chemically the same (An_{18}) as in adjacent non-quartz-bearing plagioclase, but cores of plagioclase may contain higher Ca-content (An_{39}). The plagioclase in myrmekite and adjacent non-quartz-bearing plagioclase (An_{18}) formed simultaneously.

4. Isolated veinlike myrmekite in K-feldspar consists of albite (An_{0-5}) and inclusions of sub-hedral quartz blebs. This myrmekite forms during late deformation of K-feldspar after rim and wartlike myrmekite were formed. The veinlike myrmekite occurs in fractures in the K-feldspar and is created by simultaneous crystallization during exsolution. Exsolution of albite perthite lamellae in the K-feldspar also occurred during late deformation.

5. Secondary, low-temperature K-feldspar fills late fractures in plagioclase and is adjacent to rim myrmekite bordered by albite.

6. Quartz vermicules may occur in K-feldspar that is adjacent to biotite-quartz symplectites and when quartz vermicules of wartlike myrmekite abut the K-feldspar. Origin of these quartz vermicules is by K-feldspar replacement of biotite or by K-feldspar moving back into and replacing the plagioclase of former myrmekite.

7. Myrmekite formation is complex because of the many kinds of myrmekite that are produced and may involve reversals in replacement directions.

8. Cataclasis clearly postdates myrmekite formation and never cuts calcic cores of the plagioclase.

9. Hypersthene and fayalite in the leucogranite are unlikely inherited from Bonsall tonalite in the wall rock. Association of these minerals with biotite and hornblende in the leucogranite is explained "by early crystallization of hornblende and biotite under the appropriate water content and pressure, followed by late-stage loss of water pressure during pluton emplacement which caused olivine and hypersthene to crystallize later instead (Banks, 1963)."

10. The leucogranite cannot be a charnockite because it has not been emplaced at granulite-facies depth and is not associated with anorthosite-mangerite suites (Hyndman, 1985). It was crystallized at pressures less than 5 kbar and more likely in the range of 1.0=1.5 kbar (Banks, 1963; Ague and Brimhall, 1988).

K-feldspar, plagioclase, and quartz relationships

Definitions of plagioclase-quartz intergrowths used by Hopson and Ramseyer (1990a) are different from some of those used by myself and other investigators. These different definitions cause an added complication in understanding and critiquing their paper. I and other investigators define ***rim myrmekite*** as a narrow quartz-plagioclase intergrowth on zoned plagioclase. Hopson and Ramseyer (1990a, Fig. 1h) define it to be a narrow rim of second-stage myrmekite bordering earlier wartlike myrmekite that has slightly coarser quartz vermicules than in the rim myrmekite.

Wartlike myrmekite is used in the same way as other investigators. It occurs (a) between two K-feldspar crystals (Fig. 2), (b) attached to non-quartz-bearing plagioclase and projecting into K-feldspar (Fig. 3), and (c) as inclusions in K-feldspar (Fig. 4).

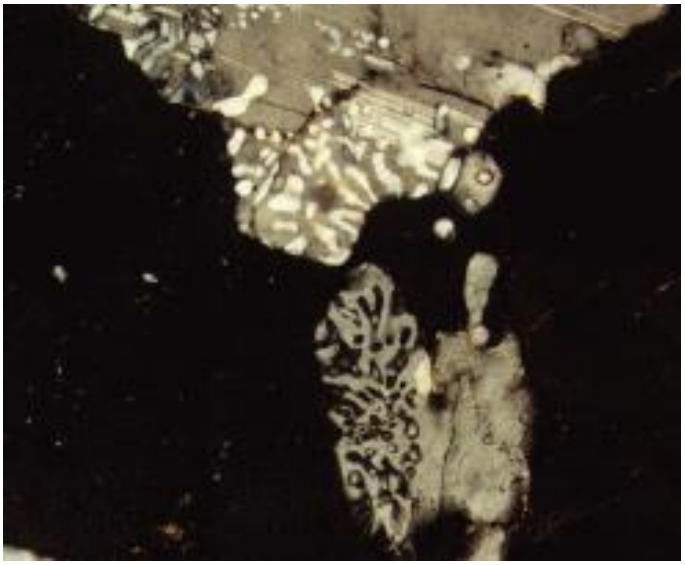

Fig. 2. Wartlike myrmekite (top center) between K-feldspar (black) and non-quartz-bearing plagioclase (light tan, top margin) in the leucogranite. Myrmekite inclusion (center) attached to plagioclase (light tan) in K-feldspar.

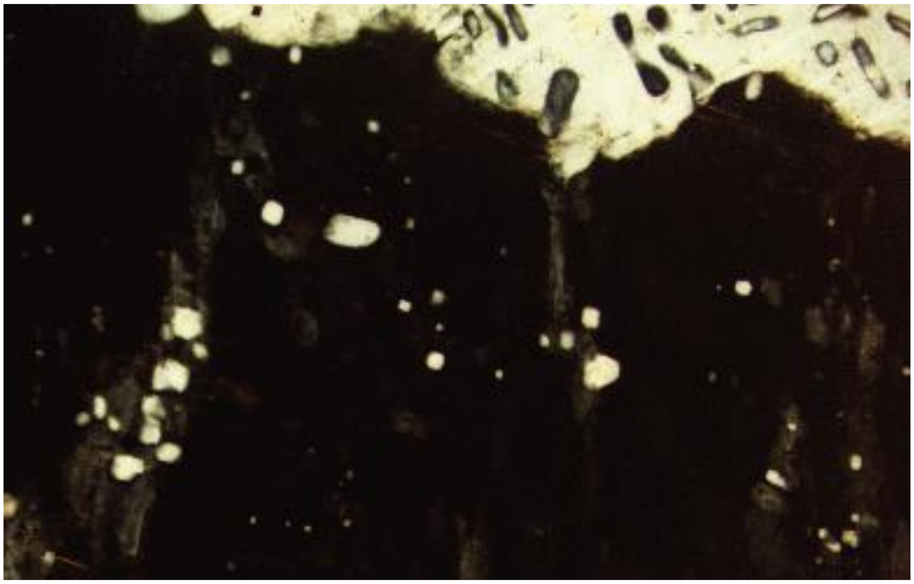

Fig. 3. Wartlike myrmekite (white with dark quartz vermicules; top edge) occurs between K-feldspar (black, bottom) and non-quartz-bearing plagioclase (top edge, beyond the image) in the leucogranite. Tiny quartz inclusions (white) occur in the K-feldspar and in albite (gray, left side; ghost myrmekite) of the same size as the quartz vermicules in the myrmekite.

Fig. 4. Inclusions of wartlike myrmekite (black with white quartz vermicules; light gray with dark quartz vermicules) in the K-feldspar (gray).

I defined ***isolated myrmekite*** as plagioclase-vermicular-quartz intergrowths occurring in rocks lacking K-feldspar (Collins, 1988). Hopson and Ramseyer (1990a, Fig. 1de) define it as quartz-bearing exsolution lamellae of albite in K-feldspar. I call this kind of intergrowth "***ghost myrmekite***" and consider it to be faint inclusions of myrmekite (albite and quartz bleb intergrowths) in K-feldspar (Fig. 5 and Fig. 6).

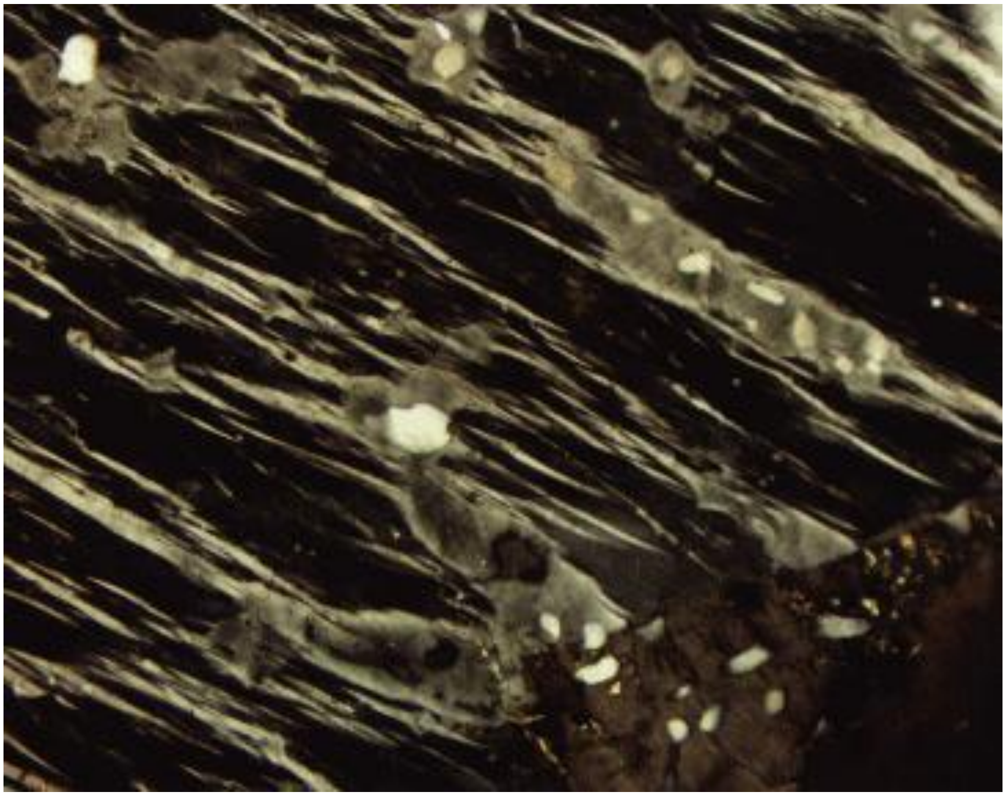

Fig. 5. Isolated vein myrmekite (ghost myrmekite). Albite (gray) occurs as spindles, veins, and enclosing quartz blebs in ghost myrmekite. Wartlike myrmekite occurs in lower right corner (brown; white quartz vermicules).

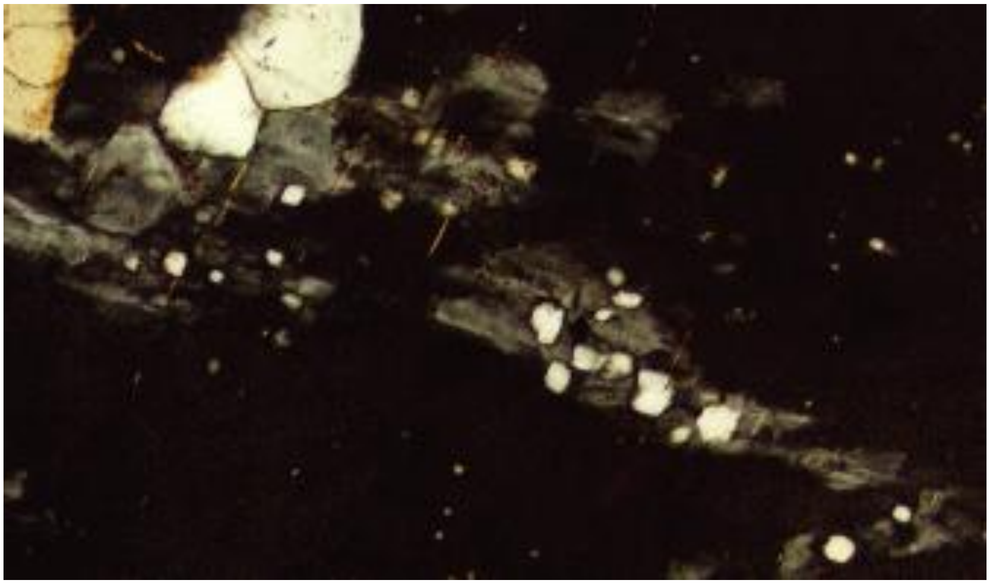

Fig. 6. Isolated island myrmekite (ghost myrmekite). Albite (gray), K-feldspar (black), quartz blebs (white), and quartz crystal inclusions (white and cream).

Arlington Avenue site

In order to respond to the aforesaid ten observations and hypotheses presented by Hopson and Ramseyer (1990ab), additional evidence is required. Of particular interest in the investigation of the origin of the Rubidoux Mountain leucogranite is the Arlington Avenue site, where hypersthene-bearing Bonsall tonalite borders the leucogranite (Fig. 1 and Fig. 7). Here, the tonalite contains scattered lenticular xenoliths of Julian schist, supporting a magmatic origin for the tonalite.

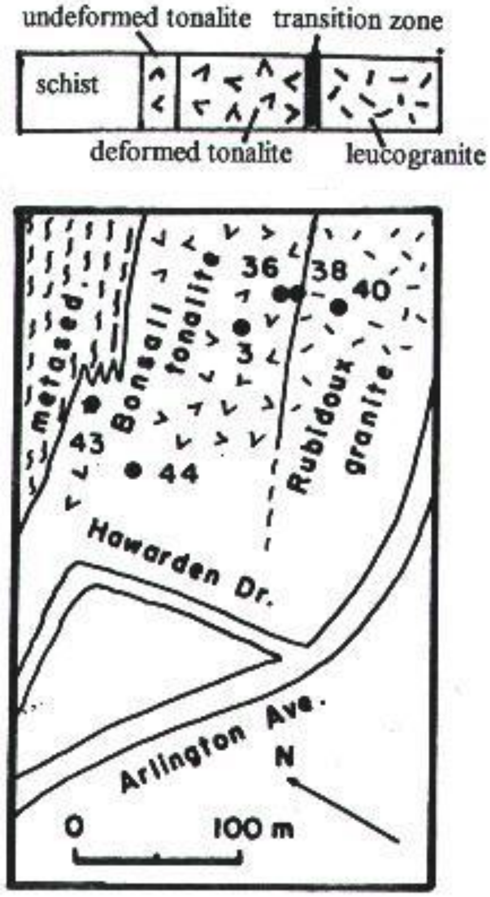

Fig. 7. Map of geology near Arlington Avenue. Numbers on map indicate chemically analyzed samples (e.g., RLG-40), but these analyses are not included in this web site. A schematic drawing shows undeformed Bonsall tonalite, slightly deformed tonalite, a 7-meter-wide gradational zone, and the Rubidoux Mountain leucogranite.

From its northwestern margin and southeastward 100 m across a hill slope (Fig. 7), the tonalite is relatively uniform in composition, grain size, and mineralogy and in undeformed areas *contains no K-feldspar or myrmekite*. Wherever the tonalite has been subjected to regional deformation, K-feldspar and myrmekite appear, and biotite in a few places develops quartz sieve textures or symplectites. Where K-feldspar and myrmekite first appear in the western side of the slightly deformed tonalite (Fig. 7), *volumes of myrmekite are commonly equal to or greater than the volume of adjacent K-feldspar*. Within 30 m of the massive leucogranite, occasional myrmekite-bearing granitic aplite and pegmatite pods (2 to 30 cm wide) occur. Adjacent to the massive leucogranite, a narrow, gradational, boundary zone (about 7 m wide) is present which contains increasing amounts of quartz, K-feldspar, and myrmekite and progressively lesser amounts of biotite, hypersthene, and plagioclase. The contact between the gradational zone and leucogranite is drawn where mostly leucogranite remains (Fig. 7). Farther into the leucogranite, the composition is about 10 vol. % biotite, 6 vol. % hypersthene, 22 vol. % zoned plagioclase, 26 vol. % quartz, 36 vol. % K-feldspar, and <1 vol. % myrmekite (sample RLG-40, on Fig. 7). Because of the presence of hypersthene, the leucogranite could be called a charnockite at this location.

Northwestward from the gradational zone in the slightly deformed Bonsall tonalite, some zoned plagioclase crystals with relatively calcic cores (An_{39}) and wide sodic rims ($An_?$) appear mottled, when seen in cross-polarized light under the petrographic microscope (Fig. 8). These mottled grains when seen under cathodoluminescence (unpublished images provided by Ramseyer) contain microcracks that extend from borders into interiors of the plagioclase crystals but not into the cores. Tiny islands of K-feldspar can be seen in these microcracks, and the plagioclase adjacent to the cracks is slightly more sodic than farther from the cracks. The occurrences of these K-feldspar islands, however, are too faint or tiny to be resolved in images presented on this web site. Significantly, this K-feldspar cannot be seen under the petrographic microscope, and, thus, the introduction of K-feldspar into deformed plagioclase (which otherwise lacks K-feldspar when undeformed) is unsuspected in the mottled plagioclase and can be confirmed only by the use of cathodoluminescence.

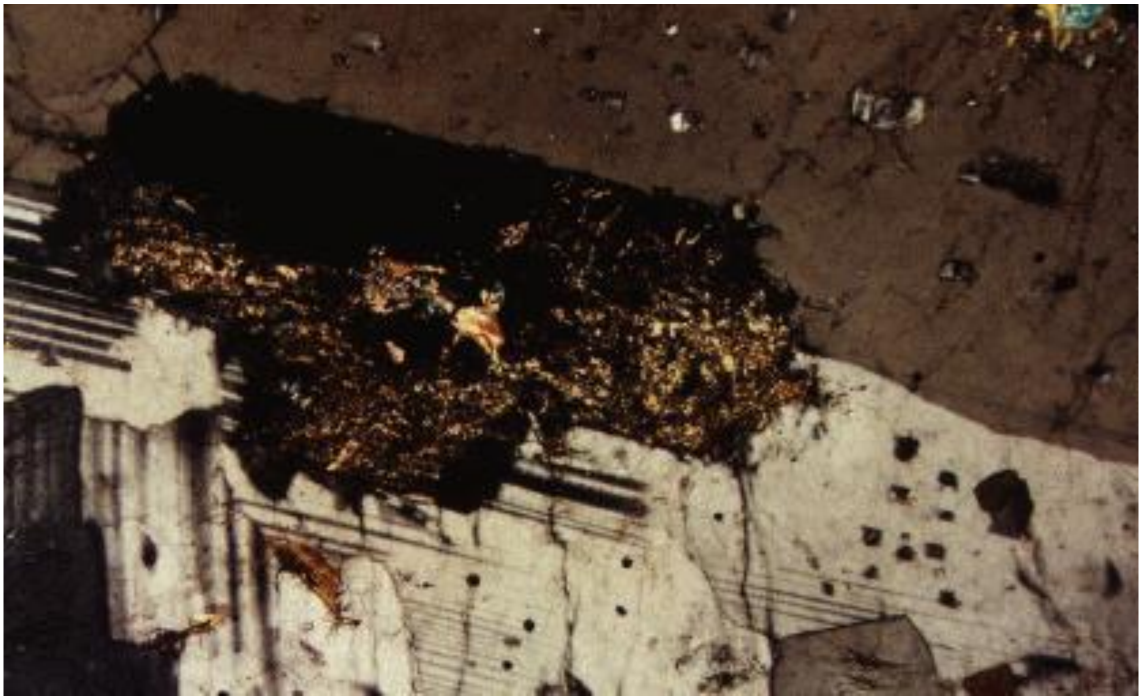

Fig. 8. Carlsbad- and albite-twinned, zoned plagioclase in Bonsall tonalite. Relatively calcic core (black, altered to sericite) of plagioclase is surrounded by a broad, relatively sodic rim. Plagioclase rim has irregular or rectangular islands of K-feldspar (black, or gray-white gingham-pattern). Biotite (brown); muscovite (blue and yellow).

Discussion

Hopson and Ramseyer (1990a) suggest that it is improper to call the Rubidoux Mountain leucogranite a charnockite because of the presence of hypersthene (Collins, 1990). I agree. No evidence exists that this leucogranite is a true charnockite formed by charnockitization of amphibolite-grade gneisses at high temperatures and pressures as in India and Sri Lanka (e.g., Ramaswamy and Murty, 1968, 1972; Bhattacharyya, 1971; Phillips, 1972; Chadha, 1980; Allen et al., 1985; Kumar et al., 1985; Perchuk et al., 1994). Nevertheless, the coexistence of hypersthene and fayalite in the leucogranite is problematic if the leucogranite were formed by magmatic processes. Hopson and Ramseyer (1990b) suggested that the occurrence of fayalite and hypersthene in the leucogranite resulted during late-stage losses of water pressure during pluton emplacement. Fayalite in magmatic granites and syenites, however, is known to be stable only at high temperatures (>900 degrees C) and where granites contain less than 5 vol. % quartz (Smith, 1971; Deer, et al., 1962). Because the leucogranite at Riverside contains 26 to 40 vol. % quartz, this high quartz content is a clue that the Hopson and Ramseyer model is unlikely. *Large volumes of late-forming quartz would make crystallization of late olivine impossible*. Moreover, during late stage of crystallization of granite magma, "second boiling" should produce an abundant release of water. In that case, dehydration of the pluton would not be expected to be sufficient enough for fayalite and hypersthene to form. Otherwise, *this phenomenon should be a common occurrence, which is not true*. Therefore, a magmatic model for the origin of a leucogranite containing hypersthene and fayalite is improbable.

Other arguments presented by Hopson and Ramseyer (1990ab) also need to be examined. Among them are: (1) the timing and degree of cataclasis relative to myrmekite formation, (2) the contacts between the Bonsall tonalite and the leucogranite, and (3) the complexities of the different kinds of myrmekite and their methods of formation.

Timing and degree of cataclasis

Hopson and Ramseyer (1990ab) pointed out that cataclastic deformation "clearly postdates the myrmekite formation." *How can these investigators be certain that cataclasis did not precede myrmekite formation if they did not observe or study the area where myrmekite first forms?* Contrary to their assertion, the *first appearance of K-feldspar and myrmekite* occurs in Bonsall tonalite only where deformation first occurs and near where K-feldspar islands in microcracks are found in the wide rims of mottled plagioclase. I agree that later, at much lower temperatures, continued deformation of the leucogranite and strain on the K-feldspar crystals most likely occurred, but *cataclastic deformation clearly predates myrmekite formation*.

I agree that albite in perthite lamellae, veins, and bordering "rim" (ghost) myrmekite is late and formed after myrmekite formation. At temperatures below which myrmekite can form, continued deformation and strain on the rock would be expected. This deformation and strain would permit Na and small remnants of Ca dissolved in the K-feldspar lattice (at the higher temperatures which permitted myrmekite to form) to exsolve and form albite lamellae, veins, or borders on "rim" ghost myrmekite. The perthite albite lamellae in the Rubidoux Mountain leucogranite and in *almost all granitic rocks containing both K-feldspar and wartlike myrmekite* are highly irregular in distribution, often being concentrated in some parts of the K-feldspar and absent in others. This is because of the different amounts of Na trapped in the K-feldspar from place to place. *Such randomly* *scattered lamellae are unlike the uniformly distributed albite lamellae in perthitic K-feldspar which crystallized from magma at high temperatures.*

Contacts

Contacts between Bonsall tonalite and myrmekite-bearing leucogranite at both Temecula and Riverside may be sharp or gradational. At Riverside, for example, sharp contacts can be seen on the west side of Mount Rubidoux and at an abandoned quarry at Quarry Hill (Fig. 1). Places with sharp contacts could be fault contacts where the leucogranite has moved plastically parallel to the fault surface or where K- and Si-replacements of deformed tonalite have occurred parallel to a contact with undeformed tonalite. Gradational contacts, on the other hand, are places where gradually increasing degrees of deformation have allowed fluids to penetrate and produce different amounts of replacements.

Complex or simple replacement

Hopson and Ramseyer (1990ab) argued that the myrmekite in the leucogranite results from replacement of primary K-feldspar by Ca- and Na-bearing fluids which react with the K-feldspar to form the quartz vermicules. Then, these investigators suggest a reversal in the replacement direction. That is, K-replacement of the plagioclase in the myrmekite then takes place, so that quartz is left behind as islands (quartz blebs) in the K-feldspar (Fig. 9).

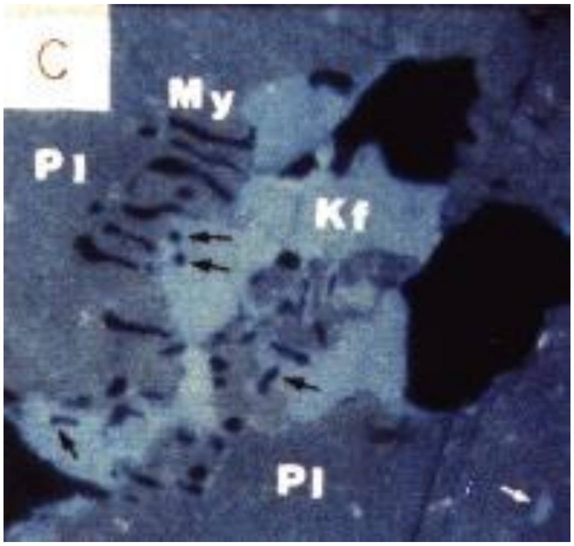

Fig. 9. Cathodoluminescence image showing quartz blebs (black) in microcline (Kf, light blue) in which the quartz blebs are the same size as in the adjacent quartz vermicules in myrmekite My) bordering plagioclase against the microcline.

These investigators also argued that both myrmekite and K-feldspar replace biotite symplectites. They seem to propose almost all theories for replacement as well as exsolution in order to fit the observed textures. Arguments against *multiple kinds and directions* of replacement (forward or backward) include the following:

(a) It is unreasonable for a chemical reaction to reverse itself inside a crystal when no logical chemical gradient exists there to cause a reversal. Once the first Ca- and Na-replacement occurs, *how can K be re-introduced to drive the reaction in the opposite direction?* If the reactions were reversed and the reactions proceeded in the way proposed by Hopson and Ramseyer (1990a) in the balanced mass-for-mass equations, why does quartz remain in the K-feldspar when the equations show that reversals should consume it?

(b) The absence of K-feldspar and myrmekite in undeformed Bonsall tonalite, the gradual appearance of K-feldspar and myrmekite in the Bonsall tonalite (where the tonalite is first deformed), and the equal volumes of K-feldspar and myrmekite at first sites suggest that both K-feldspar and myrmekite are formed simultaneously.

(c) The equal size of quartz vermicules in myrmekite in the Bonsall tonalite and in myrmekite in the leucogranite supports the hypothesis that myrmekite in both places have a common origin.

(d) The gradual disappearance of biotite and hypersthene with the simultaneous appearance of quartz, K-feldspar, and myrmekite through a gradational zone (~7 m wide) into the leucogranite adds evidence to support the connection between the two rocks and the secondary origin of the K-feldspar in the leucogranite.

(e) If plagioclase (An_{18}) in quartz-free rims and in myrmekite are formed simultaneously by Ca- and Na-replacement of K-feldspar, then *why does not all plagioclase contain quartz vermicules (as the balanced equations show should happen)?*

Finally, (f) the faint remnants of isolated myrmekite (ghost myrmekite) which occur in the K-feldspar suggest that myrmekite was *formed during earlier processes prior to the growth of the K-feldspar to larger crystal sizes*.

A problem

Presence of fayalite in the leucogranite still remains a problem because it is not a normal constituent of a tonalite, diorite, gabbro, or even a leucogranite formed at low temperatures. But how can fayalite be formed in a replacement leucogranite derived from a mafic rock in which the olivine is Mg-rich? The answer may be as follows. In other places where mafic rocks are converted to granite by replacement processes, the original high-T ferromagnesian silicates are progressively replaced by quartz, although some biotite generally remains. During that replacement process, residual recrystallized ferromagnesian silicates are enriched in iron because magnesium is subtracted at a faster rate than iron. On that basis, I speculate that the conversion of relatively Mg-rich olivine crystals in a gabbro to Fe-rich fayalite in leucogranite may go through a similar process in which the olivine is enriched in iron. I have never been able yet to verify this hypothesis by tracing myrmekite-bearing granite through gradational stages to an undeformed and unaltered mafic rock containing olivine, so this hypothesis must remain as speculation. I am still looking for such a terrane.

Conclusion

The occurrence of fayalite coexisting with 26-40 vol. % quartz in the Rubidoux Mountain leucogranite makes it clear that this pluton cannot have formed entirely from magma. *To say otherwise goes against experimental evidence*.

I agree with the interpretation by Hopson and Ramseyer (1990a) that K-feldspar has replaced plagioclase. In that case, K would displace both Na and Ca, and some of the displaced Na would recrystallize portions of the altered plagioclase in rims of zoned plagioclase to form sodic plagioclase next to the relatively-calcic core while the remaining plagioclase in the rim of the same composition would enclose quartz vermicules of the myrmekite.

I suggest that ghost myrmekite can be formed by replacement of earlier-formed myrmekite. In that case, continued deformation of tonalite, which contain both early-formed K-feldspar and myrmekite, would allow Ca in the plagioclase of the early-formed myrmekite to be subtracted so that this plagioclase would recrystallize as albite (An_{0-5}). At the same time, the coexisting quartz vermicules would be recrystallized as tiny quartz blebs because the conversion of the host plagioclase to albite consumes silica. Alternatively, the host plagioclase in the relict myrmekite could be totally replaced to leave only isolated clusters of tiny quartz blebs as in Fig. 11 of http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf. This quartz would be smaller and have less optical relief than quartz blebs in K-feldspar adjacent to wartlike myrmekite. During the replacement processes the K-feldspar would continue to grow and replace other exterior deformed plagioclase grains and produce new wartlike myrmekite while enclosing the relict ghost myrmekite.

Fig. 11 in Nr2Myrm.pdf. "*Ghost myrmekite*" also occurs in this photomicrograph of Rubidoux Mountain leucogranite. At the extinction position for microcline (black), clusters of quartz blebs (white) occur in faint traces of remnant plagioclase or as isolated oval islands in the microcline. The maximum sizes of the quartz blebs in the microcline match the maximum diameters of quartz vermicules in myrmekite (left side) where plagioclase is white and quartz vermicules are gray.

Interior replacement in the cores of plagioclase, as occurs in the tonalite at Temecula (http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf, http://www.csun.edu/~vcgeo005/Nr43Temecula.pdf, and http://www.csun.edu/~vcgeo005/Nr3Myrm.pdf) does not occur at Riverside. At Riverside, relatively calcic (An_{39}) cores change abruptly to wide, more-sodic rims, whereas at Temecula the plagioclase zonation is gradational from cores to rims. These differences mean that when plagioclase at Riverside is deformed and micro-fractured, the abrupt change from greater hardness in the calcic cores to lesser hardness in the sodic rims causes the outer, more-sodic rims to fracture before the cores are fractured. As a result, only the wide rims at Riverside are replaced by K-feldspar, unless deformation is strong enough to fracture the harder cores. In contrast, at Temecula, the fracturing tends to extend from rims completely to the cores.

Hopson and Ramseyer (1990a) offered no evidence as to why the secondary K-feldspar in fractures in plagioclase is low temperature. Presumably, it is because it fills fractures and, therefore, in their model must differ from the supposed primary, high-temperature K-feldspar of magmatic origin. All K-feldspar in the leucogranite, however, is *optically continuous* from the larger grains into fractures in adjacent plagioclase. In addition, supposed fracture walls in many places are unmatched, indicating that replacement has occurred rather than introduction of secondary K-feldspar, filling open space.

What is occurring at the Rubidoux Mountain site is not a process that happens during last stages of crystallizing leucogranite magma, but one in which different degrees of deformation of a tonalite allow for K- and Si-replacements. Because the intensity of deformation varies from slight to strong, all degrees of replacements occur, making gradational changes in mineralogical and chemical compositions between the tonalite and leucogranite. In some places, the replacement results in sharp contacts of leucogranite against relatively undeformed tonalite. (For example, at the abandoned quarry near Quarry Hill, Fig. 1, from a sharp contact against the tonalite, strongly deformed leucogranite, containing lenticular remnants of tonalite, becomes more granitic and myrmekite-bearing away from the contact.) Where deformation is concentrated and strong, the system is wide open for the addition of K and Si and subtraction of Ca, Mg, Fe, and some Al. In such places, lenticular pods of myrmekite-bearing aplite and pegmatite may be produced in which the plagioclase is quite albitic and where few ferromagnesian silicates remain. If deformation is strong and continuous throughout large volumes, then a leucogranite pluton is the final result. Should melting occur later, evidence of replacement, including myrmekite, would disappear. *Voila!* Magmatic granite.

Although petrologists generally believe today that large-scale K-metasomatism is not possible, a form of large-scale K-metasomatism has been observed by everyone who has examined weathered plutonic rocks. For example, fresh-looking zoned plagioclase crystals, in thin sections, may have cores that have been sericitized. Unseen microcracks in the plagioclase have allowed K to be introduced to produce the sericite (fine-grained muscovite mica) as Ca and Na are carried away. This occurs on a plutonic scale at temperatures less than 300 degrees C (?), At higher temperatures, greater than 300 degrees C, but below the melting interval for granite, microcracks in plagioclase at Riverside also allow introduction of K and subtraction of Ca and Na, but K-feldspar (stable at higher temperature) is formed instead of sericite. Therefore, why is it not reasonable to say that K-metasomatism can happen on a large scale?

The proposal by Hopson and Ramseyer (1990ab) requiring several different methods for producing myrmekite in a volume as small as that in a thin section is unnecessary, and a simpler method should be favored in accordance with Occam's razor. The K-feldspar replacement model is simpler because it is unidirectional, and it explains why (1) coarse quartz vermicules are formed in the myrmekite, (2) quartz is absent in recrystallized plagioclase (An_{18}) adjacent to the myrmekite, (3) vein ghost myrmekite in the K-feldspar is formed earlier but is part of the same process that produced the wartlike and "rim" myrmekite and not two different kinds of processes, (4) albite lamellae and veins exist in myrmekite-bearing K-feldspar and are formed late, and (5) mineral compositions of the leucogranite correlate with compositions of the Bonsall tonalite wall rock (Collins, 1988, 1990; Hunt et al., 1992).

For details of the K-replacement process, see:
http://www.csun.edu/~vcgeo005/Nr1Myrm.pdf;
http://www.csun.edu/~vcgeo005/Nr2Myrm.pdf;
http://www.csun.edu/~vcgeo005/Nr3Myrm.pdf.

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