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GRAPHIC GRANITE FROM THE RAMONA PEGMATITE DISTRICT, CALIFORNIA

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ABSTRACT

Typical graphic granite forms about one-third of the containing pegmatite dikes in the Romona district, California. A quartz-perthite ratio of about 1:3 characterizes this graphic granite, and the microcline-albite ratio within the perthite is about 2:1. The quartz rods in a single specimen of graphic granite generally have a single crystallographic orientation, but this orientation is different for different specimens and is not consonant with any crystallographic law. Moreover, the *c* axis of quartz is commonly not the axis of elongation of the rod, nor does the *c* axis have a systematic angular relation to the walls of the pegmatite dike. Successive surfaces cut in a block of graphic granite reveal many interconnections of the quartz rods. The features of the Ramona graphic granite and its nature of occurrence suggest that the quartz and feldspar crystallized simultaneously, probably from a vapor phase.

INTRODUCTION

Although graphic granites are readily recognized by their distinctive texture, their mode of origin and the orientation of the quartz rods have remained subjects of investigation and controversy for more than eighty years. In 1881, it was suggested by Brögger that the texture in graphic granite is due to simultaneous crystallization of the quartz and feldspar. In subsequent years, some investigators have concluded that graphic granite consists of quartz and feldspar in a ratio of about 1:3, and the relative constancy of this ratio has been cited in support of a theory of eutectic crystallization for the development of the rock. In contrast, other investigators have questioned whether the quartz-feldspar ratio is constant in graphic granites and have pointed to large variations in the quartz content as evidence that these rocks did not crystallize under eutectic conditions. Still others have regarded most graphic granites as products of replacement processes and thus have recognized no need to demonstrate a constant quartz content for such rocks.

In 1928, a German translation was published of Fersman's earlier paper (1915) on "The graphic texture of pegmatites and its causes." In these papers Fersman concluded that the quartz rods in graphic granite are separate individuals and are not branching or interfingering crystals. Fersman further concluded that because the orientation of the quartz is not due to an inner connection, it is controlled by certain directions of growth of the minerals. These controlling directions of growth were thought to be such that the *c* axis of quartz would form an angle of 42°16′ with the *c* axis of feldspar. Other investigators (Wahl, 1925; Eskola, 1928) also concluded that the intergrowths are governed by the crystallographic properties of the minerals. Wahlstrom (1939) studied a suite of graphic granite from many localities and concluded that the quartz in graphic granite does not show any constant orientation with respect to the feldspar.

Some of the reports on graphic granite have dealt with specimens from one locality or area, whereas others have been founded upon studies of material from many different localities. It seems clear that a real difference exists among the various graphic granites described in the literature and that a single mode of origin may not be applicable to all of them. The present paper represents an attempt to determine, through detailed field and petrographic investigations, the origin of graphic granite from one general occurrence, the pegmatite dike of the Ramona district, San Diego County, California.

GEOLOGIC SETTING

The pegmatite dikes of the Ramona district are granitic in composition, and occur mainly within tonalites of the Cretaceous southern California batholith. The dikes range in thickness from several inches to about 10 feet, and most are hundreds of feet long. They are subparallel, and many are anastomosing. Nearly all of them trend northwest and dip shallowly toward the west (Simpson, in prep.).

Many of the dikes are essentially homogeneous fine- to medium-grained aggregates of microcline-perthite[1] and quartz with scattered tourmaline, garnet, and muscovite. Distinct larger blocky masses and euhedral crystals of perthite with some graphically intergrown quartz are scattered irregularly throughout these aggregates.

Other pegmatite dikes in the district have well developed internal zoning; they consist of several lithologically distinct units that are arranged asymmetrically. The basal, or footwall, zone is an albite-rich aplite with thin layers of tourmaline and garnet; the uppermost zone, in contrast, is dominated by coarse-grained perthite graphic granite. Two interior zones typically are present: granitoid perthite-quartz pegmatite with abundant tourmaline and garnet and some muscovite and a core of large anhedral quartz crystals. Also present are scattered pockets containing euhedral cleavelandite and quartz with some topaz, tourmaline, and other rare minerals, discordant fracture filling of cleavelandite and quartz, and irregular units of corroded rocks containing spessartite garnet.

Graphic granite is by far more abundant in the uppermost unit within the zoned pegmatite dikes. This hanging wall zone, best defined in the Little Three dike near the center of the pegmatite district, reaches a

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[1] In subsequent pages, perthitic intergrowths of microcline and albite are termed perthite.

maximum thickness of about two feet. Contacts between the country rock and the graphic-granite pegmatite of all of the dikes are sharp. In contrast the hanging wall zone of a typical dike grades downward, commonly over distances of several feet, from rock with a typical graphic granite texture to extremely coarse-grained pegmatite with allotriomorphic texture.

The graphic granite has two general modes of occurrence: 1) Euhedral crystals of perthite, with enclosed graphic or runic-shaped rods of quartz, scattered through a finer-grained or aplitic rock. 2) Subhedral to anhedral perthite and enclosed graphic quartz that form entire rock masses.

Megascopic Features

The graphic granite is light tan to gray where fresh, and weathers tan to brown. The host perthite crystals are anhedral to euhedral, and range in size from about 5–45 cm. The typical crystal is subhedral, and 10–20 cm in its longest dimension. The crystallographic continuity is well shown on fractured surfaces of the rock by reflection from cleavage surfaces.

The quartz generally occurs in the form of rods or plates in nearly parallel orientation. These rods reach a maximum size of 2 cm in diameter, and they have an average diameter of about 0.5 cm. The plates are rarely greater than 2 cm in width and 0.5 cm in thickness, with averages of about 0.8 and 0.2 cm respectively. Both rods and plates have maximum lengths greater than 30 cm, but the average length is about 9 cm.

Small amounts of tourmaline and garnet are present in much of the graphic granite. The tourmaline prisms generally are about 1 cm in diameter and 4 to 6 cm long, but some are more than 2 cm in diameter and 15 cm long. The garnet crystals rarely are more than 1 cm in diameter.

Where the graphic granite is broken parallel to the length of the quartz rods, these rods appear to be spindle-shaped. Their boundaries are irregular, and some rods split or branch into two rods. In cross section these rods commonly have angular outlines, and appear variously as triangles, parallelograms, squares, or I-shaped, L-shaped, or V-shaped forms. On a fractured surface of the rock roughly perpendicular to the long axis of the rods, the angular forms of the quartz rods appear similar to Runic or Hebraic writing.

Microscopic Features

Microscopically, the feldspar host is perthite, in which albite occurs as irregular platy masses about 2–3 mm in diameter and 0.2 mm thick within the microcline. The albite does not form rims around the quartz rods, nor is it concentrated in their vicinity.

Each quartz rod typically consists of a single crystal; a few rods, not noticeably different in habit, consist of several crystals in different orientations.

Crystals of tourmaline, 0.1 mm to several centimeters long, and small crystals of garnet are uncommon constituents of the graphic granite. The tourmaline is dark blue and has indices of refraction in the schorlite range.

COMPOSITION

In order to determine the mineralogical composition of the graphic granite, modal analyses were made on three or more thin sections from each of 20 graphic-textured specimens collected from several of the pegmatite dikes. These thin sections, cut roughly perpendicular to the axes of elongation of the quartz rods, were stained with sodium cobaltinitrite to facilitate identification of the minerals. For each specimen an area of at least 21 square centimeters was sampled with more than 4500 counted points. The results of these modes are shown in Fig. 1 by a triangular plot of abundances of the three major minerals recalculated to 100 per cent. For all specimens the sum of the three major minerals totaled more than

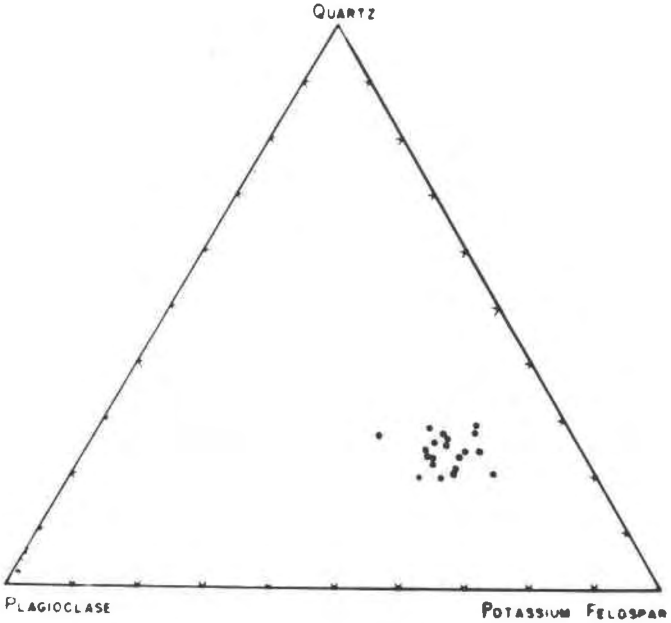


FIG. 1. Volume per cent relationship of quartz, potassium feldspar, and plagioclase in graphic granite from the Ramona district.

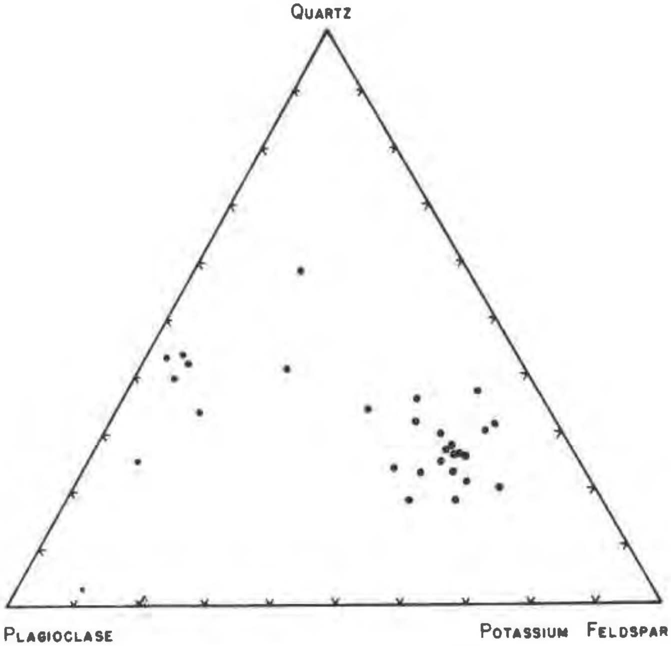


FIG. 2. Normative quartz, potassium feldspar, and plagioclase in graphic granite from other pegmatite districts. From data listed by Washington (1917), Fersman (1931) and Staatz and Trites (1955).

96 per cent, and for most specimens they totaled more than 99 per cent. Averages of the modes for quartz, microcline and albite are 24.2, 55.1, and 20.0 per cent, respectively, with individual values ranging from 19.3 to 28.9, 43.2 to 64.4, and 10.5 to 29.4 per cent. The standard deviations for the modes is 3.0, 4.4, and 4.7 for quartz, microcline and albite respectively.

A plot of the norms, with the quartz-feldspar content adjusted to 100 per cent, is shown in Fig. 2 for analyzed graphic granite reported by Fersman (1931, pp. 77–78), Washington (1917), and Staatz and Trites (1955, p. 32). It is clear that the main cluster of points in this figure is very similar to the position of the cluster in Fig. 1. To be sure, norms are being compared with modes, but the two approaches should not lead to large differences in the ratio between quartz and the alkali feldspars.

The data from the Ramona district and from other districts indicate that rocks which many investigators consider to be graphic granite, no doubt on the basis of texture, have a quartz-feldspar ratio of about 1:3. It seems likely, however, that these rocks do not represent the limits of compositional variation for the rock type. As Vogt (1921) points out,

> "In granite-pegmatite dikes we sometimes meet specimens of which one part consists of pure feldspar, free from quartz, and the other part of graphic granite, retaining the crystallographic orientation of the feldspar."

Wahlstrom (1939), in describing a specimen from Nuevo, California, states,

> "The crystal consists of a core of microcline surrounded in turn by a layer of graphic granite and an outer layer of microcline. The side pinacoid extends without interruption through the entire crystal."

These and many other occurrences emphasize the compositional variation in specimens of graphic granite. Nevertheless, the similarity in composition of many specimens that investigators report as graphic granite is a feature, not unique to the Ramona pegmatite district, that must be accounted for in considering the origin of these rocks.

Orientation of Quartz

In an attempt to account for the texture of graphic granite, Fersman (1915, 1928) advocated the so-called "trapezohedral law" because, in the specimens he examined, 88 per cent are characterized by the growth of quartz in such a manner that one of its trapezohedron zones coincides with the prism zone of the host feldspar. In such occurrences the prism edge of the feldspar is parallel to an edge between two adjacent rhombohedral faces of the quartz. Modifications have been proposed for the trapezohedral law (also known as "Fersman's Law") but both these modifications and the law stipulate that the *c* axis of the feldspar should make an angle of 42°16′ with the *c* axis of quartz.

Wahlstrom (1939) did not find any consistent orientation of the quartz in the feldspar of the graphic granite he studied, in direct contradiction to the results obtained by Fersman and others. Wahlstrom (1939, p. 690) states,

> "The present investigation is not comprehensive enough to determine whether or not quartz statistically favors any particular direction or directions in the feldspar, but it does indicate that the relation probably does not conform to the requirements of a definite set of crystallographic laws."

In order further to study the orientation relationships in graphic granite, thin sections from each of 18 specimens from the Ramona district were examined on a universal stage. The orientation of the quartz was determined by the extinction method. The orientation of the perthite was determined by attitudes of (001) and (010) cleavage planes and pericline and albite twin planes. Supplementary information concerning the orientation of the perthite was obtained from interference figures of the mineral.

An area of each thin section about 4.8 cm^2, including from 9 to 164 quartz grains was sampled. The measured orientations were plotted on an equal-area projection, and the plots then rotated so that poles to the (100) and (010) planes of the perthite lie on the periphery of the projection and the pole to the (001) plane lies 26° from the pole of the projection. With a common orientation for the perthite crystals, the results were transferable to a composite plot.

In some specimens of graphic granite all of the *c* axes of the quartz rods are parallel. In other specimens the *c* axes are variously oriented; groups of quartz rods with common *c*-axis directions may be present, but these generally are confined to different parts of the specimen. Noteworthy exceptions are specimens in which quartz rods of one optical orientation appear to interfinger with quartz rods of another orientation, and specimens in which single quartz rods contain crystals with several optical orientations.

The plot of the *c*-axis direction of the quartz rods in each of the graphic granite specimens show a well defined pattern. This pattern results from groups of the quartz rods sharing, within the limits of error in making measurements, a common optical orientation. In some plots the pattern is a single cluster of points, each of which represent the *c*-axis direction of a single quartz rod; in other plots the pattern is the result of several clusters of points. A composite plot, with a single point representing each cluster of points in the projections of the individual specimens, is shown in Fig. 3. In this plot, an equal-area projection of the data, a pattern is formed as a result of the projection of the *c* axis of quartz lying in a girdle about the (001) pole of the felspar.

Because only the optic axes of the quartz crystals were determined, these crystals could not be uniquely oriented. Additional information was obtained, however, by measuring the surfaces of contact between the quartz rods and the perthite host. This is not a simple matter, because a contact surface may be any one of the possible crystal faces of quartz or perthite, or it may have no systematic relation to the crystal structure of either mineral, or it may be related to the crystal structure but not to any known crystal face.

One specimen of graphic granite about 35 cm long with a 10 by 15 cm cross section, was used for this study. This sample, a single perthite crystal with quartz rods averaging at least 6 cm in length, was cut into three blocks and thin sections were obtained from each block. The slabbed surfaces of the specimen show a central area with well developed graphic texture adjacent to an outer edge where the texture is not so well developed. In one thin section, with good graphic texture, most of the quartz-feldspar contacts are so oriented that a plot of the poles of these surfaces on an equal-area projection forms a pattern with hexagonal symmetry (Fig. 4). This pattern suggests that the quartz-feldspar contact surfaces may correspond to prism faces of the quartz. Some also seem nearly to coincide with (010) of the perthite and others to (001) of the perthite.

Another thin section, from an area of the rock where the graphic texture is poorly developed, shows the same optical orientation of both quartz and perthite as the section just described. However, the contact surfaces of the quartz and perthite do not form distinct clusters when plotted on an equal area projection (Fig. 4). The two thin sections, one revealing a well developed graphic texture in which the mineral contact surfaces probably correspond to prism faces of the quartz and the other revealing poorly developed graphic texture and a scatter in the orientation of the mineral contact surfaces, represent areas of the original specimen about 8 cm apart in the *c*-axis direction of the quartz rods. The first section probably was cut through the prism faces of a simple skeletal crystal of quartz; whereas in the other section the cut was probably near the termination of the skeletal crystal of quartz so that contact surfaces would be quartz crystal faces $\{10\bar{1}1\}$, $\{11\bar{2}1\}$, $\{51\bar{6}1\}$, and possibly

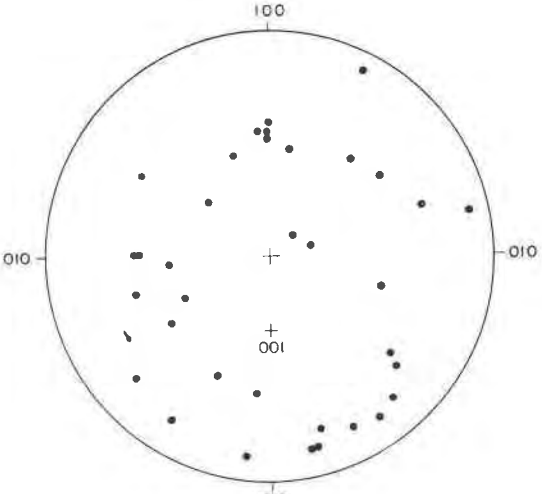
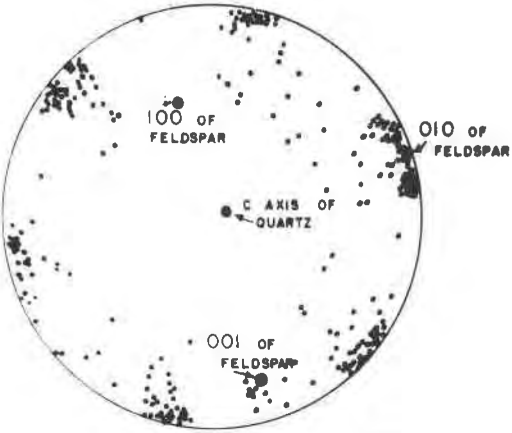
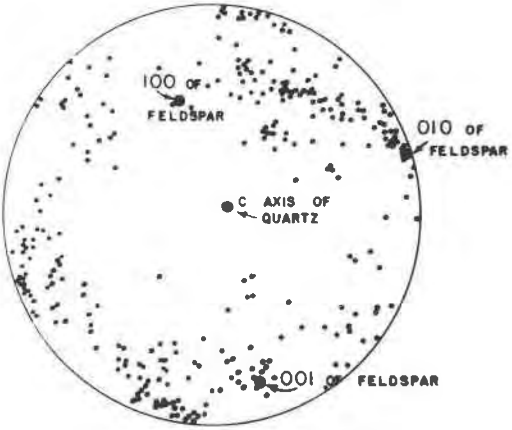


FIG. 3. Composite plot of orientation data from eighteen thin sections of graphic granite from the Ramona district showing the points of emergence of the *c* axis of quartz on an equal area projection of a monoclinic potassium feldspar.



DATA FROM THIN SECTION 57-R-23-2A



DATA FROM THIN SECTION 57-R-23-1A

FIG. 4. Equal-area projection of poles to contact planes of quartz and feldspar in graphic granite specimen 57-R-23.

$\{10\bar{1}0\}$. Poorly developed graphic texture, as well as lack of correspondence between the axis of elongation of quartz rods and the *c*-axis direction of the quartz, can be readily explained if the contact surfaces of the quartz and feldspar need not coincide with the prism directions of the quartz.

To study further the relationship between the *c* axis of the quartz and crystallographic directions of the feldspar, a histogram was constructed from the information shown in the composite plot of the orientation data (Fig. 3). For one histogram the angle between the *c* axis of quartz and the pole to (001) of the feldspar is plotted against a number of occurences in the composite plot (Fig. 3). For the other histogram the angle between the *c* axis of quartz and the pole to (010) of the feldspar is plotted. As shown in Fig. 5, there is a concentration of *c*-axis positions in several areas. One concentration is found at 50–55° from the pole to (001) of the feldspar.

In quartz the pole to a $\{10\bar{1}1\}$ crystallographic plane makes an angle of 51°47′ with the *c*-axis. Therefore, if the quartz $\{10\bar{1}1\}$ plane were coincident with the (001) plane of feldspar, the *c*-axis of quartz would be inclined 51°47′ from the (001) pole of the feldspar. A concentration of quartz *c*-axis positions was found at 50–55° from (001) pole of the feldspar.

Quartz twins by reflection across the $\{11\bar{2}2\}$ plane. As Bragg (1937) points out, a relatively large number of silicon and oxygen atoms lie in this plane or close to it. The pole of the $\{11\bar{2}2\}$ plane makes an angle of 47°27′ with the *c*-axis; hence this plane also appears as a likely possibility for the quartz-feldspar contact plane, and it may well account for the *c*-axis concentration about 50–55° from the (001) pole of the feldspar.

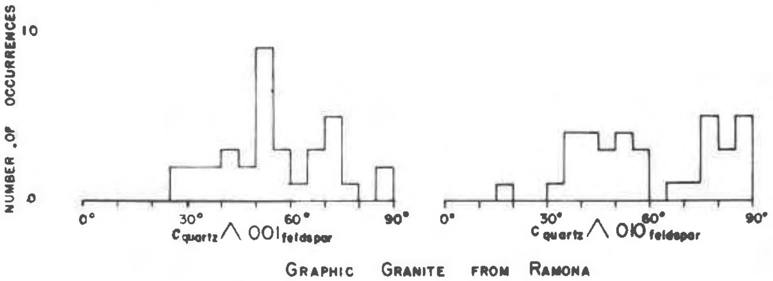


FIG. 5. Angular relation for the *c* axis of quartz and crystallographic directions of the feldspar in graphic granite.

From work with the universal stage, it is not possible to determine whether the quartz twin planes or the quartz pyramidal faces form many of the mineral contact planes. Either crystallographic plane may form the contact plane, or it may be entirely fortuitous that these crystallographic planes and the observed mineral contact planes have a similar angular relation with the *c* axis of the quartz.

The angular relationship between the *c* axis of graphic quartz and a normal to the surface of the containing pegmatite dike was determined for four specimens of graphic granite. These specimens were oriented in the field, and the *c*-axis positions were later determined from oriented thin sections of the rocks. In these specimens the *c*-axis directions of the quartz are not systematically related to the attitudes of the pegmatite dikes.

It is evident that the quartz rods in the graphic granites that were studied are not oriented according to some crystallographic law, nor is their position rigidly defined by vectorial properties of the host feldspar. One plot of the data, Fig. 5, suggests that quartz may statistically favor a position such that its *c* axis makes an angle of 50–55° with the (001) pole of the host feldspar. However, this relationship cannot be considered a crystallographic law, as it involves a crude grouping of orientation directions rather than a specific angular relationship.

Interconnection of the Quartz Rods

Having failed to find a suitable mechanism to explain the consistent orientation of quartz rods in much of the graphic granite that was studied, the writer investigated the possibility that the rods are connected within a given host crystal of perthite. To do this a block of graphic granite was cut, and a face showing good graphic texture was ground flat and photographed. The face then was successively reground and rephotographed to obtain a series of recorded sections of the block at intervals of 0.05 inch. These sections show the internal relationships of an original 0.85 by 0.9 inch block to a depth of 0.8 inch.

It was found that the quartz rods, as thus traced in the general direction of their major axes, branch and unite to form a pattern that is completely different from the original pattern 0.8 of an inch away. Major changes in form of the quartz rods occur within each interval of 0.05 inch, so that the actual connection between rods is not always recognizable. Commonly the series of photographs show several rods converging to unite and become a single rod, or in other areas a single rod splitting or branching so as to appear in some photographs as several rods. This convergence and divergence of rods, in combination with the numerous interconnections of rock shown in the photographs, indicates that all the rods probably represent the same quartz crystal. Figure 6 shows the form of a quartz rod as traced through the sequence from a rather simple form to a complicated form and finally into two separate simple forms; the same figure also illustrates the more general case, in which the quartz rods are connected by a rather narrow stringer.

The same method for the three-dimensional "micromapping" was applied to a second block of graphic granite. About one-half of this block contains parallel to subparallel plates of quartz dipping at an angle of about 30 degrees to the surface; the other half has a typical graphic texture. The quartz has the same optical orientation in both halves of the specimen. Examination of the block to a depth of 3/8 inch, in increments

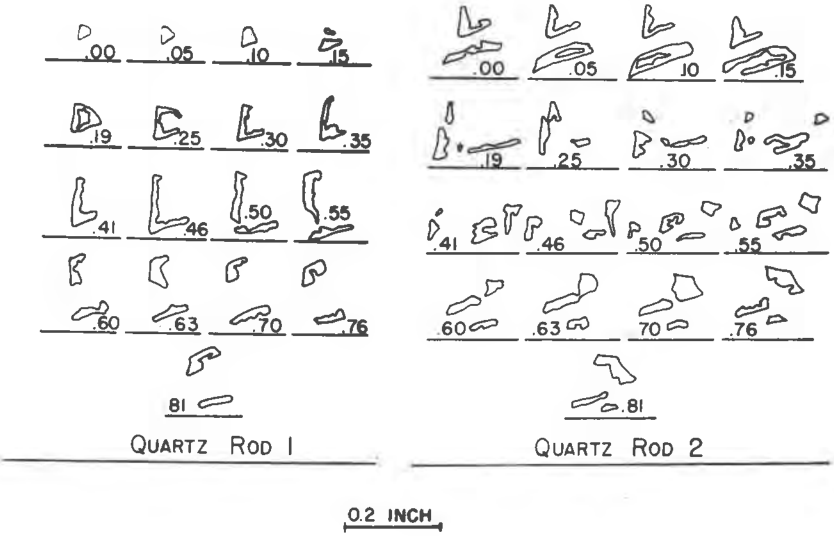


Fig. 6. Sections of two quartz rods in graphic granite specimen 57-R-20. Interval, in inches, between successive sections indicated by difference of numbers below section.

of about 0.016 inch, showed that even in this small distance many of the rods are interconnected. Furthermore, connections were found between the plates of quartz and the quartz rods in the typically graphic part of the specimen. For example, the quartz rods and plates outlined with a dashed line in Fig. 7, the first photograph of the sequence, are

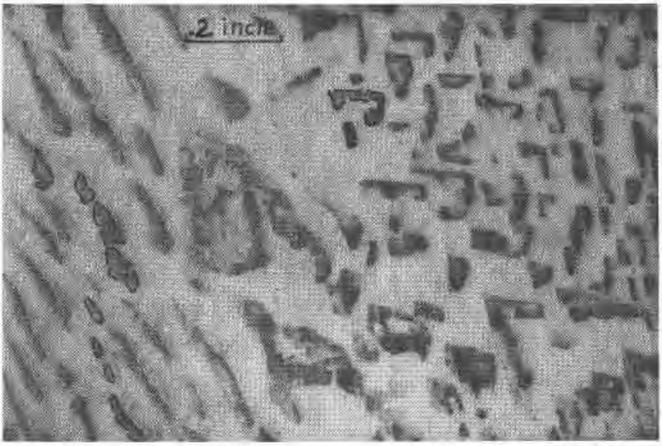


Fig. 7. Surface of a block of graphic granite, specimen 61-R-3. Quartz rods outlined with a dashed line are interconnected within the block.

known to be interconnected. These and many other known and inferred interconnections strongly suggest that all the quartz rods and plates are parts of the same crystal.

Orientation of the Quartz Rods

It seems likely that if graphic granite were formed by replacement, the rods, tablets, and runic characters of the quartz should be preferentially oriented along cleavages or other planes related to the crystal structure of the host feldspar. No relationship of this kind has been found in the Ramona graphic granite. Bastin *et al.* (1931), in discussing ore textures, point out that when replacement is proceeding in two directions the replacement textures commonly are characterized by a thickening of the replacing mineral where a replaced zone of one orientation is intersected by a replaced zone of some other orientation. In the Ramona graphic granite, tabular crystals of quartz commonly intersect at an angle of about 60°, but rarely is there thickening at the intersection. Further, if the quartz had replaced perthite, it seems likely that some veins or large masses of quartz would be present; such quartz has not been found in the Ramona graphic granite. In conclusion, there is no evidence that the quartz rods in the graphic granite formed by replacement of the perthite.

Exsolution features, as observed in ores, metals and even in silicate minerals, commonly appear very similar to textural features of graphic granite. But exsolution typically occurs along some crystallographic plane, as ilmenite exsolving from magnetite parallel to octahedral faces of the host. The graphic granite, in contrast, does not show a marked preferential orientation of the quartz with respect to the host feldspar. More compelling evidence against an exsolution origin for the quartz lies in the apparent absence of any homogeneous natural compound with composition similar to the bulk composition of graphic granite. If such a compound were to exist even metastably, it would almost certainly have been noted by Tuttle and Bowen (1958) in their detailed investigation of the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O.

A remaining possibility is that the quartz and feldspar of graphic granite crystallized simultaneously. Yet it is well known that simultaneous crystallization does not necessarily produce a graphic texture.

With conditions of simultaneous crystallization, the presence of a thermal flux offers possible mechanism for establishing a preferred orientation of the quartz rods in graphic granite. In regard to this kind of situation, Buckley (1951, p. 273) states,

> "Another means by which crystals may be oriented during growth from the molten condition is that whereby a unique crystallographic axis being also a direction of maximum

heat conduction essays to align itself with the direction of flow of the heat leaving the cooling system."

This mechanism was considered for the Ramona graphic granites by measuring the orientation of quartz rods in relation to the attitude of the containing pegmatite body. It was found that, for the samples measured, there is no correspondence between the direction normal to the surface of the pegmatite dike, the most likely direction of heat flow, and the axes of greatest thermal conductivity, the *c* axes, of the quartz rods.

It was found in two specimens of graphic granite that there are many connections between the quartz rods. In a situation where such interconnected rods are present, one can easily visualize a mechanism whereby graphic textures are developed. A crystal of quartz and a crystal of feldspar form simultaneously, and with continued growth they establish contact with each other; this contact surface need not be a crystallographic plane for either mineral. However, if one mineral were to form on the other from a very early stage, the contact surfaces would no doubt be such that structural elements of one mineral would fit onto similar structural elements of the other mineral, as is the nature of epitaxis growth.

With the quartz and feldspar in contact, continuing growth of the minerals, either simultaneously, or alternately, could yield a graphic texture in the following manner. With growth, the feldspar tends to block the direction of growth of the quartz crystal. Growth of the quartz is then only possible if the quartz changes direction of growth as a single crystal or possibly branching and growing in several directions. Further growth of the feldspar could no doubt again hinder the growth of the quartz and force it again to branch or deviate from its earlier direction of growth. Thus there would be produced an irregular, but interconnected, framework forming a single skeletal crystal of quartz which is enclosed by the simultaneous, or alternating, growth of a feldspar host. A cut perpendicular to the *c* axis of the skeletal quartz crystal would no doubt show graphic characters as a result of the development of the $\{10\bar{1}0\}$ face on the growing quartz rod.

CONDITIONS OF CRYSTALLIZATION

In establishing the conditions of crystallization for the Romona graphic granite, the following features must be considered:

a. Much of the rock has a well developed graphic texture.
b. The graphic granite is by far most abundant in the hanging wall parts of the containing pegmatite dike.
c. Both the host crystal of perthite and the contained rods of quartz are very large as compared with most crystals in granitic igneous rocks.

d. Both the quartz and the feldspar show well developed crystal faces.
e. The composition of the graphic granite does not correspond to that of the thermal minimum or even to that of any cotectic in the $KAlSi_3O_8$-$NaAlSi_3O_8$-SiO_2-H_2O system at any water pressure thus far investigated (Tuttle and Bowen, 1958).

Because of the skeletal nature of the quartz and the enclosing of this quartz framework by a feldspar host, it has been concluded that the Ramona graphic granite formed by simultaneous crystallization. It is further suggested that the Ramona graphic granite crystallized mainly from a vapor phase rather than from a silicate melt, for the following reasons:

a. Well formed crystal faces commonly are found on minerals that crystallized from a vapor phase or from an aqueous liquid phase.
b. The preferential occurrence of the graphic granite in the hanging wall parts of the pegmatite dikes is consistent with the expected distribution of vapor with respect to liquid in a pegmatite-forming system.
c. The composition of the graphic granite cannot be explained in terms of simultaneous crystallization from a melt alone without involving some special process for differentiating or otherwise changing this liquid so that the general relations in the $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O system are not applicable.
d. Vugs and cavities are present in the graphic granite, suggesting that a vapor phase was present during formation of the rocks.

To summarize, all available evidence indicates that quartz and a host feldspar crystallized simultaneously to form the Ramona graphic granite, and it suggests that this crystallization took place mainly from a vapor phase rather than from a silicate melt.

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