CRYSTALLOGRAPHIC CONTROL OF REPLACEMENT OF QUARTZ BY FELDSPAR

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ABSTRACT

Quartzite immediately adjacent to the dissemminated copper ore body at Bingham, Utah, has been replaced along the quartz grain boundaries by orthoclase. The crystal structure of the quartz has governed the position of the feldspar replacement resulting in partially replaced quartz grains which show a crystallographic outline. Measurements of these faces employing Universal stage technique reveals that the $(10\bar{1}1)$ *r* or *z*, and $(2\bar{1}\bar{1}1)$ *s* or *s'*, are the largest and most abundant forms. Dissolution of irregularly shaped crystal fragments sometimes produces well-developed definite faces and it is suggested that there might be some similarity in this dissolution phenomenon and replacement along preferred crystallographic directions.

INTRODUCTION

During the course of a study of the disseminated copper deposit at Bingham, Utah, an unusual microscopic feature involving the replacement of quartzite by feldspar was discovered, where the crystal structure of the quartz somewhat governed the place or position where it was replaced by the feldspar. This condition often resulted in a partially replaced quartzite grain which shows crystallographic outline surrounded by the replacing feldspar. Since the original study of the copper deposits

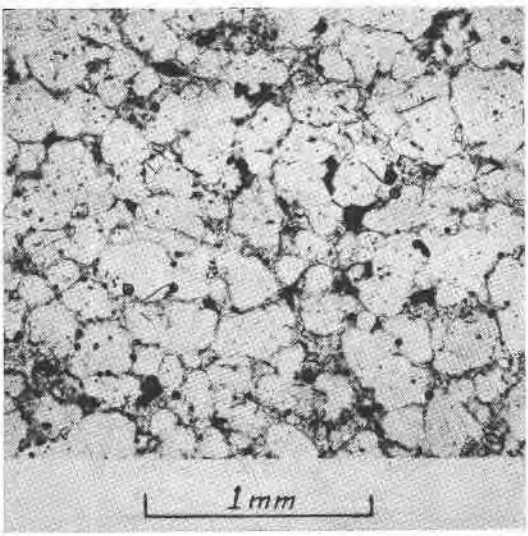

FIG. 1. Photomicrograph of feldspar network in quartzite, uncrossed nicols. Light gray, quartz with interstitial feldspar (turbed dark gray) replacing it along quartzite grain boundaries. Black is introduced pyrite.

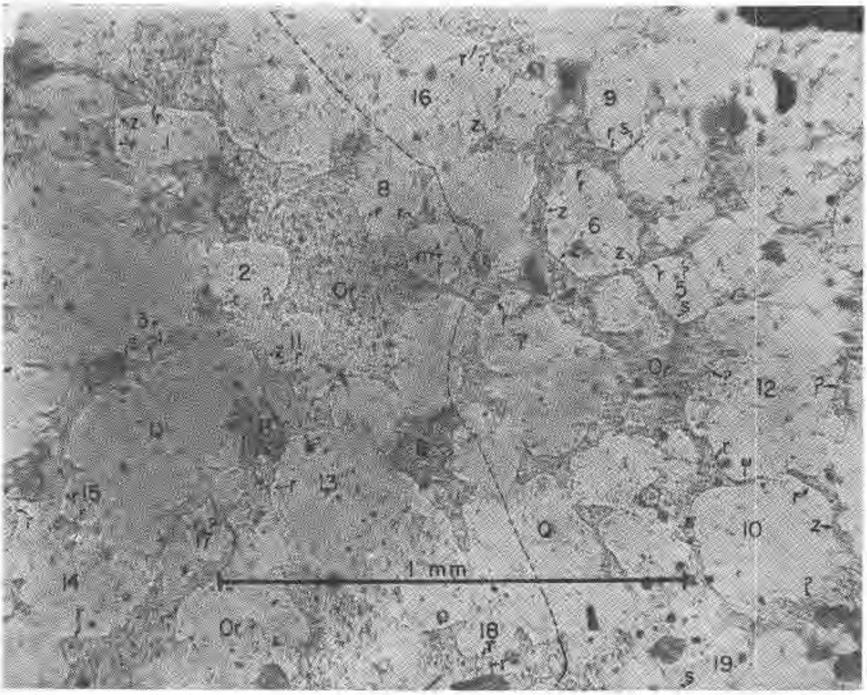

FIG. 2. Photomicrograph of feldspar network, uncrossed nicols. Shows orthoclase (*Or*) replacing quartzite grains (*Q*). Small crystals of biotite (*B*) are contained mainly within orthoclase. Edges of 19 quartz crystals in this field were measured and the crystal faces recorded. The faces questioned are those which could not be recognized as belonging to any of the simpler quartz forms. All of the orthoclase to the right of the dashed line has unit extinction and all of the orthoclase to the left of the line has unit extinction but different from that to the right.

was completed many of these quartz crystal faces have been measured and the results are presented here.

FELDSPAR NETWORK

The term "feldspar network" is used to designate the quartzite which has been replaced by feldspar since the feldspar characteristically has developed along quartzite grain boundaries and often interconnects, simulating a network appearance (Fig. 1). The quartzite containing the feldspar network occurs in areas near the main granite (dark porphyry) within which much of the disseminated ore is found. The replacing feldspar is chiefly orthoclase but plagioclase ($An_{06}-An_{12}$) is often seen. Small euhedral to subhedral biotite crystals are nearly always present in the feldspar, and although they are occasionally seen in contact with the quartz grains, the contacts between the quartz and biotite are always irregular. The feldspar characteristically replaces along the boundaries of the quartzite grains (See Fig. 2) and often where replacement has progressed to a more complete stage, isolated quartz grains are present and it is mainly on these grains that straight crystallographic boundaries are frequently observed.

Method of Measurement

The method used was to select a quartz grain having straight edges and to determine the position of the pole of the face with the aid of the universal stage. It was found that many ragged edges of grains would appear straight when tipped on the stage. The *c* axis of the quartz was always determined and the results of the whole measurement then plotted on transparent paper over a stereographic net. The *c* axis was then rotated to the center of the net and the poles of the faces rotated correspondingly. In this manner a total of 60 crystals were measured, nineteen of which are

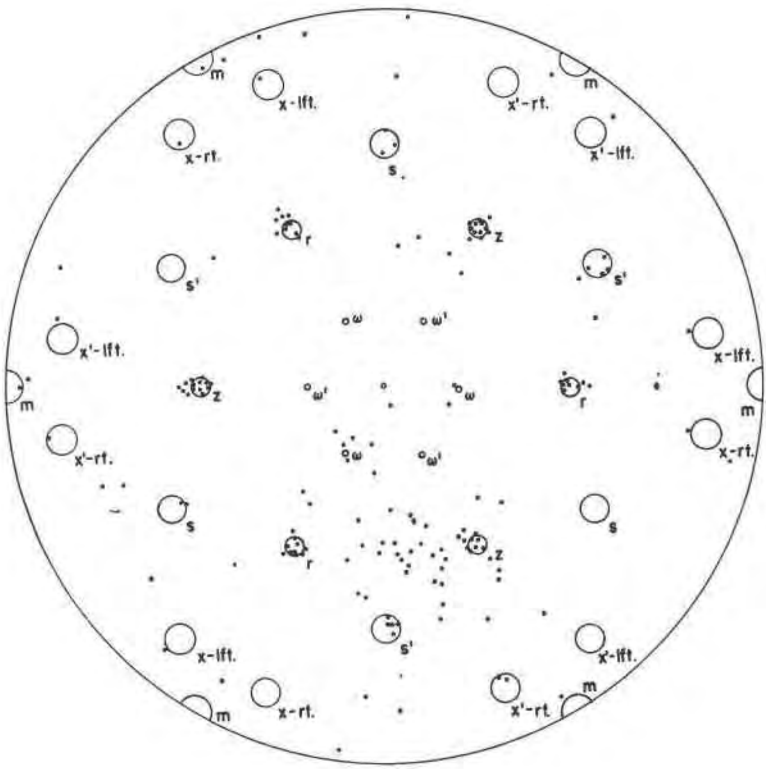

FIG. 3. Sterographic projections of the poles of the measured faces of quartz, *c* axis vertical. Circles are of 2° radius around the point of the actual pole emergence.

shown in Fig. 2. On each grain selected usually two or more faces were measured.

Using a stereographic net as a base and with the *c* axis of the quartz vertical, the exact positions of the poles of the common faces of quartz were plotted and the paper on which the measured poles of the faces of the replaced quartzite grain had been plotted was superimposed on it. In a few cases measured poles fell exactly on the poles of actual or possible quartz faces. In most cases, however, the measured poles fell at various positions within 2 to 4° of such poles indicating a moderate error in the measurement, for which it is believed the Becke line between the quartz and feldspar can be held partly responsible. Many measured poles fell in areas quite "remote" from actual common crystal face positions (See Fig. 3) and a chart carrying the actual pole positions of many of the more unusual quartz crystal forms was prepared and the measured points superimposed on it. Only a very few of the measured poles corresponded within a range of expectable error with the unusual forms.

Results of Quartz Measurements

On the 60 quartz crystals selected, 182 faces were measured (See Fig. 3) and the following forms were determined:

Form According to Dana	*Within 2° Error*	*Within 4° Error*
r and/or *z* $(10\bar{1}1)$	47	22
s and/or *s'* $(2\bar{1}\bar{1}1)$	18	1
x and/or *x'* right and/or left $(51\bar{6}1)$	5	6
m $(10\bar{1}0)$	2	4
ω and/or *ω'* $(01\bar{1}3)$	1	3
Unknown, does not fall within 4° of any form—65		

It was usually not possible to decide whether a particular face belonged to the form *r* or to the form *z*, to the form *s'* or the form *s*, since by a 60° rotation of the measured plot a face of the complementary form would have the same position; only an occasional measured plot had enough points falling on actual positions to make such distinctions possible.

The unidentified poles may be the results of large errors or they may represent faces with extremely unusual indices. It was therefore considered impractical to attempt to calculate the indices of these widely spaced poles. If several of the unknown poles had been grouped within the expectable limit of error, an attempt to calcluate their indices would have been indicated.

Details of the Quartz-Feldspar Contacts

When a quartz-feldspar contact was discovered to be parallel to a quartz crystal face, it was observed nearly always to be a plane and appeared as a sharp line when tipped to a vertical position. Often notches with straight sides indent the quartz, but most of these were too small to measure and it is not known whether the straight sides represent crystallographic directions or not. One notch was found large enough to measure, however, (see lower center of Fig. 2) and both sides were discovered to be rhombohedron faces. The irregular contacts were nearly always fairly smoothly curved in three dimensions. An interesting condition was noted on all unfractured quartzite grains in that the feldspar sought out the intergrain boundaries to replace leaving whole quartz units intact and never replaced "through" a grain leaving two quartz crystals with unit extinction. This could be attributed to accessibility of replacing solutions only along open spaces between grains.

Nature of the Feldspar and Biotite

A great majority of the feldspar units were discovered to be quite large, extending with unit extinction for a distance as much as 2 mm. In Fig. 2 only two orientations of feldspar are present. All of the orthoclase on the right side of the dashed line shows unit extinction and this crystal unit extends nearly a full millimeter beyond the border of the illustration. All of the orthoclase on the left side shows unit extinction also. No extremely fine aggregates of feldspar were noted in any of the quartzite sections containing feldspar network. The smallest feldspar anhedra had dimensions around 0.02 mm. This would suggest that when replacing solutions penetrated the rock only a few widely spaced feldspar nuclei were initiated and replacement progressed from these out into the interspaces between quartzite grains. No geometric relationship of the quartz-feldspar boundaries to the crystal structure of the feldspar could be ascertained.

The replacing solutions evidently carried a little material to form biotite and more rarely where a little lime was originally present in the quartzite to make actinolite, and small crystals of these two minerals are nearly always present within the feldspar (See Fig. 2). The orientation of these crystals being at random, they seem to bear no crystallographic relation to the feldspar or the quartz grains with which they are occasionally in contact.

The fact that the solutions carried material other than that to make feldspar perhaps warrants the application of the term granitization to the process rather than feldspathization since, if the process were more complete a granite or quartz monzonite type rock would result, or if the quartz was entirely replaced, a syenite or monzonite would be the end product.

Dissolution vs. Displacement

It is well known that irregular fragments of crystals of many substances when allowed to dissolve will have the irregularities preferentially dissolved first and if the fragment is observed during the dissolving process, it will be seen to possess crystal faces, (Buckley 1951). The Bravais (1866) law of crystal growth states that the crystallographic planes having least reticular density will grow fastest thus tending to eliminate these planes as a final crystal face. In the solution of a crystal this law should apply in reverse. Thus, for instance, if the (111) octahedron face is the fastest growing form there should be a tendency for the cube to develop on the crystal. But if the octahedron is the fastest to dissolve the octahedron should be the form resulting (Buckley, 1951). In many cases where alpha quartz crystals have been allowed to grow uninterrupted, the rhombohedron, the plane with lesser reticular density, seems to be a fast growing face resulting in large prism faces and smaller rhombohedral faces.

In the case of this replacement of quartz by feldspar, the rhombohedron is found most frequently, thus suggesting a corollary to the dissolution phenomena.

References

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