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SKELETON QUARTZ CRYSTALS

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The Occurrence and Problem

Quartz phenocrysts of unusual crystal habit were found by the author in rhyolite vitrophyres from Agate Point, forty miles east of Port Arthur on the north shore of Lake Superior. These crystals have three plates of solid quartz intersecting at 60°, whose outward extension from their intersection is terminated by two faces meeting at 120°. The space in between these plates is in part quartz (Figs. 1 and 2) and in part natural rhyolitic glass. Examination of thin sections cut almost perpendicular to the crystallographic *c*-axis showed that the quartz is in crystallographic continuity through the phenocryst. The author has since observed similar skeletons in the bipyramidal quartz crystals found in rhyolites at Deadwood, South Dakota, and at Spring Creek, Colorado.

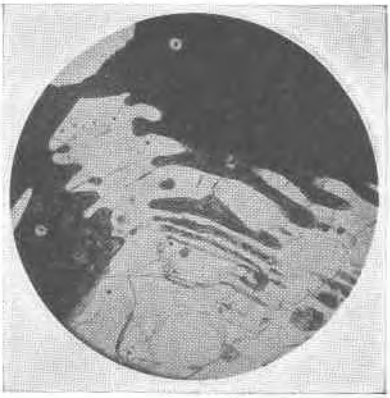

Fig. 1. Photomicrograph of a portion of a skeleton quartz crystal from Agate Point, Lake Superior. Magnification about 17 ×. Ordinary light.

The red vitrophyre (dark) at its contact with the quartz (clear) has a light turbid appearance. This turbid zone consists mainly of microcrystalline mosaic quartz.

Skeleton structures of this type might be formed in a number of ways. Two of the most outstanding are the following: (a) The skeleton is a remnant left after corrosion or partial resorption of a former quartz crystal by the vitrophyre which is replacing it. (b) The skeleton is a growing crystal suspended in liquid vitrophyre magma. This magma is being expelled from the position occupied by the crystal by the force of crystallization.

Structures Due to Resorption

Examples of resorption of both euhedral quartz phenocrysts and of skeleton quartz phenocrysts are very abundant in the Agate Point vitrophyres. An example of a typical partially resorbed quartz grain is shown in Fig. 7. The crystal is invaded by tongue-like masses of magma which show no regular behavior in their method of attack upon grains composed entirely of quartz. Therefore the regularity of the skeleton structure does not appear to be due to partial resorption of a solid quartz phenocryst.

Fig. 2. Skeleton quartz crystal from Agate Pt. Quartz shown in white, vitrophyre in black, and secondary quartz stippled.

Fig. 3. Skeleton quartz crystal from Agate Pt. The lower left hand portion of the crystal is almost completely resorbed.

Resorption effects of the vitrophyre upon skeleton crystals are shown in Figs. 2, 3, 4, and 5. For example, in Fig. 2, resorption has removed a large part of the upper right hand and upper left hand parts of the crystal and yet left the remaining parts unchanged. In this case skeleton residuals do not remain but the corroding vitrophyre has removed everything to its outer limits. Fig. 3 shows a skeleton partly resorbed, but enough "ribs" still remain to identify the position of the three intersecting plates of quartz. In this case, as well as in Fig. 2, resorption is complete to its outward limit. The process left no quartz residuals.

Fig. 4 shows a further stage in resorption of a quartz skeleton crystal. One plate and part of another is well preserved. The other parts of the quartz, however, have been dissolved in the magma solution. Fig. 5 shows a still further stage in the destruction of a crystal; only small parts adjacent to two plates remain, and of these remnants only the outer ends are preserved.

Fig. 4. Skeleton quartz crystal from Agate Pt. completely resorbed, except or half of two axial plates.

Fig. 5. Skeleton quartz crystal from Agate Pt. showing almost complete resorption. Only the ends of the axial plates are left.

Conclusions Regarding Resorption

It appears that when resorption of quartz crystals occurs, the process is complete up to the edge of the corroding solution. Corrosion at the centre may be complete before parts of the outside are even affected. No regular systematic arrangement of corroding tongues such as that shown in Fig. 2 can be found in the pure crystals. Even when the corroding magma attacks a skeleton crystal it removes both quartz and included glass entirely, instead of following narrow zones analogous to the glass separating the ribs of the skeleton crystal.

The Skeleton Structures

The most complete skeleton crystal found in the Agate Point vitrophyres is shown in Fig. 2, and a portion of the same phenocryst is reproduced in the photomicrograph shown in Fig. 1. The crystal exhibits three plates from which glass is completely absent, composed of quartz having the same crystallographic orientation. Slender plates of quartz, crystallographically continuous with the first and separated from one another by glass, play the part of supporting crossbars. The separating glass films become thinner towards the interior of the crystal and disappear before the centre is reached.

A section of this crystal cut almost perpendicular to the vertical axis was examined under the microscope with nicols crossed and it was found that the light, turbid areas surrounding the glass and occurring in it (Fig. 1) are composed of microcrystalline mosaic quartz. Thin films of mosaic quartz, having the same shape as the glass films found near the edge of the crystal, continue in toward the centre much farther than the glass itself. The mosaic of the films near the centre of the phenocryst is more coarsely crystalline than where it is associated with the natural glass and furthermore, the reorganized borders of the films are in crystal continuity with the main mass of the phenocryst. The microcrystalline quartz is clearly reorganized rock glass from which the impurities have been removed. The purified product thus formed was being recrystallized with the same orientation as that in the main part of the phenocryst.

Fig. 6. Section of bipyramidal quartz crystal isolated from a rhyolite vitrophyre found at Spring Creek, Colorado. The crystal shows almost complete growth and exclusion of magma.

Fig. 7. Normal quartz phenocryst from Agate Pt. vitrophyre which has attained growth and complete exclusion of magma but which has been resorbed at a later stage.

A number of bipyramidal quartz crystals from salic extrusives of other localities were examined. Exceptionally good skeleton crystals from which the glass had been almost completely expelled were found in the rhyolites from Deadwood, South Dakota, and from Spring Creek, Colorado. These crystals exhibited the relations of the three intersecting plates to the crystal form of the quartz unusually well. A section of a crystal from Spring Creek, Colorado, is shown in Fig. 6. And it will be observed that the plates of pure quartz emerge at the corners and that the planes about which the individual films of glass are symmetrical are parallel to the crystal faces. A suggestion of this relationship is shown in Fig. 1.

SUMMARY OF SKELETON STRUCTURES

The films of glass are parallel with the crystal faces and the planes of clear quartz emerge at the corners. At the time of the growth of the crystal the glass was being replaced by mosaic quartz which was recrystallizing in crystal continuity with the three plates emerging at the corners.

THEORY OF FORMATION OF SKELETON CRYSTALS

It has been shown that when resorption of the quartz crystals occurs, the magma completely dissolves a mass of the crystal or develops grotesque forms as in Fig. 7, instead of selecting a few narrow definitely located zones in it. The theory that the skeleton crystals are due to resorption phenomena, therefore, appears to be untenable.

Mosaic quartz has been shown to have been replacing the rock glass at the time of formation of the phenocrysts. It has also been pointed out that this mosaic was recrystallizing in crystal continuity with the three intersecting plates emerging at the six edges of the crystal. The central or pure portion of the phenocryst, therefore, is a skeleton purified by recrystallization and removal of impurities.

Crystal growth started from three "axial" plates which probably indicate three directions of greatest molecular attraction for quartz. Lateral growth from one plane to another proceeded along zones of greatest molecular attraction or zones of shortest distance between corresponding points on adjacent primary planes. Certain secondary supporting plates seem to have had more favorable conditions for growth than others, so that they sealed off portions of the magma (now glass) from the remainder in which the phenocrysts were suspended. These segregated portions have been largely purified by recrystallization and replacement and, doubtless, had the magma not been chilled to form a vitrophyre, would have been completely replaced. Resorption attacks the outside of the crystals first so that this process also helped in the removal of the glass occurring chiefly on the outer parts of the phenocrysts.

MINOR SECONDARY STRUCTURES

It might be expected that the areas of quartz should have sharp outlines comparable to those in snow crystals described by Bentley,[1] and Whitlock.[2] Careful consideration of the conditions will show that this is not necessary. For example, it is known that surface tension increases with viscosity. The viscosity of water saturated air (the magma in which the snow crystals formed) is almost zero, whereas the viscosity of the much higher specific gravity vitrophyre (magma in which the skeleton quartz crystals grew) is very high by comparison. The surface tension in the vitrophyre magma, therefore, would exert a counteracting force upon crystal growth (which was not encountered by the growing snow crystals) and quartz would separate out from the magma solution only where the force of crystallization was greater than the force due to surface tension. Liquids tend to form curved meniscus films, that is, the surface energy of the liquid is exerted to maintain a curved surface, when contained between walls. The surface of the vitrophyre magma in the films would, therefore, be determined by the equilibrium surface between the force of crystallization of the quartz and the surface energy of the liquid magma. This equilibrium surface would be curved somewhat after the fashion shown in the figures.

Figs. 2 and 4 show the ribs joining adjacent plates of quartz somewhat bent. This is probably due to deformation of the crystal at the time it was growing, rather than to a primary three-fold symmetry as suggested by the recurrence of the structure on alternate faces, as shown in Fig. 2.

ETCHING

Polished surfaces parallel to the base of pure bipyramidal quartz crystals from Spring Creek, Colorado, were prepared and gently etched with hydrofluoric acid. These surfaces showed that the planes joining the opposite edges resisted attack better than

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[1] Bentley, W. A.: Studies of Frost and Ice Crystals. *Unied States Monthly Weather Review*, **35**, 1903.

[2] Whitlock, H. P.: The Mimicry of Crystals. *Natural History*, **XXV**, 156-161 (1925).

any other part of the crystal and the entire surface gave a suggestion of the primary shape shown in Fig. 2. The tests were not conclusive, but suggested that the quartz molecule had a very much greater attraction for other quartz molecules along certain planes than others.

CONCLUSIONS

Primary skeleton quartz crystals seem to show that the quartz molecule has a greater attraction along three lines at 60° to one another than in any other direction.

Etch figures on polished surfaces of pure bipyramidal quartz crystals from Spring Creek, Colorado, seem to show the same molecular attractions within the quartz as do the skeleton crystals.

These lines of greatest molecular attraction correspond to the usual crystallographic axes and it would seem that these hypothetical axes express the directions of greatest molecular attraction.

TOPAZ AND ASSOCIATED MINERALS FROM THE EINSTEIN SILVER MINE, MADISON COUNTY, MISSOURI[1]

CLARENCE S. ROSS AND E. P. HENDERSON

INTRODUCTION

The Einstein Silver Mine of southeastern Missouri was visited by one of the writers (Clarence S. Ross) in company with Dr. W. S. Bayley and several graduate students in geology from the University of Illinois in the spring of 1917. The old Einstein Silver Mine, which is located on the banks of the St. Francois River, nine miles west of Fredericktown, Madison County, Missouri, contains a group of minerals unknown elsewhere in the Mississippi valley region.

The following notes on the mine are given by Buehler[2]:

> "Systematic prospecting was begun in 1877 and as a result a quartz vein was opened. . . . . After producing fifty tons of lead and three thousand ounces of silver

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[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Buehler, H. A., Biannual report of the State Geologist of Missouri, pp. 97, 98 (1919).