The crystal chosen for illustration is diopside, (monoclinic: $a=9.74_7$, $b=8.91_8$, $c=5.25_8$ Å, $\beta=105°\ 55'$; space group $C2/c$). The photographs were taken with the x-ray beam parallel to the c axis. The zero level is placed at the bottom, the first level is about 8 mm. above the zero level and the second level (which may not be needed) is placed 8 mm. above the first level. Both upper level nets are displaced towards the viewer's right, along the c^* axis. The reciprocal unit cell chosen is outlined by the reflections. With the three dimensional view of the reciprocal lattice in front of one, the indexing of the reflections is simplified and systematic extinctions of reflections readily observed. If more than one crystal of the substance is used, the device also helps in maintaining a uniform setting or orientation of the reciprocal cell chosen. The device should therefore be useful to experienced crystallographers as well as to students.

I wish to thank my colleague, Joseph F. Abell, who supervised the construction of the box, and to Joan R. Clark and D. E. Appleman for their helpful criticism.

THE AMERICAN MINERALOGIST, VOL. 45, JULY-AUGUST, 1960

ORIGIN OF EMBAYED QUARTZ CRYSTALS IN ACIDIC VOLCANIC ROCKS

ROBERT J. FOSTER, *Department of Earth Sciences, Montana State College, Bozeman, Montana.*

Embayed or rounded quartz crystals are ubiquitous features of acidic volcanic rocks. Most petrology textbooks offer no explanation of why the quartz crystals of these rocks, that contain abundant normative quartz, are not in equilibrium with the groundmass. Almost all authors who have described these features have noted that the embayed quartz crystals are dipyramidal and so have the form of β or high temperature quartz (Cf., Williams, Turner & Gilbert 1954, p. 123 & 126). β quartz inverts to α or low temperature quartz on cooling past its inversion point.

In a recent textbook Moorhouse (1959), in describing rhyolites and quartz latites, notes (p. 207–208),

> "Quartz phenocrysts often exhibit "corrosion" effects. . . . In the past these textures have been attributed to corrosion of the phenocrysts by the matrix. The suggestion has also been made that "corroded" quartzes are due to irregular amoeboid growth rather than corrosion. In corroded feldspars, such as those in Fig. 113A (quartz latite, San Juan Mts., Colorado), there can be little doubt that they have been attacked and invaded by the matrix. Surely these are xenocrysts foreign to the magma enclosing them. The same impression is given by the textures of Figs. 15A, B, C (quartz latites, San Juan Mts., Colorado). In these, angular, sometimes corroded chips and fragments of quartz, feldspar and ferromagnesians occur in a glassy or microcrystalline matrix of acid composition. It is

> as if the lava of the matrix had picked up innumerable fragments of wall rock and incorporated them with very little effect on itself."

Some embayed quartz crystals probably originated in this fashion, but it appears unlikely that such an accidental origin can account for a ubiquitous feature in common rocks. The shattered quartz crystals can perhaps be explained as due to volume changes in the inversion from high to low quartz and Wright and Larsen (1909) note that such shattering is characteristic of inverted crystals; however, the fact that the dipyramidal form is recognizable in many rocks suggests that well-formed but embayed quartz crystals are common.

Thus it appears that many acidic volcanic rocks contain crystals that are not in equilibrium with the groundmass. Because of the widespread occurrence of this phenomenon, most petrologists interpret it to mean that the crystals formed early, perhaps under different conditions, and are now not in chemical equilibrium with the groundmass (Turner and Verhoogen 1959, p. 63). Reaction rims of pyroxene around quartz crystals such as those described by Moorhouse (1956, p. 191) indicate that the quartz formed at high temperatures. Resorption of early formed feldspar crystals is well explained by Tuttle and Bowen (1958, p. 130–137) in light of their experimental work. Perhaps a similar explanation of embayed quartz crystals in volcanic rocks is possible.

The data presently available offer several possible explanations of embayed quartz crystals. As noted by Moorhouse they may be due to amoeboid growth in a very viscous melt, and rhyolitic magma, especially near the liquidus, is very viscous (Tuttle and Bowen 1958, p. 76–77). The fact that most of the quartz crystals in question have recognizable dipyramidal form argues against this hypothesis.

Perhaps a more likely explanation is that these embayed quartz crystals record the arrested beginning of the recrystallization that Bowen and Tuttle's experimental work indicates occurs in many granites. Tuttle (1952, p. 108–110) summarized the differences between plutonic and volcanic quartz, noting differences in inclusions, form, orientation and extinction. Tuttle and Bowen (1958, p. 137–142) proposed that the textural differences between rhyolites and granites are due to recrystallization during the slow cooling of the latter. In experimental melts (Tuttle and Bowen 1958, p. 28 & 59–61) and in volcanic rocks, quartz forms early euhedral crystals. In plutonic rocks quartz is commonly anhedral and apparently forms late, although as pointed out by Tuttle (1952, p. 120), determining order of crystallization in a plutonic rock, "is a risky undertaking at best."

A major problem in explaining embayed quartz crystals as resolution as the first step in recrystallization is the lack of a driving force for such a reaction. Tuttle and Bowen (1958, p. 138) have shown why recrystallization of feldspars takes place, but no one has shown why quartz recrystallizes; although Turner (1948, p. 192–211) and Tuttle (1952) have shown that the quartz of many plutonic rocks is recrystallized.

In the light of Tuttle and Bowen's work, the reactions between crystals and groundmass in a volcanic rock probably take place after the rock has solidified but is still hot. Such reactions could be due to a late liquid phase (Tuttle and Bowen, 1958, p. 102–103). They could also be due to a reaction between the hot glassy or cryptocrystalline groundmass and the quartz crystals, perhaps through the medium of an intergranular film.

REFERENCES

MOORHOUSE, W. W. (1959), The study of rocks in thin section: Harper and Bros., New York, 514 p.

TURNER, F. J. (1948) Evolution of the metamorphic rocks: *Geol. Soc. America Mem.* **30,** 342 p.

——— AND VERHOOGEN, JOHN (1960), Igneous and metamorphic petrology: McGraw-Hill, New York, 694 p. (Second edition).

TUTTLE, O. F. (1952), Origin of the contrasting mineralogy of extrusive and plutonic rocks: *Jour. Geol.*, **60,** 107–124.

——— AND BOWEN, N. L. (1958), Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O: *Geol. Soc. America Mem.* **74,** 153 p.

WILLIAMS, HOWEL, TURNER, F. J. AND GILBERT, C. M. (1954), Petrography: W. H. Freeman, San Francisco, 406 p.

WRIGHT, F. E. AND LARSEN, E. S. (1909), Quartz as a geologic thermometer: *Am. Jour. Sci.*, **27,** 422–447.

THE AMERICAN MINERALOGIST, VOL. 45, JULY–AUGUST, 1960

"HYDROMUSCOVITE WITH THE $2M_2$ STRUCTURE—A CRITICISM"

E. W. RADOSLOVICH, *Division of Soils, Commonwealth Scientific and Industrial Research Organization, Adelaide, Australia.*

A recent paper by Threadgold (1959) has reported chemical, differential thermal and *x*-ray diffraction data on a hydromuscovite from Mt. Lyell in Tasmania. Threadgold gives data which are claimed to show that this hydromuscovite has the $2M_2$ structure, a mica polymorph previously only found amongst the lepidolites (Levinson, 1953). Radoslovich (1959) has recently suggested, however, that the theoretical polymorphs 2O, $2M_2$ and 6H, which are based on 60° rotations between layers (Smith