DEVELOPMENT OF QUARTZ PORPHYROBLASTS IN A SILICEOUS HORNFELS[1]

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Abstract

A siliceous hornfels in the Wallowa mountains of northeastern Oregon contains small quartz porphyroblasts. In thin section the porphyroblasts show several stages of development from initial forms which are barely distinguishable from the groundmass on account of the abundance of minute inclusions, to later forms which are gradually cleared of inclusions. Some of the porphyroblasts have euhedral boundaries yet consist of several individuals of varying optical orientation. Idiomorphic pyrite is contained in some of the quartz porphyroblasts. The petrographic evidence seems to indicate a facility of crystallization in environment which might not be expected to favor idiomorphism and may indicate an initial step in the recrystallization of the rock.

Occurrence

The hornfels described in this paper forms a part of a series of pre-Tertiary metamorphic rocks situated about one mile north of the mining town of Cornucopia on the southeastern flank of the rugged Wallowa mountains, one of the higher ranges of the Blue mountains group of northeastern Oregon. Although this region lacks detailed geologic maps, several papers have already been published. Of the earlier publications, that of Lindgren[2] in the 22nd Annual Report of the United States Geological survey is the most comprehensive. Recently Gilluly[3] has given an excellent summary of the general geology of the region. In the immediate vicinity of Cornucopia steep glaciated valleys afford excellent exposures, and considerable petrologic data has also been obtained through access to mine workings. Locally the metamorphic series is traversed by numerous irregular invasions of granodiorite. The hornfels occurs as steeply dipping bands, several feet in thickness, which have a northly trend and exhibit a parallel jointing in the same direction. One of the outstanding characteristics of the hornfels is an almost cherty appearance imparted to it by its siliceous composition and by its compactness, brittleness, and subconchoidal fracture. It is light to medium gray in color and may be liberally sprinkled with dark greenish spots, or may be nearly free from them. Small cubes of pyrite are visible with the aid of a hand lens and where oxidized they appear as brown specks,

[1] Presented at the thirty-fourth meeting of the Cordilleran Section, Geological Society of America, Palo Alto, 1935.

[2] Lindgren, W., Gold belt of the Blue mountains of Oregon: *U. S. Geol. Survey, 22nd Annual Rep.*, Pt. **II**, pp. 561–776, 1900–1901.

[3] Gilluly, J., Reed, S. C., Park, C. F. Jr.: Some mining districts of eastern Oregon: *U. S. Geol. Survey, Bull.* **846A,** 1933.

due to the oxidation of the pyrite. For this reason surface outcrops and joint cracks are somewhat stained with limonite.

Under the microscope the unspotted hornfels exhibits a cryptocrystalline groundmass which appears as a sutured interlocking aggregate of minute irregular anhedra of quartz, filled with inclusions which consist chiefly of very small flakes of a pale green slightly pleochroic mineral, probably a member of the chlorite group. Some of the sections show very

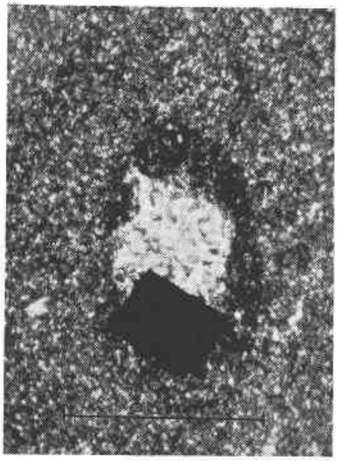

FIG. 1. Photomicrograph of a segregation spot and associated pyrite crystal. The outer zone of the spot shows a slight tendency to form a crystal face. Crossed nicols.

minute isotropic grains which may be garnet, and a few grains of what is probably epidote. Most of the dust-like material in the groundmass is too fine to be determined. There are many minute opaque grains that suggest pyrite and some of these are oxidized to limonitic material. Quartz porphyroblasts are common in this variety of unspotted hornfels.

The spotted hornfels shows a profusion of small (about 0.5 mm.) dark greenish spots, covering from 10 to 30 per cent. of the rock. Under the microscope it is seen that these spots have a nucleus of a slightly coarser aggregate of quartz anhedra, surrounded by a wide ring containing a greater concentration of the same green flaky mineral of low birefringence, which is common in the groundmass of both varieties. The color and low birefringence suggests that it is one of the chlorites. Some of the spots contain small grains of pyrite and some are adjacent to large pyrite porphyroblasts (Fig. 1). Although most of these spots have a rounded or irregular outline, there are some which in shape suggest the expression of crystal faces of quartz while others are gradational into later forming quartz porphyroblasts (Figs. 1, 2*a*, 2*b*). In one section there are several quartz porphyroblasts in various stages of development from the segregation spots. The first step is a change in texture from a fine to a coarser grained mosaic. Then crystal faces begin to appear and the texture becomes still coarser until a compound porphyroblast is developed. In the final stage the porphyroblast is a single crystal.

Fig. 2*a* (Nicols not crossed)

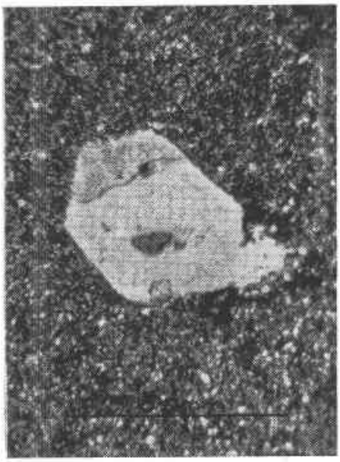

Fig. 2*b* (Crossed nicols)

The photomicrograph taken with uncrossed nicols shows that the minute inclusions common to the groundmass are distributed through the quartz porphyroblast. Under crossed nicols the crystal faces are clearly delineated. The quartz porphyroblast is associated with a segregation spot.

However, it is not certain that segregation in these spots always precedes the porphyroblasts in formation for there are many porphyroblasts quite independent of the spot-segregations, and with no indication that spots had ever formed. In some sections small initial porphyroblasts have apparently been formed by the coalescing of the minute interlocking anhedrons of the groundmass. Some of these porphyroblasts are irregular in outline while others, even when very small, show a tendency to develop a crystal outline.

Most of the quartz porphyroblasts are of small size, about 0.5 mm. in diameter. Some show prism and rhombohedron faces, some are distorted and others appear to be gradational with respect to either segregation spots or to the groundmass of the hornfels. Even though the prism faces may be unevenly developed trigonal symmetry is commonly noticeable.

Some of the porphyroblasts are difficult to distinguish in plane light, although they are readily discernible with crossed nicols (Figs. 2*a* and 2*b*, 3*a* and 3*b*). This difficulty of recognition is due to the fact that an abundance of minute inclusions of the groundmass extends through the quartz crystals. Other porphyroblasts do not contain as many inclusions, and in some a clearer outside rim is present. Euhedral pyrite crystals are associated with some of the porphyroblasts and are even found near the center of quartz crystals (Fig. 4).

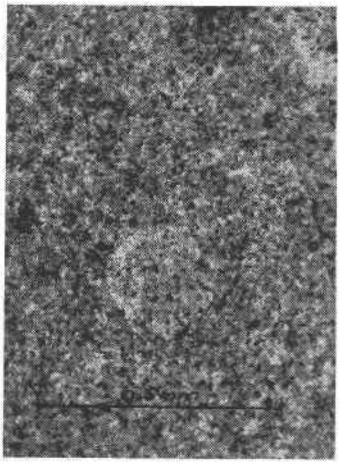

FIG. 3*a*
(Nicols not crossed)

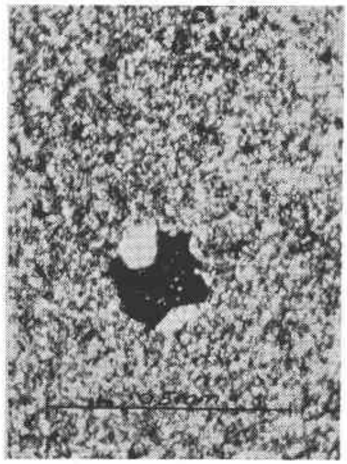

FIG. 3*b*
(Crossed nicols)

In the photomicrograph taken with uncrossed nicols the quartz porphyroblast is barely discernible while with crossed nicols the compound character of the crystal is evident.

Many of the quartz porphyroblasts are compound crystals, each individual having a different orientation and yet having certain faces in common (Fig. 3*b*). Under plane light a crystal may exhibit what appears to be a basal section of a single crystal, while with nicols crossed a compound crystal is evident.

In his discussion regarding the mechanism of crystal growth, Davey[4] states that if the strength of the crystal is in excess of the strength of the surface forces, the crystal will be polyhedral in shape, whereas if the strength of the crystal is less than that of the surface forces, it will have a rounded exterior. He is also of the opinion that if two crystals having different orientations meet in the body of a solid, there is at the interface

[4] Davey, W. P., *A study of crystal structure and its applications*. McGraw-Hill Book Co., **1934.**

a thin layer of molecules whose positions represent a compromise between the locations demanded by one of the crystals and those demanded by the other. As crystal growth occurs it is necessary for one of the crystals to align the molecules of this semi-disorganized intercrystalline layer according to the pattern set by its own orientation. Then a new intercrystalline layer would be formed at the expense of the less favorably oriented crystal. The molecules of this layer would then be aligned to conform to the pattern of the growing crystal and the cycle repeated

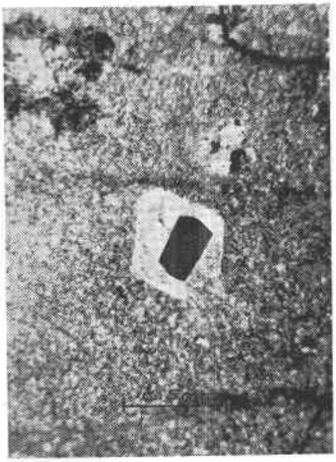

FIG. 4
(Nicols not crossed)
Photomicrograph showing irregular segregation spots and a subhedral quartz porphyroblast with an included crystal of pyrite. One of the faces of the quartz porphyroblast is gradational into the groundmass.

until the less favorably oriented crystal disappears. Such a mechanism might offer an explanation for the irregular boundaries commonly present between differently oriented portions of a quartz porphyroblast.

CONCLUSIONS

Quartz is usually placed near the end of the crystalloblastic series and most authors state that it rarely, if ever, forms euhedral crystals under conditions of recrystallization. Especially in a siliceous rock it might be expected that there would be many centers of crystallization for quartz, so that recrystallization would produce a mosaic texture. However, Tokarski[5] has noted idiomorphism in quartz developed in a sandstone

[5] Tokarski Juljan, Uwagi o Rosenbucha regule "Kolnosce crystalizacji mineralow w magmie" Kosmosu, Tom **50,** Zesz 1, 1925.

which had been subjected to a "regeneration process." From the study of the porphyroblasts in this hornfels it is believed that idiomorphism occurs even under conditions which might be expected to be unfavorable for crystal growth. It is possible that these conditions have been changed by the gradual diffusion of volatiles through the rock, or by the local concentration of volatiles or solutions along minute fractures. The formation of the quartz crystals in this hornfels was crystalloblastic since growth took place in an essentially solid medium and the small inclusions of the groundmass were surrounded and included in the growing porphyroblasts. Then as crystallization proceeded, they cleared themselves of inclusions, perhaps in part, through the agency of crystallization pressure.[6]

The fact that these porphyroblasts which contain crystals of pyrite are usually clearer, suggests that the iron sulphide has acted as a collecting agent (Fig. 4). The formation of pyrite gives evidence of volatiles or solutions while the trigonal symmetry of the quartz indicates a temperature of formation less than 573°C.

It is possible that a hornfels such as just described might casually be interpreted as a quartz porphyry. Detailed studies, however, show that this interpretation is not compatible with the observed facts. Further studies of the metamorphic rocks of the Cornucopia district indicate that this hornfels may represent a transitional development toward rocks more completely recrystallized.

[6] Harker, Alfred, *Metamorphism*, Methuen, **1932.**