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DEVELOPMENT OF PLAGIOCLASE PORPHYROBLASTS[1]

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ABSTRACT

Porphyroblastic textures are common to hornfels in the Cornucopia area of the Wallowa Mountains of northeastern Oregon. Recent petrographic studies indicate that they are also common to some of the rocks of the Cascades of Washington. Plagioclase porphyroblasts range from initial allotrioblastic forms to fully developed idioblastic crystals. They exhibit many characteristic features which may include poikioblastic structures, helizitic inclusions and complex aggregates. The arrangement within the crystal of inclusions of either identifiable minerals or turbid material, is apparently directly related to the stage of development of the porphyroblast. This included matter differs chiefly in its arrangement from the products of endogenetic or subsequent alteration.

Recognition of these metamorphic textures and structures is one of the points essential to the interpretation of recrystallization-replacement as applied to igneous-appearing rocks which are believed to have been formed in situ by processes of additive hydrothermal metamorphism.

In a previous paper the writer outlined the development of quartz porphyroblasts in a siliceous hornfels.[2] The quartz porphyroblasts in the siliceous hornfels were too small (0.5 mm.) to be conspicuous in the hand specimens, but were readily seen under crossed nicols, although in plane light they merged almost completely with the groundmass of the hornfels, and contained the same abundance of small inclusions as the groundmass. The siliceous hornfels is not the most abundant; biotitic and hornblendic varieties are far more common. They vary in color from dark green to black, although in surface exposures the prevailing color is brown due to the oxidation of minute disseminated grains and veinlets of pyrite.

These hornfels form a part of the metamorphic rocks of the Wallowa Mountains of northeastern Oregon, where in the vicinity of the mining town of Cornucopia, pre-Tertiary sediments and volcanics are now metamorphosed to schists, hornfels and greenstones, and are adjacent to emplacements of granodioritic and associated rocks such as porphyries, granophyres, aplites, pegmatites and quartz veins.

[1] Presented to the Cordilleran Section, Geological Society of America, Berkeley, California, April 1937.

[2] Goodspeed, G. E., Development of quartz porphyroblasts in a siliceous hornfels: *Am. Mineral.*, vol. **22**, pp. 133–138, 1937.

Petrographic study of many specimens from underground mine workings as well as the surface outcrops shows that the hornfels varies considerably in microtexture and structure. In some of the finer grained varieties, the interlocking crystals of the groundmass are so small as to be barely distinguishable, while in the coarser varieties the microtexture approaches that of a granulite. Most hornfels sections show a xenoblastic intergrowth of unstriated plagioclase, quartz, biotite and hornblende. The two latter minerals commonly exhibit some alignment, and either mineral may predominate. This suggests a period of dynamic metamorphism preceding that of thermal metamorphism. In some sections, however, a

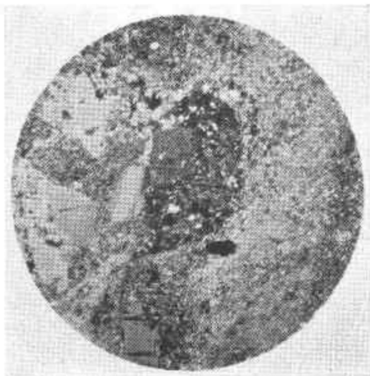


FIG. 1. Development of a plagioclase porphyroblast showing a shadow-like extension from a clear nucleus. The incipient porphyroblast shown in the photomicrograph is 1.5 mm. in length.

decussate structure is present, and a few sections appear to be typical "garbenschiefer" with plumed porphyroblasts of anthophyllite. Other sections contain varying amounts of garnet, diopside, epidote, titanite, chlorite, magnetite and pyrite. Garnet, diopside and epidote occur in irregular patches and lenticular veinlets which probably are similar in origin to the quartz-diopside-garnet veinlets commonly found in this area.[3]

Porphyroblastic textures are common. Some of the plagioclase porphyroblasts are from 2 to 5 mm. in size, so that megascopically the hornfels may easily be mistaken for a dark colored porphyritic igneous rock. Under the microscope the porphyroblastic nature is shown by the following evidence. Sieve structures, helizitic structures and crenulated borders are common. All gradations in development of porphyroblasts may be seen.

[3] Goodspeed, G. E., and Coombs, Howard, Quartz-diopside-garnet veinlets: *Am. Mineral.*, vol. **17**, pp. 554–561, 1932.

In the earliest stages of growth, some of the plagioclase porphyroblasts are anhedral, some are even amoeba-like in form, surrounding and including all other constituents. Some show a shadow-like enlargement starting from a clear feldspar nucleus and including the adjacent groundmass of the hornfels. One of the most bizarre forms of initial growth is the development of ring-like forms of clear unaltered plagioclase enclosing, or partially enclosing, the finer grained constituents of the hornfels or portions of the kaolinized groundmass. On casual inspection some of these ring-like forms might be explained by differential altera-

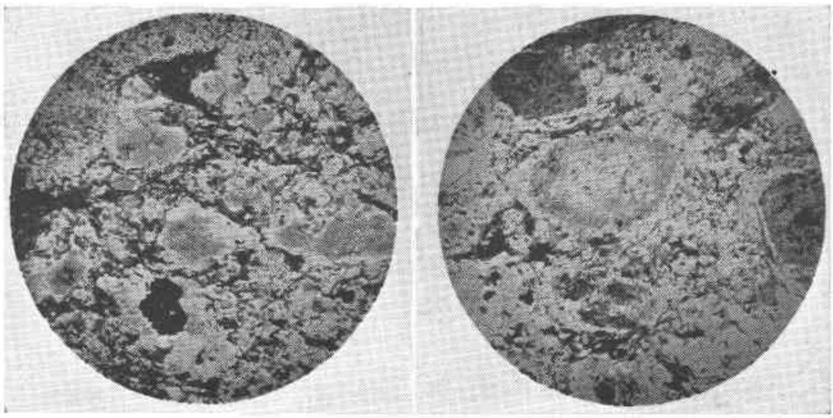


FIG. 2 FIG. 3

Plagioclase showing initial ring-like forms surrounding the groundmass. These initial porphyroblasts shown in this photomicrograph are ½ mm. in size.

tions, but the identical nature of the material enclosed by the feldspar with that of the groundmass and thin extensions of clear feldspar into the groundmass precludes this possibility.

The ring-like forms show slight variations in sodic and calcic content as is indicated by the variation in the extinction angle. In some the inner portion of the ring is more calcic than the outer portion, in others the outer portion of the ring-like crystal is more calcic. Some of the plagioclase porphyroblasts are similar to quartz porphyroblasts in that they are hardly discernible in plane light, although easily seen in crossed nicols.

Another point of similarity to the quartz porphyroblasts is the relationship of some of the porphyroblasts to ill defined spots or segregations of feldspathic material. One side of a spot may show a vague crystal outline, while another side has an irregular gradational contact with the groundmass. As might be expected, the stages of early crystalloblastic development are characterized by abundant inclusions. Even in these stages some crystals show Carlsbad and albite twinning, a feature which is similar to the twinning of cordierite in early stages. If crystallization proceeds from a center, these inclusions are forced to the periphery of the crystal, and then the porphyroblast tends to become free of inclusions.

Two or more plagioclase porphyroblasts may be grouped together, and for such groups it is proposed to use the term *glomeroblastic*, or if porphyroblasts of different minerals such as plagioclase and hornblende form the group, the term *cumuloblastic*. In some glomeroblastic groups the out-

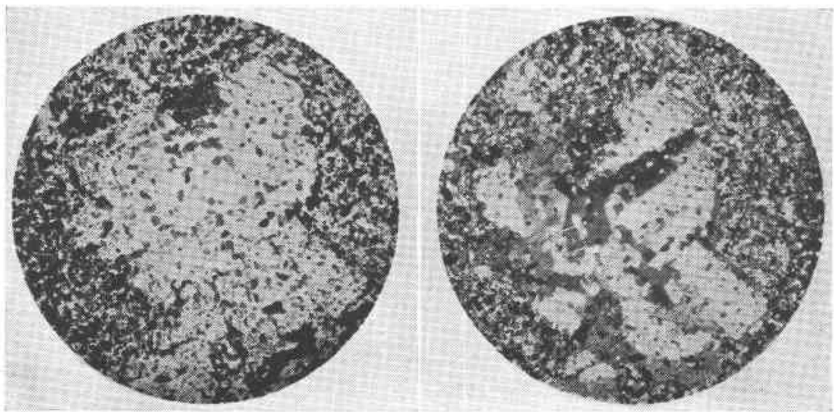
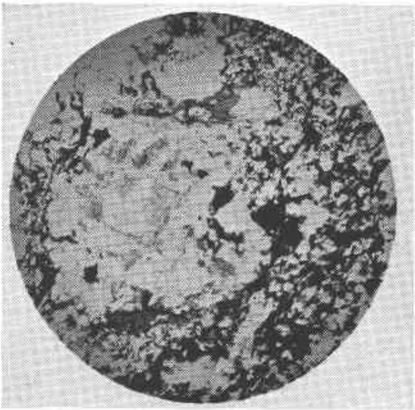


FIG. 4. Nicols not crossed. FIG. 5. Crossed nicols.
Photomicrographs showing the development of glomeroblastic aggregates 2 mm. in size.

lines of each crystal are traced by lines of inclusions forced out from the growing crystals. However, as these groups develop there is a tendency for the individual plagioclase crystals to coalesce and to form one individual. Both the outline and the internal structure of such crystals clearly reflect their mode of origin. In outline, sharp reentrant angles may be the result of the irregular growing together of several individuals. The original difference in composition in these crystals, as evidenced in zonal structure, may persist in the larger compound crystal giving rise to a very complex porphyroblast.

The association of kaolinitic material with some plagioclase porphyroblasts may persist throughout their development while others are clear even in the initial stages. It seems apparent that turbidity is in part dependent upon the size of the included material, and the sections seem to show that this included material may have been some of the original finest constituents of the rock, or may have been formed by hydrothermal alteration just prior to the formation of the porphyroblast, or perhaps contemporaneously with its development. Upon further growth the plagioclase porphyroblasts became subhedral with the kaolinitic material evenly distributed throughout the crystals. Then in later stages the turbid kaolinitic material appears to be segregated usually in the central portions of the crystals while in the last stages it is irregularly distributed or segregated along twinning planes.

The segregation of kaolinitic material may be analogous to the movement of inclusions by crystallization pressure.[4] The distribution of included material may be in part controlled by the initial form of the



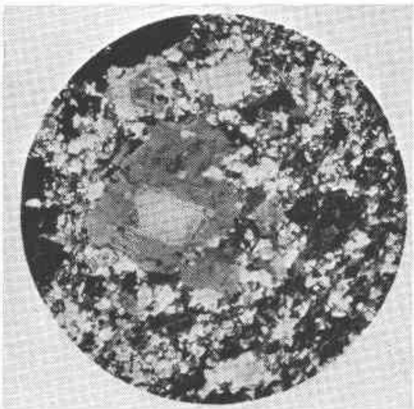


FIG. 6. Nicols not crossed. FIG. 7. Crossed nicols.
Coalescing of several smaller individuals to form a plagioclase porphyroblast, 1 mm. in size.

feldspar porphyroblast. In the growth of a ring-like form it would be reasonable to expect a tendency for the surrounded material to become concentrated in the center of the crystal. In the other forms a centrifugal rather than a centripetal direction of movement of inclusions would occur. Kaolinitic material thus associated with plagioclase porphyroblasts bears some resemblance to the product of subsequent hydrothermal alteration, but may be differentiated from it by careful petrographic study. Subsequent alteration material usually occurs as an infiltration along cleavage cracks of originally clear crystals or in traversing veinlets. This material is commonly associated with sericite, while the kaolinitic material which has accumulated during the crystallization of the feldspars is much finer in grain and more homogeneous. Kaolinitic material of both these modes of origin is quite distinct from that due to surface weathering. Many of the sections studied were taken from mine workings hundreds of feet below the surface.

[4] Harker, A., *Metamorphism*, Methuen & Co., London, **1932**.

In many sections, plagioclase porphyroblasts appear to have developed sporadically without any structural control. In others they seem to be genetically associated with small feldspar veinlets. The plagioclase in these veinlets is usually sodic in composition and the crystals commonly show random orientations in the veinlets. Plagioclase porphyroblasts extend from these veinlets into the groundmass of the hornfels. These sections suggest that hot aqueous solutions, probably alkaline in character, were one of the important activating agents in the feldspathization of the hornfels. During the crystalloblastic development of the plagioclase, varying amount of calcium might be derived by the replacement of calcium-rich materials. The more calcic zones of the porphyroblasts might be explained as due to the assimilation of included material which may have previously been segregated.

Recent petrographic studies of certain rocks of the Cascade Mountains of Washington reveal some excellent examples of porphyroblastic development of plagioclase crystals.[5] Transitional facies of an indurated sandy shale into an igneous-appearing rock afford an opportunity to contrast and compare authigenic with allogenic constituents. The plagioclase porphyroblasts commonly show a gradational relationship with surrounding material, as contrasted with the even boundaries of the detrital grains. The porphyroblasts may have hair line extensions into the surrounding material whereas the allogenic grains are usually minutely fractured and show an infiltration of the cementing materials into these fractures. In these rocks the feldspar porphyroblasts may be euhedral and usually exhibit an even distribution of turbidity in contrast to the clearness of the allogenic grains even of very small size. This turbidity is probably due in part to the inclusion of material and in part to the development of kaolinitic material incident to the formation of the feldspar.

The recognition of porphyroblastic development is one of the essential points of petrogenetic significance in the consideration of igneous-appearing rocks which have apparently been formed by recrystallization-replacement incident to additive hydrothermal alteration.[6] Doris L. Reynolds has recently pointed out that an igneous appearance both in hand specimen and thin section does not constitute evidence that it has crystallized from a magma.[7] These studies of porphyroblasts show that many features such as zoning, complex twinning or selective "alteration" are not necessarily limited to the crystallization of magmas and lavas.

[5] Goodspeed, G. E., and Coombs, Howard A., Replacement breccias of the lower Keechelus: *Am. Jour. Sci.*, vol. **34**, pp. 12–23, 1937.

[6] Goodspeed, G. E., Small granodioritic blocks formed by additive metamorphism: *Journal Geology*, vol. **45**, pp. 741–762, 1937.

[7] Reynolds, Doris L., Demonstrations in petrogenesis from Kiloran Bay, Colonsay. I. The transfusion of quartzite: *Mineral. Mag.*, December, **1936.**