3-D Analysis of Garnet Porphyroblast with Computed High-resolution X-ray Microtomography

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Introduction

Garnet porphyroblasts occurring in the marginal part of the Schneeberg Complex (Italian Alps) form ellipsoidal pods consisting of thousands of tiny garnet grains that are very small in the center and larger along the porphyroblast margin. Orientation contrast (OC) imaging by using the scanning electron microscope reveals that the larger marginal garnet grains comprise a number of orientation subdomains (Fig. 1).

Electron backscatter diffraction (EBSD) shows that small, individual garnet grains are randomly oriented. Large marginal garnet grains and subdomain-bearing garnet grains have a strong preferred orientation, clustering around a single garnet orientation.

FIG. 1. OC image of ellipsoidal garnet porphyroblast from the Schneeberg Complex. Subdomains with different crystallographic orientations have contrasting grey shades.

The available compositional data are explained best by a porphyroblast growth mechanism [1] that implies simultaneous, multiple nucleation, followed by growth and amalgamation of individual garnet grains.

The crystallographic orientation data suggest that individual garnet grains rotated toward coincident orientations once they came into contact with each other.

Although the principles of the porphyroblast growth mechanism within the Schneeberg Complex [1] are explained satisfactorily, two important questions remain unsolved. (1) What controlled coalescing garnet grains to align toward a common crystallographic orientation? (2) What kinetic factors determined that within the marginal part of the Schneeberg Complex, garnet grains coalesced partially, whereas in the rest of the Schneeberg Complex, they coalesced completely to form large, single-garnet porphyroblasts?

Methods and Materials

A potential explanation for the single crystallographic orientation of coalesced garnet grains may be that at the time of nucleation, a 3-D network of nuclei with a preferential orientation existed, which forced all other grains to rotate toward this orientation during coalescence. If this preferred crystallographic orientation of nuclei were statistically not dominant in 2-D, it would not have been recognized from the distribution of orientation data plotted within pole figures. Verifying this assumption requires 3-D analysis of the porphyroblasts with EBSD and, therefore, serial grinding. In order to select the appropriate porphyroblast for EBSD serial analysis, precise preliminary information on the degree of coalescence and the size of the ellipsoidal pods that will be analysed is needed. This can only be obtained by high-resolution computed x-ray microtomography.

Results

High resolution x-ray microtomography has been performed at GeoSoilEnviro Consortium for Advanced Radiation Sources (GSECARS) station 13 on seven cylinders 21 mm in length and 10 mm in diameter drilled through the mica schists of the Schneeberg Complex. A spatial resolution of 14 μm/pixel was used to obtain information on the shape, size, and degree of coalescence of the ellipsoidal garnet porphyroblasts contained within the mica schists. Figure 2 shows a single microtomographic slice through one of the rock cylinders. The brightly colored ellipsoidal objects within the darker matrix are the garnet porphyroblasts. Biotite within the matrix can be distinguished from white mica, quartz and feldspar because of the lighter grey shade. The very bright spots are ilmenite crystals.

The porphyroblast in the lower central part of Fig. 2 has been cut off from the cylinder for further analysis at higher resolution (Fig. 3). The resolution in Fig. 3 (7 μm/pixel) is so powerful that even the smallest garnet grains within the ellipsoidal pod can be recognized.

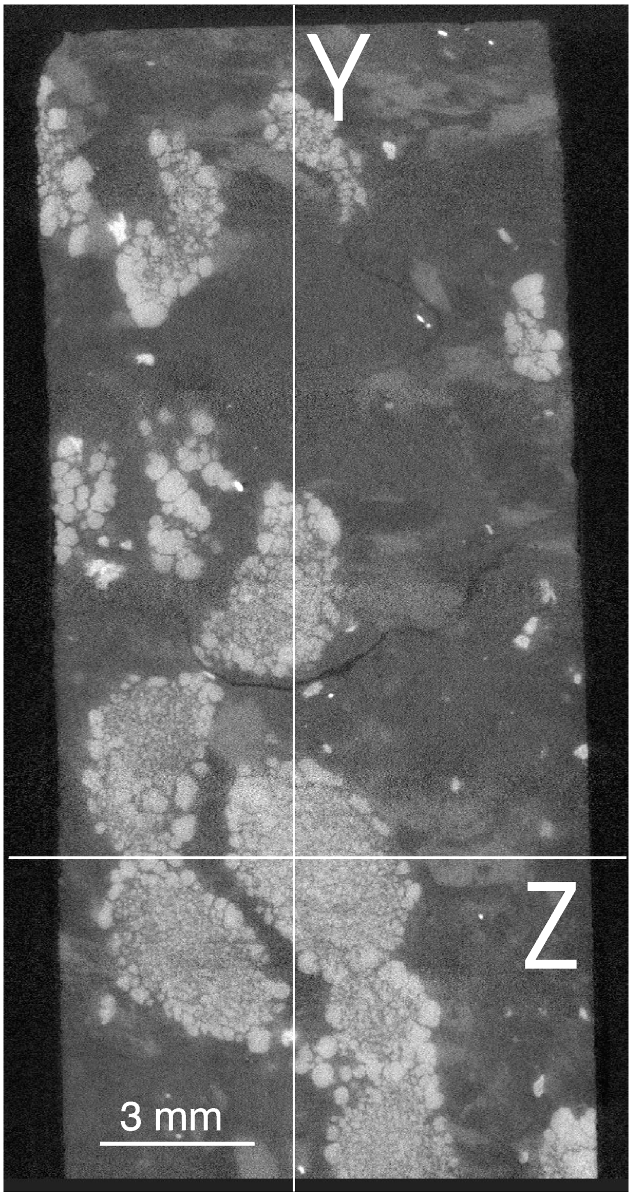

FIG. 2. Single microtomographic slice through a cylinder of mica schist from the Schneeberg Complex (length of cylinder = 21 mm). Slice is parallel to the foliation/X-slice). Garnet grains (bright) form ellipsoidal porphyroblasts. The matrix around the porphyroblasts consists of biotite (light grey), quartz, plagioclase, and white mica (all dark grey). Very bright spots are ilmenite crystals.

Discussion

The slices through the cylinders have been used to precisely localize the porphyroblasts that are used for EBSD serial grinding analysis. This work is under progress and will eventually result in a complete 3-D reconstruction of the Schneeberg garnet porphyroblast and a more thorough understanding of the mechanism that led to the porphyroblast formation.

High-resolution images like that in Fig. 3 will be used for cluster size distribution (CSD) analysis in order to compare the CDS within the pods with the CDS predicted by a numerical porphyroblast growth model [2]. This approach will be used to solve the problem on the kinematics that controlled the porphyroblast formation in the Schneeberg Complex.

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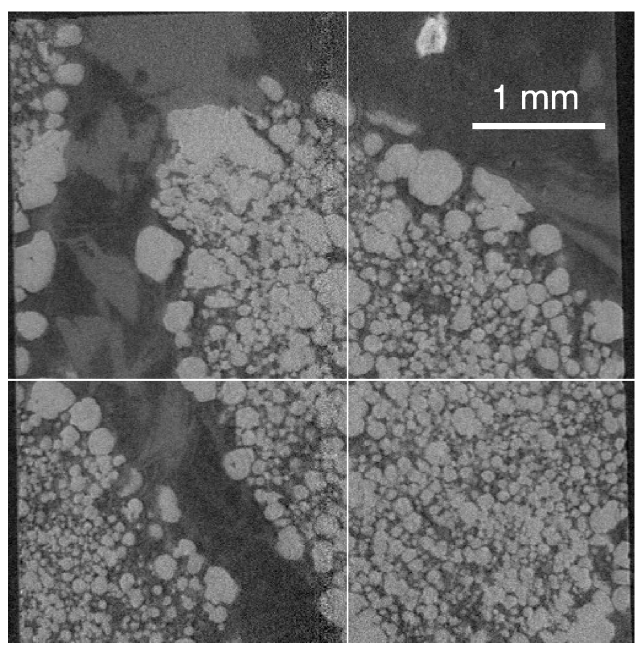

FIG. 3. Single microtomographic slice through the porphyroblast in the lower center in Fig. 2.

References

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