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Short-distance melt migration during crystallization read from spatial distribution of minerals

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In this presentation, the author shows (1) clustered spatial distribution of minerals observed in granite specimens, (2) clustering phenomenon of crystal grains occurred in cooling experiments with diopside-anorthite system, and finally (3) conclusion obtained through the comparison between the natural and experimental textures.

The observation of granitic rock textures gives the author the impression that the many granitic rocks have clustering texture of minerals. Since the random spatial distribution also shows some clustering portions, a spatial distribution analysis is required in order to confirm whether granitic rocks really have the clustering texture. The author performed spatial distribution analysis of minerals in two granite specimens with 'nearest neighbor spatial analysis method' proposed by Jerram et al. (1996). Large thin sections of the granite specimens were made and all crystal grains were extracted (traced) and digitized (as binary image) using two polarizing films. The coordinates of center points of all grains in the binary images were determined by image analysis and the spatial distribution of the center points was analyzed using the method by Jerram et al. This analysis revealed that the crystal grains of each mineral (quartz, K-feldspar and plagioclase; except biotite) has clustered spatial distribution. If we assume the nucleation at random points and subsequent growth during cooling, the final texture should have random spatial distribution. The clustered distribution is not agreement with the simple crystallization model.

The author discovered the clustering phenomenon in experiments using diopside-anorthite binary system. The starting material with chemical composition of diopside 90 + anorthite 10 (wt%) was hold in the solid (diopside) + melt region in the phase diagram of the binary system. Subsequently the sample was cooled to quenching temperatures. The ratio of solid-melt interfacial energy to solid-solid grain boundary energy (corresponding to dihedral angle at solid-melt-solid triple junction) varied with temperature and cooling conditions. When the interfacial energy ratio exceeded a threshold value, diopside clusters including no melt were formed as a result of melt expulsion. On the contrary, when the interfacial energy ratio decreased by the change of cooling condition, the clusters collapsed into individual diopside grains as a result of melt infiltration into grain boundaries. These textural changes probably occurred to decrease total interfacial energy in the system. Short-distance melt migration (expulsion and infiltration) is an elementary process of such textural change. Of course, the melt migration here is not 'flow of melt' but presumably 'material transport depending on the chemical processes such as dissolution, diffusion and precipitation'.

The clustering texture observed in granite specimens is similar to the clustering texture obtained in the experiments. Thus the clustering texture in the granite specimens is considered to be formed by the short-distance melt migration (melt expulsion) depending on the high value of the interfacial energy ratio. It is not clear that such short-distance melt migration influences on the large-distance melt migration of magma and large-scale magmatic processes, though Nakamura & Watson (2001) showed that the interfacial energy-driven aqueous fluid migration (infiltration) could contribute to fluid flax in the Earth at least over a short-distance. Finally in this presentation, the author suggests that it is possible to read the traces of short-distance melt migration during crystallization by spatial distribution analysis of minerals in igneous rocks.

[References] Jerram et al. (1996) Contrib Mineral Petrol, vol.125, 60-74 ; Nakamura & Watson (2001) Geofluids, vol.1, 73-89