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Fluid flow along cracks inferred from the textures of the polymineralic veins from the Sanbagawa belt

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Sealed cracks in high-pressure metamorphic rocks provide direct evidence of earlier fluid-filled cracks that existed within subduction zones, but the implications of such cracks for fluid flow and material transport are poorly understood. Pelitic schists of the Sanbagawa metamorphic belt in the Nagatoro area, Kanto Mountains, contained commonly two types of veins at the time of exhumation of the rocks: quartz + albite + K-feldspar + chlorite (Type I and I') and quartz + albite + calcite (Type II). Type I veins contain elongate quartz and albite grains that grew from the vein walls (stretched crystal texture) and show a mineral distribution related to compositional bands within the host rocks. Type I' veins show the elongate-blocky textures. Type II veins are characterized by euhedral to subhedral quartz grains with concentric zoning (blocky texture) and a homogeneous mineral distribution along the vein length. The degree of microstructural variation within the observed veins was controlled by the crack aperture during multiple crack-seal events: less than 0.08 mm for Type I and 0.5-10 mm for Type II. These observations suggest a transition in the dominant transport mechanism of vein components with increasing crack aperture, from diffusion from host rocks (Type I) to fluid advection (Type II).

Blocky veins are commonly found in various geological settings. However, there are few studies that focus on this microstructure, because blocky texture can also be secondary due to plastic deformation or annealing subsequent to vein formation (Bons, 2000). The euhedral shape and concentric zoning of quartz in Type II veins clearly indicate a primary texture related to homogeneous nucleation and growth in fluid-filled cracks. When fluid within a crack was static during the formation of Type II veins, the settling of quartz grains should have rapidly proceeded as similar to accumulation in magmatic dikes. However, low viscosity of water (10^{-4} Pas) and large density difference between quartz and water (1.7 x 10^{3} kg/m^{3}) are quite different with those for magmatic ststem. Following the Stokes's law, the settling velocity increases with increasing grain size. In contrast, in the case that a number of grains existed within a single crack, the settling velocity lowered with increasing volume proportion of particles (Barnea and Mizrahi, 1973). Considering quartz grains with size of 0.01 - 0.1 mm observed in Type II veins, the settling velocity is calculated to be 0.01 - 0.05 m/s. This simple estimates suggests that quartz grains should have settled within a interval of 20 - 100 seconds in an open crack with the vertical length of 1 m.

Nevertheless, there is no evidence of crystal settling during the formation of Type II veins. Quartz grains with euhedral and concentric growth zoning indicates the grain growth without the affect of vein walls, and their crystal size distributions also indicate continuous nucleation and growth without significant affects of crystal segregation. A possible explanation for crystallization of quartz within a crack without the settling is that fluids flowed upward with the velocity that was balanced with that of crystal settling. Thus, the settling velocity estimated above (0.01 - 0.05 m/s) may indicate the extremely high velocity of the upward fluid flow through Type II veins.

References

Bons, PD (2000) Journal of Explore.

Barnea E, Mizrahi J (1973) Chemical Engineering Journal, 5, 171-189.