Kinetics and textural development of quartz vein

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Quartz veins are common in various geological settings such as low- to medium grade metamorphic rocks, fault rocks, and hydrothermal systems. These veins may provide direct evidences of fluid flow under crustal conditions. Quartz veins in natural systems generally contain two types of textures. First type is characterized by elongate crystals that grow from quartz crystals within vein walls (elongate-blocky, fibrous, stretch crystals textures). Second type is filled with euhedral to subhedral crystals (blocky texture). Such a variation in vein texture may result from relative rates of nucleation and epitaxial growth during crystallization within fluid-filled cracks, but the controlling factors to generate textual variation arepoorly understood.

We conducted hydrothermal flow-through experiments in order to understand the dissolution/precipitation kinetics of quartz and development of quartz vein texture. The experimental conditions are 150 - 430 degreeC at 30 MPa. At this pressure, quartz solubility is maximum at 360 degreeC (CSi = 450 ppm, [1]). The experiment apparatus is composed of two parts: dissolution (R1) and precipitation (R2) tubes, which temperatures are controlled independently. Solutions before and after passing R2 tube were sampled and the compositions were measured by ICP-AES.

As the first series of runs, we observed dissolution of 31g of quartz sand (1 - 2 mm) using only R1. We sampled the solution after passing through R1 at constant flow rate of 1.01 g/min. The Si concentration in solution increases 0.6 to 290 ppm with increasing temperature from 150 to 390 degreeC. In this experimental design, the reaction time decreases with increasing temperature depending on a change of the specific volume of water. The precipitation rate constant, k-, can be obtained from these data using the equation of

k- = - (M/A)(1/t) ln (1 - C/Ceq), (1)

where A and M indicate non-dimensional parameters of reactive surface area, and mass of water, respectively [2]. From the slop of the Arrhenius plot, the activation energy of precipitation is estimated to be 51.1 kJ/mole. This value of the activation energy is very consistent with the estimates of Rimstdt and Barnes [2] by batch experiments under temperature less than 300 degreeC (49.8 (11.9) kJ/mole). Rimstdt and Barnes [2] suggested that the rate-limiting process will change around 300 degreeC from surface-control to diffusion-control. However, our result show that there is no mechanism change over temperature range of 150 - 400 degreeC.

In the second series of runs, we set granite plates with size 4.5 x 4.5 x 30 mm in both R1 and R2 tubes. Temperatures of R1 and R2 were set at 360-370, and 390-430 degreeC, respectively. In R1, quartz was preferentially dissolved. At the precipitation sites, we found two types of precipitation textures as follows. On the granite surface, quartz grew epitaxially on pre-existing quartz grains within granite. In other parts, sedimentation of euhedral quartz crystals with size of 0.01-0.5 mm was observed on the surface of SUS tube. These textures in different sites are very similar to elogate-blocky and blocky textures in natural quartz veins, respectively. Growth zoning of quartz can be observed by SEM-CL imaging. A theoretical consideration suggest that homogeneous nucleation rate of quartz drastically increase under conditions C/Ceq larger than 20, whereas the experimental condition is C/Ceq = 2 - 4. We do not know why epitaxial growth and nucleation + growth occurred simultaneously in our experiments, and what control the crystallization processes, but one of essential factors may be relative ratio of quartz surface area / mass of water.

[1] Founier and Potter (1982) Geochim Cosmochim Acta 46,1969-1973.
[2] Rimstdt JD, Barnes HL (1980) Geochim Cosmochim Acta, 44, 1683-1699.