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Silica nanoparticles produced by flash vaporization and their rapid diagenesis in hydrothermal fluids

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Dissolution and precipitation of silica play dominant roles on spatial and temporal changes of hydrological and mechanical properties of the Earth's crusts, and on evolution of geothermal reservoirs and hydrothermal mineral deposits. Since the solubility of quartz is a function of water density, decompression of geofluids is one of the plausible causes of silica precipitation [1, 2]. Weatherley and Henley [2] suggested that at the time of earthquakes, decompression could occur to the level below hydrostatic pressure (i.e. vapor) at fault jogs, and that such flash vaporization produces gold-quartz veins. However, the mechanism of silica precipitation is quite unclear under such extremely high-supersaturated conditions related to phase transition of water, because silica has several polymorphs, including quartz, cristobarite and amorphous silica [3]. In this study, we carried out a series of silica precipitation experiments by flashing from sub- and supercritical conditions. We also examined the diagenetic changes of the produced silica particles in hydrothermal fluids.

The flashing experiments were carried by using 110 cc autoclave (inner wall was made by titanium). In each run, we put the high Si solution (Si 258 mg/kgH_2O; Al 5.8 mg/kgH_2O; Na 6.8 mg/kgH_2O; K 7.7 mg/kgH_2O), which was prepared by dissolution of granite + quartz sand at 350 ˚C and 35 MPa. After rising temperature and pressure, the stop valve was opened to release the fluids to air, and the silica precipitates were caught by the alumina filter. We conducted a series of flashing experiments with different initial P-T conditions; 250, 350, 400, 450 ˚C at 36 MPa.

In all experimental conditions, the nearly isothermal decompression occurred to the vapor pressure within 1 second. Spherical silica particles were stacked on the alumina surfaces with size of 0.1- 2 μm, indicating that silica was precipitated as amorphous silica, regardless the difference in the type of H_2O phase transition (from liquid to vapor, from supercritical fluid to vapor). Some of silica precipitates were moved to the second diagenesis experiments, where the silica particles were placed in the batch autoclave at the same temperature with flashing. After the diagenesis experiments, we found the systematic changes of silica particles to more stable phases. At 250 ˚C, the silica particles changed to bladed cristobarite aggregates after 1 week. In contrast, at 350 ˚C, the transformation to cristobarite proceeded within a few days, and changed to quartz within 1 week. At 400 ˚C, the transformation of quartz proceeds within few days, which skipped the cristobarite stage. Such rapid transformation following the Ostwald step rule occurs due to high temperature and fine particle size. Such formation of silica nanoparticles, and rapid transformation to quartz is and causes the rapid clogging of the fractures and mineralization within the shallower parts of the crusts.

References

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