Characteristics of precipitation of amorphous silica and its influences on permeability of fractured granite in superhot geothermal environments

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Superhot geothermal environments (above ca. 400˚C) represent a new geothermal energy frontier. However, the networks of permeable fractures capable of storing and transmitting fluids are likely to sealed by a rapid precipitation of amorphous silica in response to an occurrence of high-level of supersaturation for amorphous silica due to a phase change between liquid water, steam, and supercritical water. Here we report results of two sets of hydrothermal precipitation experiments at 400-500 ˚C and 20-35 MPa, which were respectively conducted to investigate characteristics of precipitation of amorphous silica and its influences on permeability of fractured granite in superhot geothermal environments. In the first set of the precipitation experiments, liquid water with a prescribed Si concentration, which was prepared from water that dissolved granite at 360 ˚C and 35 MPa, was injected to a stainless-steel pipe, in which amorphous silica was precipitated at a prescribed combination of temperature (400-500 ˚C), pressure (20-35 MPa) and degree of saturation (1.5-2.5). As a result, spherical particles of amorphous silica of <10 μm (typically, 0.2-1.0 μm) were precipitated at all conditions. These particles tended to become smaller and aggregated with increasing temperature or degree of saturation (i.e., with increasing rate of nucleation), while there was no significant influence of pressure. Based on this finding, the second set of the precipitation experiments to investigate influences of the amorphous silica particles on permeability of fractured granite was conducted at 450°C, 25 MPa, and different degrees of saturation. The above-mentioned liquid water with a prescribed Si concentration was injected into a thermally fractured granite containing multiple fractures at an effective confining stress of 10 MPa, where initial permeability of the fractured granite was relatively high (ca. 10^{-16} m^2) because of the presence of fractures having relatively large apertures of >10 μm. As a result, permeability did not decrease with time at both conditions for the formations of larger and dispersed particles, and smaller and aggregated particles. This finding indicates that precipitation of amorphous silica does not always reduce permeability of fractured granite immediately, and silica particles will move to other locations after its formation. Therefore, in producing superhot geothermal energy, amorphous silica particles will be produced via a production well or will be trapped within fractured granite having a relatively lower initial permeability, therefore relatively smaller apertures. Although the present study has not been completed yet, it is suggested that in case of a superhot geothermal reservoir with permeability aperture large enough to transmit the amorphous silica particle, the permeability may not be destroyed even if precipitation of amorphous silica occurs rapidly.