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The maximum depth of the hydrothermal-convection zone in the crust controlled by the precipitation of silica minerals

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Precipitation of silica minerals ubiquitously occur in crustal environments. Quartz is the most stable phase of silica. Metastable silica polymorphs, such as amorphous silica, cristobalite, and chalcedony, also form in the surface and subsurface silica deposits. The dissolution-precipitation of silica minerals has a significant effect on both mechanical and hydrological properties of the Earth's crust. However, the structure of the crust has been studied mostly in geophysics, not in geochemistry.

Here we interpret the maximum depth of the hydrothermal-convection zone at Kakkonda geothermal field, Japan, on the dissolution-precipitation of silica minerals. The drilling of the well WD-1a at Kakkonda encountered the temperature exceeding the hydrostatic boiling-point curve, over 500 C at 3729 m depth (Doi et al., 1998). The boundary between the hydrothermal-convection zone and the heat-conduction zone was found at 3100 m depth because of the critical change of permeability.

First we calculated the quartz solubility along the P-T conditions of the WD-1a (Ikeuchi et al., 1998). The quartz solubility had the local minimum value at 3100 m depth which coincided with The boundary between the hydrothermal-convection zone and the heat-conduction zone, suggesting that quartz could precipitate from both upflow and downflow fluid at the boundary.

Next we conducted the hydrothermal flow-through experiments to investigate the temperature dependence of the precipitation of silica minerals. The P-T conditions for precipitation were from 170 to 430 C and 24 MPa. Any rock/mineral substrates were not used in the precipitation vessel. The initial solution was made by dissolution of granite at 350 C and 24 MPa. The Si concentration in the input solution, from 330 to 350 ppm, rapidly decreased to the quartz solubility at over 400 C. The experimental results indicated that quartz precipitation associated with nucleation occur dominantly at high temperature whereas it associated with quartz growth on quartz surfaces only occur at low temperature.

A large amount of quartz precipitate is expected to seal the fractures and to block the downflow fluid efficiently. The maximum depth of the hydrothermal-convection zone in the geothermal fields may reflect the significant precipitation of quartz at high temperature.

References) Doi, N., Kato, O., Ikeuchi, K., Komatsu, R., Miyazaki, S., Akaku, K., and Uchida, T., Geothermics, 27, 663-690, 1998.; Ikeuchi, K., Doi, N., Sakagawa, Y., Kamenosono, H., and Uchida, T., Geothermics, 27, 591?607, 1998.

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