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The formation of the permeable-impermeable boundary within the Earth's crust revealed by silica precipitation

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Silica is one of the dominant constituents of the Earth's crust. The permeable-impermeable boundary corresponds to the brittle plastic transition at 300-450 C [1]. Ubiquitous occurrence of quartz vein is one of the evidences that the spatial and temporal variations in permeability within the Earth's crust are affected by silica precipitation in aqueous fluids. However, the role of silica-water interaction on fracture permeability is still unclear.

The Kakkonda geothermal field, Japan, has the well WD-1a that penetrated the boundary between the hydrothermal convection zone and the heat conduction zone [2]. Calculation of quartz solubility along the well WD-1a revealed that (1) the depth of a local maximum of quartz solubility correlates with that of the strong reflector in seismic data at 350 C isotherm [3], and that of a maximum of fracture numbers revealed by the logs of FMI [4], and (2) the depth of a local minimum of quartz solubility correlates with that of the permeable-impermeable boundary, in either case of hydrostatic or lithostatic conditions [5]. These results indicate that (1) the preservation of open fractures at the margin of the Kakkonda granite is controlled by dissolution of quartz, and (2) the quartz precipitation could occur from both downwards- and upwards-moving fluids, which could divide the hydrothermal convection zone and the heat conduction zone.

The hydrothermal experiments of temperature dependence of silica precipitation were conducted at 24 and 31 MPa and 170-430 C, by using the solution made by dissolution of granite. The large amount of silica precipitation occurred only in the supercritical conditions of water (>390 C). Strong temperature dependence can be explained by the homogeneous nucleation of quartz in the surface energy of quartz of 130 mJ/m^2 [5].

The results of the calculation of silica solubility at the Kakkonda geothermal field and the hydrothermal experiments of silica precipitation suggest that rapid quartz precipitation via nucleation could occur when fluids are brought to the depth in the supercritical conditions of water. The forming and sustaining the permeable-impermeable boundary within the Earth's crust could be controlled by precipitation of silica minerals.

References
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