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Porosity structure and permeability reduction by mineral dissolution in a fracture

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Fractures act as dominant fluid pathways within the crust. Fluid usually control transport of energy and heat. Silica solubility generally increases with increasing pore pressure and temperature, and thus dissolution and precipitation of silica would provide significant effects on fracture permeability. Even by dissolution of minerals within a single fracture, dissolution at free (non-contact) areas increases the aperture, whereas dissolution at the contact areas decreases the aperture, therefore it is not clear how fracture permeability evolves by mineral dissolution under confining pressure.

In this study, we conducted the hydrothermal flow-through experiments at 350 ℃, 20˜34MPa under confining pressure 10˜15MPa to understand the evolution of porosity structure of a fracture and permeability change in granite by mineral dissolution. For this purpose, we developed a novel reactor, which has a inner tube in the vessel. Two types of granite core (Aji granite, ϕ10mm) were used, first one (85mm length) contained a slit with thickness of 0.5mm as parallel prates flow path. The other one contained the tensile fracture with no shear displacement. During the experiments under constant flow rate, we monitored the fluid pressures, and periodically sampled the solutions. After the experiments, we analyzed the porosity structure by X-ray CT (resolution was 10μm/pixel).

In slit-core experiment, the concentrations of Si was 100˜120 mg/kg, whereas the concentration of Al, Na, K were 7, 5 and 8 mg/kg respectively, indicating that the ration of dissolved volume of quartz, plagioclase and K-feldspar are 10:2:1. The X-ray CT also revealed that preferential dissolution of quartz, and that the average aperture increases especially near the inlet.

In tensile fracture experiment, fracture permeability decreased continuously from 10^{-13} to 10^{-15} (m^2) during the experiment of 90h. An increase in flow rate did not enhance the reduction whereas that in confining pressure accelerated the permeability reduction. The X-ray CT images revealed the complex structure of porosity: quartz dissolution made the local increase in the aperture, but the overall aperture decreased by dissolution of quartz and feldspar at contact areas, which is responsible the permeability reduction.

Keywords: permeability, fracture, hydrothermal experiment, dissolution