Channeling flow generated by dissolution of granite fracture under hydrothermal conditions.

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Fractures act as dominant fluid pathways within the crust, and provide significant influences on transport of energy and heat. As silica solubility increases with increasing pressure and temperature, dissolution and precipitation of silica would provide significant effects on fracture permeability in the crust. Even for mineral dissolution within a single fracture, dissolution at free (non-contact) areas increases the aperture, whereas that at the contact areas decreases the aperture; therefore it is not clear how fracture permeability evolves by mineral dissolution under confining pressure.
The aim of this study is, based on the hydrothermal flow-through experiments, to reveal a porosity structure and permeability evolution during the dissolution of granite fracture. We developed a novel reactor, which enables us flow-through experiment under confining pressure at sub to supercritical condition (up to 350 ℃, and examined the porosity structure by X-ray CT repeatedly. In the experiments, fine-grained Aji granite core (Φ10 mm, 400 mm in length) was used. We conducted two series of hydrothermal experiments. First one is fluid flow through a slit (parallel plates) in the rock core. The analyses of solution chemistry passing through the slit and surface morphology revealed that quartz dissolved preferentially; Qtz was dissolved about five times greater than plagioclase.
Second experiments were performed with a tensile fracture introduced by Brazilian test, in which there was no shear displacement. In this fracture, very fine-grained gouge (granite powder) existed within some parts of the core sample. This experiment was conducted in three steps; at all steps, the fluid pressure was 20 MPa and confining pressure was 40 MPa (the effective pressure of 20 MPa). The first step was the flow through experiment (0.5 ml/min) at room temperature. At this stage (0-140h), fracture permeability decreased from 2.3×10^{-10} to 6.7×10^{-12} (m^2), which is consistent with decrease in mean aperture from 65 to 36 μm revealed by X-ray CT images. At the second step (140-290 h), the core sample was set without fluid flow (stagnant fluid) at 350 ℃. At this stage, permeability continuously decreased from 6.7×10^{-12} to 4.0×10^{-12} (m^2), corresponding to the decrease in aperture from 36 to 21μm. During the interval of stages 1 and 2, the aperture decreased uniformly for the entire fracture plane. These finings indicate that the aperture decrease attributes to the compaction of gouges within the fractures. At the final stag (290-300 h), flow though experiment (0.5 ml/min) was conducted at 350 ℃. At this stage, permeability recovered immediately toward 8.5×10^{-12} (m^2), and complex aperture structure was developed by mineral dissolution. Preferential dissolution occasionally occurred at the quartz grains as found in the experiment with a slit, but an interesting feature is that connected porosity network was developed regardless the minerals on the fracture plane. A flow simulation with using the X-ray CT-based 2D aperture distribution indicates that the preferential flow path (channeling flow) was developed along this porosity network. We interpret that this flow path was developed by preferential dissolution of gauge in the fracture. In contrast, the preferential dissolution of quartz does not contribute the flow due to the isolated distribution of quartz in granite. In natural settings, gauge was produced in fractures during fracturing or faulting of a rock. Our experiments suggest that, even when the initial aperture was very small for these gauge regions, the preferential dissolution occur due to significant surface areas of the gauges, which would significant effects on the formation of the preferential flow path under hydrothermal conditions.

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