G061-012 Room: C409 Time: May 29 13:30-13:45

Gas permeability evolution of cataclasite and fault gouge during tri-axial deformation at high pressures

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Fault zones are generally under differential stress in a stress field that may change through the cycle of fault activity. The permeability evolution of fault rocks during deformation should therefore be investigated in constructing a realistic model for permeability structure of fault zones. However, few data exit on permeability evolution of faults rocks during deformation. In this study, we performed axial compression experiments to investigate the axial permeability evolution during deformation of cataclasite and fault gouge, which are considered typical fault rocks experiencing brittle deformation or cataclastic flow.

Fault rocks measured in this study were collected from the fault zone of the Median Tectonic Line in Oshika, Nagano prefecture, central Japan. The host rock of the cataclastite is thought to be Ryoke tonalitic mylonite. The cataclasite is cemented by calcite. In this study, we collected samples from two cataclasites AK0916A and AK0916C. Fault gouge, which is black and relatively coarse (0.1-0.25mm in modal diameter), consists mainly of clay minerals. The samples were cylindrical in shape, with diameters of 20mm and 25mm for cataclasite and fault gouge respectively, and lengths of 22-25mm (AK0916C), 40-44mm (AK0916A) and 37-44mm (fault gouge). We made samples of cataclasite by laboratory coring from blocks using a 20mm internal diameters diamond core. Samples of fault gouge were collected by pushing a steel tube of 25 mm in diameter into the outcrop approximately parallel to foliation. Samples were dried at a temperature of 80 degrees for several days prior to permeability measurements to eliminate any pore water. We measured permeability with a gas-medium deformation apparatus at Kyoto University, using nitrogen as pore fluid at room temperature. For each rock, the experiments were done under three different effective pressures (20, 50, 80MP for fault gouge and AK0916C; 10, 20, 50MPa for AK0916A). The axial velocity was 0.001mm/sec for all samples of fault gouge and AK0916C, and was 0.0001-0.001mm/sec for AK0916A. Permeability was measured using the pore-pressure oscillation method under a pore pressure of 20MPa, or gas-flow method for constant pressure difference (- 2MPa for upstream pore pressure, and atmospheric pressure for downstream pressure). The strength of samples was also measured during deformation. Axial and circumferential strains were measured during deformations for the samples of AK0916A by putting strain gauges on them in directions parallel and perpendicular to the sample cylinder axis.

The experiments revealed marked effects of deformation on the permeability of fault rocks. Permeability of fault gouge, which was 10^-15 - 2x10^-14m^2 before deformation, decreased rapidly by about 2 orders of magnitude during initial loading and continued to decrease slowing even during inelastic deformation. When axial strain was 20%, permeability was 5x10^-18 - 2x10^-16m^2. The initial drop in permeability is much smaller for cataclasite (at most about 2 orders of magnitude), after which permeability abruptly increases upon failure (when the strength was around 1/3 to 2/3 of the failure stress). The permeability of cataclasites before deformation was 5x10^-20 - 7x10^-19m^2 (AK0916A) and 3x10^-19 - 10^-17m^2 (AK0916C), and 10^-20 - 10^-17m^2 (AK0916A) and 4x10^-18 - 4x10^-16m^2 (AK0916C) after deformation. The overall change of permeability correlates well with the initial, nearly elastic contraction and subsequent fracture dilatancy upon the initiation of inelastic deformation. If cemented cataclasites deform prior to or during earthquakes, cataclasite zone can be a site of fluid flow. But gouge zones are unlikely to switch to a permeable zone upon the initiation of fault slip. Thus permeability structures may change abruptly prior to or during earthquakes; the permeability of the fault gouge zone may decrease, while that of the cataclasite zone may increase.