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Evolution of Microstructure and Flow Properties of Fault in Neogene siliceous Mudstone

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When we evaluate patterns of flow and mass transportation through underground space, fractures and faults in rocks cause severe uncertainties. The uncertainties are partly from those in flow properties of a single fracture or fault. The flow properties of a fault and fracture generally depend on several factors such as intact rock properties or stress conditions. It is therefore important to evaluate dependencies of flow properties through a single fault on several factors, for evaluation of their effects on flow properties of bulk rock mass.

We operated laboratory experiments to measure flow rate through a mudstone specimen during axial deformation under confining pressure, with siliceous mudstone from Koetoi and Wakkanai Neogene Formations, Horonobe, Hokkaido. Main origins of Koetoi and Wakkanai Formation (Fm.) mudstones are the same, fossil diatoms, but phases of amorphous silica are different; at the boundary between these Fms., the phase changes from Opal-A to Opal-CT. Therefore Wakkani Fm. mudstone is denser and harder than Koetoi Fm. mudstone. Japan Atomic Energy Agency (JAEA) has done detail researches relating to flow properties of rock mass at underground situation, including by drilling cores or borehole explorations down to the depth of several hundred meters to a few kilometers in this region. Previous studies indicated that in-situ flow path tends to concentrate at some locations, which seems to match with the locations of faults and fractures in Wakkanai Fm., while, in Koetoi Fm., this tendency is weak. This difference can reflect differences on characteristics of flow properties of faults. Therefore we operated laboratory experiments with these rocks and tried to examine this possibility.

We adopted a specimen arrangement similar to experiments of Takahashi (2003, JGR); we put a cylindrical mudstone specimen of 20mm in length and 20mm in diameter between cylindrical Berea sandstone specimens of 10mm in length and 20mm in diameter. The mudstone specimen is intact, but the sandstone specimens have saw-cut plane of which an angle is 30 degrees with respect to the axis of the specimen. The sandstone specimens are set at the both side of the mudstone specimen so that the saw-cut planes are on the same plane, in order to induce shear zone in the mudstone specimen when axial force is applied. The advantage of this method is that we can see if flow rate along induced shear zone, or fault, is effectively large comparing to the intact part of mudstone.

We set confining pressure and average pore pressure as 8.3 and 4.9MPa, respectively, considering the condition of a depth of approx. 500m in this region. We used distilled water as a pore fluid and operated the experiments under room temperature. We applied an axial displacement with a constant velocity, 0.2um/sec, and measured permeability of the axial direction by oscillation pore pressure method. We used specimens prepared from three locations of the drilling core of HDB 10; 43.2m, 264.0m, (Koetoi Fm.), and 385.0m (Wakkanai Fm.) in depth.

Main results of the laboratory experiments and microstructure observations are as follows. (1) Measured permeability is similar to permeability before deformation, or intact permeability, for Koetoi Fm. mudstone, while, in the case of Wakkanai Fm. mudstone, permeability increases after deformation. (2) Micro focus X-ray computed tomography images of induced shear zones indicated that the shear zone in Koetoi Fm. mudstone is compacted, while that in Wakkani Fm. mudstone is dilative and fractures are observed around the shear zone, which suggested that the shear zone may work as a conduit. The differences of shear zone flow properties in laboratory experiments between two Fms. may be related to differences in observed in-situ flow.

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Keywords: fault flow property, laboratory hydro-mechanical experiment, siliceous mudstone, Horonobe, permeability, micro focus X-ray CT