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A possible dependence of the seal potential of fault smear on the stress condition

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Studies on fluid transport property relevant to the fault at shallow level of subsurface have been concluding that the plane distribution of fine gain in fault zone results in the increment of seal potential caused by porosity reduction. While cataclasite and gouge are known well as fine sized fault rocks induced by the cumminution, the fault smear is made up of entrained originally low-permeable unit such as shale into the fault zone. Especially in the study field of the hydrocarbon exploration, the seal potential of fault having continuous smear was considered as most effective structure of preventing the fluid flow across the fault. In this study, using a tri-axial testing machine, an attempt was made to simulate the smear in an artificial fault zone to clarify the relationship between the fault smear development and the permeability change with deformation increasing. Using the oscillation method, we measured water permeability across the fault smear without stopping the fault sliding. The Berea sandstone and Byoubugaura siltstone (10^-18 m^2 before starting the deformation) cylindrical assembly of 40 mm in diameter and 95 mm in length was prepared to simulate the high-permeable and low-permeable layers' interbedded sequence, and was pre-cut oriented 30 deg. to the axis to limit a fault sliding to the surface. It was subjected to 40 MPa or less than 30 MPa of effective normal stress on the pre-cut surface with the 20 MPa, 10 MPa or 5 MPa of mean pore pressure and 2 MPa of the amplitude of the pore pressure at the upstream of the specimen. The normal stress was controlled to be constant during the run by decreasing the confining pressure with responding to the axial loading increment.

From the results of the permeability changes with the axial displacement increasing, three characteristic regimes were appeared; 1 ~ 1.5 order of magnitude of permeability rapidly reduction were observed until the frictional coefficient overcame the yield point (R1), then the minimum permeability was maintained for a while (R2) and finally the permeability recovered the value gradually (R3). When the value of the axial displacement normalized by the siltstone final thickness measured in observation of the experimental product was defined as D/H, the transition among permeability regimes which were plotted against D/H were uniform but differences on the values of transitions in D/H were found clearly between the case of the effective normal stress less than 30 MPa and the case of the effective normal stress = 40 MPa. The transition B1 (from R1 to R2) and B2 (from R2 to R3) were 0.50 and 2.10 respectively for the effective normal stress less than 30 MPa, while the transition B1 and B2 were 0.99 and 3.30 respectively for the effective normal stress = 40 MPa. From the observations on experimental products, the continuous smear could be observed until drawn smear factor (DSF) reached 5.0 for the effective normal stress less than 30 MPa and 6.5 for the effective normal stress = 40 MPa respectively, which DSF was defined as the fault throw normalized by the low-permeable layer thickness. By comparing the values at B1 with the compacted ratio of siltstone thickness against the siltstone final thickness, the transition B1 could be regarded as the end of the compaction on siltstone. Therefore, the true offset in siltstone layer would start from B1, and the range of R2 (1.60 for the effective normal stress less than 30 MPa and 2.31 for the effective normal stress = 40 MPa respectively) became the minimum permeability regime of DSF. On both the range of R2 and the threshold values of DSF for continuity, the values from the case of the effective normal stress = 40 MPa were larger than those from the case of the effective normal stress less than 30 MPa; the seal potential would be higher at higher effective normal stress condition. There might be a possible positive relationship between the seal potential of fault smear and the effective normal stress.