Dehydration and dehydroxylation-induced frictional strength changes on clays and natural fault gouges from TCDP Hole-B core

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Recently, it has been considered that low-permeable property of the fault gouge plays an important role in the thermal pressurization (TP) mechanism. The pore pressure abruptly increases because the pore water tends to expand due to the frictional heating when the gouge is nearly under undrainage condition. Then the fault sliding is accelerated, causing the large earthquake. Therefore, to investigate the role of clay gouge in impeding the fluid flow from the gouge zones, under high temperature condition is very important. However, we did not have enough data on the effects of temperature-increase during an earthquake on the property of clay, causing the change in mechanical behavior of the fault. Temperature-induced chemical reaction such as dehydration/dehydroxylation of clay minerals occurred at high temperatures, releasing the water from the clay crystal. The dehydrated/dehydoxylated water is expected to raise the pore pressure. That suggests that the TP will occurre in dry rock consisting of hydrated/ hydroxylated minerals. Focusing on the effect of dehydration/dehydroxylation reaction of clay on the mechanical property of the clay gouge, we carried out shearing experiments with increasing temperature using Na-montmorillonite, kaolinite gouges and natural fault gouge sampled from Chelungpu-fault, Taiwan (TCDP Hole-B core).

In our triaxial testing machine, the frictional heating could not be generated due to slow slip velocity at the simulated gouge. In spite of the natural heating such as the cosiesmic fault movements, we raised the temperature by a furnace placed around the specimen assembly with increasing the shear displacement along the 30 deg. of precut surface of cylindrical alumina spacers. To compare the conditions of drainage and undrainage, we prepared two types of the alumina spacers, cylindrical halves with no-holes and porous halves. In this study, the confining pressure of 80 MPa was kept constant throughout the experiments. We used 1 g gouge for each experiment. To shear the gouge zone, the axial piston was loaded with a constant velocity of 0.1 micrometer/sec. After the frictional stress reached the steady-state, we started to heat the specimen up to 500 deg.C. The heating rate was 10 deg.C/min. After maintaining 500 deg.C for a while, temperature was decreased with a cooling rate of 3.3 deg.C.

With increasing temperature, the frictional coefficient increased for all gouges under the drainage condition, in which porous pre-cut alumina was used. On the other hand, the clay gouges showed various results to the temperature increasing under the undrainage condition. The Na-montmorillonite gouge indicated gradual decrease of the frictional coefficient with increasing of temperature from c.a. 110 deg.C. The kaolinite gouge indicated abrupt decrease of the frictional strength at around 490 deg.C. Comparing the frictional data of undrainage and drainage cases, we can estimate the pore pressure increase in the gouge zone, due to the dehydration or dehydroxylation of clay minerals. The pore pressure increased toward c.a. 72 MPa and c.a. 65 MPa for Na-montmoeillonite and kaolinite gouges, respectively. The natural fault gouge (named as black gouge zone) sampled from the Chelungpu-fault, Taiwan (TCDP Hole-B core) did not show the significant reduction of the frictional strength since the gouge did not include much amount of clay minerals.

We here suggest that the dewatering from much amount of clays during faulting contributes to the acceleration of fault movement (TP) even under the dry condition. Moreover, the dehydroxylation could be more effective for fault movement to be unstable than the dehydration. However, due to fewer amounts of clay minerals in gouge, natural gouge sampled from Chelungpu-fault did not indicate significant pore pressure increasing.