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Frictional property of fault gouges in high-velocity and high-fluid pressure condition

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Fluid in fault zones will influence on fault dynamics and cause water-rock interaction in the fault zone during earthquakes. Frictional heating during friction can increase pore pressure in a fault zone due to the thermal expansion of fluid, and that will reduce the effective normal stress on the fault. This pore pressure rise is also induced by an increase of fluid volume that associates with a dehydration of hydrous minerals or decarbonation of carbonate minerals. Recently laboratory friction experiments demonstrated that high velocity friction can cause remarkable fault weakening and chemical-reaction which is induced by rapid heating during friction. However, a correlation of fluid and pore fluid pressure with friction property and chemical-reaction had not been well investigated. Therefore, we carried out the high velocity friction tests by controlling fluid pressure under high pore pressure condition. We used shale in the fracture zone from the Taiwan Chelungpu Fault Drilling Project (TCDP Hole B, 1090.88 m depth) as simulated gouge materials for friction tests. Shale (Chinshui Shale) is mainly made up by quartz, feldspar, and clay minerals. We made powders with less than 0.125 mm grain size from shale by crushing and sieving. Frictional experiments were performed (1) under constant normal pressure and pore fluid pressure, and (2) under constant normal pressure without controlling pore fluid pressure. Pore pressure was applied from 2 to 5 MPa, and normal stress was from 2 to 12 MPa. We also controlled slip velocity by keeping constant from 0.1 to 0.5 m/s. Total slip displacements were reached to 15 m or 30 m at the end of sliding.

In all friction tests, shear strength was decreased with sliding, and then reached to steady state values over $\sim$10 m displacement. For friction tests without controlling pore pressure, pore pressure was gradually increased with sliding. Even though the effective normal stress was decreased by the pore pressure increase, friction coefficient was not changed much. Peak friction was lager for the pore pressure control tests than that for the test without controlling pore pressure. Steady state shear stress was proportional to effective normal stress, and 0.2 of friction coefficient was evaluated for both tests. Temperatures around the slip surface were increased up to 400 degrees Celsius. Lithium concentration in the gouge was decreased after friction tests, and high temperature water-rock interaction at more than 300 degrees Celsius for 60 seconds can explain the anomaly of Lithium concentration. This result agrees with the observation of surface temperature. However, the chemical anomaly we detected was generally small, therefore much higher slip velocity is necessary to occur the water-rock interaction effectively.