High-velocity frictional behavior of fault gouges in the presence of pore fluid

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Recent observations of slow earthquakes in the vicinity of high pore-fluid pressure suggest that variation in pore-fluid pressure plays a role in the underlying mechanism of the slow earthquakes. However, little is known of the frictional properties of subduction-zone materials in the presence of pore-fluids. To study the effect of pore-fluid on the seismic faulting process in subduction-zones, we performed friction experiments on the sediments entering to the Costa Rica subduction zone. Rotary-shear friction experiments were conducted on the input biogenic ooze material collected at reference sites U1381A during IODP Exp. 334 (Vannucchi et al., 2012) at normal stresses of 2.0–5.0 MPa and at various slip velocities V of 0.3–130 mm/s. The collected samples were oven dried at 60 degree Celsius for 24 hours, and gently disaggregated using a pestle to be used as the experimental gouges. We prepared two types of experimental conditions: impermeable and permeable conditions. Impermeable conditions consist of a pair of gabbro cylinders (25.0 mm in diameter) with an intervening thin layer of gouge (0.5 g). For permeable conditions we used a permeable sandstone (Berrea sandstone) instead of using gabbro for one side of the rock-cylinder pair. On both permeability conditions, distilled water (0.8–1.0 ml) was added to prepare pore-fluid saturated condition of the gouge initially. Under impermeable conditions, experiments performed at higher slip velocities (>3 mm/s) show a dramatic decrease in frictional coefficient values upon the initial shear loading. The value of the friction is as high as ~0.6 at the onset of sliding, following which it rapidly decreases to attain a value as low as ~0.1. The decreased friction value is constant at the lowered level for duration of slip as long as 100s, then it increases gradually to attain roughly steady-state value of ~0.6. Under permeable conditions, such a dramatic decrease and the following increase in frictional strength is not observed. The frictional behavior of the gouges under permeable conditions is similar to the behavior observed at the lowest slip velocity (0.3 mm/s) under impermeable conditions when friction is plotted against elapsed time. We suggest that the slip weakening and the following strengthening behavior observed at high velocity test under impermeable conditions is likely attributed to a transient change in fluid pressure inside of the fault zone during the shearing of the gouge. Magnitude of the pore-fluid pressure change should depend on the degree of pore-space change and the compressibility of the fluid filled gouge material. The experimental results suggest importance of studying how pore-fluid pressure evolves during faulting process to understand the frictional behavior of faults in subduction zones.

Keywords: gouge friction, pore pressure, slip weakening, slip strengthening

