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Dynamic weakening of smectite-rich faults at intermediate velocities and its importance for rupture propagation

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Shallow portion of the subduction interface had long been assumed to be aseismic and releasing stress by creep. However, the 2011 Tohoku-oki earthquake clearly demonstrated that the subduction zone earthquakes can propagate to the surface and causes devastating tsunamis resulted from large seafloor displacements. Recent high velocity friction experiments and dynamic modeling are revealing dynamic weakening processes and rupture propagation to the shallow aseismic regions (Faulkner et al., 2011, GRL; Noda and Lapusta, 2013, Nature). Here we provide frictional properties of smectite-rich, synthetic fault gouges (bentonite-quartz mixtures) under the various slip velocities to understand the processes of interseismic loading and coseismic weakening. Experiments were conducted under the normal stress of 2 MPa and slip rates of 30 um/s to 1.3 m/s, using rotary-shear, low- to high-velocity friction testing apparatus. Synthetic fault gouges were saturated with deionized water and placed between gabbro host rock (slider). At the low slip rates of 30 to 150 um/s, friction coefficient remains constant values without visible slip weakening or hardening for any fraction of mixtures. On the other hand, friction becomes unstable at the slip rates of few mm/s, and exhibits noticeable slip weakening at the slip rates faster than 22 mm/s. Intense slip weakening can be observed from 20 to 35 % bentonite mixtures in particular. The velocity, which starts to appear dynamic weakening, comes from 1-2 order of magnitude lower than previous study (Di Toro et al., 2011, Science). According to the slide-hold-slide test, specimens after the slip weakening recover its strength logarithmically with time, but not correspond with temperature decay. Additionally, slip weakening can not be observed from the experiments with highly permeable host rock. These results suggest that the dynamic weakening at the velocity range of mm/s can be attributed to mechanically and/or thermally activated pressurization of pore fluids. These experimental results can explain high friction at interseismic loading and dynamic weakening associated with coseismic rupture. Dynamic weakening at intermediate velocity may assist rupture propagation to the shallow portion of the subduction interface.

Keywords: Smectite, Fault gouge, Friction experiment, Dynamic weakening, Thermal pressurization, Tsunamigenic earthquake