Frictional properties of hydrated clay minerals and its application to tsunami earthquakes

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Tsunami earthquake excites larger tsunami than expected from its seismic motion. It is possibly related to slow fault motion at the shallow part of the subduction boundary where large amount of clay minerals are dominated. Accordingly, the frictional properties of clay minerals are important to understand the mechanism of tsunami earthquake. Seno (2002) suggests that tsunami earthquakes are induced by existence of pore fluid pressure, because high pore fluid pressure reduce effective normal stress and clay minerals exhibit unstable sliding under such low effective stress. Although previous studies were mostly carried out at dry conditions, frictional property of under hydrate state have not been understood. In this study, we conducted velocity step test under water saturated condition and analyzed the frictional property of hydrated clay minerals. Based on these data, we discuss the possible mechanism of tsunami earthquakes at shallow part of subduction zone.

Friction experiment were conducted by using a biaxial testing machine. The clay gouges were composed of smectites (Na-montmorillonite and Ca-bentonite, saponite). Samples were dried by the vacuum furnace for 24 hours at 100˚C prior to experiments, and for hydrated experiment, we used the water tank to saturated fluid in the simulated fault zones. We investigated frictional strength and velocity dependence over a range of normal stresses from 10 to 60 MPa and sliding velocities from 0.3 to 33 μm/s. The velocity dependence was determined from the change in steady-state friction after the abrupt change in sliding velocity. Velocity-strengthening behavior shows an increase of friction coefficient with increasing sliding velocity. In contrast, velocity-weakening behavior shows a decrease friction coefficient with increasing velocity.

Fluid saturated samples exhibited markedly lower friction coefficient than dried samples, and velocity dependence was influenced by the presence of water. Under dry condition, Na-montmorillonite and saponite exhibited velocity-strengthening over a range of studied normal stress, whereas Ca-bentonite tends to exhibit velocity-weakening under low normal stress (< 40MPa). Ca-bentonite showed a transition from velocity-weakening to velocity-strengthening with increasing normal stress. Under hydrated condition, velocity dependence on friction has a relatively small, and all samples show the neutral velocity dependence at low normal stresses.

We applied these experimental data to subduction environments where abundant clay minerals exist under fluid-saturated and low effective normal stress. In such situation, velocity dependence of clay mineral could exhibit neutral velocity dependence. Consequently, seismic slip can propagate through at shallow part of subduction zone. This behavior will generate a relatively slow slip motion compared to regular earthquake, which is consistent with the characteristic of tsunami earthquake.

Keywords: tsunami earthquakes, subduction zone, clay minerals

