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Frictional properties of basalt-derived fault rocks and implications for subduction earthquakes

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Recent seismic reflection surveys in subduction zones such as Nankai Trough suggest that subduction earthquakes mostly occurred along the upper part of oceanic crust composed of basaltic rocks (e.g., Bangs et al., 2009). Hence, frictional properties of basalt appear to be keys for understanding earthquake nucleation and rupture propagation during subduction earthquakes, yet they remain poorly understood. In the Upper Shimanto accretionary complex of eastern Shikoku, basalt and tectonic melange are repeated by thrusts, representing duplex structure associated with underplating (Ikesawa et al., 2005). Underplating-related thrusts develop in basalt and consist of basalt-derived foliated cataclasite and ultracataclasite. Fluidization of comminuted material and mineralogical signatures of frictional heating were reported from a few centimeters-thick ultracataclasite (Ujiie et al., 2007; 2008; Kameda et al., 2011). We examined the frictional velocity dependence at slip rates of 0.0028-0.28 mm/s and high-velocity (1.3 m/s) frictional properties of disaggregated pillow basalt and basalt-derived foliated cataclasite and ultracataclasite. The samples from pillow basalt show velocity-weakening behavior, while those from foliated cataclasite and ultracataclasite exhibit velocity-strengthening behavior. All samples show slip weakening behavior during high-velocity friction experiments, with the samples from ultracataclasite marked by smaller stress drop, slip weakening distance, and fracture energy. The compositions of materials and preliminary microstructural observations suggest that velocity-weakening samples show lower clay content (21 wt.%) and grain-size reduction, while velocity-strengthening samples exhibit relatively high clay content (29-50 wt.%) and clay foliations. Our results suggest that earthquake nucleation likely occurs in subducting basalt, but slip tends to be stable when clays and clay fabrics are formed by hydrothermal alteration and shear deformation, respectively. The results of high-velocity friction tests suggest that earthquake rupture propagates easily through ultracataclasite rather than foliated cataclasite and pillow basalt, which is consistent with the fact that the geological evidence of earthquake faulting was found from the ultracataclasite.

Keywords: subduction earthquakes, basalt, frictional velocity dependence, high velocity friction