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An effect of grain size on high velocity slip behaviors of olivine aggregates

KINOSHITA, Chihiro[1*], HIROSE, Takehiro[2]

[1]Graduate School of science,Kyoto University, [2]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology

Olivine is a key mineral that controls the slip behavior of seismic faults in deep oceanic crusts at mid-ocean ridges and subduction zones. However, its frictional property is not well understood, especially at coseismic slip velocity (i.e. >0.1 m/s). In this experimental study we crushed and sieved San Carlos olivine into four grain size ranges (3, 5, 15, 35, and >50 micron). The olivine aggregates of 0.5 g were deformed dry to >10 m displacement at velocity of 0.0013-1.3 m/s and normal stress of 0.5-2.0 MPa using a rotary-shear apparatus, in order to reveal the effect of initial grain size on slip behavior at high velocities. In addition, we examined the microstructures of the simulated fault zone that control the high-velocity slip behaviors using a FE-SEM.

The experiments at high velocity showed a typical slip weakening behavior: friction coefficient is 0.7-0.9 at the initiation of slip and it decays exponentially to a steady-state stage of 0.2-0.3 over a slip weakening distance Dc. Dc decreases from 40.0 to 4.0 m as increase in normal stress from 0.5 to 2.0 MPa, respectively, following a power-law relation. There is no clear grain size dependence of friction level and Dc. In contrast, slip weakening behaviors are invisible at velocities of < 0.13 m/s. Such slip-weakening and velocity-weakening behaviors of olivine aggregates are quite similar with other rocks sheared at high velocities (e.g., Di Toro et al., 2011).

A slip localized zone forms during high-velocity sliding and is composed of fine-grained olivine with less than 1 micron. Interestingly thickness of the localized zone tends to become thinner for initially finer grains: thickness of localized zone is 50,33 and 3 micron, respectively. This implies that a positive feedback process between grain-size reduction and slip localization could operate within a gouge zone during cosesmic sliding leading to the dynamic weakening of faults.