

Frictional rate dependence of thrust materials in accretionary prisms and its implication for VLFES

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Recent seismological studies identified that very low frequency earthquakes (VLFES) occurred on thrusts within accretionary prisms or at plate interfaces. On the other hand, clay-rich accreted sediments commonly show velocity-strengthening behavior, which may be unfavorable for occurrence of slow slip events. Here we examined the characteristics and the frictional rate dependence of the thrusts in the Eocene Shimanto accretionary complex of Okinawa Island (Kayo Formation).

The Kayo Formation consists of coherent trench-fill turbidites and it was deformed by folds and thrusts during off-scraping accretion under the subduction of young oceanic crust, possibly representing an on-land analog of the Nankai and Ryukyu subduction zones where VLFES occur on thrusts within accretionary prisms. Two representative thrusts in the Kayo Formation develop in quartz-rich sandy materials, and the fault zones are composed of cataclastic slip zone, amalgamated slip zone, foliated zone, fibrous quartz veins, and sandstone cemented by quartz, suggesting the fluid saturated conditions during faulting.

To determine the friction rate dependence on the thrust materials, the frictional experiments were conducted on the samples taken from the cataclastic slip zone showing random fabric, the foliated zone, and the host rock (quartz-rich sandstone) at slip rates of 0.0026 - 0.026 - 0.26 - 2.6 mm/s and normal stress of 1.0 MPa under wet conditions using a rotary-shear friction testing apparatus in Kyoto University. At slip rates of 0.0026 - 0.026 - 0.26 mm/s, the cataclastic zone and the host rock show velocity-weakening behavior with frictional rate dependence parameter (a-b) ranging -0.0038~-0.0013 and -0.0032~-0.0016, respectively, whereas the foliated zone exhibits velocity-strengthening behavior (a-b=0.0003~0.0012). At slip rate of 0.26 - 2.6 mm/s, all samples show velocity-strengthening behavior. Microstructural and XRD analyses reveal that velocity-weakening samples show the localized cataclasis along the boundary between gouge and specimen with its quartz and clay minerals contents being 58.9 - 75.8 wt.% and 4.9 - 7.7 wt.%, respectively, while velocity-strengthening sample indicates the clay foliation outside the localized slip zone with lower quartz content (51.5 wt.%) and higher clay content (23.9 wt.%). These features are consistent with occurrence of the fault rocks along the thrusts in the Kayo Formation.

In summary, our field and experimental data suggest that frictional instability tends to generate along quartz-rich material (e.g., quartz-rich sandy materials and quartz veins) but frictional stability increases at higher slip rates of 0.26 - 2.6 mm/s regardless of mineral composition, which will be favorable for VLFES occurrence in accretionary prisms.

Keywords: very low frequency earthquakes, Kayo Formation, velocity-weakening, quartz-rich sandy materials