Correlation between frictional properties and deformation textures in frictional experiments on the biogenic sediment collected from the oceanic plate offshore Costa Rica

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Various seismic behaviors such as large earthquakes, episodic slow slip events, or silent earthquakes are observed in subduction zones. This variation likely reflects spatial variations in frictional properties along the seismogenic portion of plate-boundary megathrusts (e.g., Bilek and Lay, 1998). A number of studies revealed frictional properties of clay sediments collected from the Nankai Trough (e.g., Brown, 2003). However, available experimental data have been limited mostly to clayey subduction-zone materials. In this study, to reveal the frictional properties of the biogenic sediments, we performed a series of friction experiments on silicic to calcareous ooze. The samples tested in this study were collected at a reference site of offshore Costa Rica (Site U1381) during the IODP expedition 334 and 344.
Namiki et al. (2014) have shown that the frictional properties of the silicic to calcareous ooze were different from those of the clay sediments as the following: (1) the steady-state μvalues of the silicic to calcareous ooze are high, measuring 0.6 to 0.8; and (2) the μvalues of the silicic to calcareous ooze samples show negative velocity dependence of friction at velocities of 0.0028 to 0.28 mm/s and positive velocity dependence at velocities of 0.28 to 2.8 mm/s. The second property is important because velocity-weakening behavior implies potentially unstable fault motion.
To understand the mechanism of generating such characteristic frictional properties of the silicic to calcareous ooze, a series of friction experiments were performed on biogenic amorphous silica as an end-member component of the silicic to calcareous ooze. We dissolved calcite by acid treatment, and gained amorphous silica whose particle size and shape were similar to natural sediments. The biogenic amorphous silica shows the following frictional properties: (1) the steady-state μvalue is high, measuring ~0.6, and (2) the biogenic amorphous silica shows negative velocity dependence of friction at velocities of 0.0028 to 2.8 mm/s. The first property suggests the frictional steady-state strength of the biogenic amorphous silica is similar that of the silicic to calcareous ooze. The second property suggests mixing amorphous silica and calcite probably influences positive velocity dependence of friction of the silicic to calcareous ooze at velocities of several mm/s.
Microstructures of the sheared samples are observed by SEM. The silicic to calcareous ooze, which displays positive velocity dependence of friction at velocities of 0.28 to 2.8 mm/s, shows distributed deformation texture. The silicic and calcareous shells show preferred orientation inclined to the shear zone at an angle in the range of about 30°. Both distributed and localized deformation textures are observed for the amorphous silica sample, which shows negative velocity dependence of friction at velocities of 0.0028 to 2.8 mm/s. Preferred orientation of silica grains characterizes the distributed deformation textures. Two types of localized deformation textures are observed: zones of random fabric and shear fractures. In the random-fabric zones, silica grains are rounded. The rounded silica does not show the typical shape of the shells. The shear fractures intersect with the shear zone at an angle in the range of 10° to 20°. Preferred orientation of the silica grains parallel to the orientation of the shear fractures are observed within one of the shear fractures. Ikari et al. (2013) mentioned the nannofossil chalk, which showed negative velocity dependence of friction, exhibited prominent Riedel shears. It is likely that the localized deformation textures observed in our amorphous silica experiments are Riedel shears.

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