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Frictional behavior of incoming pelagic sediments to the Tohoku subduction zone

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The 2011 Tohoku earthquake (Mw 9.0) off the Pacific coast of Japan produced huge slip (˜50 m) on the shallow part of the megathrust fault (e.g., Fujiwara *et al*., 2011), resulting in destructive tsunamis. Although the multiple causes of such large slip at shallow depths is expected, the frictional property of sediments around the megathrust, especially at coseismic slip velocities, may significantly contribute to large slip along the fault. We thus investigate the frictional properties of pelagic sediments to be subducting beneath the Tohoku region at seismic velocities and large displacement toward understanding the rupture processes to cause large slip at the shallow portion of the subduction plate boundary.

We have conducted friction experiments on incoming pelagic sediments on the Pacific plate (DSDP, Leg56, Site 436, Core 38 (358 mbsf) and Core 40 (378 mbsf)). The site locates about 100 km northeast from the Hole C0019E drilled during the IODP Expedition 343 (J-FAST). Core 38 is diatom-rich clayey sediment, while Core 40 contains mainly smectite which could correspond to black-colored sheared clay in the plate boundary fault zone recovered during Expedition 343. Experiments are performed at slip velocities of 2.5 x 10^{-4} to 1.3 m/s, normal stresses of 0.8 to 2.0 MPa and slip displacement of ˜16 m under brine saturated conditions, using a rotary-shear friction apparatus. One gram of gouge was placed between rock cylinders of sandstone or gabbro of 25 mm diameter with Teflon sleeve outside to contain gouge. Both gouge sample and host rock were saturated with brine before the experiments.

In both Cores 38 and 40, a typical slip weakening behavior appears at slip velocity of 1.3 m/s; friction coefficient of the sediments rapidly increases at the onset of sliding (initial peak friction) and then progressively decreases to $<$0.1 with displacement. However, at low velocities there is significant difference in friction level between two. Steady-state friction coefficient of Core 40 is remarkably low ($<$ 0.2) over a wide range of slip rate (2.5 x 10^{-4} to 1.3 m/s). In contrast, steady-state friction of Core 38 is high values of ˜0.6 at low velocities, but decreases to $<$0.1 toward seismic slip velocity of 1.3 m/s. This marked difference in frictional strength between two sediments could be attributed to smectite content and initial grain size: clay minerals align preferentially along most shear planes in Core 40, whereas fracturing and subsequent shear enhanced compaction seems dominant deformation processes in Core 38. In addition, peak friction of Core40 is far smaller than that of Core38 and steady-state friction of Core 40 is smaller than that of similar studies conducted on other fault gouge (e.g., Mizoguchi *et al*., 2007; Ujiie and Tsutsumi, 2010). These results suggest that the incoming pelagic zone in Core 40, possibly source material of the current plate boundary fault zone, is energetically very easy for earthquake ruptures to propagate at shallow portion of the Tohoku subduction zone, leading to large slip near the trench.

Keywords: Tohoku earthquake, High-velocity friction, Pelagic sediments