

Extreme Low Friction of the Tohoku Plate Boundary as a possible factor for seismic slip propagation toward the trench

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Shallow portions of subduction plate boundaries have been generally considered to behave aseismically. However, seismic slip during the 2011 Tohoku earthquake propagated up-dip from the depth along the plate boundary, leading to unexpected large seafloor displacement of more than 50 m near the trench. To further understand mechanical explanations for this unexpected behavior, we have conducted laboratory friction experiments on core samples of the Tohoku plate-boundary fault zone, along with sediments from above and below the zone (i.e. wall rocks), collected during IODP Expedition 343 (the Japan Trench Fast Drilling Project). In the experiments, we sheared ~2 mm-thick disaggregated samples at slow (1 $\mu\text{m/s}$) to coseismic slip velocities (1 m/s) under a constant normal stress of 20 MPa and fluid pressure of 10 MPa. The experimental conditions (slip velocity and effective normal stress of 10 MPa) are very close to the in-situ conditions at which seismic faulting would have occurred at the drilling site of the plate boundary.

Our preliminary results indicate that the friction coefficient (μ) for all samples tends to increase with velocity toward velocities of the order of mm/s (which we call a frictional barrier at intermediate velocity) and that above this velocity range it progressively falls to <0.1 at 1 m/s with marked slip-weakening behavior. However, the absolute frictional strength of samples from the plate boundary fault is very different from that of the wall rocks. The fault-zone material, which is rich in smectite shows (1) very low friction coefficient of <0.15 over a wide range of velocity (1 $\mu\text{m/s}$ to 1 m/s), and (2) a small frictional barrier at intermediate velocity ($\Delta\mu < 0.02$). In contrast, the friction coefficients of others samples are 0.25-0.5 at velocities of <3 mm/s and the frictional barrier is much larger than that of the fault-zone material (e.g. $\Delta\mu > 0.2$ in sample just below the fault zone). Smectite-rich incoming sediments (i.e. source material of the current plate boundary fault zone) to the Tohoku subduction, which were retrieved from DSDP Leg 56, display similar frictional behaviors to those of the plate boundary. Our result suggests that extremely low frictional strength, which is characteristic of smectite-rich materials within the plate boundary over slow to coseismic velocities allowed earthquake slip to easily propagate up-dip along the Tohoku plate boundary, facilitating the huge displacement near the trench.

Keywords: Tohoku earthquake, plate boundary, fault, friction, smectite