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Frictional behavior of the plate boundary décollement zone in the Japan Trench, sampled during the Japan Trench Fast Drilling Project (JFAST): Implications for shallow coseismic slip propagation

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One of the outstanding features of the 2011 Mw = 9.0 Tohoku earthquake was unusually large coseismic slip which propagated all the way to the trench. The fault zone processes that allow shallow reaches of subduction faults to rupture to the seafloor, rather than arresting slip, remains a critical and outstanding question. High-velocity friction experiments have shown that rupture propagation is aided by a variety of dynamic weakening effects, but these only become active at rates of $\geq$ 1 cm/s. Coseismic slip propagation must also probably be governed by the frictional properties of the fault zone at lower slip rates, as it is driven from low to high sliding velocity. Drilling offshore in the Japan Trench was undertaken a year after the Tohoku earthquake during Integrated Ocean Drilling Program (IODP) Expedition 343, the Japan Trench Fast Drilling Project (J-FAST). During this expedition, core samples were recovered from a one-meter-thick highly sheared scaly-clay layer interpreted to be the plate-boundary fault zone, as well as from the overlying prism and underthrust sediments. We conducted laboratory experiments in a true-triaxial double-direct shear device to measure the frictional strength and velocity-dependence of these samples (wall rock as intact wafers, décollement as fault breccia) under stress conditions approximating those in situ. We observe that the décollement sample is weak (coefficient of friction μ = 0.17) compared to the hanging wall and footwall (approximately 0.5). The velocity-dependence of friction increases from velocity-weakening at sliding velocities $\leq$ 1 μm/s to velocity-strengthening at higher rates. The décollement is more velocity-weakening than the wall rock at these low velocities. Flow-through measurements made perpendicular to the shear direction after deformation show that the décollement sample exhibits permeability which is nearly 2 orders of magnitude lower than the sheared wall rock samples. X-ray diffraction analysis of the < 2 μm size fraction shows that the smectite content of the décollement sample is >20