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Slip-dependent weakening revealed for a shallow megasplay fault in the Nankai subduction zone

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The Nankai Trough megasplay fault likely hosts different modes of fault slip, from slow to megathrust earthquakes, and is responsible for related phenomena such as tsunamis and submarine landslides. All types of slip events require some kind of frictional weakening process (e.g. slip and/or velocity weakening) in order to nucleate and propagate. Most frictional earthquake studies analyze the velocity dependence of friction but disregard the slip dependence of friction observed in experimental friction studies.

We tested fluid-saturated powdered megasplay fault samples from Integrated Ocean Drilling Program Site C0004 in a direct shear apparatus under effective normal stresses from 2 – 18 MPa to investigate the velocity- and slip-dependence of friction of the megasplay fault. For every tested effective normal stress, we performed one velocity-step experiment and two constant velocity experiments (no velocity step). In the velocity-step experiments the samples were sheared to a total displacement of 10 mm, with an initial sliding velocity $V_0 = 0.1 \mu\text{m/s}$ for the first ~5 mm (run-in) followed by a velocity step increase to $V = 1.0 \mu\text{m/s}$ over the last 5 mm. During the constant velocity experiments, the shearing velocity (0.1 and 1.0 $\mu\text{m/s}$ respectively) was held constant for 10 mm of displacement.

The velocity-stepping tests showed an evolution from velocity weakening at low effective normal stresses to velocity strengthening at high effective normal stresses. All experiments revealed strong slip-weakening behavior, with the slip dependence having a much larger effect on friction than the velocity dependence. The friction slip dependence is also controlled by the effective normal stress, showing large weakening rate at low effective normal stresses and smaller weakening rate at higher effective normal stresses. Therefore, both frictional weakening mechanisms on the megasplay fault become more effective at shallow depths. This may amplify seafloor deformation by shallow coseismic slip and could increase the tsunamigenic potential of the fault zone.