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Fluid pressurisation and earthquake propagation in the Hikurangi subduction zone

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In subduction zones, seismic slip at shallow crustal depths can lead to the generation of tsunamis. Large slip displacements during tsunamogenic earthquakes are attributed to the low coseismic shear strength of the fluid-saturated and non-lithified clay-rich fault rocks. However, because of experimental challenges in confining these materials, the physical processes responsible of the coseismic reduction in fault shear strength are poorly understood. Using a novel experimental setup, we measured pore fluid pressure during simulated seismic slip in clay-rich materials sampled from the deep oceanic drilling of the Pāpaku thrust (Hikurangi subduction zone, New Zealand). Here we show that seismic slip is characterized by an initial decrease followed by an increase of pore pressure. The initial pore pressure decrease is indicative of dilatant behavior. The following pore pressure increase, enhanced by the low permeability of the fault, reduces the energy required to propagate earthquake rupture. We suggest that thermal and mechanical pressurisation of fluids facilitates seismic slip in the Hikurangi subduction zone, which was tsunamigenic about 70 years ago. Fluid-saturated clay-rich sediments, occurring at shallow depth in subduction zones, can promote earthquake rupture propagation and slip because of their low permeability and tendency to pressurise when sheared at seismic slip velocities.