Geophysical Research Abstracts
Vol. 21, EGU2019-1084, 2019
EGU General Assembly 2019
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Frictional behavior of sediment inputs to the Hikurangi subduction margin (New Zealand) at plate-rate and slow slip velocities.

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The Hikurangi subduction margin hosts shallow slow slip events (SSEs) that may propagate up to the seafloor. The incoming sedimentary sequence is therefore representative of the shallow fault material where these events will take place once they enter the subduction zone. These sediments were sampled during IODP Expedition 375 and are used in laboratory experiments to test which rock types are most likely to host these events and to characterize their frictional behavior. We performed experiments on both intact and powdered rock samples from the major lithologies entering the subduction zone. The experiments were conducted under room temperature, at effective normal stresses representative of the sample recovery depth, and saturated with brine to simulate in-situ conditions. The testing procedure includes initial shearing at 10 μm/s, after which we lower the shear speed to 5 cm/year (near the plate convergence rate), followed by a velocity increase to a rate characteristic of shallow slow slip at the Hikurangi margin (160 cm/year), and finally a return to 5 cm/year to reach a steady state microstructure for imaging and analysis. The frictional changes caused by the velocity steps are modelled following the rate- and state friction laws, to find (a-b) values that indicate if the material is velocity-strengthening (a-b>0) is velocity weakening (a-b<0).

Out of the five tested lithologies (siltstone, marl, chalk and 2 types of volcaniclastic conglomerates; one calcite-cemented and one with a red cement), all except the red-cement volcaniclastic conglomerate show velocity-weakening behavior when stepping to a higher velocity. The calcite-cemented volcaniclastic conglomerate has the lowest (a-b) value, whereas the siltstone shows a value close to 0. Velocity downsteps exhibit slightly higher (a-b) values, including velocity-strengthening values for the siltstone and marl. Two samples produced laboratory SSEs; the intact marl sample shows one SSE with a duration of about one hour and having a 45 kPa stress drop, but the powdered equivalent did not produce any SSEs. The chalk sample shows many repetitive SSEs, both in the intact and in the powdered sample. The observed SSEs in the chalk last about one hour and have an average stress drop of 20 KPa. At a constant driving speed of 5.3 cm/year, the sample displacement slows down to values of 2.2 cm/year (marl) and 2.6 cm/year (chalk) before SSEs, after which it increases to peak values of 16 cm/year (marl) and 11 cm/year (chalk), which is significantly lower than the slip speeds observed in natural SSEs. Collectively, these data suggest that the chalk layer is the most likely source of the shallow SSEs. The velocity-weakening behavior in the overlying sediments suggests slip can propagate along faults up to the seafloor. Ongoing work includes characterization of the frictional behavior of the heterogeneous lowermost unit, measuring the roughness of the sheared fault surfaces to explore a possible connection between roughness and friction or slow slip parameters, and microstructural analyses of the sheared samples to identify the possible mechanisms responsible for producing SSEs.