The Hydrologic, Metamorphic, and Frictional Habitat of Shallow Slow Earthquakes

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Slow slip events (SSE) and very low frequency earthquakes (VLFE) in the outermost forearc of subduction zones demonstrate that unstable slip nucleates at shallower depths and nearer the trench than previously recognized. These events provide an opportunity to unravel the physical processes governing the nature of slip on subduction megathrusts; their source regions are accessible by drilling and well-imaged by geophysical surveys, enabling investigation of the properties and state of the plate interface. Here, we describe recent drilling, modeling, and laboratory results that, collectively, advance our understanding of the habitat of these events.

Estimates of in situ pore fluid pressure obtained by combining laboratory measurements on core samples with P-wave velocities from regional geophysical surveys show that the slow earthquake source regions are highly and locally overpressured, with pore pressures 75–90% of lithostatic. Kinetic models of smectite-illite transformation show that the reaction and peak fluid release occur mostly updip of the slow earthquake source areas; this may contribute to fluid overpressure, but is unlikely to be the primary driver. Laboratory frictional experiments on samples from subduction faults document primarily velocity-strengthening behavior, suggesting that nucleation of unstable slip is unlikely. However, a minimum in friction rate dependence (*a-b*) occurs at sliding velocities of ~1-10 μm s^{-1}, and we note increasing rate weakening with increased quartz content. Additionally, slip-weakening trends in these materials occur over larger distances (several mm) than commonly used to define frictional rate dependence, and are quantitatively consistent with several characteristics of slow earthquakes.

The emerging picture is that VLFE occur in a zone of highly overpressured fluids, low stress, and transitional frictional behavior. Although illitization is largely complete updip of the events, clay dehydration may augment fluid overpressures generated by disequilibrium compaction, and the accompanying release of SiO_2 may lead to greater tendency for unstable slip. Taken together, elevated pore fluid pressure and low effective normal stress, coupled with a minimum in frictional rate dependence at slow slip rates likely produces a fault zone with transitional frictional stability and reduced rigidity, favoring long rise times and slow rupture.

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