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Enhanced dewatering and non-deforming upper plates: Facilitating high slip near the trench at non-accretionary margins?

Demian Saffer[1*]

[1]The Pennsylvania State University

In subduction zones, both earthquake nucleation and large coseismic slip are typically restricted to depths >~10-15 km. However, for some earthquakes, regions of high slip extend to shallow depths, and in some cases to the trench. A subset of such events also excite tsunamis that are anomalously large with respect to their seismic magnitude; these are termed "tsunami earthquakes" and are characterized by longer source durations than typical earthquakes. Although the sample size is small, events exhibiting high slip at shallow depths commonly occur at non-accretionary or sediment-starved margins, including both tsunami and "normal" earthquakes (for example, the 1896 Sanriku, 1992 Nicaragua, 1960 and 1996 Peru, 1994 Java, 1995 Jalisco, and 1963 and 1975 Kurile events). Here, I explore the hypothesis that non-accretionary subduction zones facilitate large shallow slip through a combination of two processes: (1) enhanced drainage, resulting from complete subduction of a typically thin sediment section; and (2) lack of permanent anelastic deformation in the upper plate. In contrast, at accretionary margins, the sediment section is thicker, and as a result, the subducted sediments have lower porosity and permeability - leading to a greater propensity for fluid overpressure. Sediment accretion also leads to large lateral compactive strains in the upper plate, such that the net long-term displacement rate across the plate boundary decollement near the trench is a small fraction of the plate convergence velocity. Numerical modeling studies, as well as estimates of in situ pore fluid pressure, are consistent with the idea that the thin sediment section at non-accretionary margins globally (mean of 600 m) should allow more efficient drainage than at accretionary margins where the sediment is typically thicker (mean 2200 m). Ultimately, this enhanced drainage should lead to higher effective normal stress along the subduction megathrust in the outer forearc, and thus increase the potential for locking and unstable slip. In conjunction with the lack of permanent anelastic deformation in the upper plate, this may provide a mechanism to explain why the majority of events that exhibit large shallow slip occur at non-accretionary subduction zones. This idea is also consistent with observations of small (M 3.8-4.9) very low frequency earthquakes that release modest stored elastic strain in the seaward-most reaches of accretionary margins, but which apparently do not occur at their non-accretionary counterparts.

Keywords: pore pressure, tsunami earthquakes, subduction zones