The role of subduction erosion on seismicity

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Subduction zones outline much of the Pacific plate, producing many of the largest and most destructive earthquakes recorded. Thus there is considerable interest in understanding the tectonics and dominant processes associated with these margins, as variations in these processes may be a factor in the behavior of the earthquakes. These margins are usually classified as either accretionary, with material actively added to the overriding plate, or erosional, where material is removed from the base of the overriding plate. Much of the early research of subduction zone dynamics focused on accretionary margins; models for erosional margins have only matured in the past 15 yr. However, seminal papers that describe structural features of each margin and quantify the relative amount of erosion in the global subduction zones suggest that roughly 57% of worldwide subduction zones are erosive instead of accretional (von Huene and Scholl, 1991; Clift and Vannucchi, 2004).

Various models for erosive margins are contradictory. One class of models suggests that fault friction is high, perhaps with the presence of a subducted topographic feature such as a seamount, leading to the removal of material at the base of the overriding plate through abrasion (e.g., Hilde, 1983; Adam and Reuther, 2000; Dominguez et al., 2000; Bangs et al., 2006). Another model proposes a weaker fault and suggests that the subduction erosion occurs because of hydrofracturing of the upper plate, allowing upper plate material to enter the subduction zone, thinning of the upper plate resulting in measurable subsidence, and fluid seeps along the normal faults in the upper prism (von Huene et al., 2004; Ranero et al., 2008). However, neither model has successfully predicted all the structural features characteristic of erosive margins.

Wang et al. (2010, p. 431 in this issue of Geology) describe a model for erosive margins that has significant implications for the seismicity patterns at these margins. Their model is an extension of the dynamic Coulomb wedge concept that has been used to successfully describe features and seismicity at accretionary margins, such as wedge geometry, activation of splay faults, shallow afterslip, and very low frequency earthquakes (Wang and Hu, 2006). They apply the same concept of temporally varying fault strength over the seismic cycle to subduction erosion, using the steeper wedge slope and dip geometries found for erosive margins relative to accretionary prisms. During the period of time between earthquakes, the middle prism is strong relative to the underlying basal fault that has a higher fluid pressure ratio. Updip of an earthquake, coseismic slip causes compression in the prism and dilation in the subducting material. As a result, the fluid pressure ratio increases in the wedge and decreases in the underlying plate. Thus, the basal fault strengthens as the overlying middle prism weakens, facilitating erosion at the base of the prism. Erosion is temporarily limited to the coseismic rupture and the period of rapid postseismic deformation shortly after seismic slip, which is linked to the continued readjustment of the stress state in the shallow portion of the fault.

This model has implications for seismicity, such as relating rare shear localization along a plane in the shallowest portion of the subduction channel to long rupture times for earthquakes that occasionally occur in this updip region. Seismic data support this claim. Tsunami earthquakes, those events that produce large tsunami relative to their seismic moment (Mo) and unusually long time to rupture, arise from slip in the shallowest portion of subduction zones (e.g., Kanamori, 1972; Kanamori and Kikuchi, 1993; Satake and Tanioka, 1999; Polet and Kanamori, 2000; Abercrombie et al., 2001; Bilek and Lay, 2002; Ammon et al., 2006). These tsunami earthquakes are primarily located in erosive margins (Fig. 1A), suggesting that these events might be connected to the processes described by Wang et al. (2010). The largest events on record (those with a magnitude greater than 9) tend to occur only at accretionary margins, not at erosional ones (Fig. 1A); likely related to differences in geometry and friction conditions between the

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two margins. Within the accretionary margins, the region where earthquakes are possible because of frictional behavior that allows for slip (velocity weakening) extends further seaward than within erosive margins, allowing for wider areas for coseismic rupture and leading to much larger magnitude earthquakes.

Catalogs of subduction zone earthquake rupture durations (Bilek et al., 2004; Bilek, 2007, 2009) also suggest differences between types of margins, although with additional complexity. The maximum moment-scaled durations for the shallowest earthquakes (upper 15 km) in erosive margins tend to be larger than accretionary margins, with the exception of the Alaska-Aleutian subduction zone (Fig. 1B). The discrepancy with the Alaska-Aleutian subduction zone introduces new questions about its accretionary classification and possible along-strike variations in its nature. The longer source durations observed at erosional margins might be indicative of similar conditions to those required for tsunami earthquake generation. Median and 75\textsuperscript{th} percentile durations are similar across all regions, suggesting that the erosive margins produce fewer, but longer-duration shallow earthquakes than accretionary margins. Thus, the model proposed for the dynamics of erosive margins can be linked to earthquake observations, and further advancement in our understanding of subduction zone seismicity will come through continued theoretical development of models such as that proposed by Wang et al., combined with additional seismic and geodetic observations of seismic cycle deformation.

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