Spatial Distribution of the largest megathrust earthquakes: variations in plate tectonic parameters or sampling bias?

Seth Stein and Emile Okal, Northwestern University

An important question is whether the largest (Mw > 8.5) trench earthquakes can occur only at certain trenches as a result of their mechanical properties, which may be describable in terms of factors such as convergence rate, plate age, and trench sediment thickness. This issue is important for understanding the mechanics of the subduction process and assessing tsunami hazards. The challenge in the latter application is that although most trenches seem capable of generating Mw > 8 earthquakes, the danger of an oceanwide or far-field (as opposed to local) tsunami, is low for earthquakes with Mw < 8.5, significant for larger moment magnitude, and extreme for Mw > 9.

Prompted by the December 2004 Sumatra earthquake, we have been revisiting these issues. Although Ruff and Kanamori (1980) proposed that Mw 9 earthquakes occur only when young lithosphere subducts rapidly, much of this correlation vanishes using new plate motion rates and other data not then available. Among the problems are that we do not know if the largest trench events were interplate thrusts, and the possibility that due to short historic record some large events were missed.

An alternative that seems likely is that instead of some trench segments but not others being prone to Mw > 8.5 events, some of these apparent differences may reflect the short earthquake history sampled. This possibility is suggested by the variability in rupture mode along trench segments. For example, the Nankai Trough history shows that sometimes the entire region slipped, whereas in other intervals slip was divided into several events over a few years. Similarly, the seismic slip rate, estimated from slip in the great Mw 9.6 Chilean 1960 earthquake and historical records indicating major earthquakes ~ every 130 years in past 400 years, exceeds the convergence rate. Hence either the frequency in past 400 years was higher than the long-term average, or earlier earthquakes were significantly smaller than 1960 event. This prediction has recently been confirmed by paleoseismic studies showing that the 1837 and 1737 earthquakes where smaller than the 1960 event, whereas the 1575 one was comparable.

Hence if Mw > 8 events are three times more common than Mw 8.5, following a Gutenberg-Richter prediction, then Mw > 8.5 will be rarer and thus absent from the short record available for some trenches. This effect will be enhanced if the larger earthquakes are rarer than this prediction, which is the case globally.