Understanding megathrust earthquakes through ocean drilling

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Abstract

In the past few years, we have learned much more about earthquakes and tsunami at subduction boundaries. Major events such as the 2004 Sumatra, 2008 Maule and 2011 Tohoku Great Quakes have led to enhanced interest – and major surprises – in our understanding of megathrust events. Direct drilling of the megathrust has been a prime focus of the first decade of IODP. Three large projects have received multiple legs of drilling. NantroSEIZE is targeting the shallow-dipping plate boundary of the accretionary margin in the Nankai Trough, offshore southwestern Japan. It is the largest project ever carried on in the history of scientific ocean drilling: 10 expeditions and the deepest hole, >3000 mbsf, ever drilled so far, with the goal of reaching the seismogenic plate interface ~5200 mbsf. CRISP has focused on the erosive subduction margin where the Cocos Ridge subducts beneath Middle America. There the plan is to reach the seismogenic plate interface in a tectonic setting similar to the Japan Trench responsible for the Tohoku Earthquake in 2011. The first phase of shallow drilling in Costa Rica was completed in 2012. Finally, J-FAST has studied the region of the 2011 Great Tohoku Quake, and penetrated the décollement in the area of the frontal rupture. NantroSEIZE and CRISP will continue during the next phase of IODP, with their ultimate goal being to drill through the seismogenic megathrust fault zone at each of these sites. After the surprising discovery of slow-slip by 'episodic tremor' along the plate interface, an additional site, Hikarangi offshore New Zealand, has received intense interest as a possible place where a tremor-region may be reachable by deep-sea drilling from the Chikyu.

This talk focusses on plate boundary seismogenesis; what we are discovering and can discover from drilling-based studies. It presents these ideas within the broader context of what we can learn from complementary geological and geophysical studies of fossil and active megathrust systems. Several major new findings from drilling-based research include: the discovery that the frictional properties of fault zone material, not fluid overpressure, are the controlling factor responsible for fault strength and rupture propagation to the toe; the discovery of striking differences and similarities between erosive and accretionary forearcs such as the finding that both can have high rates of sediment input, but with different distributions of sediment accumulation within the forearc; and the finding of complex principal stress orientations within these diverse forearc study areas.