Deep Tremor in Subduction Zones: The transition from stick-slip to stable sliding

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Deep, non-volcanic tremor is a long-duration, low amplitude signal resembling volcanic tremor. The first report of the signal was in SW Japan (Obara, 2002) from high sensitivity (Hi-Net) velocity recordings. The Hi-Net array in Japan is composed of high sensitivity seismic stations and was installed across the Japanese archipelago after the 1995 Hyogoken-nanbu Earthquake by the National Research Institute for Earth Science and Disaster Prevention (NIED). The average spacing of Hi-Net stations is 20-30 km, and includes three-component seismometers buried at a depth of at least 100 m. The high quality of these instruments in tandem with comprehensive coverage across Japan enabled the NIED to discover tremor and explore the systematics of its behavior. Since its discovery in SW Japan, deep tremor has also been observed in other subduction zones such as Cascadia, Alaska and Costa Rica (Schwartz and Rokosky, 2007). Although ideally suited for detecting tremor, high sensitivity, borehole seismic instruments are not absolutely required.

More recently it was shown that deep tremor in SW Japan consists of a swarm of low frequency earthquakes (LFEs). LFEs are small, slow earthquakes (*Katsumata and Kamaya*, 2003; *Ide et al.*, 2007) that occur primarily during periods of deep tremor and occur as slow shear slip on the down-dip extension of the primary seismogenic zone of the plate interface (Shelly et al., 2007). Deep tremor in Cascadia and Costa Rica is also composed of LFEs on the down-dip extension of the plate interface (see attached Fig., Brown et al., 2009). In each case, the LFE locations suggest tremor occurs as a transient swarm of LFEs in a transitional zone between stick-slip seismicity and aseismic stable sliding of the plate interface.

Although deep tremor has turned into one of the fastest moving fields in modern seismology, the signal and faults that produce it remain mysterious. For example, deep tremor comes from a diverse range of subduction zones. Some are hot (SW Japan), while some are cold (Costa Rica). Moreover, incoming plate age does not seem to be a controlling factor (e.g. Cascadia vs. Alaska) in whether tremor occurs. Another mystery is the differing recurrence intervals of deep tremor. We are very much in the early days of understanding tremor, however, as recording capabilities and methods improve our understanding will improve, and new questions will emerge.

Finally, one of the biggest remaining questions about tremor is the spatial and possible temporal relationship to large earthquakes on the adjacent locked portion of the plate interface. Tremor may outline the down-dip extent of large earthquake rupture (*Chapman and Melbourne*, 2009), which is a critically important factor in seismic hazard estimation. Slip in the deep continuation of the plate interface should increase the stress in the up-dip portion of the fault, potentially increasing the probability of a large earthquake during or soon after a transient slip episode (Rogers and Dragert, 2003). This motivates earthquake seismologists to monitor deep tremor because it may contain useful information for studying time-dependent seismic hazard.

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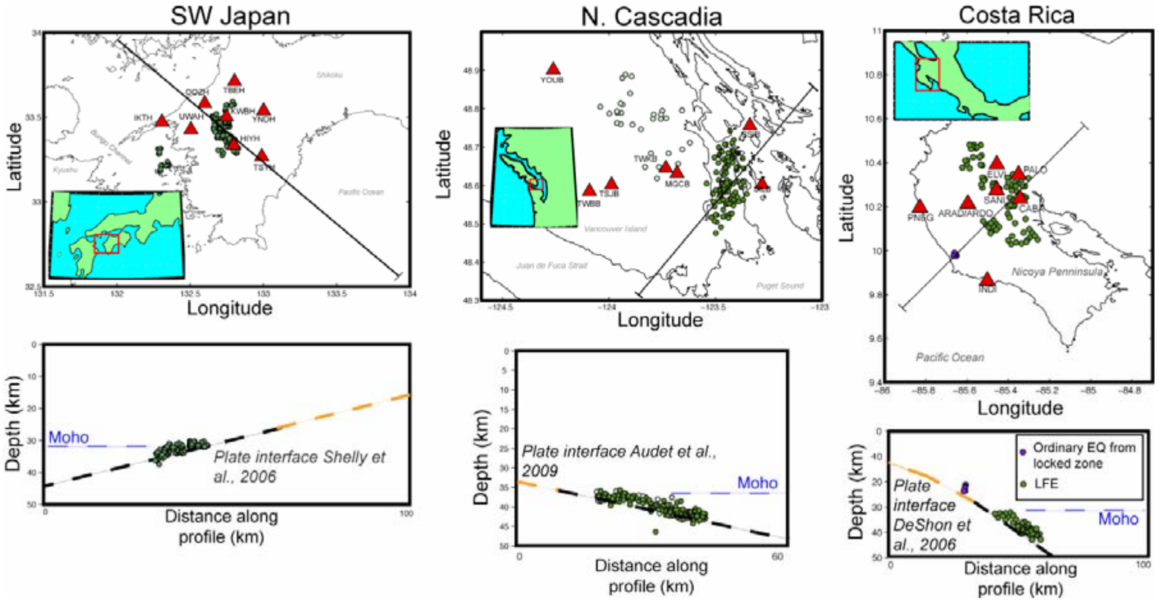
SW Japan
N. Cascadia
Costa Rica
Latitude
Longitude
Depth (km)
Distance along profile (km)
Moho
Plate interface Shelly et al., 2006
Plate interface Audet et al., 2009
Plate interface DeShon et al., 2006
Ordinary EQ from locked zone
LFE
Nicoya Penninsula
Pacific Ocean