Investigating Relationships of Episodic Tremor and Slip and Seismicity Along the Northern Cascadia Margin

H. Dragert, H. Kao, G.C. Rogers, K.Wang, J.F. Cassidy, and S. Mazzotti
Geological Survey of Canada, Pacific Geoscience Centre, Sidney, B.C. V8L 4B2 Canada

Episodes of prolonged occurrences of non-volcanic tremor and of slow slip have now been documented for the southern Vancouver Island region for the past 25 years and 14 years respectively. Based on these combined seismic and GPS observations, we currently define Episodic Tremor and Slip (ETS) empirically as repeated, transient ground motions at a plate margin, roughly opposite to longer-term elastic deformation motion, accompanied by distinct, emergent seismic signals in the 0.5 to 5 Hz band. Although all the processes involved in ETS are not fully understood, these observations to date suggest spatial and possibly temporal relationships between ETS and the three types of regional earthquake activity that characterize Cascadia seismic hazard. Spatially, ETS and regional seismicity tend to be mutually exclusive. Although the last Cascadia subduction thrust earthquake pre-dates written historical records, instrumental observations of non-volcanic tremor in the Nankai subduction zone of southern Japan (Obara, 2002) suggest that the ETS zone may mark the landward limit for megathrust rupture (Dragert et al., 2004). Furthermore, the northern Cascadia ETS zone appears to be confined to a region overlying the descending Juan de Fuca plate where fewer in-slab earthquakes occur. Detailed observations of more recent tremor episodes have not only established an extended depth distribution for tremor sources but also suggest tremors occur in regions where fewer crustal earthquakes are found (Kao et al., 2006). Epicentres of the large (M>6) crustal earthquakes that occurred on central Vancouver Is. in 1918 and 1946 fall outside of observed tremor concentrations, suggesting crustal stress relationships between large earthquakes and tremor.

Temporal relationships are more conjectural. If ETS episodes are the direct result of slip on the deeper plate interface, it is conceivable that a slip event could develop into a trigger for rupture on the locked portion of the thrust fault lying directly up-dip of the slip region. Commensurately, the cumulative weekly conditional probability for a megathrust event is increased at the time of an ETS event (Mazzotti and Adams, 2004). How significant such an increase in probability may be is not clear since ETS episodes occur with different repeat intervals along the full extent of the Cascadia margin (Brudzinski and Allen, 2006) and triggering of the megathrust earthquake could occur anywhere along the margin. Any ubiquity of ETS activity over time would require anomalous changes in the character of a particular ETS episode in order to make it useful as a precursor of a megathrust earthquake. A search for changes of rates of in-slab earthquakes coincident with ETS events has produced ambiguous results so far, showing marginal changes in seismicity rates for some of the ETS events but not for others. Coulomb stress from a slip on the deeper subducting plate interface would tend to retard the occurrence of a normal in-slab rupture directly down-dip of the slip but promote normal in-slab rupture directly up-dip of the slip. No convincing temporal correlation has yet been established between ETS occurrence and low-magnitude crustal seismicity. Interestingly, the July 2004 M6.4 earthquake that occurred 40 km offshore from central Vancouver Is. coincides with an "out-of-sequence" ETS event in northern Vancouver Is., again suggesting stress interactions between ETS and large crustal earthquakes.

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