Tectonic Tremor Triggered along Major Strike-Slip Faults around the World

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Research Question
How does triggered tremor differ on strike-slip faults around the world?

Background
Deep tectonic tremor, which generally occurs in the lower crust beneath the seismogenic zone where earthquakes occur, has been observed at several major plate-bordering faults around the Pacific Rim. In order to investigate the potential link between tremor and earthquake nucleation, further study of when, where, and how tremor occurs is needed. Tremor is known to occur intermittently, sometimes in association with GPS detected slow-slip events but could also be triggered by small stress perturbations arising from solid earth tides as well as passing seismic waves from distant earthquakes. Because triggered tremor occurs on the same fault patch as ambient tremor (Grossby, 2009) and generally has a higher signal-to-noise ratio, it is relatively easy to identify.

We present a review of triggered tremor in 4 strike-slip regions: (1) the Eastern Denali Fault in Yukon, Canada, (2) the Queen Charlotte Fault near Haida Gwaii, Canada, (3) the San Andreas Fault near Parkfield, CA, and (4) the Enriquillo-Plantain Garden Fault in the southern Haiti peninsula. We characterize triggered tremor as broadband signals with long durations that are coincident with surface waves from a distant earthquake. We locate tremor sources using the envelope noise ratio, it is relatively easy to identify.

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Methods
Select a study region
Strike-slip faults with no tremor observations, comparable to the San Andreas Fault
Select earthquakes as potential triggers
Shallow, less 100 km depth
Magnitude > 5.5
Distance > 100 km
Peak dynamic stress > 14 ps

Retrieve, process, and analyze seismic data
Instrument connection
Filtering
Triggered tremor identification
Triggered tremor location

Results
Figure 1. Illustration of the brittle, fast-sliping seismogenic zone (red), and slow-slip zones (yellow) and stable sliding zones (blue) for a variety of faults. Blue line is where tremors and earthquakes generally occur. Tremor generally occurs in the region marked by the symbols. From Kavanagh (2008).

Figure 2. Location of tremor sources around the world, with regions where tremor has not previously been observed (this study) marked as red stars. So few examples of triggered tremor have been observed to date that it is not known whether it is a world-wide phenomenon or if it is not a world-wide phenomenon. This study seeks to answer this question.

Figure 3. Triggered tremor near the Eastern Denali Fault of eastern Canada.

Figure 4. Triggered tremor triggered near the Queen Charlotte Fault of western Canada. From Aiken et al. (2013).

Figure 5. Triggered tremor triggered near the San Andreas Fault of Parkfield, CA.

Figure 6. Triggered tremor triggered near the Enriquillo-Plantain Garden Fault of Haiti (Figure 5). Amplitude Spectra (cm/s/Hz)

Figure 7 (LEFT). Theoretical example of triggered potential as a function of wave amplitude (i.e. stress), depth (i.e. frequency), and incidence angle on a vertical strike-slip fault. From Hill and Presley (2015).

Figure 8 (RIGHT). Triggering earthquake characteristics for all earthquakes studied in Yukon, Canada. (a) Peak transverse dynamic stress vs. angle of seismic wave incidence. (b) Surface wave velocity spectra. Event labels in (b) also permit to outline color in (a) and in map for this region (Figure 3).

Figure 9 (LEFT). Triggering earthquake characteristics for all earthquakes studied in Haida Gwaii, Canada. Symbols and notations are the same as in Figure 7. Event labels in (b) also permit to outline color in (a) and in map for this region (Figure 6).

Figure 10 (RIGHT). Triggering earthquake characteristics for all earthquakes studied near Parkfield, CA. Symbols and notations are the same as in Figure 7. Event labels in (b) also permit to outline color in (a) and in map for this region (Figure 5).

Figure 11 (LEFT). Time dependent dynamic stress computed for the Enriquillo-Plantain Garden Fault at 20 km depth with a friction coefficient of 0.2. (TOP) Vertical and tangential displacement seismograms. (MIDDLE) Dynamic “stress”gradients for vertical and transverse components. (BOTTOM) Trigger and envelope.

Conclusions
• We discovered triggered tremor on 3 strike-slip faults where tremor was not previously reported.
• We located the tremor sources to be on or near the fault traces in each of the regions.
• Our triggering observations are in agreement with the Coulomb failure criterion (Hill and Presley, 2013).
• Long period, large amplitude surface waves are responsible for triggering tremor in these regions, as has been observed elsewhere.
• The Parkfield segment of the San Andreas Fault is more easily triggered than the other regions, which reflects recent strength properties of the fault.

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Literature Cited


