A FEW TINY INTRAPLATE EARTHQUAKES TRIGGERED BY NEARBY EPISODIC TREMOR AND SLIP IN CASCADIA

John Vidale[1], Alicia Hotovec[1], Abhijit Ghosh[1], Ken Creager[1], Joan Gomberg[2]

[1]University of Washington, Department of Earth and Space Sciences; [2]USGS, Seattle

ABSTRACT

Episodic tremor and slip (ETS) has been observed in many subduction zones, but its mechanical underpinnings as well as its potential for triggering damaging earthquakes have proven difficult to assess. Here we use a seismic array in Cascadia of unprecedented density with a novel detection method to monitor seismicity before, during and after a moderate ETS episode. We observe five tiny earthquakes within the subducting slab during the 16-day episode, and only one more in the same area, which were just before the next ETS burst, in the four months we examined. The pattern of earthquakes suggests slow slip has a more continuous temporal and spatial pattern than the tremor loci, which notoriously appear in bursts, jump, and streak. The earthquakes concentrate along the sides and updip edge of the ETS region, consistent with greater stress concentration there than near the middle and downdip edge of the tremor area. At least one normal-appearing earthquake was very near the tremor, rather than there being a spatial separation between tremor and normal earthquakes. Most of the seismicity is below the megathrust, with a similar depth spread as the background intraslab seismicity. Intraslab earthquakes may, if they follow this pattern more generally, correlate in space and time with the presence of nearby slow slip episodes.

BACKGROUND

We closely examine the small 6 to 21 March 2010 ETS episode because it occurred mostly within an area that was well instrumented by our recent EarthScope Array of Arrays dense seismometer deployment. Occasional nearby earthquakes were obvious on individual seismograms, even during tremor, due to the broadband impulsive energy visible first as vertically-polarized compressional waves, then a few seconds later as horizontally-polarized shear waves. We produced a "detector" time series with an algorithm seeking isolated P and S arrivals with minimal coda, and with the P and S waves separated by 3 to 8 s.

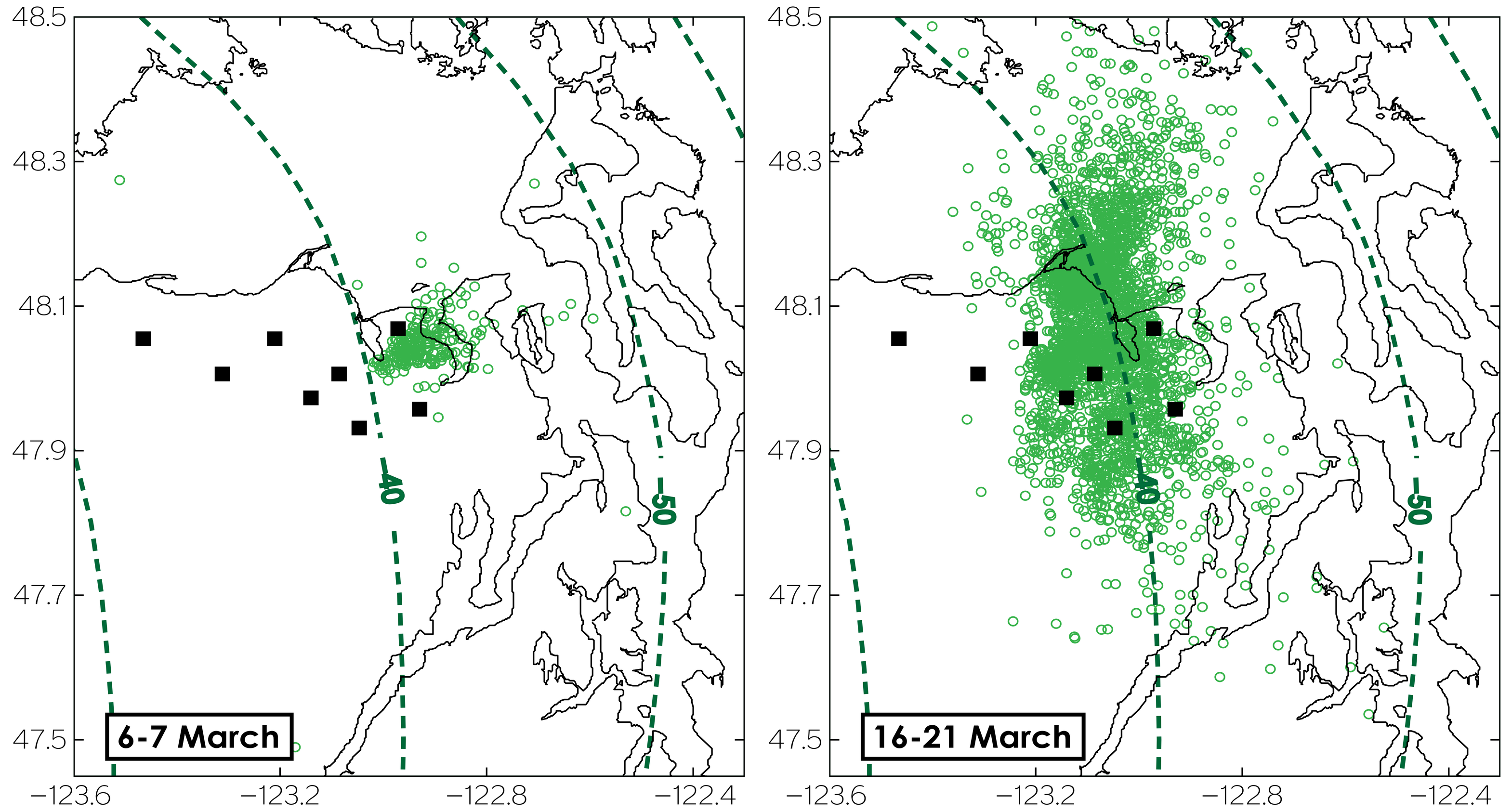


Figure 1. Map of ETS locations that occurred 6 to 7 March 2010 (left) and 16 to 21 March 2010 (right). Black squares mark array locations, tiny green circles mark detections of tremor in 1-minute intervals using multi-beam backprojection. Slab-depth contours are marked with dashed lines, and numbers indicate slab depth in km.

DATA ANALYSIS

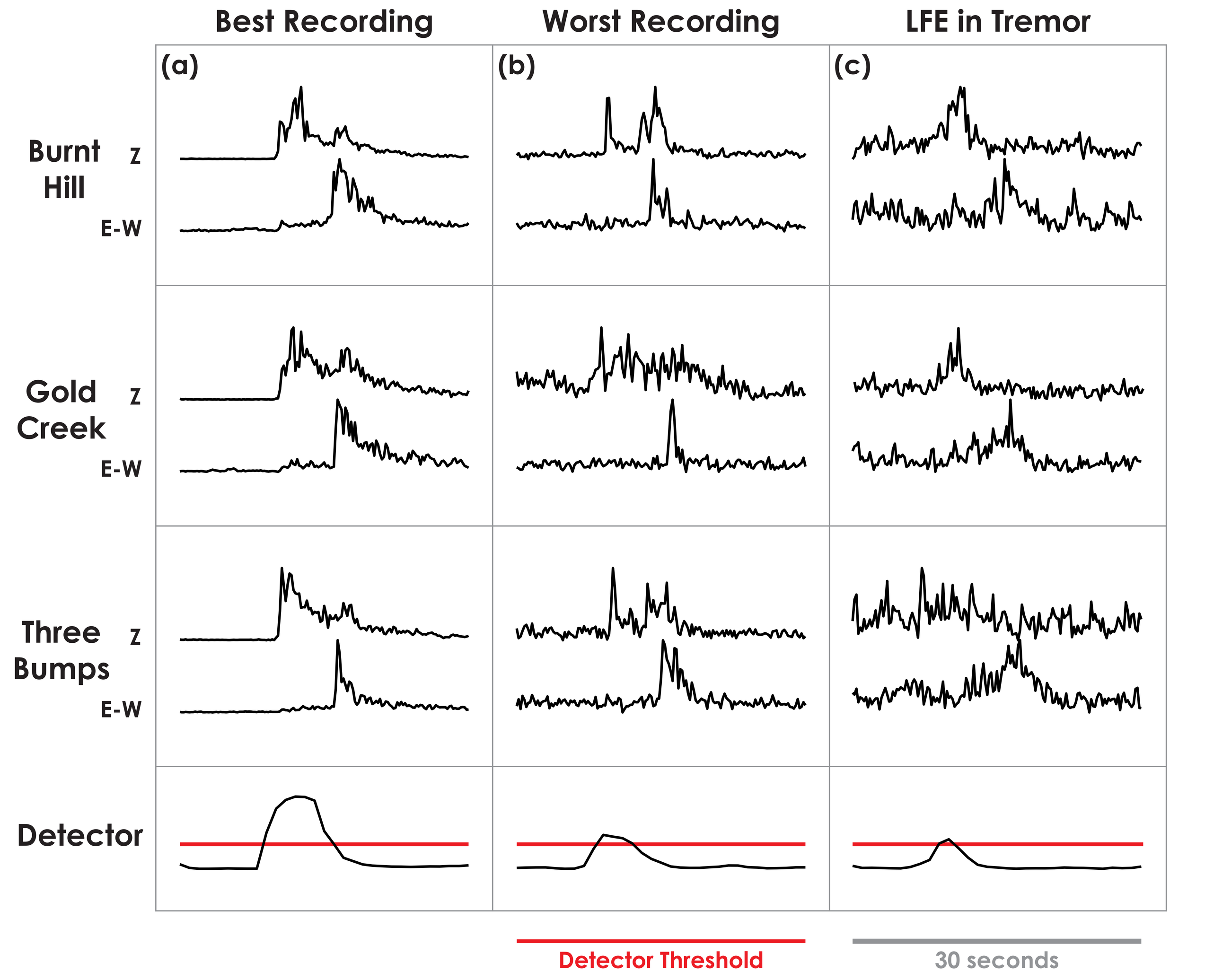


Figure 2. Comparison of the vertical and horizontal stacks from 3 representative arrays for (a) the largest earthquake at 12:31:13 on 17 March 2010, (b) the earthquake at 12:13:20 on 13 March 2010, which is the weakest of the triggered earthquakes, and (c) tremor at 13:55:50 on 15 March 2010. The "Z" traces are stacks of the envelopes of 10-15Hz bandpass-filtered vertical-component seismograms across the named array. The "E-W" traces are stacks of the envelope of 2-8Hz bandpass-filtered east-west-component seismograms across the named array indicated in the y-axis label. The detector is tuned to find isolated P waves on the vertical, followed a few seconds later by isolated S waves on the east component, detected on many arrays within a few seconds.

TIMELINE

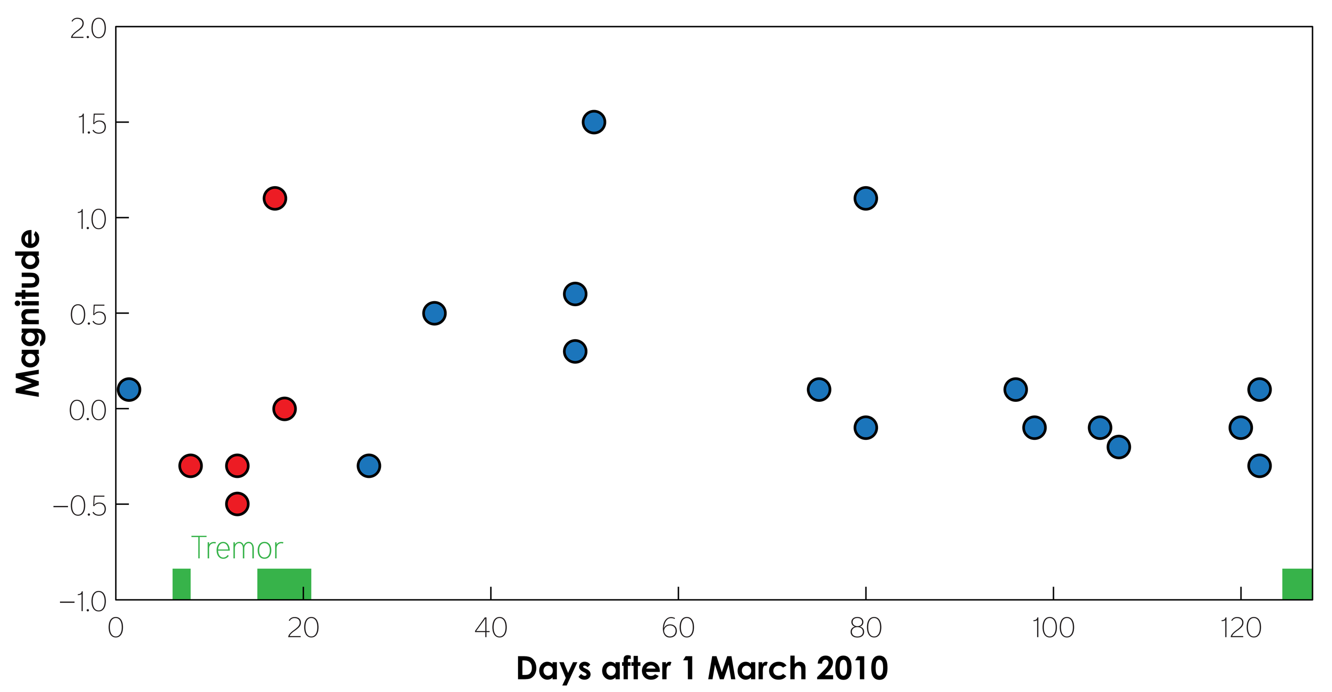
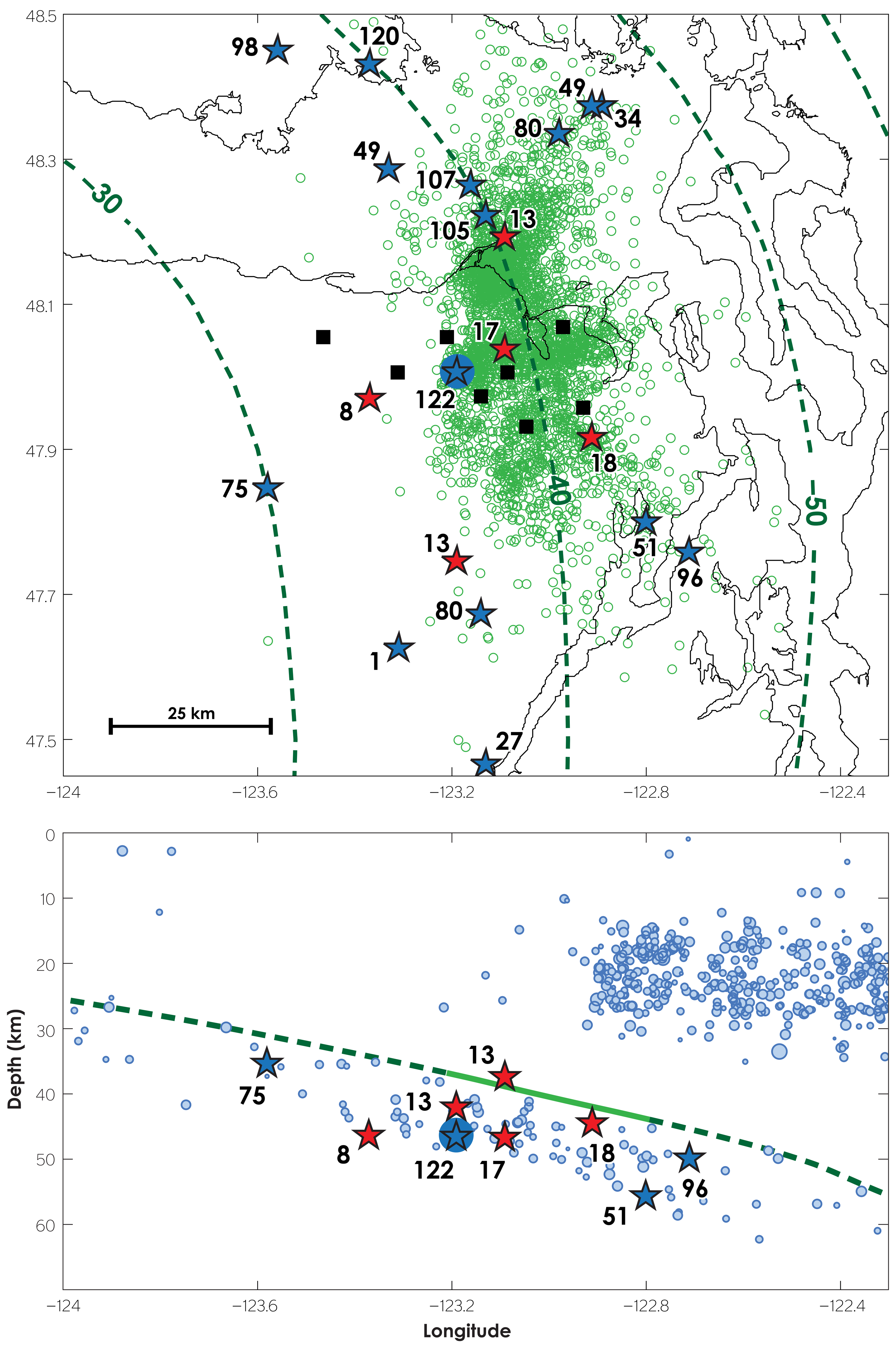


Figure 3. Timeline indicating the occurrence times of the located earthquakes (circles), and tremor (green rectangles). Earthquakes during tremor are red. Magnitude estimated simply from the amplitude of stacks such as are shown above, and likely have uncertainty of at least 0.3.

RESULTS & INTERPRETATIONS



Timing of the earthquakes near the tremor, combined with their locations, inidcate the two are related. Five of the six earthquakes in the central region occurred during the March tremor, and the last just two days prior to the next minor episode in July.

The rate of earthquakes across the entire area is several times higher when it is two or less days from tremor activity than the rest of the time, with 7 earthquakes in 15 days vs. 14 earthquakes in 107 days.

The timing of potentially triggered earthquakes also suggests slow slip is more continuous than tremor in the ETS, with earthquakes often preceding tremor.

Earthquakes concentrate near the updip limit of tremor, suggesting the stress concentration is greatest there, and is consistent with observations of tremor generally starting deep and migrating updip.

The low tremor density zone to the south is mostly free of earthquakes for the 4-month period, very speculatively suggesting it is not as prone to slow slip episodes as the tremor dense core, and rather the interface can only maintain lower stress in the outer halo.

The coincidence of ETS and these earthquakes shows intraplate slab earthquakes are at least sometimes triggered by nearby slow slip in a measurable way.

If can ETS trigger larger, more damaging earthquakes is yet to be determined.

Figure 4. Map (above) and cross-section (below) of ETS and earthquake locations. Tiny green circles on map mark detections of tremor in 1-minute intervals, and its lateral extent has been projected onto the slab interface as a solid green line. Red stars indicate earthquakes during the tremor episode, and blue stars are earthquakes at other times. The blue circle marks the earthquake striking two days before and nearby the tremor in July. Numbering indicates how many days after 1 March the earthquakes occurred. Background seismicity from 2000 to 2010 is marked as light blue circles on the cross-section, and was located by the PNSN using the same velocity structure as we located the events with the Array of Arrays.

Selected References

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