Subducting Slab Ultra-Slow Velocity Layer Coincident with Silent Earthquakes in Southern Mexico

Teh-Ru Alex Song[1], Don V. Helmberger[2], Michael Brudzinski[3], Rob Clayton[1], Paul Davis[4], Xyoli Pérez-Campos[5], Shri.K. Singh[5]

1.Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, NW, DC 20015,

corresponding to asong@ciw.edu 2.Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125. 3.Geology Department, Miami University, 114 Shideler Hall, Oxford, OH 45056 4.Department of Earth and Space Sciences, Center of Embedded Network Systems (CENS), University of California, Los Angeles, 595 Charles Young Drive East, Los Ageles, CA 90095-1567 5.Instituto de Geofísica, Universidad Nacional Autónoma México, Circuito de la Investigación Científica s/n, Ciudad Universitaria, 04510 México D. F

1 Abstract

Great earthquakes occurring on the subduction zone interface are known to be spatially persistent in a few shallow dipping subduction zones, where the subducting and overriding plate are strongly locked in the shallow portion of the plate interface. Silent earthquakes are recently discovered at the down-dip extension of the locked zone and are potentially changing the state of stress on the locked zone. However, it is not known if the zone of slow-slip is also spatially persistent and how it changes along strike within a given subduction zone. Here we show that locally observed converted SP arrivals and teleseismic underside reflections arrivals sampling the top of the subducting plate in southern Mexico reveal a spatially varying ultra-slow velocity layer (USL) ($3-5$ km, S wave velocity $\sim 2.0-2.7$ km/s). The majority of reported slow slip patches coincide with the presence of the USL and they are bounded spatially by the absence of the USL. The persistence of the USL before, during and after the slow slip events suggests its longevity, whereas the spatial extent of the USL delineates the zone of transitional frictional behaviour. We suggest that temporal variations in the coupling of the lock zone likely dictate the occurrences of slow-slip events in the transition zone.

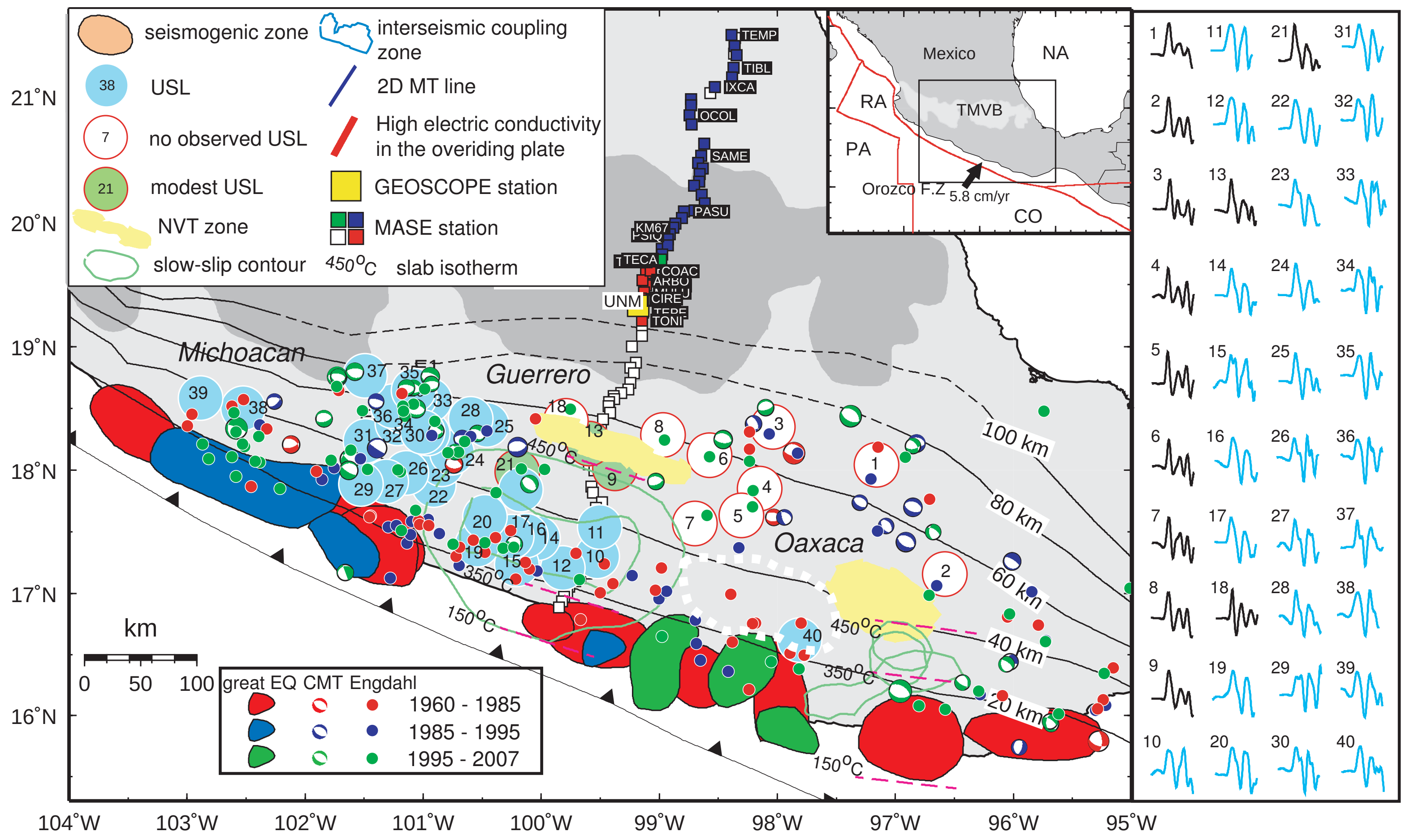

Figure 1: Mapping of the ultra-slow velocity layer (USL) beneath southern Mexico.P wave data ($0.01-0.6$ Hz)associated with blue circles (blue traces) are characterized by a large converted SP wave arriving about $2-3$ seconds after the first P wave (see Figure 2).

2 Observations of Regional Waveform Data

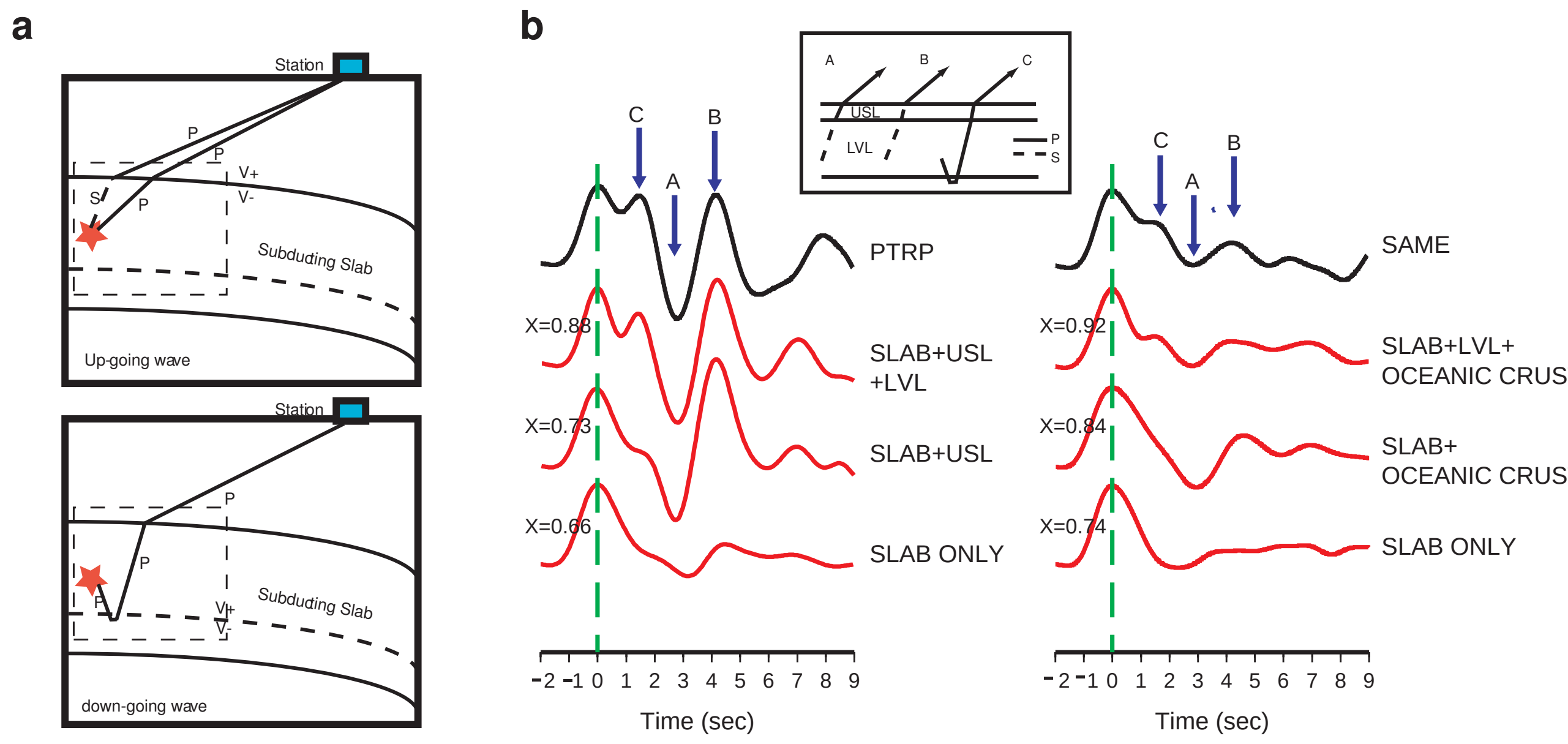

Figure 2: Pulse A and pulse B are SP converted arrivals from the bottom and the top of the USL, respectively; pulse C is possibly a turning P wave from the boundary of the LVL (see also inset), but it requires future investigation.Synthetics (USL = 3 km, -40%) explain the pulse A and pulse B at station PTRP.

3 Observations of Teleseismic Waveform Data

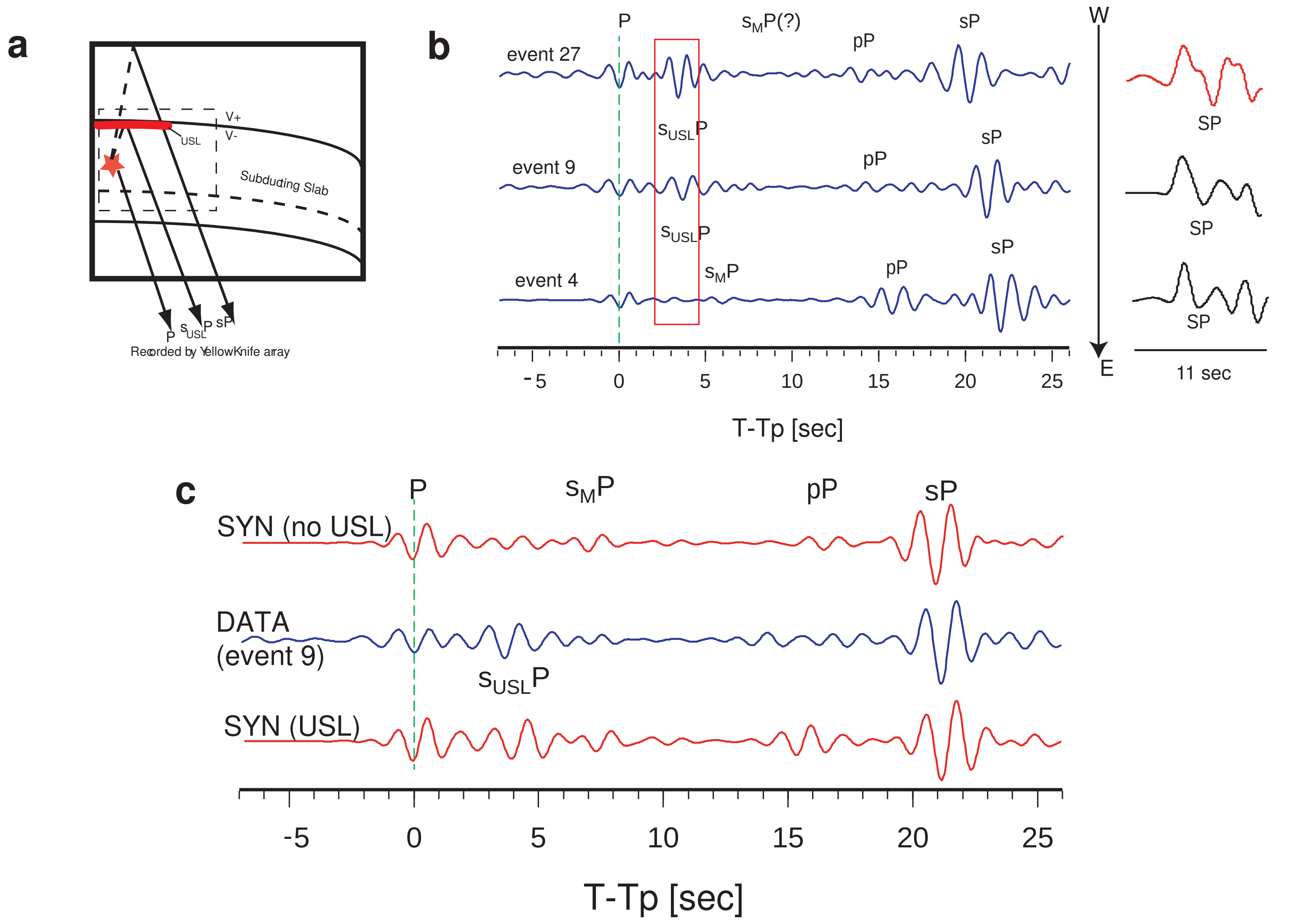

Figure 3: Modelling of the teleseismic waveforms verifies the USL. (a) Near source ray paths for down-going direct P wave, free-surface reflection pP wave, sP wave and underside reflection s_{USL}P from the USL. (b) Stacking traces from the array stacks from event 4 (no USL), event 9 (near edge) and event 27 (USL) recorded by the Yellowknife short-period array in Canada, while local P waveforms for these events are on the right. (c) Predictions match the amplitude of the sUSLP from event 9 when the USL has half the velocity reduction needed to model event 27. Synthetics computed from the model without the USL explain the data from event 4.

4 Monitoring Transition Zone and Slow-Slip Events

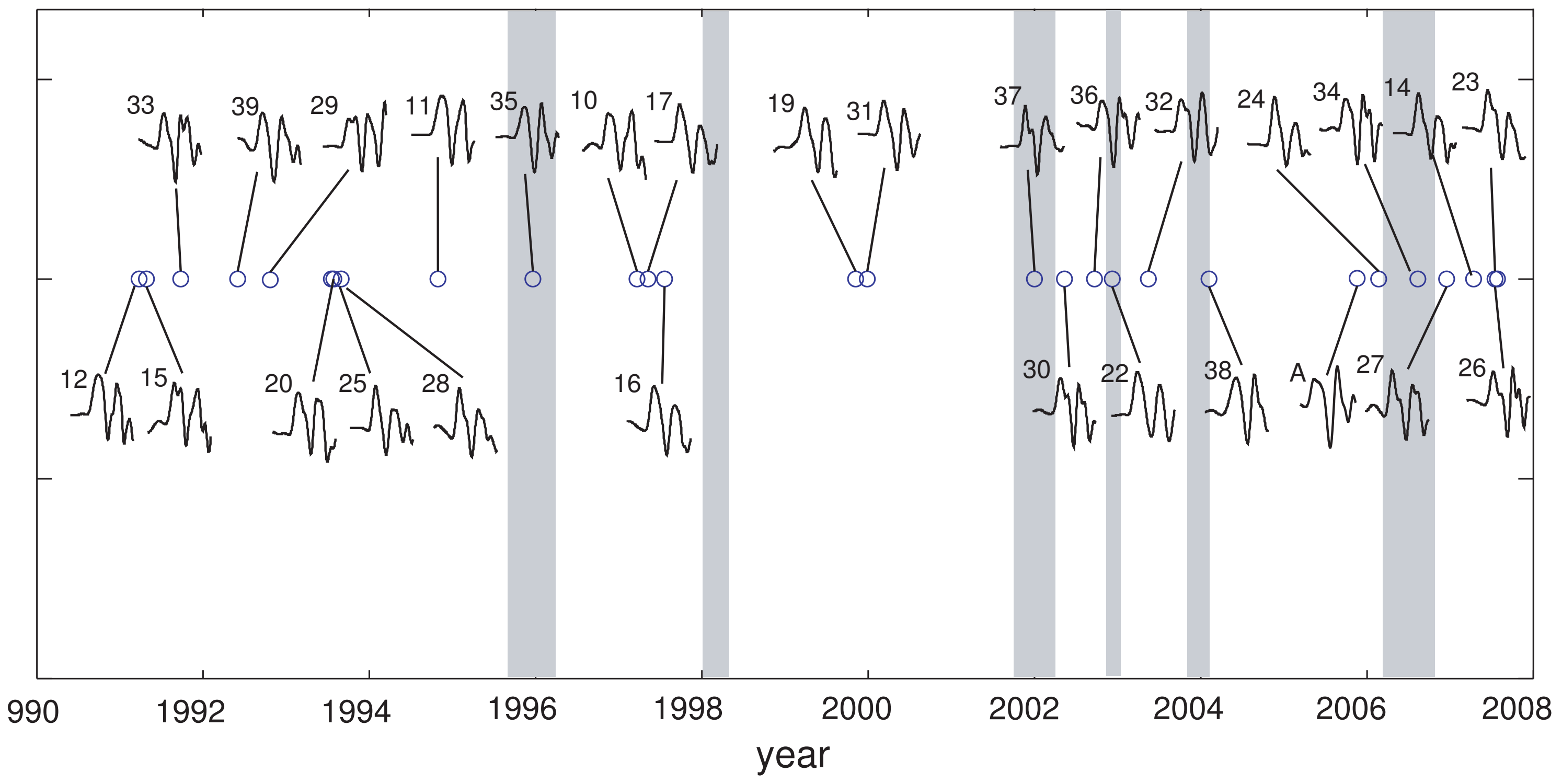

Figure 4: Temporal relationship between the USL and the slow-slip events (SSEs). Our observations of SP arrivals that travel through the USL occur at various times between 1991 and 2007, we can directly sample the USL before, during and after a SSE (grey zones) to see whether there is a temporal variation in the USL associated with slow slip. Data between 99^oW and 102^oW near Guerrero are included to demonstrate that strong SP waves from the USL are not only observed during the SSEs, but also are observed before and after the SSEs. We propose using the local converted SP wave from intra-slab events to monitor the zone of episodic slow slip and tremor over longer time scales and broader spatial scales to see whether the USL is a critical factor during the earthquake cycle and potentially into geologic time scales.

5 Summary

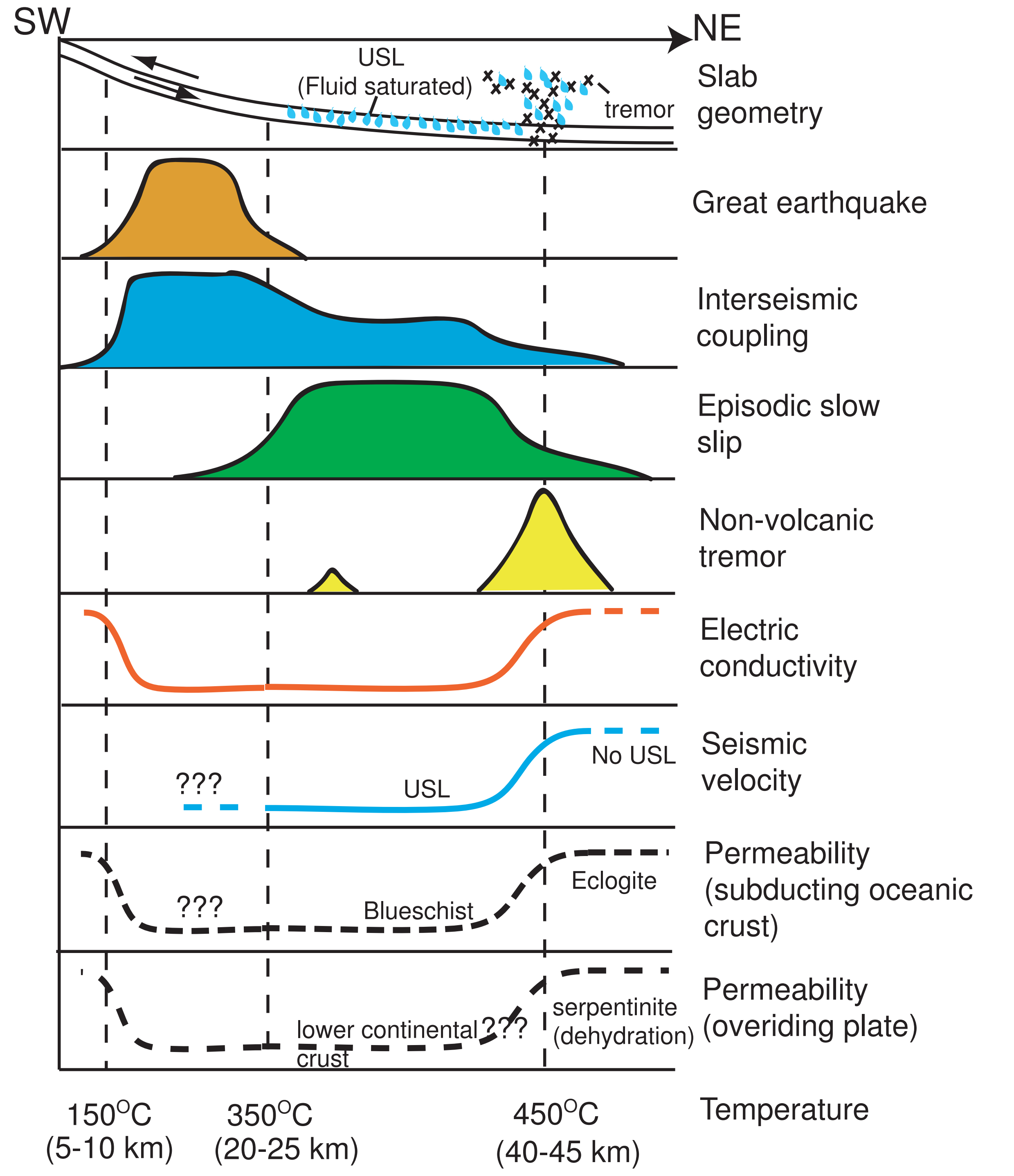

Figure 5: Summarizing observations and interpretations in southern Mexico.

6 A Perspective on Megathrusts, Intraslab Earthquakes and Slow-Slip Events

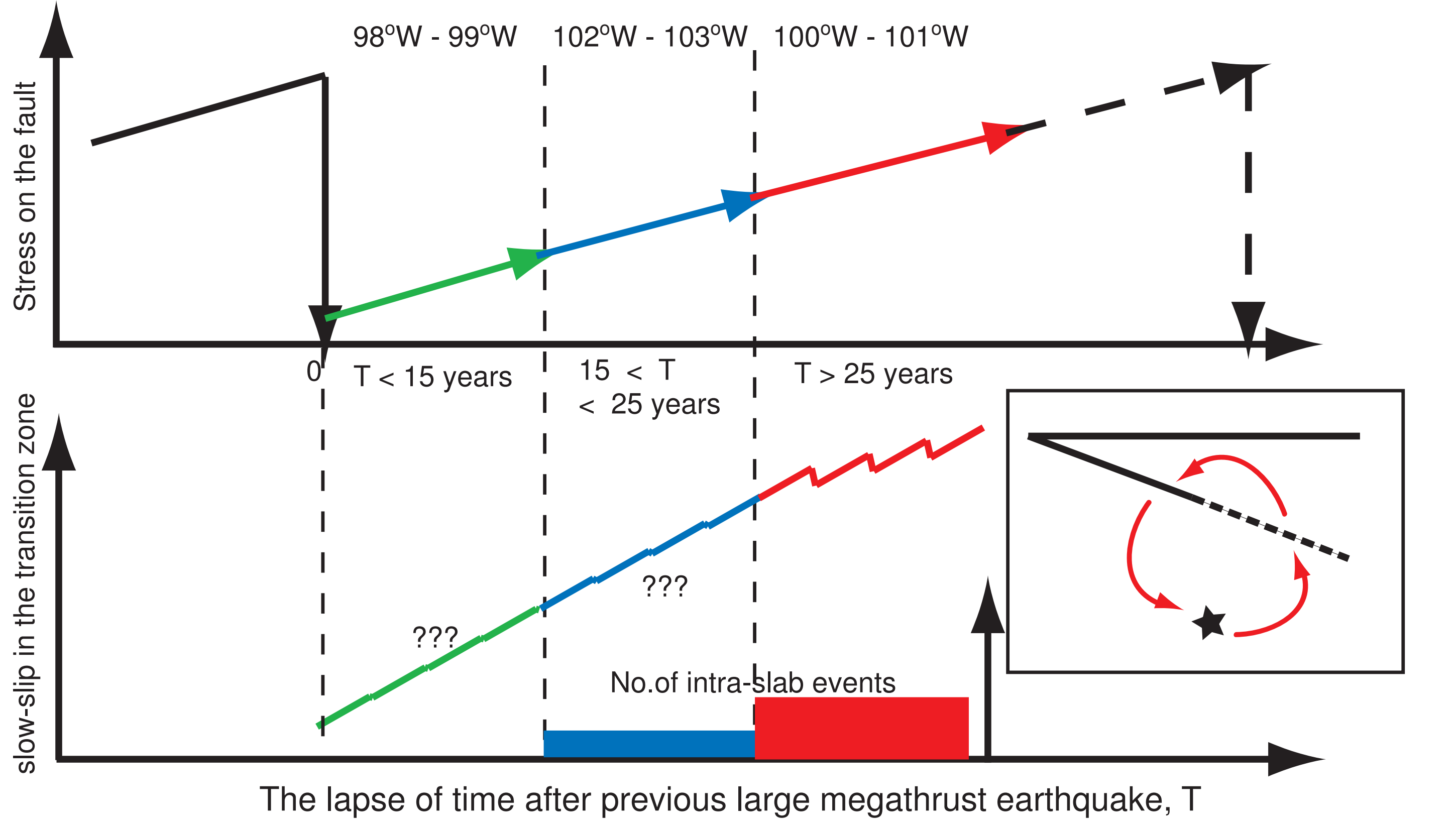

Figure 6: We purpose a stress feedback system where megathrust earthquakes, intra-slab events and SSEs are linked (see inset). In such a system, temporal variation in the degree of coupling at the plate interface manifests in the occurrences of intra-slab earthquakes and SSEs and it may provide a way to monitor mid-term seismic potential in subduction zones. Recurrent SSEs near Guerrero are likely to stress the seismic gap close to failure. Our hypothesis suggests that SSEs do not currently exist beneath western Oaxaca (98^o-^{o}99W, 16.9^o-17.4^{o}N, see also Figure 1), or are much smaller than the detection limit of current GPS instrumentation. Currently, there is no evidence showing significant transient slow slip beneath western Oaxaca during the 2006-2007 slow slip event.