

PALEOSEISMOLOGY AT THE CENTRAL CASCADIA SUBDUCTION ZONE

Ben Horton, Simon Engelhart, Andrea Hawkes, Alan Nelson, Kelin Wang, Pei-Ling Wang and Rob Witter

Paleoseismology at the Cascadia subduction zone addresses two questions guiding the GeoPRISMS SCD Initiative:

1. *What governs the size, location and frequency of great subduction zone earthquakes and how is this related to the spatial and temporal variation of slip behaviors observed along subduction faults?*
2. *How does deformation across the subduction plate boundary evolve in space and time, through the seismic cycle and beyond?*

Coastal paleoseismology addresses amounts and rates of Cascadia megathrust deformation throughout complete earthquake cycles, that is, over periods of hundreds to thousands of years. We measure subduction-zone strain accumulation and release indirectly by inferring coastal land-level changes from small (<2m) changes in relative sea level (RSL) that occur both instantaneously (coseismic) and gradually (interseismic). Measuring how and when the Cascadia plate boundary deforms facilitates our understanding of subduction at other plate boundaries and improves assessments of earthquake and tsunami hazards in western North America.

Some consider Cascadia to be the type area of subduction-zone paleoseismology. Its coasts harbor an extensive archive of land-level changes that are inferred from stratigraphic evidence. Regional sea-level rise at rates of ~1 mm/yr along the central Cascadia margin since 5-6 ka has resulted in largely continuous records of tidal sedimentation. This creation of accommodation space allows for the preservation of the sedimentary record. As inferred from couplets of interbedded organic and muddy sediment beneath tidal wetlands, the Cascadia coastal stratigraphy may record up to twelve great earthquakes that ruptured much of the central and southern subduction zone since 6.5 ka. By comparison, the Holocene sedimentary and/or morphologic record of coseismic and interseismic land-level changes at many other subduction zones is incomplete. For example, south-central Chile has only fragmentary evidence for earthquake-induced land-level movements because of falling sea level since 6 ka combined with probable near complete postseismic recovery following great earthquakes. Southern coastal Alaska has a potentially extensive sedimentary record but constructing a megathrust history for this region has been hampered by large tidal ranges, high sedimentation rates, logistical challenges, and problematic ¹⁴C ages. In Sumatra, U-Th-dating of coral heads yields an extraordinarily precise and detailed record of land-level changes, but only for the past two centuries. In Hokkaido, tidal stratigraphy above deep parts of the Kuril megathrust shows evidence for repetition of slow postseismic uplift over 2.8 ka.

And yet the potential quantitative record of land-level changes during many earthquake cycles at Cascadia remains largely unexamined. Although several recent studies of the history of tsunami inundation are quite detailed, most paleoseismic fieldwork completed prior to 1995 understandably focused on overall stratigraphic framework and ¹⁴C dating of buried soils interpreted as evidence for sudden subsidence. A common approach was to describe the stratigraphic evidence of the most recent AD 1700 earthquake, now estimated at magnitude M8.8-9.2, and then assume that earlier earthquakes were similar. All but the most recent estimates of the amount of coseismic subsidence at Cascadia are too imprecise (errors of >±0.5 m) to distinguish, for example, coseismic from postseismic land-level movements, or to infer differences in amounts of subsidence or uplift from one earthquake cycle to the next.

One of the most precise ways of re-dressing this deficiency is to apply recently developed statistical transfer functions to microfossils, such as foraminifera and diatoms, collected from Cascadia estuarine sediments. Similar studies of sea-level change on other continents have obtained an unprecedented vertical resolution of ± 0.2 m.

We propose that the improved vertical resolution of land-level reconstructions throughout multiple earthquake cycles will: (1) yield more precise measures of coseismic and interseismic deformation over timescales of decades to centuries; (2) improve comparisons with the earthquake history inferred from offshore turbidites; (3) test hypothetical rupture segmentation boundaries; (4) provide some of the first measures of post-earthquake vertical deformation for prehistoric earthquakes; (5) examine evidence for or against precursory deformation just prior to great earthquakes; (6) help constrain regional slip models of Cascadia megathrust rupture for tsunami simulations; and (7) test hypotheses of slip-predictable, time-predictable, and slip-time-unpredictable strain accumulation.

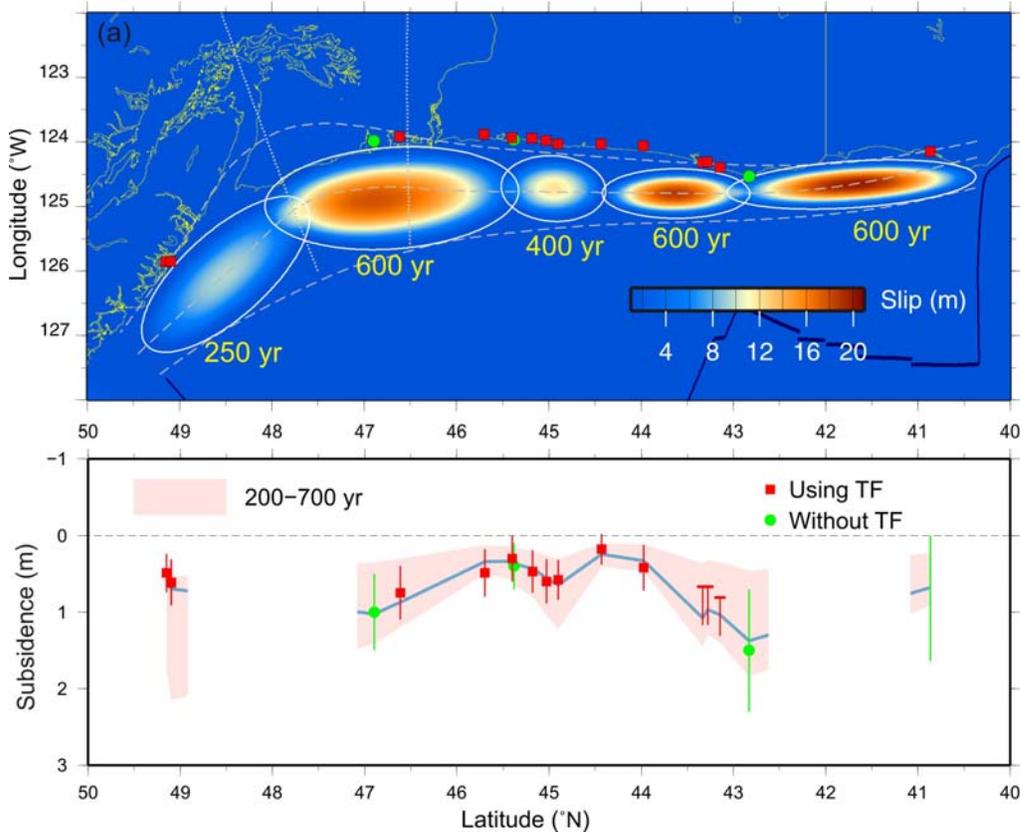


Figure 1: A preliminary dislocation model of the 1700 Cascadia earthquake to illustrate how paleoseismic data can help constrain rupture heterogeneity and what critical data are still missing. The model uses 3-D fault geometry and spatially variable slip distribution. (a) Slip distribution consisting of high-moment slip patches, with patch boundaries delineated by white lines. Peak slip (reddest point) for each patch is measured in terms of equivalent time of plate convergence. (b) Model-predicted coseismic subsidence in comparison with paleoseismic observations. TF: transfer function. The shaded band is bounded by results for uniform slip of 200 yr and 700 yr. Uncertainties in the paleoseismic data are described as follows: symmetric error bars indicate normal distribution, one-sided error bar indicate minimum subsidence estimate, and a bar with no symbol indicates uniform distribution.