Paleoseismology at the Hikurangi Margin

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Paleoseismology along Hikurangi Margin coastlines contributes to 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 can address amounts and rates of Hikurangi megathrust deformation throughout complete earthquake cycles over periods of hundreds to thousands of years. We aim to 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 the magnitude and timing of Hikurangi plate boundary deformation improves assessments of earthquake and tsunami hazards in New Zealand as well as far field locations.

Marshes and tidal inlets from NE New Zealand contain an extensive sedimentary archive of Holocene earthquakes and tsunamis originating from the Hikurangi Margin (Cochran et al., 2005; 2006; Hayward et al., 2006). Multiple cycles of tectonic subsidence have been preserved in the sedimentary record. As inferred from couplets of interbedded organic and silty sediment beneath coastal wetlands, the Hawke's Bay coastal stratigraphy may record up to six great earthquakes over the last 7100 years (Hayward et al., 2006). This is similar to Holocene sedimentary sequences of coseismic and interseismic land-level changes at several other subduction zones such as Cascadia. Here, the sedimentary record has validated a 3-D elastic dislocation model for the Cascadia margin that allows the slip to vary both along strike and in the dip direction (Wang et al., in press). In contrast, other subduction zones (e.g. south-central Chile) have 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.

An improved paleoseismic record of the Hikurangi Margin is valuable to the GeoPrisms SCD initiative because it will aid in defining the source for paleoearthquakes. This would involve investigations of new sites along the Hikurangi Margin and increasing the resolution of radiocarbon age control for known events from new and existing sites (e.g. Cochran et al., 2005; 2006). An improved record will also quantify the vertical resolution of land-level changes throughout a seismic cycle. Statistical transfer functions will be developed to infer tidal elevations from microfossils (e.g. diatoms, foraminifera, pollen; e.g. Sawai et al., 2004). Existing studies of the history of Hikurangi Margin earthquakes and tsunamis indicate that a complicated pattern of land-level changes occur over short distances (Cochran et al., 2005). One of the most precise ways to resolve these patterns is to apply high resolution, microfossil-based, sea level reconstructions to Hikurangi coastal sediments. These reconstructions can then be compared with the well established northern Hikurangi turbidite record, which provides a continuous paleoearthquake history over the last 18 ka (Pouderoux et al., 2012).

Defining the extent of paleoearthquakes and quantifying the vertical land-level motion throughout multiple earthquake cycles will: (1) begin to clarify the relationship between upper plate fault movement and movement on the subduction thrust; (2) yield more precise measurements of coseismic and interseismic deformation over timescales of decades to centuries; (3) test hypothetical rupture segmentation boundaries; (4) provide more extensive measurements 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 Hikurangi megathrust rupture for tsunami simulations; and (7) test hypotheses of slip-predictable, time-predictable, and slip-time-unpredictable strain accumulation.

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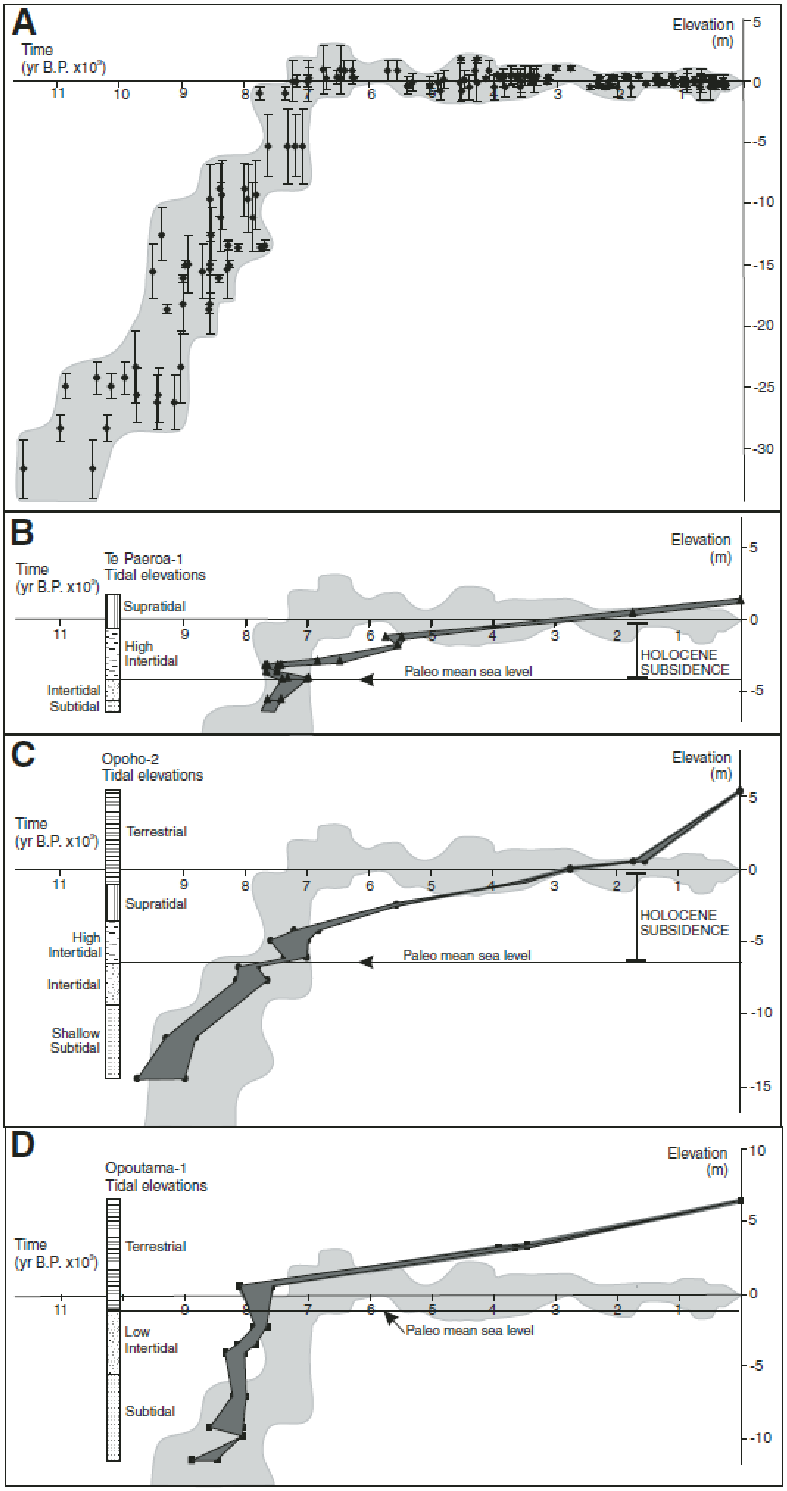

Figure 1: Using sea level reconstructions to estimate vertical land-level changes throughout a seismic cycle. (A) Holocene eustatic sea level curve for New Zealand. (B, C, D) Age-depth curves for select cores taken from Hawke's Bay, compared to Gibb's (1986) New Zealand sea level curve (shown in grey). Tidal elevations inferred from paleoenvironmental reconstructions are shown at left and indicate the position of paleo mean sea level. The inferred net Holocene subsidence is shown at right (Cochran et al., 2006).