Evidence for Great Earthquakes at Southern Humboldt Bay, California in the Past 3000 years

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Great (magnitude = 8) earthquakes have caused large areas of vertical land level change along the Cascadia subduction zone (Csz) from Cape Mendocino, in the south, to Vancouver Island, in the north. Sudden relative sea-level change induced by coseismic subsidence of the land preserved evidence of these earthquakes in the form of buried tidal-marsh soils. In an effort to determine subsurface stratigraphy, paleoseismic history, and relative sea level history along the historic and prehistoric margins of Humboldt Bay, we conducted geologic investigations within and adjacent to South Bay. The primary purpose of this study was to investigate the total extent of buried tidal marsh soils interpreted as evidence for Cascadia subduction zone earthquakes. This work is significant because it supports a related investigation being carried out by Witter et al. (2000, 2001) that focuses on the relations between great subduction zone earthquakes and upper-plate earthquakes on the Little Salmon fault. During the summer of 2001 Witter discovered four buried soils over a 1-km transect near Hookton slough in southern Humboldt Bay. Two of the buried soils show evidence for abrupt submergence and are associated with sand deposits. We interpret these features as stratigraphic evidence for earthquake-induced subsidence and tsunami inundation. During the summer of 2002, we found two buried marsh soils, each of which we infer was buried by coseismic subsidence. A candidate tsunami deposit overlies each buried horizon.Humboldt Bay lies along the southern margin of the Cascadia subduction zone.The Csz is a convergent tectonic plate boundary where the Gorda subducts to the east under the North American. The plate boundary spans almost 1,000 km from Vancouver, British Columbia to near Cape Mendocino, California. To the east of the subduction zone the upper plate is deformed by thrust faults and folds in the accretionary prism. This fold-and-thrust belt comes onshore in the Humboldt Bay region. These upper plate thrust faults pose a significant hazard to the residents around Humboldt Bay because they have the potential to generate strong ground motion, liquefaction, and surface fault rupture.

The Little Salmon fault zone is a northwest striking, upper plate fault zone that extends more than 40 km. Field investigations have demonstrated that the Little Salmon fault zone is active and consists of three distinct traces that together exhibit the largest estimated slip rate of all upper plate faults in the region (Carver and Burke 1988). Carver and Burke (1988) investigated the western trace of the Little Salmon fault and estimated that in the past 2000 years three earthquakes have occurred with 3.6 to 4.5 m of slip per event providing an average slip rate of 5.5 mm/yr.

Witter et al. (2000, 2001) found a moletrack scarp that projects into a marsh near the Swiss Hall, east of HWY 101. Using a core sampling strategy, followed by trenching, they found 4 to 5 slip events along the Little Salmon fault in the past ~3,000 years. In addition to detecting multiple slip events, Witter also documented broad areas of land level deformation (Witter et al., 2000, 2001).

This project, 1.5 to 2.5 km to the west of the Witter site, demonstrates that the areal extent of the strata preserved at the Witter is widespread and confirms that prehistoric earthquakes caused the broad areas of the estuary to subside. Stratigraphic investigations were conducted with the use of 3-cm diameter "gouge" core samples along a one km transect in order to identify and measure subsurface stratigraphy, followed by 7.5-cm diameter vibra-core to recover radiocarbon and biostratigraphic samples. The gouge cores were hand driven, while the vibra-cores were driven by vibrations from a portable gas engine.

Two buried tidal-marsh to upland soils are abruptly overlain by a tsunami deposit. Diatom biostratigraphy confirms the abruptness of this lithostratigraphic change. The oldest buried soil was likely an upland setting that was suddenly buried by a candidate tsunami deposit. The next oldest buried soil was a low marsh also suddenly buried by a tsunami

Assuming a one-mm/yr sedimentation rate, the oldest event is estimated to have occurred between 2 and 3 ka. The next oldest event is estimated to have occurred between 1 and 2 ka. The radiocarbon results will give a better estimate to the age of these events. The ages of two potentially correlative buried soils at the site investigated by Witter et al. (2000, 2001) have maximum radiocarbon age estimates of 1,340-1,510 yr BP (years before 1950) and 1,040-1,150 yr BP, respectively.

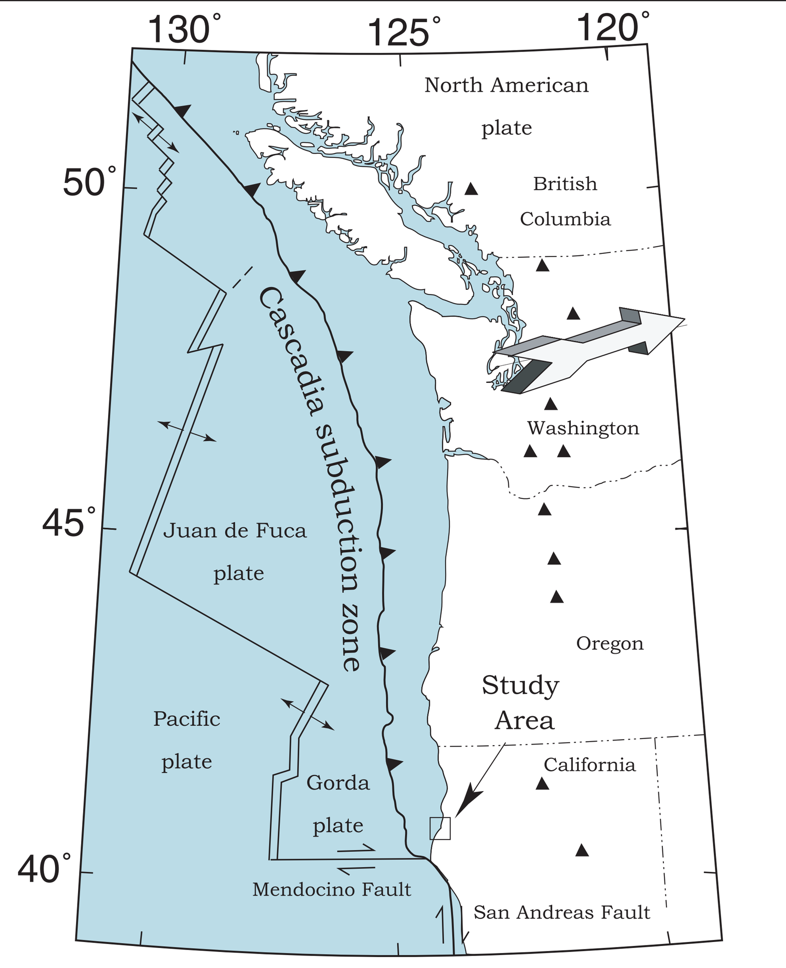
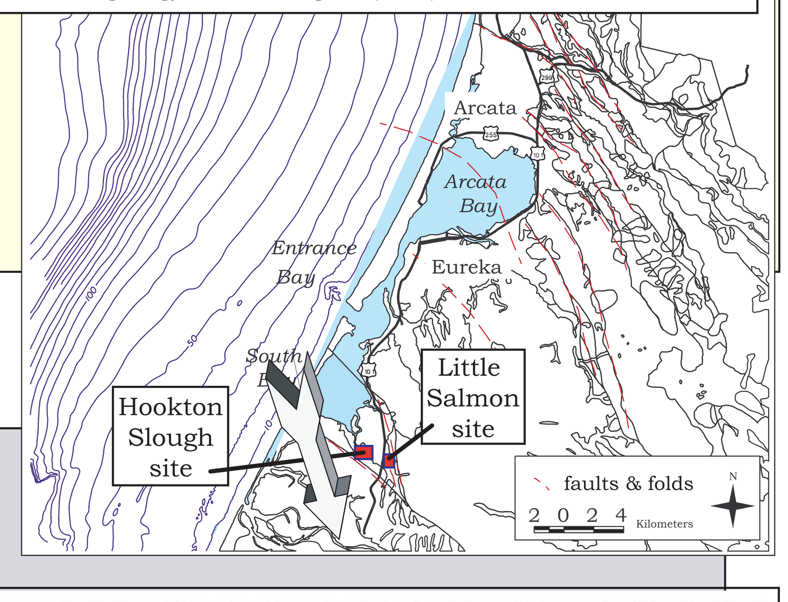


Figure 1. Cascadia subduction zone.

modified from Valentine (1992.)

Figure 2. Humboldt Bay and geologic structures.

source: geology from McLaughlin (2000), USGS 1:100,000 DLG roads



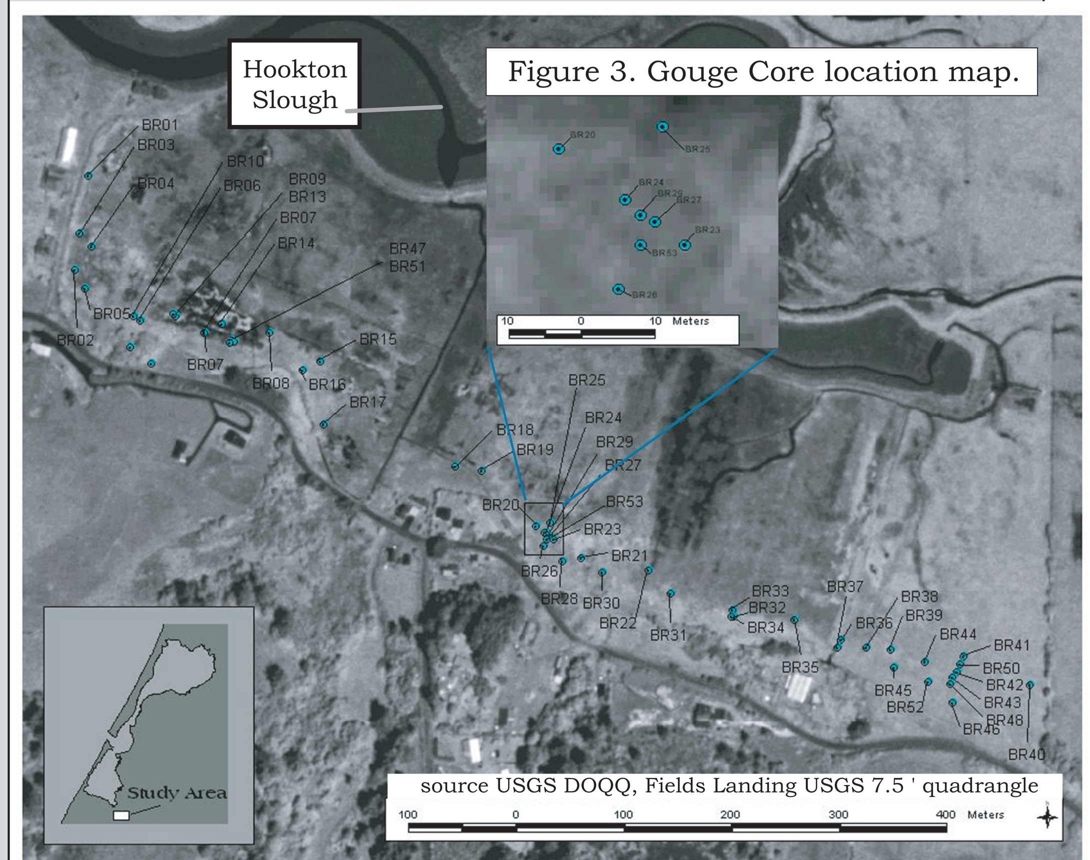
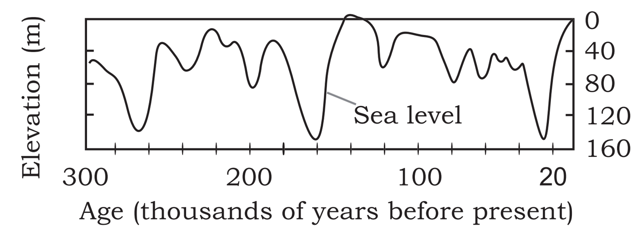


Figure 3. Gouge Core location map.

Figure 4. Late Pleistocene and Holocene sea-level curve.



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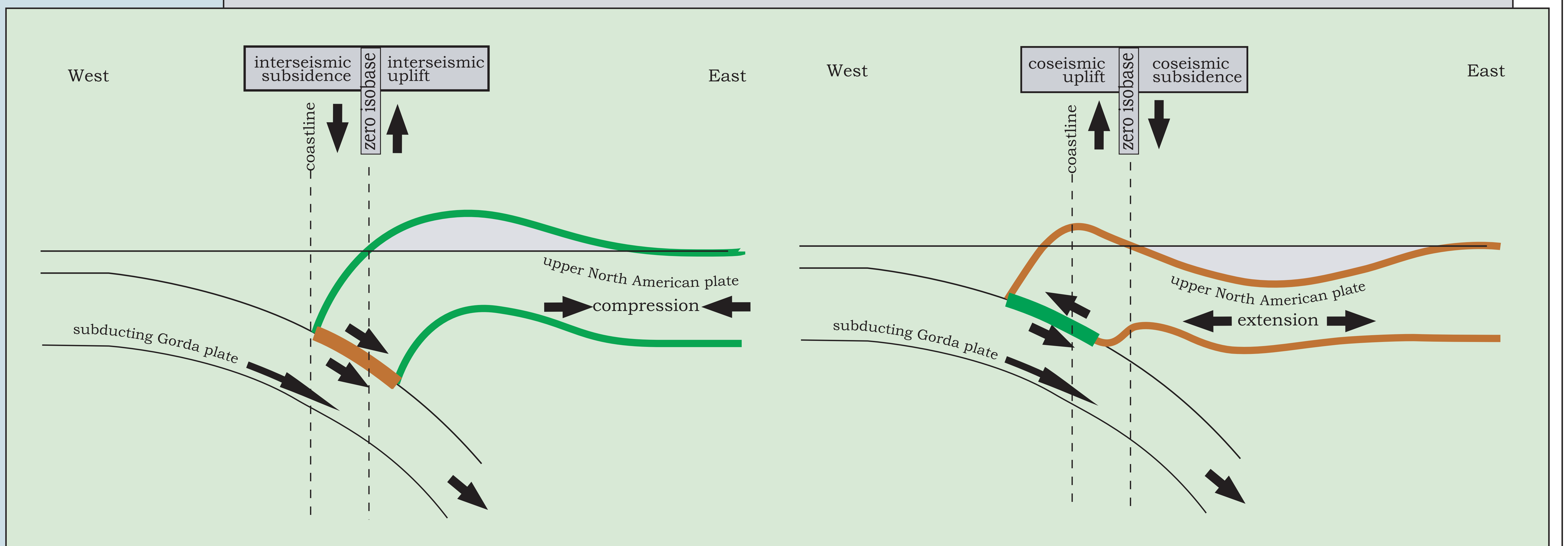


Figure 5. The earthquake cycle produces uplift and subsidence in areas that relate to the distance to the zero isobase.

modified form Nelson (1996)

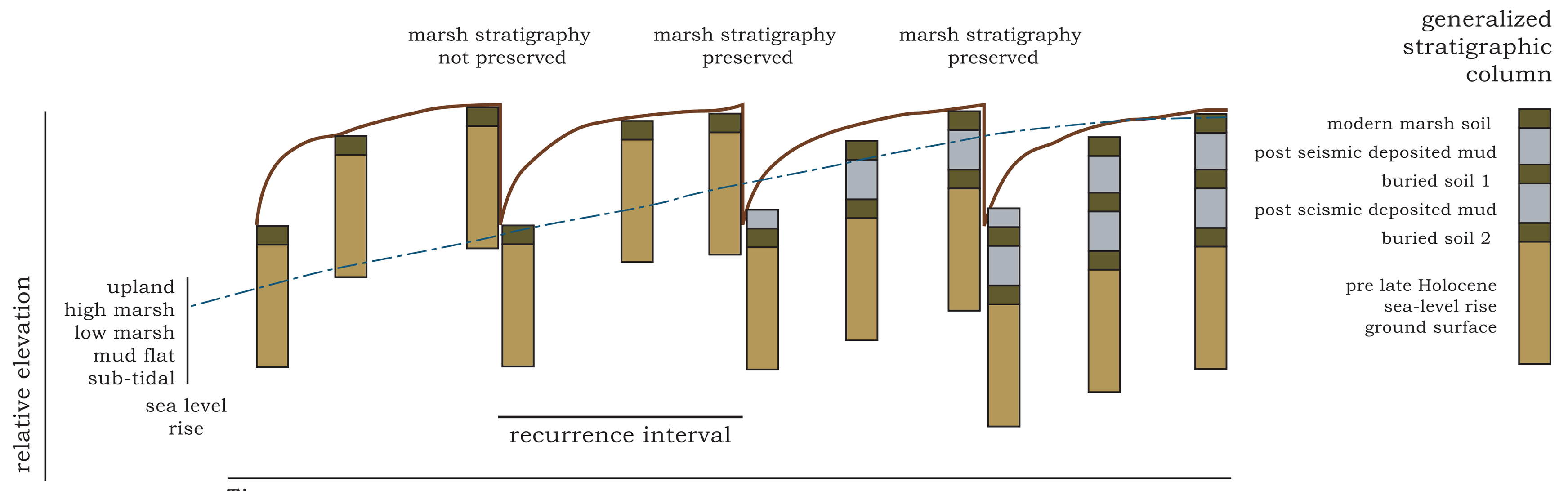
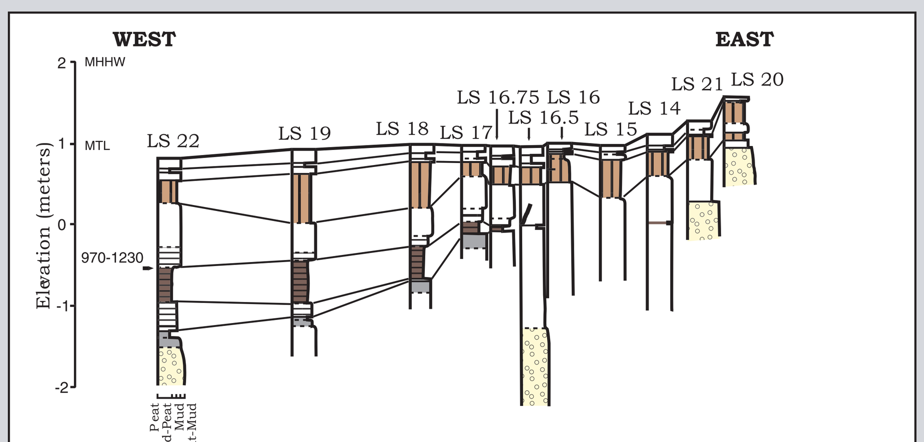


Figure 6. The earthquake cycle and relative sea level change is sometimes recorded stratigraphically

modified after Atwater *et al.* 1997



modified from Witter 2000

Figure 7. Stratigraphy found at the Little Salmon site.

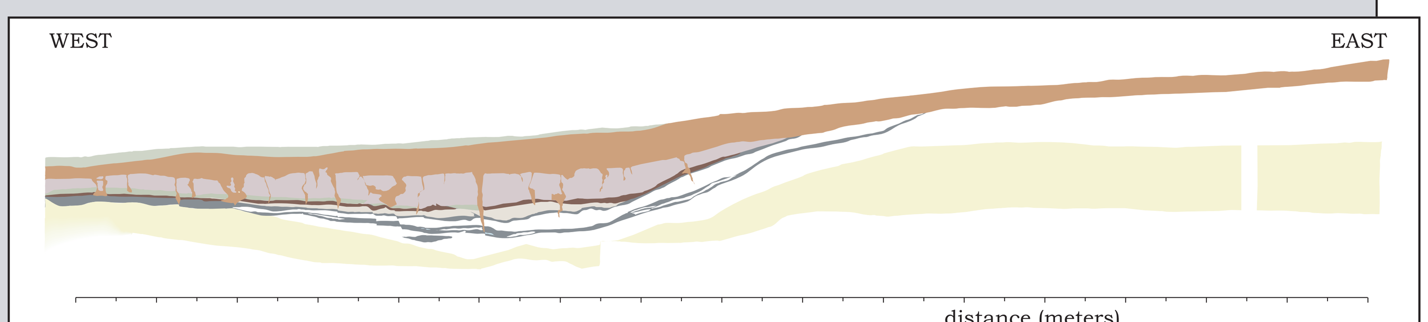


Figure 8. Folded strata exposed in trench 1-A.

modified from Witter 2000

In Humboldt County, emergency services planning must seriously consider risk from tectonic hazards. Hazards include strong shaking, infrastructural collapse, and tsunamis. From this research we learn more about the style of land deformation during large magnitude earthquakes. This will help in the management of our infrastructure. The data collected in this study will contribute directly to the knowledge of Cascadia tectonic deformation. People from the greater Eureka and Arcata area and surrounding communities will benefit from this project. This information is very important for emergency services agencies because they will be required to respond to these disasters.

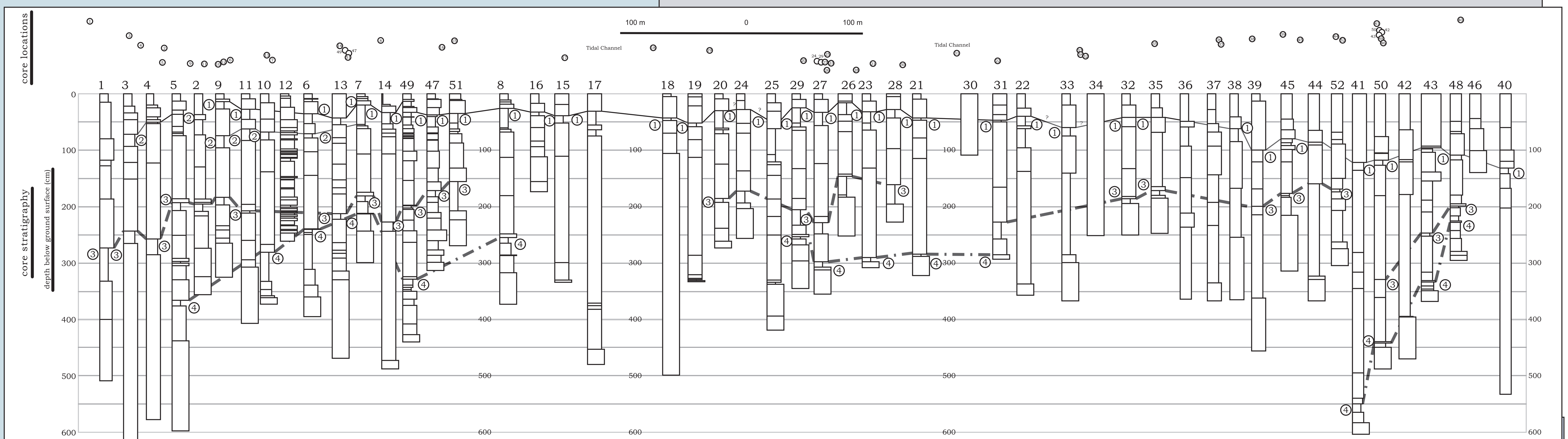


Figure 9. Gouge core stratigraphy at the Hookton Slough site.

The future most certainly contains the next great Cascadia subduction zone earthquake. The future should also include more detailed studies like this one. A modern diatom assemblage is an essential part of this necessary work. Paleoearthquake chronologies must also be refined with more field studies and more radiocarbon age estimates.

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Witter, R.C., Carver, G.C., Patton, J. R., Kelsey, H.M., Koehler, R. D., Garrison-Laney, C. E., and Page, W. D., 2001. Evidence for Progressive Folding of Late Holocene Tidal Marsh Deposits along the Western Little Salmon Fault, Humboldt Bay, Northern California. Proceedings of the Seismological Society of America, April 2001.

Acknowledgements:
We would like to thank the following for their contributions. Humboldt State University, Department of Geology, Gary Carver, Rob Witter, Harvey Kelsey, Rick Koehler, Eileen Hemphill-Haley, Carrie Garrison-Laney, Bill Page, Steve Bacon, Joanna Redwine, Andy Lutz, Doug Cox, Tom Leroy, Pacific Gas and Electric, USGS NEHRP, US Fish and Wildlife Service, Humboldt Bay National Wildlife Refuge, etc, etc, etc.

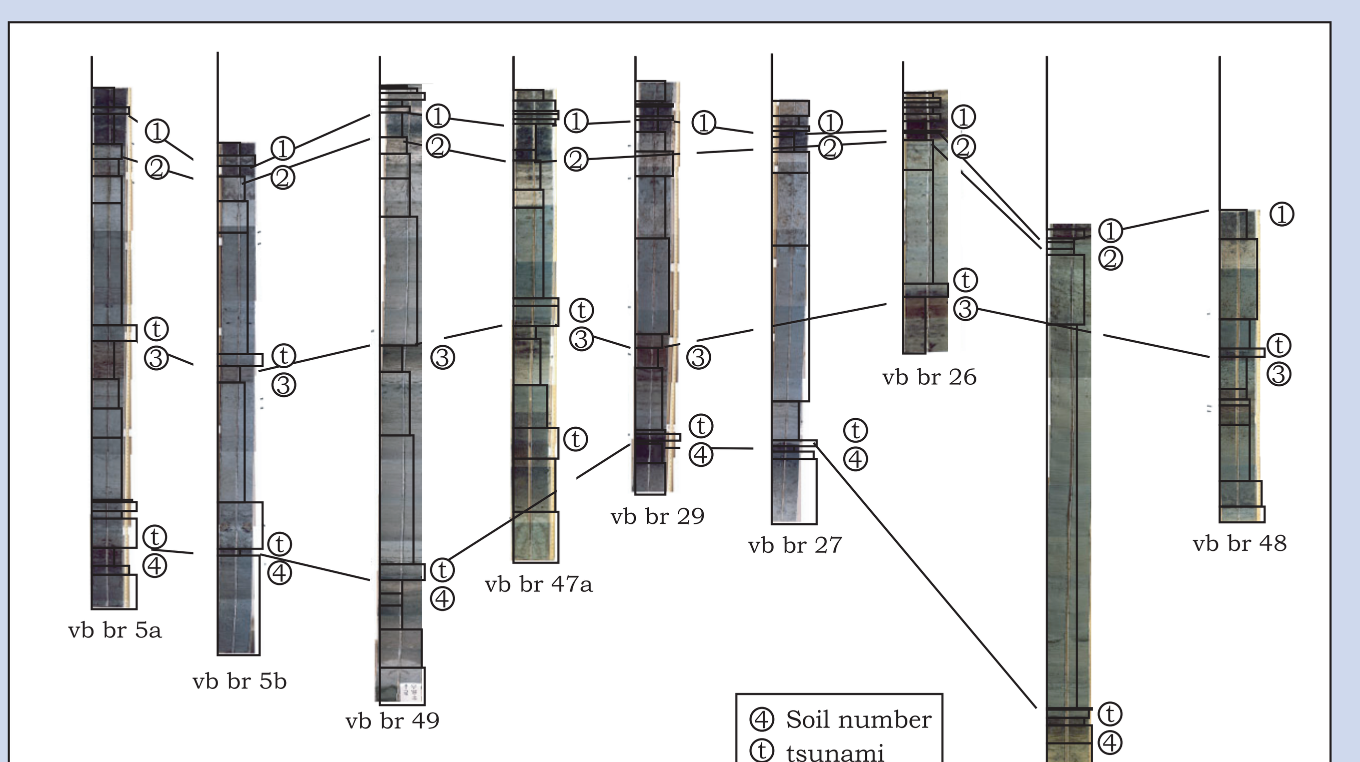

Figure 10. Vibra-core stratigraphy at the Hookton Slough site.