Replicability of coseismic subsidence estimates using foraminifera from northern Humboldt Bay, California

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Introduction

Estimates of coastal vertical deformation during megathrust earthquakes can be derived from microfossil analysis of wetland stratigraphic sequences. Along the coasts of the Cascadia subduction zone, quantitative relative sea-level reconstructions based on foraminiferal transfer functions yield precise (≤0.3m) estimates of coseismic vertical deformation(Hemphill-Haley, 1995; Guilbault et al., 1996; Nelson et al., 2008; Hawkes et al, 2011; Engelhart et al., 2013). We extend application of this approach to the southern Cascadia margin to evaluate within-site and within-bay depositional variability from megathrust earthquakes and test the reproducibility of a validated foraminiferal transfer function at northern Humboldt Bay, California (~44.8°N, -124.2°W). We examine four abrupt mud-over-peat (coseismic subsidence) contacts along a 6-km transect at Jacoby Creek, McDaniel Creek and Mad River. Our quantitative reconstructions of relative sea-level rise across each contact using a foraminiferal transfer function give subsidence estimates to ±0.24 m resolution. We analyzed 20 sediment cores containing the four mud-over- peat contacts; six for the AD 1700 contact (average of 0.37 m subsidence), five for the ~870 cal yr BP contact (average of 0.33 m), five for the ~1125 cal yr BP contact (average of 0.43 m), and four for the ~1600 cal yr BP contact. The estimates for the 1600 cal yr BP contact are only minimums because the contact formed above the upper limit of foraminiferal habitation (the largest is ≥0.56 m).

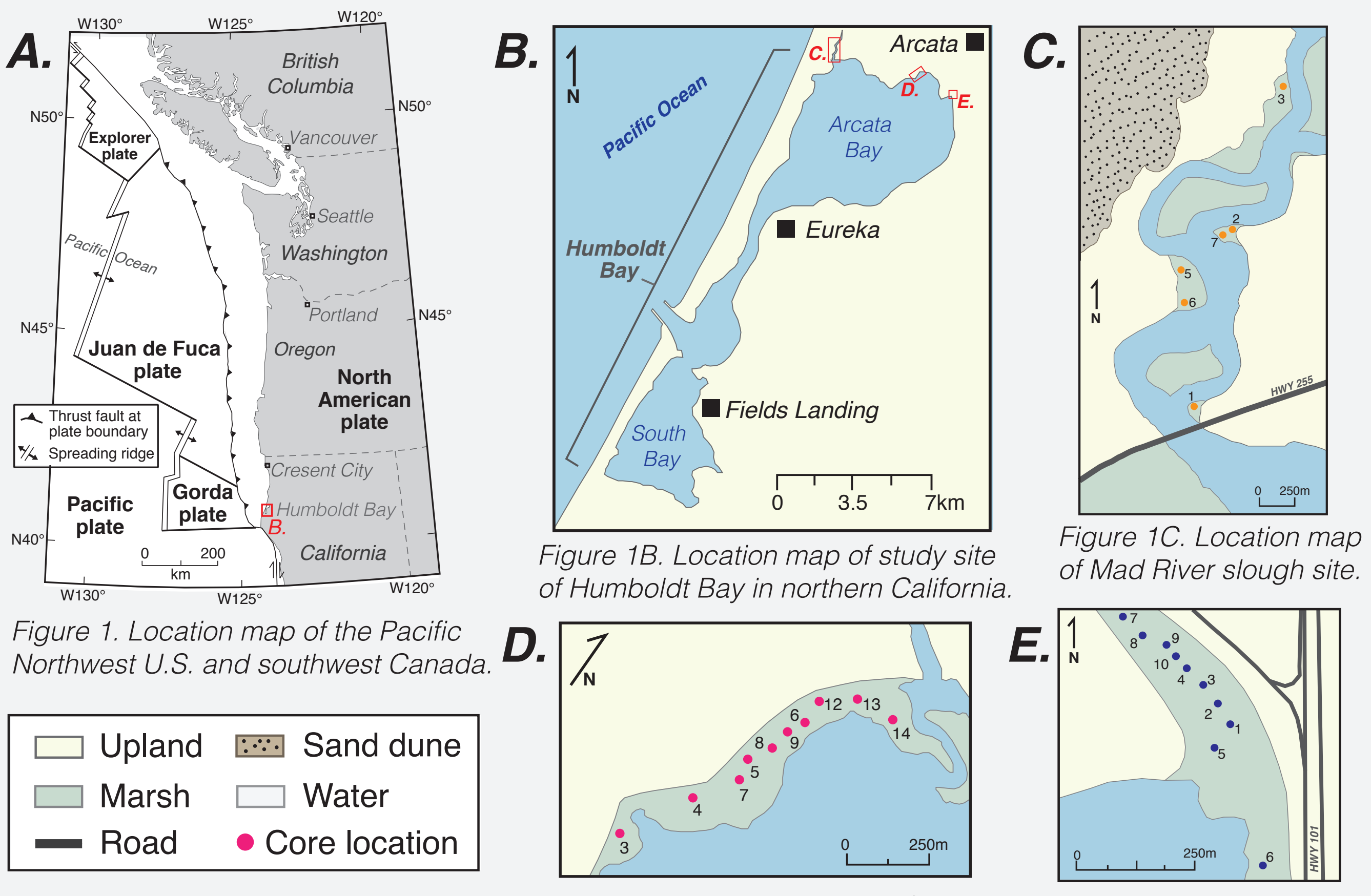

Figure 1. Location map of the Pacific Northwest U.S. and southwest Canada.

Figure 1B. Location map of study site of Humboldt Bay in northern California.

Figure 1C. Location map of Mad River slough site.

Figure 1D. Location map of McDaniel Creek slough site.

Figure 1E. Location map of Jacoby Creek site.

Bayesian Age Models

Thirty-one radiocarbon ages on plant macrofossils were obtained (Table 1) and used as constraints for each of the Bayesian age models to improve the paleoseismic chronology at northern Humboldt Bay. Two Bayesian age models were applied to the dates, OxCal 4.2 (Bronk Ramsey, 2008) and Bchron 4.1.2 (Haslett and Parnell, 2008) to estimate the time of subsidence. In Oxcal, we employ the Sequence-Phase method, which does not utilize sample depths in core. In contrast, Bchron incorporates the position of samples to further constrain the age estimates.The refined ages of earthquakes 2, 3 and 4 are presented in figure 9. For earthquake 4, both the minimum and the maximum ages are taken from directly above and below the contact. Therefore, the impact of Bchron taking sedimentation rate into account is not apparent and both models broadly agree. For earthquake 3, the minimum age comes from 4.5 cm above the contact. Because Bchron incorporates the depth of the sample, it trims the predicted age resulting in a more precise estimate but that may be misleading if sedimentation was faster post-earthquake than long-term average.

Table 1. Summary of northern Humboldt Bay radiocarbon ages

Site name	Lab identifier	Lab-reported age (^{14}C yr BP at 1σ)	Calibrated age range (cal yr BP at 2σ)	Provenance interpretation
McDaniel Slough	MD.14.06.168.5-169.5	955±15	940-970	Minimum
McDaniel Slough	MD.14.06.C.169.5-170.5	990±15	975-1005	Maximum
Jacoby Creek	JC.14.02.C.125.5-126	1,130±20	1,110-1,150	Minimum
Jacoby Creek	JC.14.02.D.130-130.5	1,280±20	1,260-1,300	Maximum
Jacoby Creek	JC.14.02.C.167.5-168	1,710±20	1,690-1,730	Minimum
Jacoby Creek	JC.14.02.C.170-171.5	1,710±15	1,695-1,725	Maximum
McDaniel Slough	MD.14.05.B1.306.5-307.5	1,740±15	1,725-1,755	Minimum
McDaniel Slough	MD.14.05.B1.308-309	1,720±15	1,705-1,735	Maximum

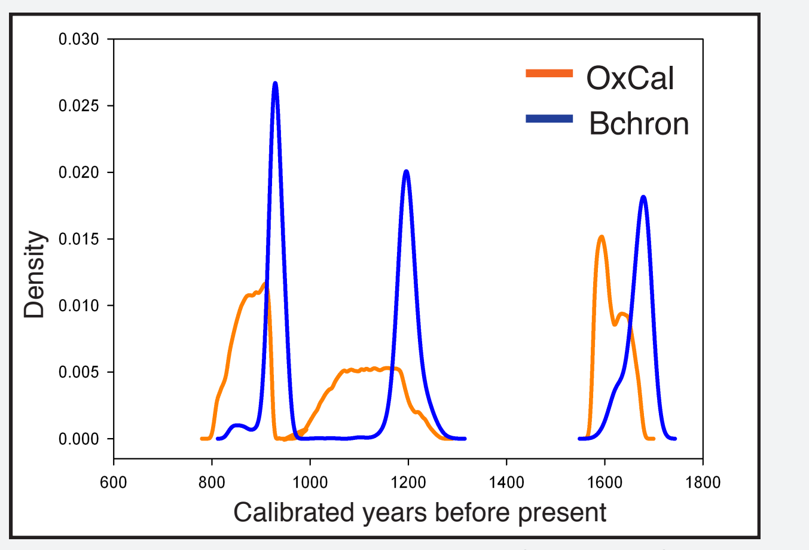

Figure 9. Age probabilty distribution functions for three earthquakes, includes 31 calibrated radiocarbon dates.

Stratigraphic Correlation

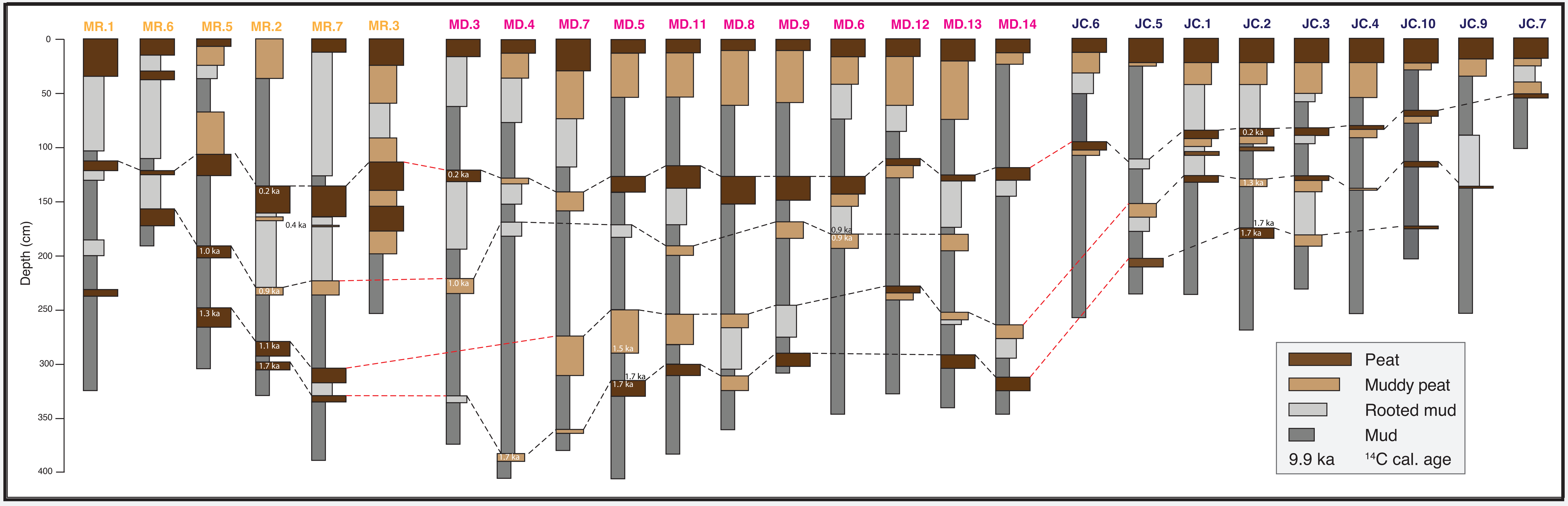

Figure 7. Stratigraphy of the northern Humboldt Bay salt marshes.

Stratigraphic Analysis

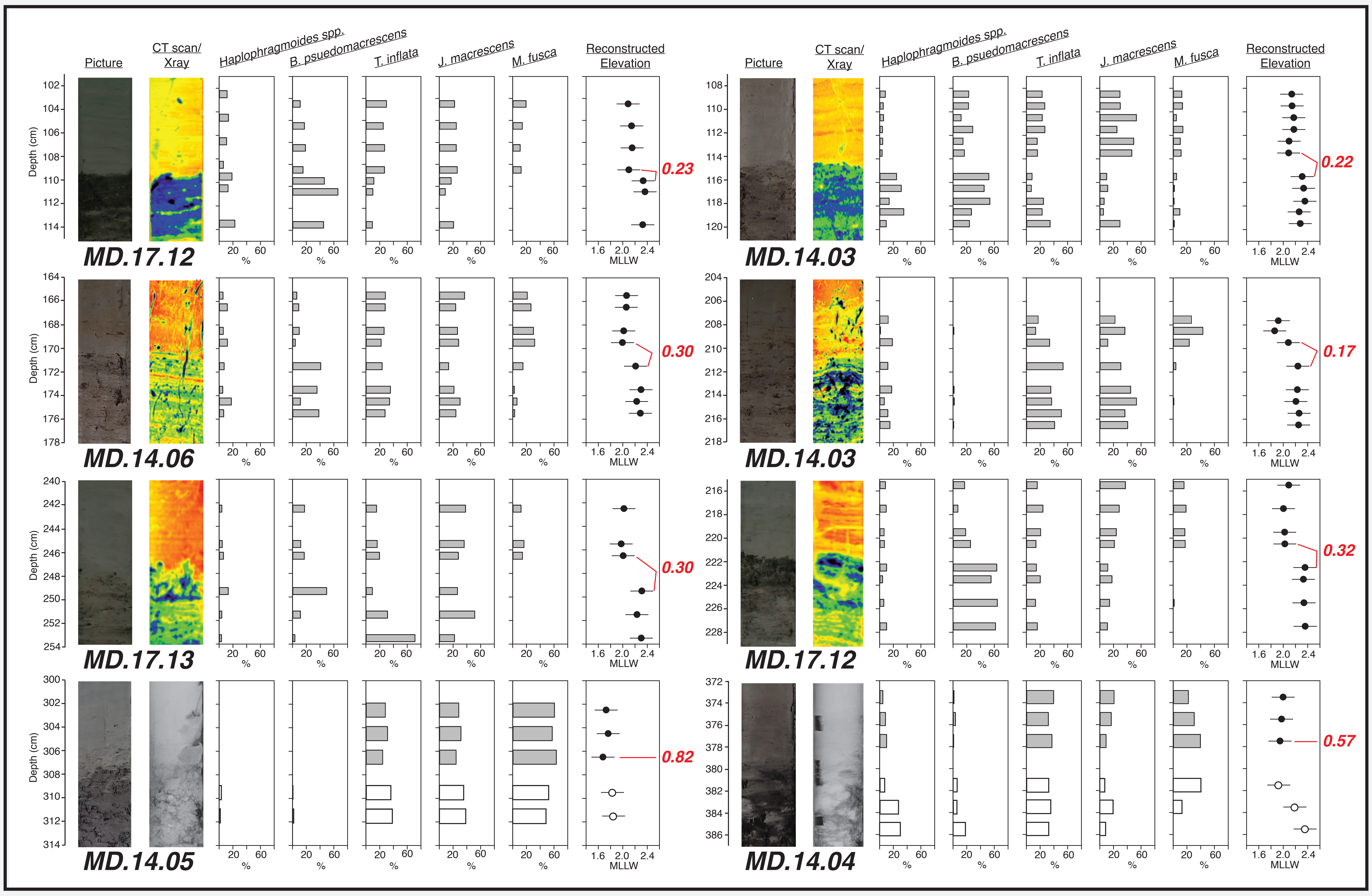

Figure 8. Plots showing stratigraphy including pictures, CT scan (warm colors=denser; cool=less dense), percent foraminifera (grey bar; white bar=not represenatative of paleoenvironment) and result of transfer function analysis used to reconstruct elevation relative to mean lowest-low water. To calculate the amount of subsidence (red) we subtracted the interval elevation above the contact from the interval elevation below the contact.

Subsidence Estimates

	Average
AD 1700 -----	**0.34 m**
JC.14.03	0.29 m
MD.14.03	0.22 m
MD.17.12	0.23 m
MR.14.03	0.39 m
MR.14.02	0.32 m
MR.14.05	0.64 m
870 cal yr BP --	**0.29 m**
MD.14.03	0.17 m
MD.14.06	0.30 m
MR.14.02	0.50 m
MR.14.03	0.09 m
MR.14.05	0.39 m
1125 cal yr BP -	**0.38 m**
JC.14.03	0.36 m
MD.17.13	0.30 m
MD.17.12	0.32 m
MR.14.05	0.52 m
MR.14.02	0.40 m
1600 cal yr BP	**≥0.65 m**
JC.14.03	≥0.39 m
MD.14.05	≥0.83 m
MD.14.04	≥0.57 m
MR.14.02	≥0.48 m

Figure 8. Current preliminary subsidence estimates.
Subsidence estimates have ±0.24 m error.

Conclusions

1) The stratigraphy at northern Humboldt Bay suggests four megathrust earthquakes have occurred over the past 1700 years.

2) McDaniel Creek has the most consistent stratigraphic record of past megathrust earthqaukes at northern Humboldt Bay.

3) Fossil foraminiferal data and transfer function analysis suggest similar coseismic subsidence estimates for the last three earthqauke stratigraphic sequences and the 1600 cal yr BP stratigraphy records the highest subsidence estimates.

4) Differences in inter-site subsidence estimates range from 0.22 m for the ~1125 cal yr BP contact to 0.44 m for the 1600 cal yr BP contact.

5) The variability of intra-site subsidence estimates range from a minimum of 0.01 m for the AD 1700 contact at McDaniel Creek to a maximum of 0.32 m for the AD 1700 contact at Mad River.

Acknowledgments

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