CRUSTAL DEFORMATION FROM BODEGA BAY TO THE RUSSIAN RIVER, CALIFORNIA AS RECORDED BY MARINE TERRACES

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INTRODUCTION

Development of geomorphic landscapes in northern California along the Pacific Plate and North American Plate (NAM) boundary is controlled by right lateral strike-slip motion along the San Andreas Fault (SAF). Right lateral motion along the plate boundary is estimated at 5 cm/yr, with the majority of motion occurring along the SAF (Wallace, 1990).

Along its northern portion, the SAF extends offshore north of San Francisco and cross-cuts onshore and offshore to its termination point at the Mendocino Triple Junction (MTJ) ~380 km north of San Francisco (Fig 1. in Merritts, this volume). At Bodega Head, CA, 105 km north of San Francisco, the SAF comes onshore for approximately 1.5 km. The fault continues offshore trending northwest until it comes back onshore at Ft. Ross, CA, 10 km northwest of the Russian River. From the town of Bodega Bay, CA northwest 12 km to the Russian River, the coastal headlands preserve flights of discontinuous, marine terraces that can be used to examine vertical deformation and sea level fluctuations during the Quaternary. Though the SAF cuts onshore near Bodega Bay, the fault lies 5-6 km offshore near the Russian River (Fig 1. in Merritts, this volume).

Preserved wave-cut platforms record both elevation of paleo-sea level and elevation change from localized tectonic deformation. Once the wave-cut platform is exposed above the sea level, it becomes a marine terrace. The formation of a marine terrace is tied to a unique sea level highstand. Long-term fluctuations in sea level result in the formation of flights of wave-cut platforms that may be preserved given appropriate geologic controls and regional uplift. If terraces that formed during succeeding highstands are preserved, the terraces act as a chronological recorder of sea-level fluctuation (Bull 1984). Long-term coseismic uplift in the form of earthquakes can preserve terrace units if vertical uplift is large enough to compensate for sea-level fluctuations (Lajoie 1986). If a marine terrace forms at a given highstand, and vertical deformation does not exceed the differences in succeeding highstands, then the marine terrace is never expressed in the geologic record. Terrace inner edge elevations, which form at paleo mean sea level, are correlated to a sea level curve to resolve tectonic deformation.

Terrace Correlation

Ten GPS transects covering 12 km of coastline from Bodega Bay, CA to the Russian River were conducted to survey marine terraces (Fig. 1). Data was collected using a real-time, differentially correcting, Trimble GeoXT GPS receiver. Real-time correction was achieved through a signal broadcasted by the FAA WAAS (Wide Area Augmentation System) satellite. Differential correction results in a decimeter horizontal accuracy and a submeter vertical accuracy. Inner edge terrace elevations are the feature corresponding to the paleo mean sea level. Transect cross-sections were created and inner edge elevations were correlated along the coast. A California

Highway 1 transect was also surveyed since it is a useful manmade feature that closely mimics existing coastal topography. Aerial photographic mapping was preformed and aided in distinguishing discontinuous terraces through the study area. Inner edge elevations were plotted along with the Highway 1 transect against elevation and terraces were correlated along the coast (Fig. 2). Eight discontinuous marine terraces were identified throughout the study area. Monotonic tilt to the south results in the merging of lower terraces as the SAF approaches the coastline at Bodega Bay. A large, composite platform representative of two highstands can form as a result of a higher terrace platform tilting and being reoccupied by a subsequent sea-level highstand transgression.

Sea Level Correlation

A composite sea level curve modified from Darter (2000), Hampton (2000) and Lambeck and Chappell (2001) was used to assign terraces to Quaternary sea level highstands. A method assuming constant uplift rates for a given time period was used in the correlation (Lajoie, 1986; Merritts and Bull, 1989, and Muhs 2000). Six transects were correlated to

Marine Terrace Unit	Age (ka)	OIS
Qt1	1250?	-
Qt2	970?	-
Qt3	670	19
Qt4	410	11
Qt5	330	9
Qt6	195	7
Qt7	125	5e
Qt8	108	5c

Table 1. Age and Oxygen-Isotope Stage (OIS) assignments for terraces

sea level highstands (Fig. 3; table 1). Uplift rates (U) were calculated by finding the slope of the line connecting the sea-level highstand to the inner edge elevation

U=_elevation (m)/ _age (ka)
(Eq. 1)

A correlation model in which a change in uplift rate occurs at 130 ka enabled correlation to successive highstands. Uplift rates decrease by a factor of 6 prior to 130 ka and by 2 after 130 ka from the Russian River down to Bodega Bay.

Transect	Pre-130 ka Uplift (m/ka)	Post-130 ka Uplift (m/ka)
Shell Beach	0.60	0.22
Hendren	0.51	0.18
Irish Hill	0.46	0.10
Coleman Valley Road	0.31	0.10
Chanslor Farm	0.28	0.09
Furlong	0.08	0.08

Table 2. Calculated uplift rates using the sea level correlation and inner edge elevations

DISCUSSION

Proximity of the SAF to the coastline controls marine terrace uplift rate in the study area. At Shell Beach where the SAF lies 5-6 km offshore, uplift rate is the highest in the study area. As the SAF approaches the coastline, uplift rates steadily decrease to a point in which uplift pre-130 ka and post-130ka are equal. The observed monotonic tilt to the south is a result of a decrease in uplift rates. Transverse motion along a strike slip fault was modeled using POLY3D-GUI. Simple strike-slip with oblique components of motion and faults that slightly dip failed to account for greater amounts of observed uplift away from the fault. A constraining bend combining two small right lateral strike-slip faults was modeled and the result was analogous to field observations. Uplift rates increased away from the fault and decreased to the south.

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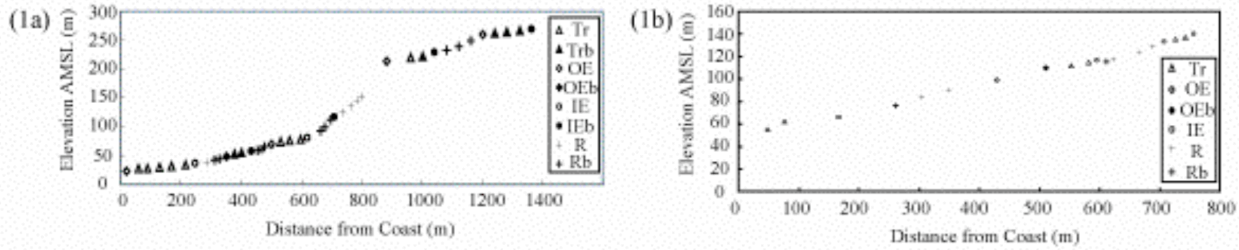

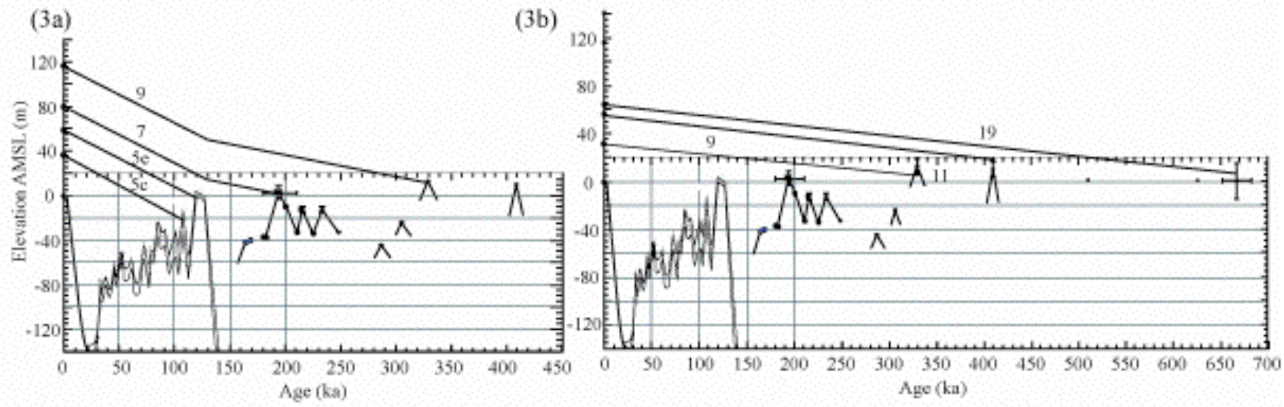

Figure 1. Transect cross sections for Hendren transect (a) and the Furlong Property transect (b)

Figure 3. Sea level correlation for Hendren (a) and the Furlong transect (b); uplift rates significantly decrease down the coast

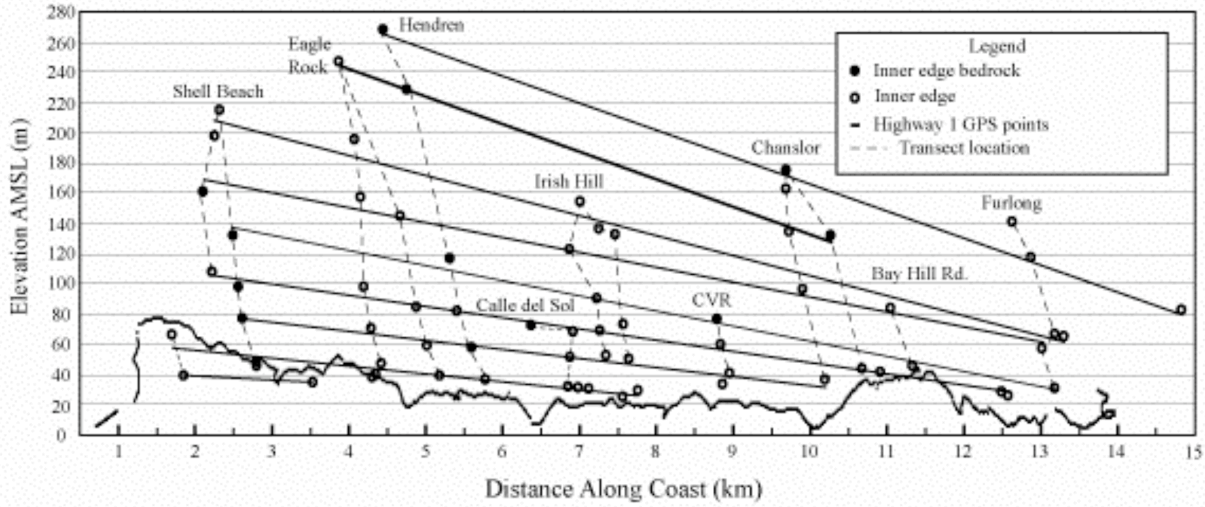

Figure 2. Terrace correlation down the coast relative to CA Highway 1