Uplift of Holocene marine terraces along the San Andreas fault: Fort Ross to Gualala, California

Erica Richardson
Department of Geology, Carleton College, 300 N. College St., Northfield, MN 55057
Faculty sponsor: Dave Bice

INTRODUCTION

The Gualala block in Northern California (Merritts, this volume) marks the northern most exposure of the North American plate west of the San Andreas Fault. Exposed Pleistocene marine terraces dominate the topography of Northern California's coastline. These elevated wave-cut platforms result from a combination of sea-level fluctuations and tectonic uplift along the seismically active plate boundary between the North American and Pacific plates. Terraces in coastal regions provide a relatively complete and detailed record of Quaternary crustal deformation over great distances. As a result, the Gualala block terraces provide an opportunity to examine the lateral offset and uplift rates along this segment of the fault.

This study will focus on the deformation that occurred from the Russian River to the Town of Gualala. A series of thirteen transects was completed in the field and provided the profiles necessary to make uplift correlations. Using the displacement of these marine terraces from their original formation elevation to present day location, I calculated the uplift rates along this section of the San Andreas Fault. I considered the rate of lateral offset along the fault using the displacement of the entire block northward. Missing terrace platforms south of the Gualala block, east of the San Andreas fault create a rough gauge of lateral motion.

METHODS

In the field. Transect locations were chosen using aerial photos and topographic maps. Using Global Positioning Systems (GPS), we mapped out the positioning of the terraces within centimeter accuracy. Localized relief along platforms cause elevation variation (Bradley & Griggs, 1976); therefore, we collected data points throughout the transects creating a more complete and accurate cross-section image. Points of consideration included inner edges (IE), outer edges (OE), mid treads (MT), and mid risers (MR). In conjunction with the landform type, the distance to bedrock was also recorded. By creating this highly accurate, detailed database I hoped to correlate the different aged terraces with higher precision.

In the Lab. The plots using the GPS data displayed the terrace elevations from two perspectives. Profiles of individual terraces displayed individual platforms. By combining all of the transects along the coast I attempted to correlate each terrace platform laterally along the coast.

The differences in altitudinal spacing of paleo-terraces create a framework for determining the tectonic activity in an area (Lajoie, 1986; Merritts & Bull, 1989; Muhs et al., 1990). Using a recently compiled sea level curve, I completed terrace correlations despite the lack of dateable material along the northern coast of California.

Using these data, the Gualala terraces are applied to the sea-curve for correlation. These correlations allow for uplift rates to be calculated by subtracting the real sea-level from relative sea-level (Lajoie, 1986).

apparent (uplift) = relative(terrace elevations) – real(sea-level curve)

By plotting the difference between the original elevations of the terrace in comparison to its present day elevation I hope to determine the nature of variations in uplift rate along the San Andreas fault.

RESULTS

Using the thirteen transects (Fig. 1) covering the southern half of the Gaulala block I distinguished six different wave-cut platform elevations. When compared to the New Guinea sea-level curve the Gualala terraces correlate to sea-level high-stands ranging from 80 ka to 330 ka (Fig. 2). Once the correlation of terrace platforms have been made, uplift rates can be calculated. However, along the Gualala block the limited supply of datable coral samples complicate the terrace correlation process.

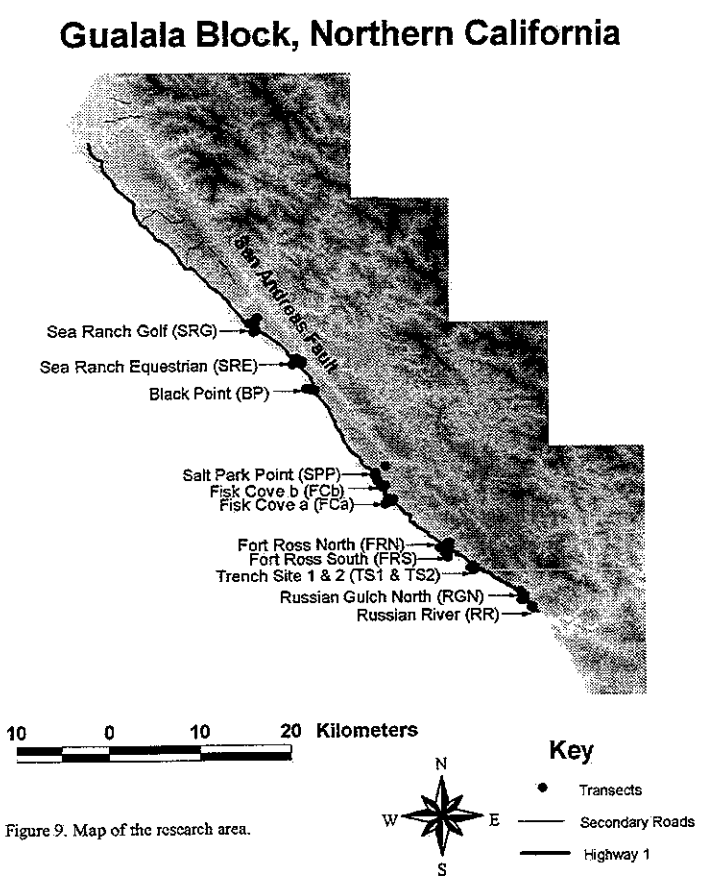

Figure 9. Map of the research area.

DISCUSSION

Transect Correlation. The lowest terrace along the Gualala block remains the only dated terrace in this region. Near the lighthouse at Point Arena, Kennedy collected *Balanophyllia* corals from two localities (Kennedy, 1982). The team used Uranium-series dating to determine this benchmarking terrace as an erosional expression of the 80K high stand.

There is a certain level of subjectivity when correlating sea-level high-stands with terraces plotted on the YZ plot, where Y runs parallel to the coast and Z indicates elevation. In the case of the Gualala block, due to the lack of dated platforms, even more assumptions are made. The area near Sea Ranch produced the most reliable correlations, while the alignment of southern transects proved more obscure. The area experiencing the greatest amount of confusion lies at the southern most edge of the Gualala block where the transects are closest to the San Andreas fault.

A series of questionable terrace platforms appear in the southern transects at roughly 60m of elevation. One explanation for the unexpected southern terrace is that the platform reflects the 194 high-stand that was poorly developed in the northern areas of this section. In fact, a complete sequence of terraces at a single transect location rarely occurs (Bull, 1984). This terrace correlation seems unlikely considering the fact that the northern section displays the most complete terrace sequence with between 5 and 7 platforms at each transect.

After further consideration, I determined that the most plausible explanation for this 60m terrace resulted from a series of psuedo inner edge points. Poor satellite reception on the day of the Fisk Cove transects seems to have resulted in misplacements in the GPS data record. Vertical precision prior to the Fisk Cove transect generally hovered around .5 m; however, during the Fisk Cove transect precision was as high as 2.36 m. Overall, the GPS data provided high level of accuracy; however, in this situation, the unusually high PDOP value warrants re-consideration of the presumed elevation.

The other transects with a record of a 60m platform appear at the southern most point of the Gualala block. Here, the flight of terrace platforms are truncated by the San Andreas fault. Under these conditions, the fault scarp creates an apparent inner edge elevation. Throughout the entire region, the fault and subsequent landslides obscure the original platform shape and location. Under these assumptions, the 60m southern platform does not exist and should not factor into the uplift rate calculations (Fig. 2).

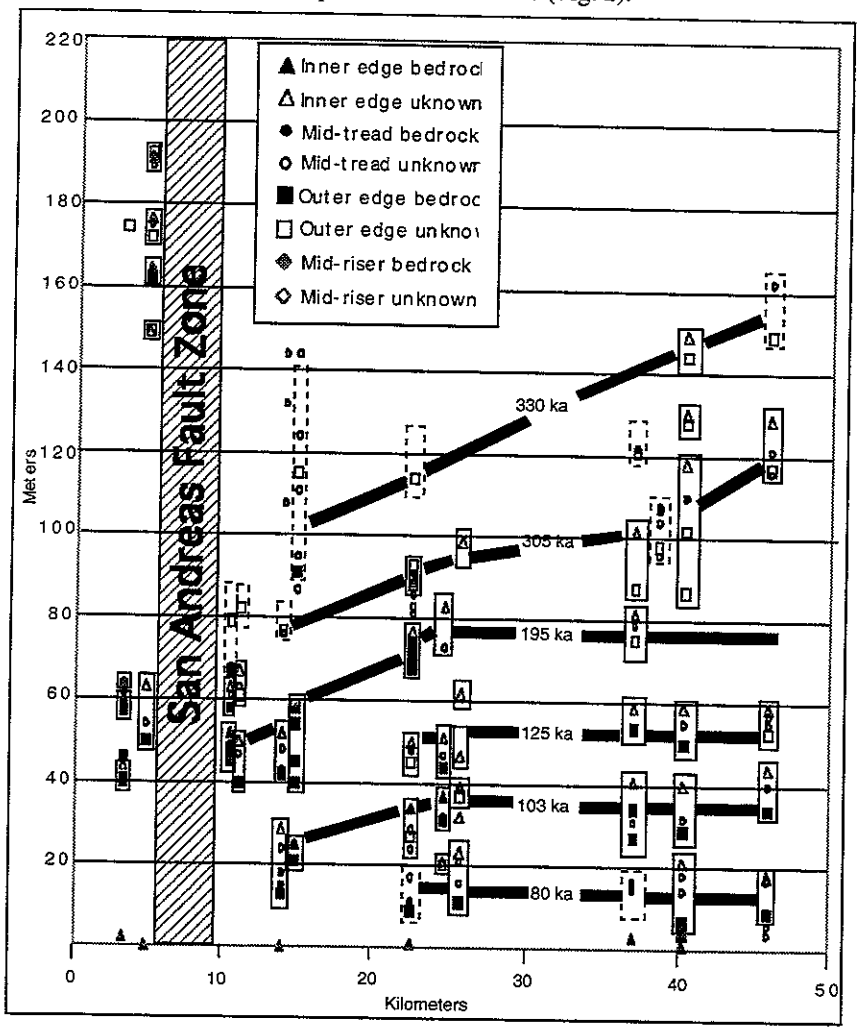

Figure 2. YZ plot with terrace correlation. Dashed boxes represent assumed platform positions where inner edges were not determined. The bold lines connecting the terraces follow general platform locations except in the case of bedrock exposed inner edges which are then connected directly. This diagram assumes the 60 m platform on the southern transects to be a misrepresentation of information.

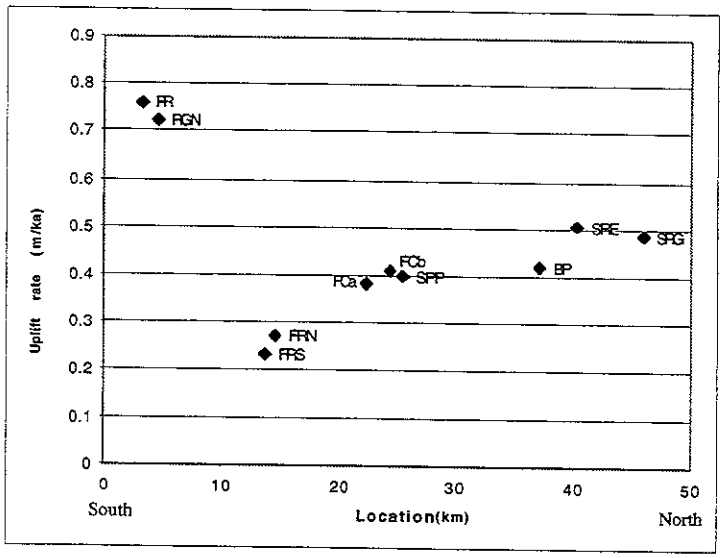

Figure 3. Uplift rates along the y axis. The progression of uplift rates following the coast line. Each uplift rate represents an individual transect. The San Andreas Fault zone lies around 10km.

Uplift Rates. Assuming the terrace correlations previously discussed, it appears that the uplift rates increase towards the north from .24 m/ka at Fort Ross to .58 m/ka at Sea Ranch Equestrian (Fig. 3). Fort Ross South transect provides the southern uplift rate on the Gualala Block, as the two southern most profiles labeled trench site 1 and trench site 2 preserved only one platform. On the North American plate east of the San Andreas, the uplift rate is considerably higher. The Russian River and Russian Gulch North profiles revealed rates of .77 m/kyr and .72 m/kyr respectively. This drastic change in uplift rates seems possible considering the shift in location across the fault. These changes in uplift rates correspond to the overall trends in uplift along the San Andreas.

Lateral Offset. The coastline south of the Gualala block consists of steep cliffs over 300 m high that extend for 5.3 km before the terrace formations reappear just north of the Russian River Valley. Due to the San Andreas right lateral displacement, the fault transported the terraces along with the Gualala block northward. By determining the age of the terraces on both ends of the cliff face, I calculated a rudimentary rate of lateral offset. The youngest terrace exposed at the southern most tip of the Gualala block corresponds to the 125Ka marine terrace at an elevation of approximately fifty meters. The first terrace to the south of the cliff sequence stands at a similar elevation suggesting that Russian River terraces also result from the 125Ka high stand.

distance/time = Lateral slip rate

Therefore:

5.3 km / 125 ka = 4.3×10^5 km/year or 4.3 cm/year

This calculation supports the present estimates of 4.8cm/y of relative movement between the North American Plate and the Pacific Plate (DeMets, 1987).

CONCLUSION

The marine terraces found along the Gualala Block seem to provide reasonable evidence for calculating uplift rates along the San Andreas Fault despite the absences in datable material. Through the data collected and the terrace correlations made, uplift increases towards the north. While the results of this study revolve around a number of assumptions, the general trend of increasing uplift towards the north is clearly established. The rates I found ranging from .24 m/ka to .58m/ka seem to correlate well with other rates calculated along the coast during this KECK project. Further studies attempting to pin point the exact elevations of past sea-level high-stands will strengthen these results.

REFERENCES CITED

Bull, W.B., 1984, Correlation of flights of global marine terraces *in* Morisawa, M., and Hack, J., eds., Tectonic Geomorphology: Boston , Allen & Unwin, p. 129-449.

DeMets, Charles, Gordon, Richard G., Stein, Seth, Argus Donald F., 1987, A revised estimate of Pacific-North America motion and implications for western North America plate boundary zone tectonics, Geophysical Research Letters, 14 (9), p. 911-914.

Kennedy, G.L. and Lajoie, K., Aminostratigraphy and faunal correlations of late Quaternary marine terraces, Pacific Coast, USA: Nature, v. 299, p. 545-547.

Lajoie, Kenneth, 1986, Coastal Tectonics *in* Usselman, T.M. eds., Active Tectonics: Washington, D.C., National Academy Press, p. 95-124.

Merritts, D. and Bull, W. B., 1989, Interpreting Quaternerary uplift rates at the Mendicino triple junction Northern California, from uplifted terraces: Geology, v. 17, p. 1020-1024.

Mesolella, K.J., Matthews, R. K., Broecker, W. S., and Thurber, D. L., 1969, Astronomical theory of climatic change: Barbados data. Journal of Geology, v. 77, p. 250-274.

Muhs, D., Kelsey, H., Miller, G., Kennedy, G., Whelan, J., and McInelly, G., 1990, Age Estimates ad Uplift Rates for Late Pleistocene Marine Terraces: Southern Oregon Portion of the Cascadia Forearc: Journal of Geophysical Research, v. 95, p. 6685-6697.

Prentice, C., Merritts, D., Beutner, E., Bodin, P., Schill, A., Muller, J., 1999, Northern San Andreas fault near Shelter Cove, California. Geological Society of America Bulletin, v. 111, p. 512-523.