**Final Technical Report for USGS/NEHRP #07HQGR0019 (UofO #238891)**

Project Title: Paleoseismic Investigation of the San Andreas Fault at Coachella, California and Comparison With Previous Studies

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Project Period: January 1, 2006 – December 31, 2006 (extended to December 31, 2007)

## SUMMARY

This project was to carry out a paleoseismic investigation on the Coachella segment of the San Andreas fault, near the town of Coachella, and to compare the results to other sites along the San Andreas fault. The project included collaboration with several geotechnical firms, who allowed access to and assistance in working in more than $70,000 worth of excavations, tremendous field and office contributions from USGS colleagues Tom Fumal and Katherine Kendrick, and NSF salary support for the principle Graduate Student, Belle Philibosian, who worked on this project. We succeeded in characterizing and dating the past 5 (and possibly up to 7) prehistoric earthquakes that ruptured the San Andreas fault at this site. We also correlated the events with other sites along the San Andreas fault, which included a substantial effort to more consistently re-date the Pallett Creek paleoseismic chronology.

## 1. COACHELLA

This project completed the field work and analyzed the data collected from the Coachella paleoseismic site (Figure 1). This site was recognized as a target of opportunity on the critical southernmost San Andreas fault, that has not ruptured for at least 300 years. The walls of several huge excavations across the San Andreas fault (cut by geotechnical firms for AP zonation work) were photographed, mapped and samples for radiocarbon dating were collected. Subsequently photomosaics were assembled (soon to be published as a USGS Open-File Report, Philibosian et al in press), field mapping compiled onto the photomosaics and radiocarbon samples analyzed.

Key results include determining the age of the past 5 earthquakes, summarized in the table below and compared to the ages of earthquakes at other sites along the San Andreas in Figure 2. The ages support the widely held hypothesis that the southernmost San Andreas fault has an average recurrence interval of ~200 years and that it has been ~300 years since the last earthquake, highlighting the danger of this segment of the fault. In addition, this study provides what might be the best record of the timing of the past 6 lakes in the Salton Depression, and the relationship between earthquakes and lake level, which several authors have suggested are linked.

| Age | Uncertainty |
|---|---|
| EQ1 1680 AD | +43 -19 |
| EQ2 1640 AD | +39 -70 |
| EQ3 1300 AD | +90 -25 |
| EQ4 1060 AD | +95 -16 |
| EQ5 980 AD | +24 -74 |
| EQ6+ | 1124 BC – 780 AD |

Publications include a USGS Open-File Report, an MS Thesis, and 4 Abstracts (listed below); we are also working on a BSSA paper to be submitted in October 2008. While the principle Graduate Student working on this project, Belle Philibosian, was supported by an NSF Fellowship, 2 graduate students and 2 undergraduates were partially supported to help with the project.

## 2. RE-DATING PALLETT CREEK

The goal of this part of the proposal was to re-date paleoearthquakes at the Pallett Creek site using accelerator mass spectrometry (AMS) radiocarbon dating method, instead of the conventional method as originally used by Sieh et al. (1989) (Hereafter Sieh, 1989).

Activities completed pursuant to this project include:

1. Field visit to Pallett Creek site. Scharer and Appalachian State University undergraduate student Teri Gerard visited the site in July of 2007 and collected oriented, brick-sized sample blocks of the organic layers from existing exposures. Layer identification was determined by examining labeled photographs and the stratigraphic column in Sieh (1978; 1984; 1989) (Figure 1).

2. Physical preparation and chemical pretreatment of individual samples. We found that charcoal was a dominant portion of the organic layers and focused on selecting single charcoal grains for analyses (Figure 2). The chemical pretreatment was completed at the University of Oregon Archeometry Lab by Scharer and Gerard. A total of 40 samples have been analyzed for this project; 28 from the 2007 work and 12 completed before the proposal were submitted.

3. Comparison of layer and earthquake ages. Scharer and Gerard built OxCAL models to compare the new dates with the Sieh (1989) dates (Gerard and Scharer, 2008). In general, when multiple samples per layer were analyzed, the new dates span a wider range than the conventional dates, and the youngest single charcoal piece per layer is younger than the bulk date reported in Sieh (1989). Unless bioturbated, charcoal ages are generally treated as maximum ages, that is they are equal or older than the age of the layer the charcoal is deposited in. Consequently, our revised OxCAL model removes dates that are significantly older than others in the same layer. When compared with the ages of the seven earthquakes that predate 1857, four earthquake ages are equal or younger, two earthquake ages completely overlap, and one is older than the ages published by Sieh (1989) (Figure 3). Before these results can be finalized, we must (a) correct the ages with the c13 values and (b) evaluate the effects of different earthquake age models - Sieh (1989) are based on the sample dates with corrections for peat accumulation rate whereas OxCAL determines earthquake ages using the bounding layer ages.

4. Completion of Senior Thesis. Teri Gerard completed her Senior Thesis for the Department of Geology based on her work in this project (Gerard, 2008).

5. Mini-workshop at Lawrence Livermore National Lab. Scharer taught Philibosian, T. Dawson, and K. Kendrick chemical pretreatment methods for radiocarbon dating of charcoal and peat samples.

## 3. MANUSCRIPTS AND PRESENTATIONS COMPLETED DURING THIS PROJECT


Gerard, T. 2008. Re-dating Pallett Creek paleoearthquakes with AMS carbon-14 techniques, *Senior Thesis*, Appalachian State University Department of Geology.

Gerard, T. and Scharer, K., 2008. Re-dating Pallett Creek paleoearthquakes with AMS carbon-14 techniques, *Southeastern Section GSA Annual Meeting*, 23-19.

Philibosian, B., Fumal, T., Kendrick, K., Ray J. Weldon, R., Scharer, K., Bemis, S., Burgette, R., and Wisely, B., 2008, Photomosaics and logs of trenches on the San Andreas fault near Coachella, California, *U.S. Geological Survey Open-File Report 2008-xxxx*

Philibosian, B., 2007, Paleoseismology of the San Andreas fault at Coachella, California, MS Thesis, University of Oregon, Eugene, OR, 75 pages.

Philibosian, B, Weldon, R. Kendrick, K., Scharer, K., Bemis, S., Burgette, R., and Wisely, B., 2007. Recurrence of ground rupturing earthquakes on the southernmost San Andreas fault at Coachella, CA, *SCEC Annual Meeting, Proceedings and Abstracts, Vol XVII.*

Philibosian, B., T. Fumal, K. Kendrick, and R. Weldon (2006a), Paleoseismic investigation of the San Andreas fault at Coachella, California, *Eos Trans. AGU* **87,** no.52, Fall Meet. Suppl., Abstract T21C-0438

Philibosian, B., T. Fumal, K. Kendrick, R. Weldon, S. Bemis, R. Burgette, and K. Scharer (2006b), Paleoseismic investigation of the San Andreas fault at Coachella, California, *2006 SCEC Annual Meeting Proceedings XVI* 143-144.

Coachella Earthquake chronology contributed significantly to the San Andreas recurrence record in:

WGCEP (Working Group on California Earthquake Probabilities; Weldon coauthor), 2007, The uniform California earthquake rupture forecast, Version 2 (UCERF 2): *U.S. Geological Survey Open-File Report* 2007-1437 & *CGS Special Report* 203.

## REFERENCES

Gerard, T. 2008. Re-dating Pallett Creek paleoearthquakes with AMS carbon-14 techniques, *Senior Thesis*, Appalachian State University Department of Geology.

Gerard, T. and Scharer, K., 2008. Re-dating Pallett Creek paleoearthquakes with AMS carbon-14 techniques, *Southeastern Section GSA Annual Meeting*, 23-19.

Sieh, K., Stuiver, M., and Brillinger, D. 1989. A more precise chronology of earthquakes produced by the San Andreas fault in southern California. Journal of Geophysical Research, vol. 94. pp 603-623.

Sieh, K. 1984. Lateral Offsets and Revised Dates of Large Prehistoric Earthquakes at Pallett Creek, Southern California. Journal of Geophysical Research, vol. 89. pp 7641-7670.

Sieh, K. 1978. Prehistoric Large Earthquakes Produced by Slip on the San Andreas Fault at Pallett Creek, California. Journal of Geophysical Research, vol. 83. pp 3907-3939.

## FIGURES

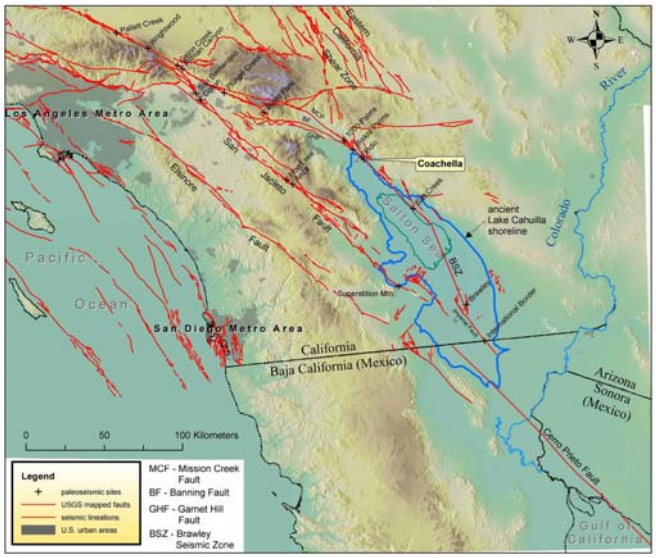


Figure 1. Index map for the Southern San Andreas fault the Coachella site lies at the critical transition between the transtensive Salton Sea/ Gulf of California and transpressive Transverse Ranges portions of the San Andreas system.

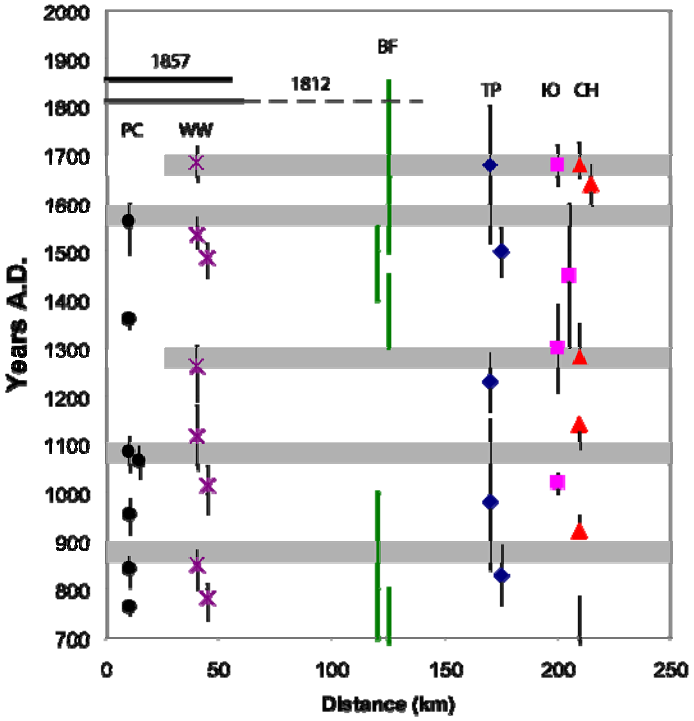


Figure 2. Proposed correlation of paleoseismic events along the Southern San Andreas fault. Symbols represent best estimate with 95% error bars in dating; gray bars are proposed correlations. PC= Pallett Creek, WW= Wrightwood, BF=Burro Flat, TP=Thousand Palms, IO=Indio, and CH=Coachella

Figure 3. Field photo showing layer identification based on labeled photographs in Sieh (1978; 1984; 1989).

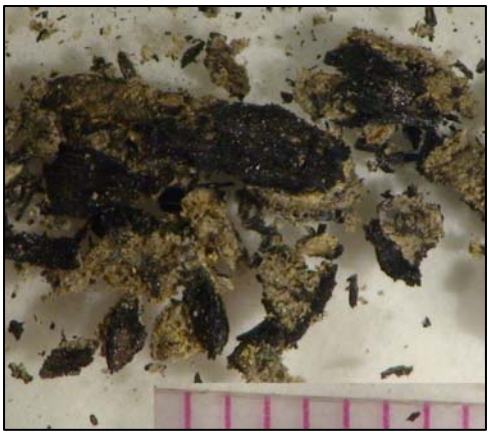

Figure 4. Photograph of individual charcoal piece (broken during sampling) submitted for AMS radiocarbon dating. Red bars on ruler at base are 1 mm apart.

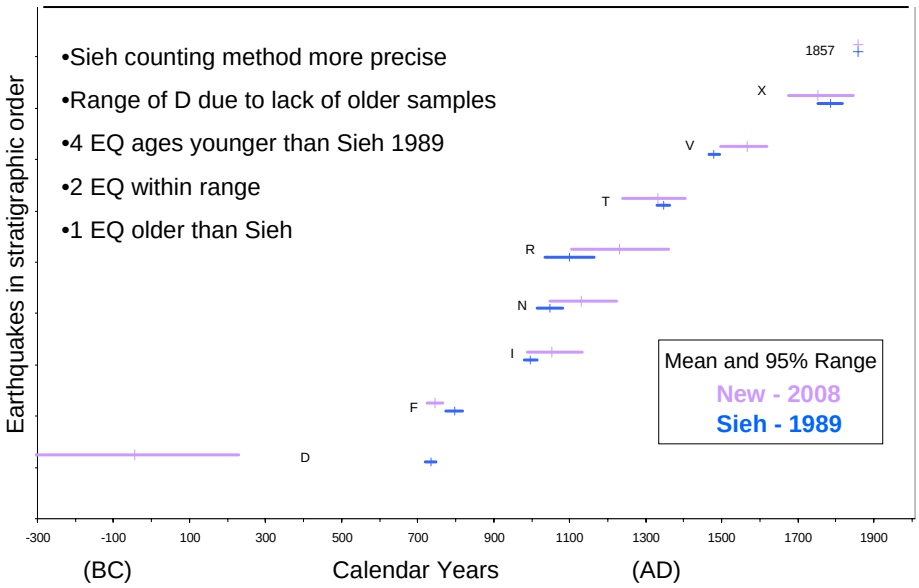


Figure 5. Preliminary comparison of new earthquake ages determined from new dates and OxCAL model versus ages reported in Sieh (1989).