Development of earthquake slip and age constraints
Southernmost San Andreas fault, California

USDI/USGS Awards 04HQGR0012 and 04HQGR0003

Principal Investigators:

Patrick Williams
P.O. Box 1492
West Tisbury MA 02575
(508) 274-9618
plw3@earthlink.net

Gordon Seitz
San Diego State University
14706 High Valley Road
Poway, CA 92064-2712
925-980-4997
seitz3@earthlink.net

Program Element III: Research on earthquake occurrence, physics and effects
Keywords:
Trench Investigation, Quaternary Fault Behavior, San Andreas fault, Coachella Valley, Salton Sea

1. Introduction

The southern San Andreas fault (SSAF) is perceived to be the most likely source of a great earthquake in southern California (e.g. working group, 1995), and this length of the San Andreas has numerous geologically-determined slip-magnitude and event-age constraints. These data are leading to fundamental insights into the earthquake process (e.g. Fumal, Rymer and Seitz, 2002; Weldon et al., 2004). Unfortunately the southernmost section of the SSAF , the ~100-km-long Coachella Valley segment (Fig. 1) (Williams et al, 1990), is arguably the most poorly understood major portion of the SAF with regard to slip rate, earthquake chronology, and consequently, earthquake hazard. No large earthquakes have occurred on the Coachella Valley segment (CVS) for more than three centuries (Sieh and Williams 1990). Given that CVS recurrence behavior of ~200 years was found at Thousand Palms Oasis (Fumal, Rymer and Seitz, 2002), long quiescence points to a particularly high seismic hazard.

2. Investigations undertaken at the SCN Paleoseismic Site

The Salt Creek and Indio sites are the only locations where a substantial thickness of lake Cahuilla sediments is known to mantle the San Andreas Fault (SAF). These lake deposits are the basis of age control at both sites. In the original 1980's Salt Creek study, no exploratory trenches sought lake records older than the three prominent surface deposits. The possibility that an older stratigraphic sequence exists at the site was the focus of the present study. We proposed to renew investigations at the Salt Creek North (SCN) site (Figure 1), to deepen mapping of section beneath the prominent stream bank fault exposure (Figure 2), in hopes of extending the site record to older lake deposits and thereby to capture a longer earthquake record. In short, no older lake strata are present.

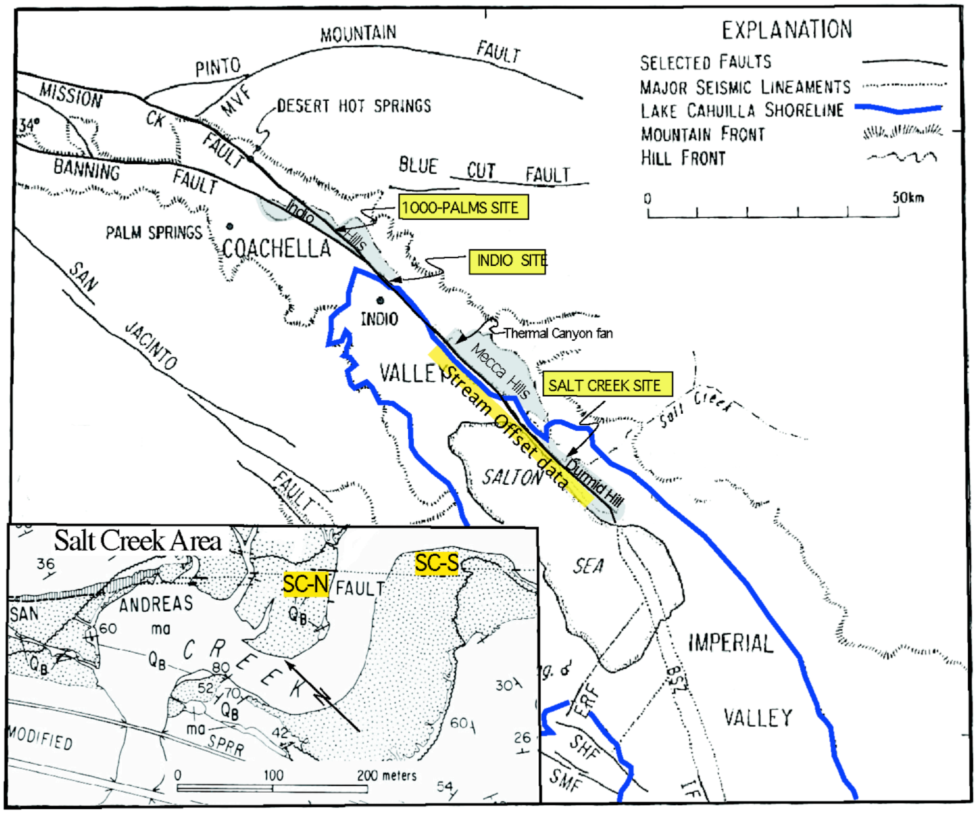

Figure 1. Location map for Salt Creek site. Abbreviations are: BSZ: Brawley seismic zone, ERF: Elmore Ranch Fault, IF: Imperial fault, MVF: Morongo Valley fault, SC-N, SC-S (Inset): Salt Creek North/South field sites, SHF: Superstition Hills fault, SMF: Superstition Mountain fault. Note area of stream offset documentation in this project extends from southern Durmid Hill to northern Mecca Hills Thermal Canyon Fan.

A new road was blazed to bring a small excavator to SCN fault exposure. Trenches were excavated 2.0 to 2.5 m to reveal the base of the Lake 3 unit deposited over massive alluvial sands and gravels. A composite log of the SCN exposure is being developed for publication in 2005.

Williams (1989) developed evidence of two slip events offsetting distinct lake strata at the SCN site. Displacements are 3.2 m (ultimate event), and 6.3 m (ultimate + penultimate events). These slip parameters are consistent with those developed at Indio, 70 km further north, where Sieh (1986 and unpublished data) recovered a 3-event chronology. Age control used for the SCN offsets by Williams (1989) was entirely dependent on age dating at the Indio site, due to the results of conventional radiocarbon dating of composite detrital charcoal. Given good evidence of event correlation between SCN and Indio, the original SCN analyses provided event ages that were clearly too old.

In this study we have used single fragment AMS dating to develop a new independent chronology for the SCN section. More than 20 new AMS dates have been obtained, and two of these substantiate the SCN section as representing the latest two fillings of the Salton Basin (Figure 3). The new chronology is reasonably consistent with Lake Cahuilla ages from other sites, and points out gaps and problems in the basin-wide chronology. With the new radiocarbon dates, and application of the Bayesian statistical constraints incorporated in the OXCAL program, we have developed a new age model for the two event offsets recorded at SCN. Age and SCN lateral offset data are being prepared for publication in a manuscript that we intend to be ready for submission in early 2005.

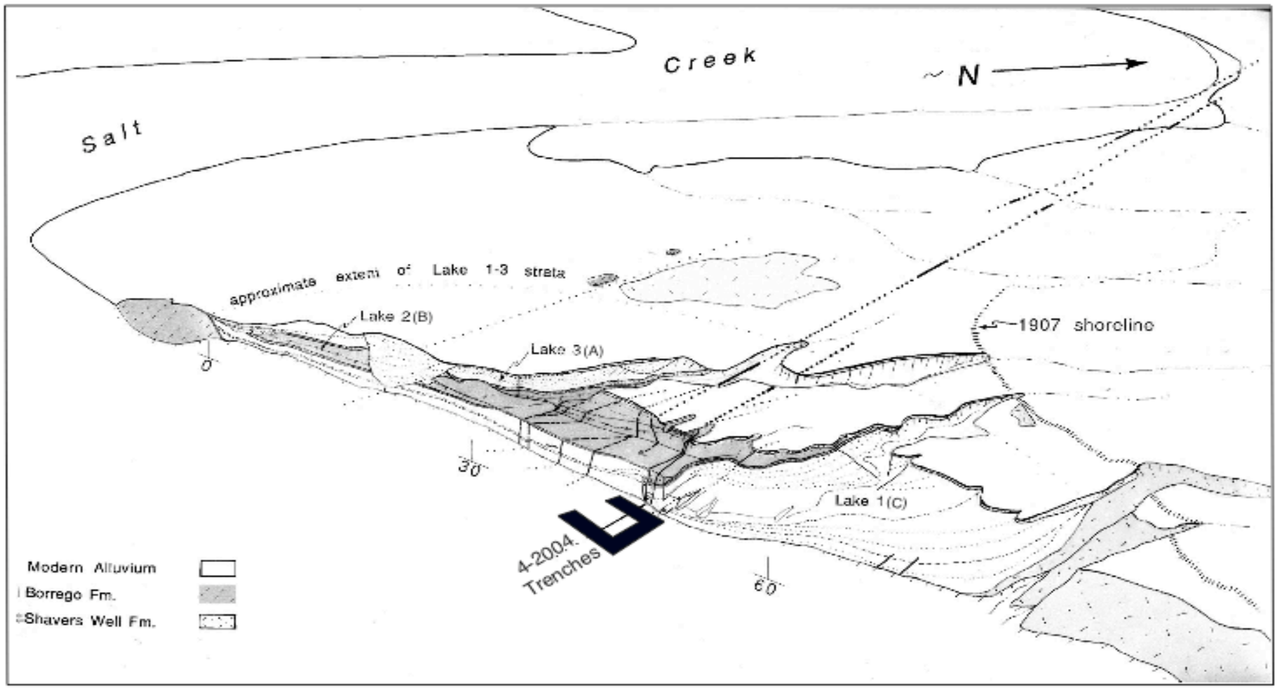

Figure 2. West-looking oblique view of the Salt Creek North study area. Excavations made in this project are illustrated. Exposed in these trenches were Lake 1(C) clays deposited over sand and coarse gravel stream alluvium of Salt Creek. No older lake deposits were found. We thus shifted the project focus to documenting a longer section of lacustrine deposits at a site immediately across Salt Creek to the southeast, which is denoted as *Salt Creek South*, and to documenting high quality geomorphic offsets along the southern 50 km of the SSAF (Figure 1, 4).

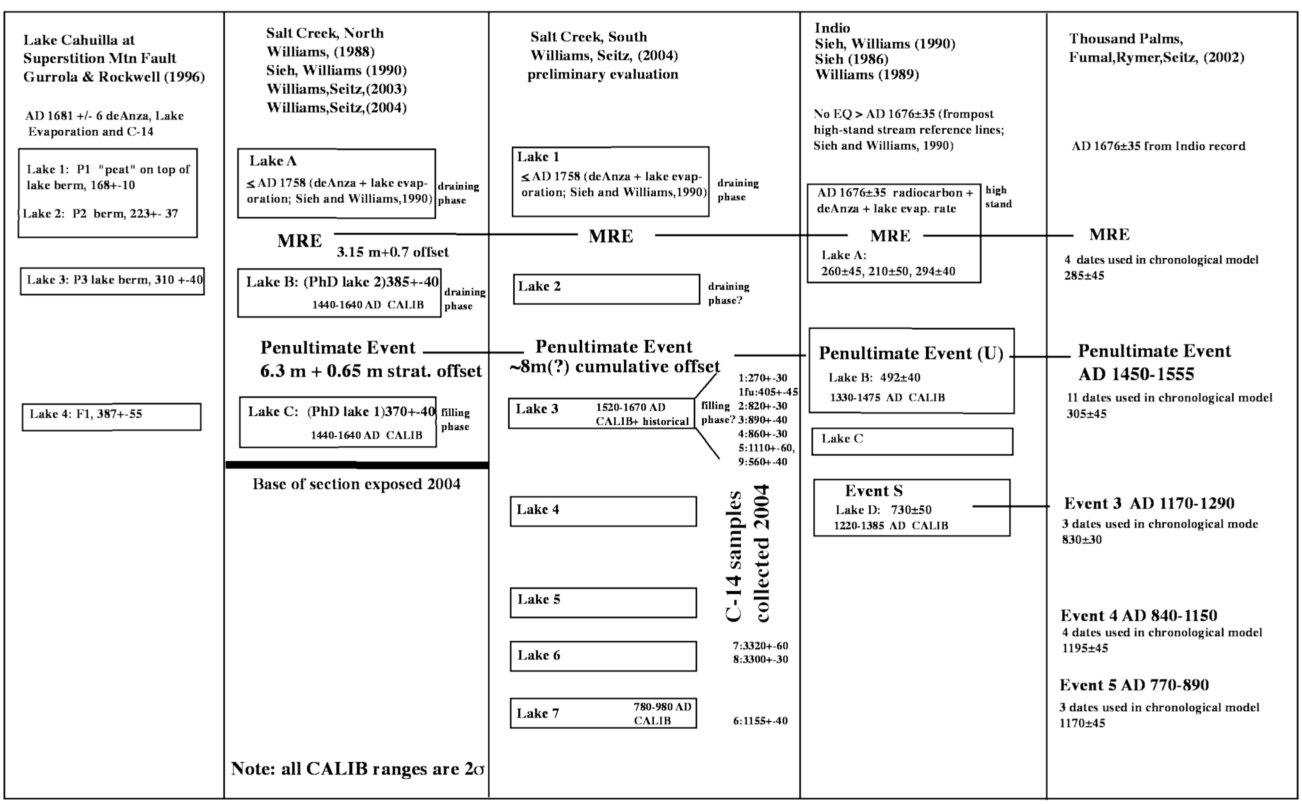

Figure 3. Preliminary relationships of Salton Trough paleoseismic sites. Data from SCS Lake 3 and 7 are used to place the section relative to other sites. Dating of SCN is near final. Ages of more than 30 detrital carbon samples were determined for SCN, and the dates shown here are the youngest pair from this large set.

2. Investigations undertaken at the SCS Paleoseismic Site

NEHRP-2004-funded field work resulted in the discovery and detailed reconnaissance of a new paleoseismic site at Salt Creek, ~15 km from the south end of the SAF: the "Salt Creek-South" site (SCS) (Figure 1). This new site has clear potential to: 1) disclose long-term recurrence behavior of the CVS; 2) disclose the slip-per-event of the CVS; 3) provide short and long term slip rate data for the CVS using stratigraphic offsets with ages extending through several earthquake cycles; and 4) (by use of highest-quality channel offset data from the surrounding area) determine the southern CVS spatial slip pattern.

Our 2004 field work at SCS consisted of detailed mapping of the boundaries of Lake Cahuilla deposits in the area; initial logging a 115m stream bank exposure of 6-7 clearly delineated lake deposits (Figure 4); and cleaning a natural gully exposure across the SAF main trace. The gully exposure shows evidence for two events with apparent displacements down to the east. Evidence for a possible third event exists with a fissure fill and possible upward termination. Most importantly, an auger boring of 2.75 meters depth from the bottom of the exposure, confirms the existence of late Holocene-age lacustrine sediments at the fault to a minimum depth of 4.25 meters. In addition we flew the fault with an ultralight aircraft to collect >500 hand-held digital air photos for the purpose of documenting the highest quality stream offset sites between Durmid Hill and the north end of the Mecca Hills (figure 1). We developed evaluation criteria for offset evaluation and documentation, and identified 32 high- to very-high-quality ephemeral offsets with individual displacements ranging from 3 to 24 meters (e.g. Figure 5).

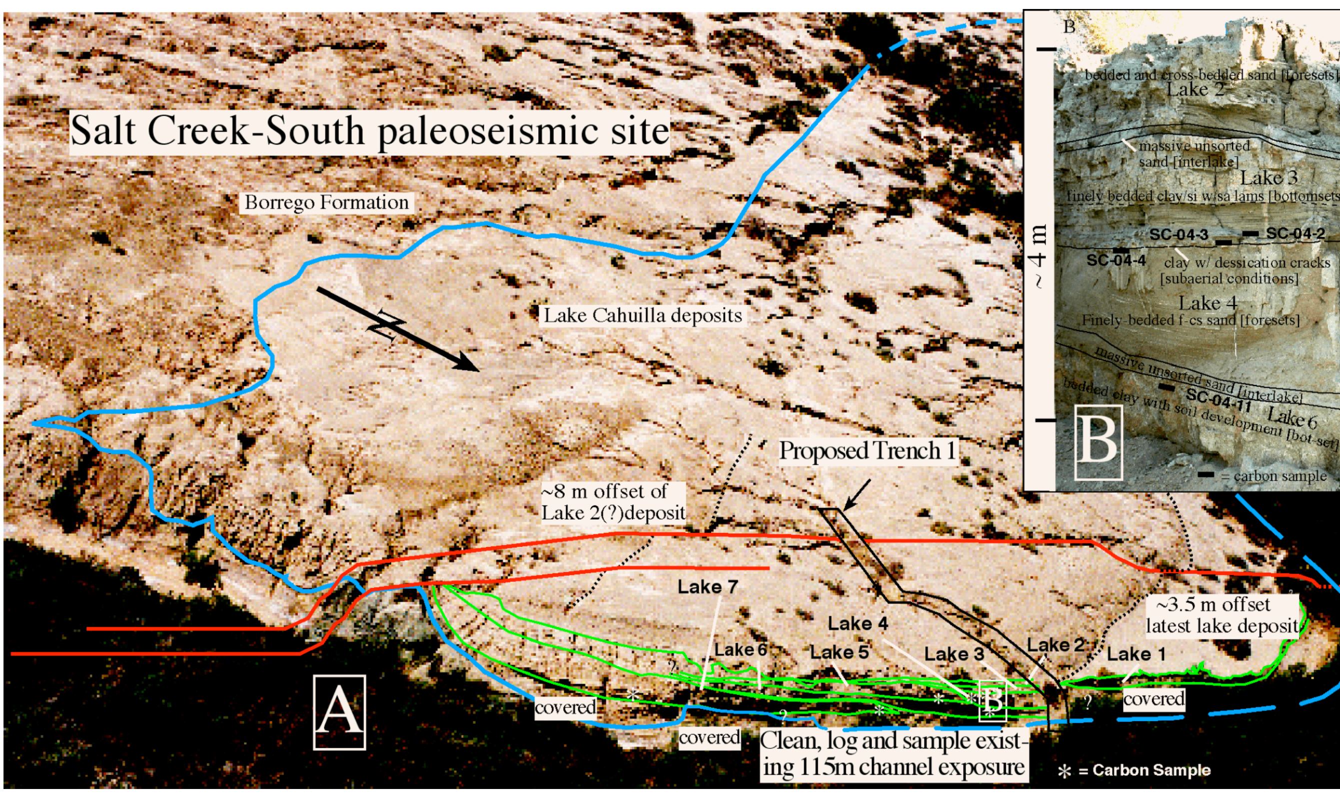

Figure 4A. Aerial view of SCS to the SW. Note thick section of Lake Cahuilla deposits protected behind an offset slice of the Durmid Hills ridge. This thickness of lake materials across the fault is unique to the Salt Creek area. The site records at least 7 Lake Cahuilla fillings between 900 and 1700 AD. The San Andreas fault bisects the section. The fault-parallel length of the mapped section is 115m.

Figure 4B. Inset shows stratigraphic detail and basis for some interpreted lake intervals. Lakes are distinguished by evidence of subaerial conditions separating successive lake materials.

Figure 5. Sample air photo of offset stream-terrace riser in southern Thermal Canyon fan area. Fault location "A" quality. Piercing features "A" quality. Ground measurement a to a' 42.6' = 13m. Uncertainties propagated using root of sum of squares. This clear 13 m offset is believed to record cumulative displacement in three fault ruptures. Smaller displacements measured nearby are ~7±1m and ~3±1m. Two additional features indicated fault displacement of 13±2 near Salt Creek and 14.5(+2)(-3.6m) in the northern Thermal Canyon fan area. Nearby areas of Thermal Canyon fan are being stripped by gravel operations, including a large swath across the fault itself. Field work is ongoing.

4. FY 2004 Accomplishments

1) Negotiated CEQA permit with California State Park administrators and scientists;
2) created new route to bring small excavator to SCN fault exposure;
3) excavated 2.0 to 2.5 m to reveal oldest SCN lake beds deposited over massive alluvium;
4) mapped boundaries of Lake Cahuilla deposits in SCS area;
5) logged 115m stream exposure of 7(6?) lake deposits in SCS area;
6) cleaned natural gully exposure across the SAF main trace in SCS area;
7) collected carbon samples from SCS section and obtained ages for 2 of 7(6?) lake deposits;
8) drafted reconnaissance log to illustrate site and provide context for new age data;
7) flew area from S. Durmid Hill to N. Mecca Hills to photograph stream offsets;
8) developed evaluation criteria for stream offset evaluation and documentation;
9) identified 32 high-quality stream offsets and made initial field descriptions.

5. Non-Technical Summary

The southern San Andreas fault (SSAF) is perceived to be the most likely source of a great earthquake in southern California (e.g. working group, 1995). The Salt Creek and Indio sites are the only locations where a substantial thickness of lake Cahuilla sediments are known to mantle the SSAF. These lake deposits are the basis of age control at both sites. In the original 1980's Salt Creek study, no exploratory trenches sought lake records older than the three prominent surface deposits. The possibility that an older stratigraphic sequence exists at the site was the focus of the present study. We proposed to deepen mapping of section beneath the prominent stream bank fault exposure in hopes of extending the site record to older lake deposits and thereby to capture a longer earthquake record. In short, no older lake strata were found. We thus extended out study to search for sites where a longer record might exist, and to search for additional offset features with which to construct a high quality slip-per-event record. A promising site with a longer earthquake record was discovered. A large number of very large-scale air photos were obtained to document stream offsets along the southernmost ~50 km of the fault.

References

Fumal, T. E., M. J. Rymer, and G. G. Seitz ,2002, Timing of large earthquakes since A.D. 800 on the Mission Creek strand of the San Andreas fault zone at Thousand Palms Oasis, near Palm Springs, California, Bull. Seism. Soc. Am., vol.92, No. 7, pp 2841-2860.

Gurrola, L. D. and Rockwell, T. K., 1996, Timing and slip for prehistoric earthquakes on the Superstition Mountain fault, Imperial Valley, southern California: Journal of Geophysical Research, v.101, B3, p.5977-5985.

Sieh, K. E. , 1986, Slip rate across the San Andreas fault and prehistoric earthquakes at Indio, California (abstract), EOS, Trans. Amer. Geophys. Union, 67, 1200.

Sieh, K. E. and P. L. Williams, Behavior of the San Andreas fault during the past 300 years, 1990, J. Geophys. Res., 95, 6629-6645.

Stuiver, M. and G. W. Pearson, High precision calibration of the radiocarbon time scale (CALIB computer program), 1986, AD 1950-500 BC, Radiocarbon, 28, 805-838,

Weldon, R., K. Scharer, T. Fumal and G. Biasi, Wrightwood and the earthquake cycle: what a long recurrence record tells us about how faults work, 2004, Geol. Today, 4-11.

Williams, P. L., Late Holocene displacement across the southernmost San Andreas fault, California, Ph.D. Thesis 276 pp., Columbia University, 1989.

Williams P.L. and G.G. Seitz, San Andreas fault in the Coachella Valley at Salt Creek: Development of Long-Term earthquake chronology and event offsets, 2004, Abstract for SCEC Annual Meeting.

Williams P.L. and G.G. Seitz, Improving southernmost San Andreas event-displacement and event-age constraints with new data from Salt Creek, Coachella Valley, California, 2003, Abstract for SCEC Annual Meeting.

Williams, P.L., L.R. Sykes, C.N. Nicholson, and L. Seeber, 1990, Seismotectonics and stress field, Easternmost Transverse Ranges, California: relevance for seismic potential of the San Andreas fault,Tectonics., 9, 185-204.

Working Group on California Earthquake Probabilities, Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024: *Bull. Seismol. Soc. Amer*., 85, 379-439, 1995.

REPORTS PUBLISHED

Williams P.L. and G.G. Seitz, San Andreas fault in the Coachella Valley at Salt Creek: Development of Long-Term earthquake chronology and event offsets, 2004, Abstract for SCEC Annual Meeting.