SCEC Annual Report 2013

Project Title:

Collaborative Research: Expansion of the stratigraphic and paleoearthquake record at the Elizabeth Lake paleoseismic site, central Mojave section of the San Andreas fault

PI's:

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Project Summary:

Despite the recent development of several high-quality paleoseismic records for sites on the southern San Andreas fault (Figure 1), the distance between some of these sites remains too great to reliably test models of earthquake behavior and understand possible persistent segmentation of earthquake ruptures. Because the earthquake record from Bidart Fan (Akçiz et al., 2010) and Frazier Mountain are very similar (Figure 2), but quite different from that of Pallett Creek (Scharer et al., in review), in 2012 we began new paleoseismic investigations at Elizabeth Lake, CA. This location splits a 100 km gap between Pallett Creek and Frazier Mountain that is large enough to generate its own M7 earthquakes, and the site has the stratigraphic potential to provide important constraints on the extent and timing of ruptures along the Mojave section of the southern San Andreas fault over the past >2000 years (Bemis et al., 2013). We have determined a record of up to five earthquakes that occurred between ca. 100 – 1500 A.D. However, we have not located the most recent ~500 years of the record.

Results of 2013 SCEC-funded research at Elizabeth Lake:

The SAF near Elizabeth Lake (EL) is characterized by a long, south-facing geomorphic scarp that traps sediments shed from the north-facing slopes of the San Gabriel mountains (Figures 1 and 3). Our SCEC-funded reconnaissance investigations (PI's Bemis and Scharer in 2012 and Dolan in 1998) focused on a 40 m by 350 m fault-parallel depression bounded by two sharp scarps oriented N65°W. In 1998, we excavated trench "ERT" and established that recent fluvial units buried the fault, which guided the 2013 trench locations targeting the most recent events on the SAF. Trench EL1 in 2012 was excavated across a 50 cm high, fault-parallel ridge ~1 m from the NE scarp. EL1 revealed a localized fault zone within the trough between the ridge and the scarp, and deposits that thickened into the depression. Trench EL2 was excavated across the SW scarp and exposed two massive, gravelly debris flow units and no evidence of faulting.

In summer 2013 we excavated four new trenches across the NE scarp. Two trenches (EL3 and EL4, Figures 3 and 4) near ERT display two recent faulting events over an ~10 m wide zone. These events are separated by a single soil horizon. Trenches EL5 and EL6, located in the eastern half of the site, exposed thinly bedded fine sand and organic-rich horizons, providing the best stratigraphy at the site (Figure 5). The primary fault zones in EL5 and EL6 are similar in structure, consisting of two primary shear zones that parallel the geomorphic scarp and are well-aligned between the trenches (Figure 3). The southern shear zone is 1 m wide and separates bedded sediments on the south from massive, clay-rich gravelly colluvium and the northern shear zone is ~10 cm wide and separates this colluvium from bedrock on the north. The bedrock is extensively fractured and several shear zones occur within the bedrock, but these shear zones do not interact with young stratigraphy. Earthquake evidence from EL5 and EL6 is derived from secondary deformation within the bedded sediments. Trench EL6 was excavated in an intermediate location in order to exploit the good stratigraphy of EL5 and the broader fault zone observed in EL3/EL4, and does exhibit more distributed deformation than EL5. We returned to the site during November 2013 and excavated

EL7 (Figure 3), which extends EL5 southward across the depression, with the purpose of documenting evidence of young surface ruptures along the south side of the depression. However, this stratigraphy simply onlaps onto the margin of the depression and contains only localized soft-sediment deformation, but no faulting.

<u>Preliminary Earthquake Evidence</u>

Five of the trenches targeted the sharp geomorphic scarp along the northern margin of the fault-parallel depression because this represents the most obvious geomorphic target (Figure 3) and our initial excavations revealed earthquake evidence in the shallow subsurface (Figures 4 and 5). In the field we assumed that the youngest event was 1857, and stratigraphically lower events predated the historic rupture. However, the radiocarbon age results demonstrated that the deformed deposits adjacent to the geomorphic scarp only contain the record of earthquakes that are older than ~1500 AD. The 28 radiocarbon dates are largely stratigraphically consistent, suggesting that we are still missing the last 500 years of earthquakes through the site.

Our current earthquake record is defined as follows (based upon EL4 with correlations made to EL5 and EL6 where possible:

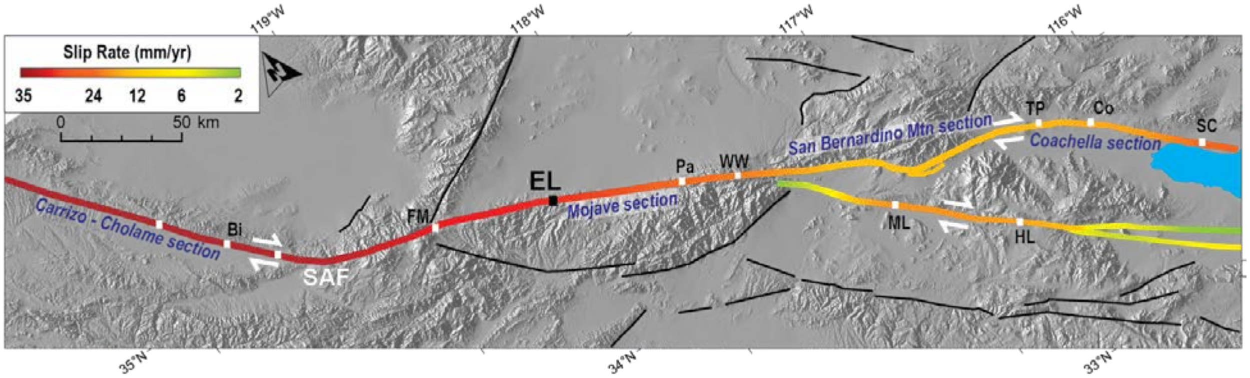
<u>EQ1</u>: The youngest event recorded in the existing trenches is defined by faulting and deformation that extends to the top of Unit 50 that produced a topographic trough subsequently filled by Unit 45. This relationship is best defined in EL4 (Figure 4). Considering a bulk sediment radiocarbon age from just below the Unit 45/50 contact and the charcoal ages from Unit 40, our preliminary age control indicates this earthquake occurred between 1450- 1700 AD (Figure 2).

<u>EQ2</u>: This event is defined by the thickening of Unit 50 into the graben near the middle of EL4, the spatial extent of which corresponds with several fault zones (Figure 4). Trenches EL5 and EL6 show clear evidence of ruptures propagating up-section into Unit 50 (EQA on Figure 5), but the stratigraphic resolution does not allow the separation of EQ1 and EQ2. This event is constrained in EL4 by the bulk radiocarbon age and two charcoal ages from Unit 60, with a preliminary age range of 1300-1480 AD.

<u>EQ3</u>: This event is interpreted based upon the significant thickness change in Unit 50 across a major fault that does not propagate up into the unit. Unit 60 also displays a significant facies change across the fault.

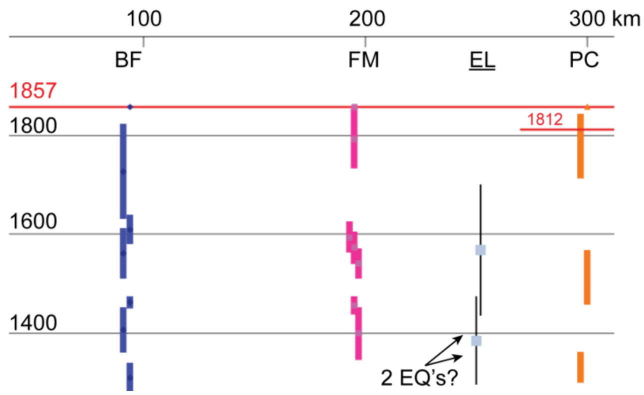
<u>EQ4</u>: This event is suggested based upon the thickening of Unit 60 into the middle of EL4 (Figure 4), indicating this earthquake created a topographic trough that was filled by Unit 60. This is possibly equivalent to EQB in EL5 (Figure 5).

<u>EQ5</u>: This event is indicated by the pinch-out of units and significant facies changes across faults in EL4 (Figure 4) and likely correlates with EQC or EQD that are well-defined within trench EL5 (Figure 5).



(previous page) Figure 1. Map of the southern San Andreas/San Jacinto fault systems. The Elizabeth Lake site is shown as "EL", approximately halfway between Frazier Mountain (FM) and Pallett Creek (Pa). Other labeled paleoseismic sites: Bi = Bidart Fan, Co = Coachella, HL = Hog Lake, ML = Mystic Lake, SC = Salt Creek, TP = Thousand Palms, WW = Wrightwood.

Figure 2. Correlation diagram for Elizabeth Lake relative to the three paleoseismic sites on the northern half of the southern SAF with paleoearthquake catalogs for the past ~600 yrs. We have not excavated sediments at EL yet that are yonger than 1700; this will be the focus of 2014 investigation. Colored vertical bars represent the age range for earthquake ages at each site. Data from Scharer et al. (in review), Akciz et al. (2010), and this study.



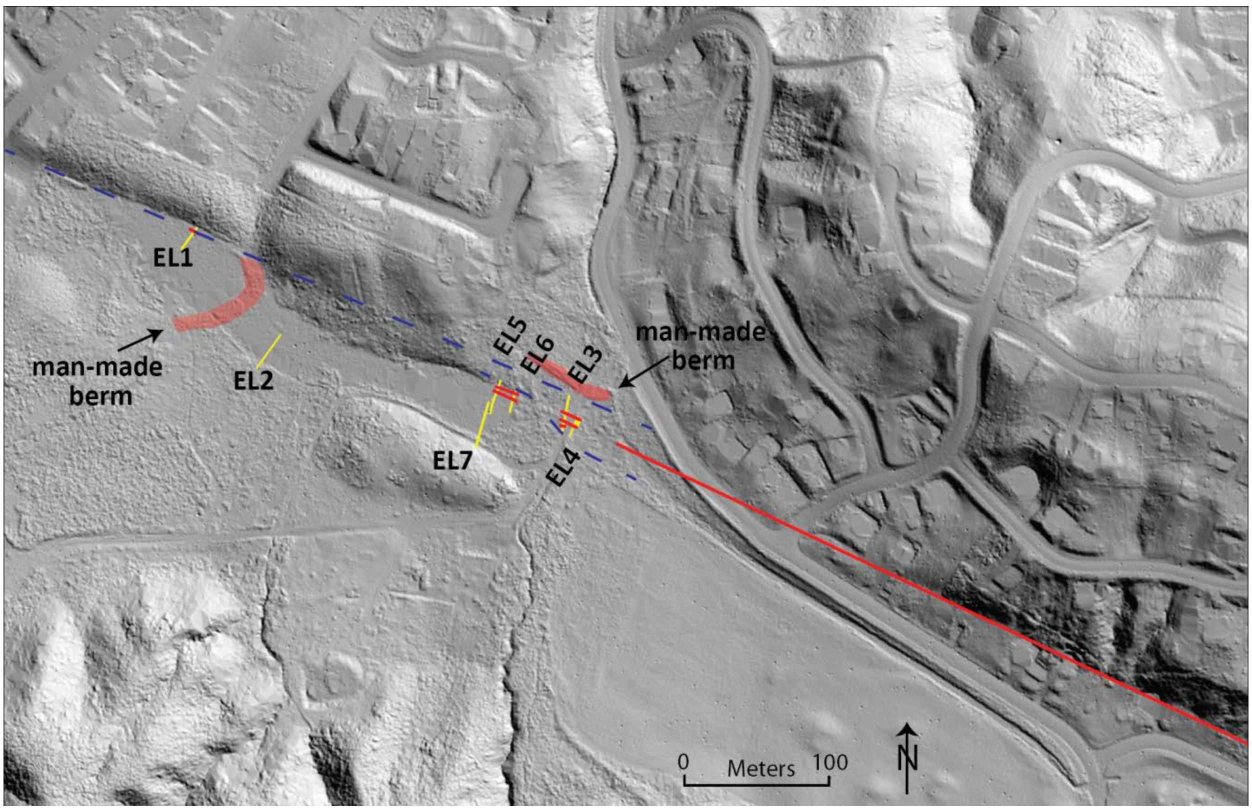


Figure 3. Locations of existing trenches excavated during 2012 and 2013 (yellow lines) at Elizabeth Lake site. Trenches EL1 and EL2 were excavated by Bemis and Scharer in 2012, and EL3-EL7 were excavated during 2013 with the support of this SCEC award. Short red lines across trenches depict the major fault zones exposed in these excavations. The long red line to the southeast illustrates the prominent linear slope break/scarp and how it projects into our site. The dashed blue lines show possible fault traces for earthquakes during the past ~500 years.

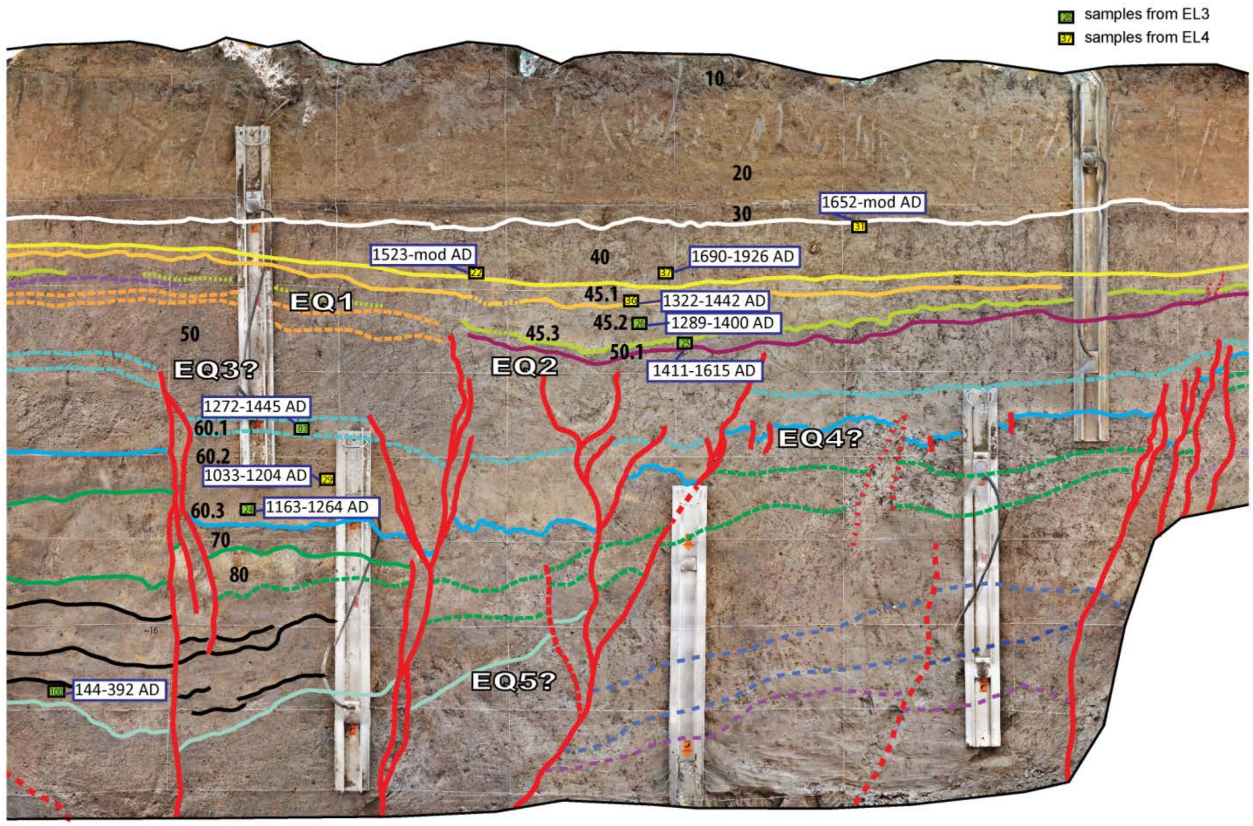
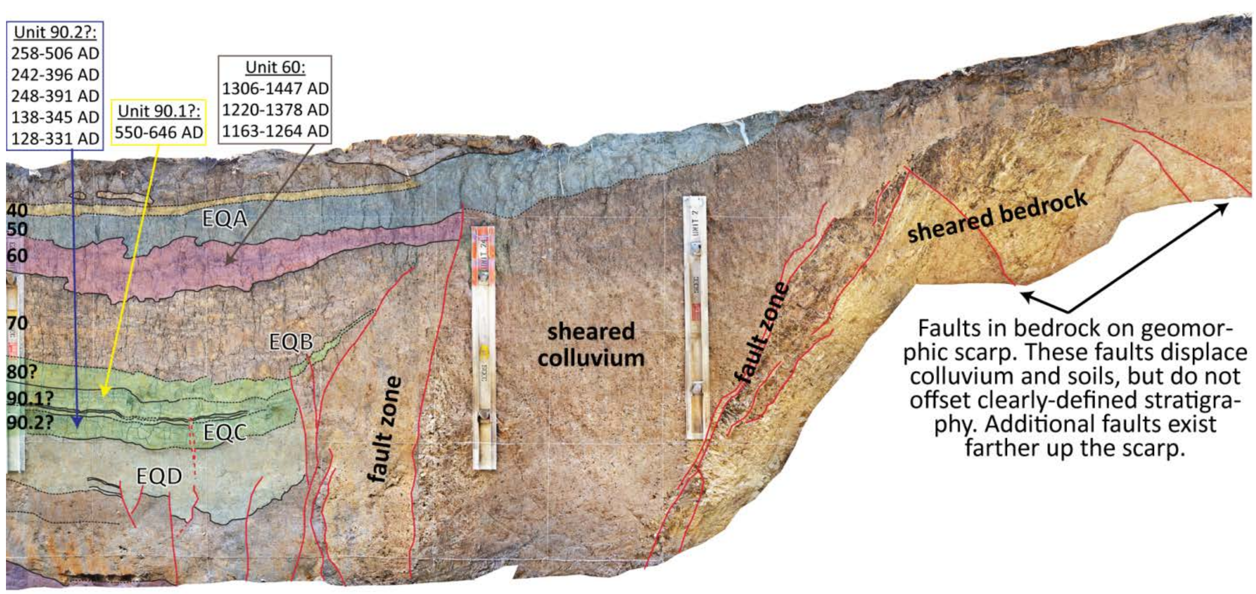


Figure 4. Portion of the EL4 west wall photomosaic and basic trench log. The stratigraphy of EL3 and EL4 contain a higher resolution stratigraphic record for the past ~900 years (Unit 60 and above) relative to EL5 and EL6 (Figure 5). However, no faulting extends above Unit 50.1 (~1500 AD), so the last ~500 years of earthquakes, including 1857 must have ruptured other paths through the site.



South North

Figure 5. Portion of the trench log from the north end of the EL5 (west wall). Well-bedded stratigraphy on the left is juxtaposed against the bedrock-cored geomorphic fault scarp across a complex, ~4 m wide fault zone. Additional

faults cut the bedrock on the right, but no other significant faults cut stratigraphy for the rest of the trench to the south. We infer that the last ~500 years of earthquakes have ruptured the bedrock-sheared colluvium fault zone, and thus cannot be differentiated or dated at this location. Units are tentatively correlated with EL4 (Figure 4) based upon field and stratigraphic interpretations and supported with age control, but become less confident with depth. Stratigraphic levels of earthquakes based upon evidence contained on both walls of this trench, and evidence for EQC is not well-expressed on this wall. EL5 and EL6 have well-bedded stratigraphy from between ~0-1400 AD. Events are noted here as A-D because correlations between EL3/4 and EL5/6 need additional dating and stratigraphic controls through additional trenching. Radiocarbon ages shown are synthesized for each dated horizon from samples collected throughout the trench.

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