2017 SCEC REPORT
RESEARCH AWARD NUMBER 16084

CERRO PRIETO-SAN JACINTO FAULT CONNECTION: MISSING SLIP DISCOVERED NEAR US-MEXICO BORDER

Principal Investigators:

Phillip Hogan, Fugro USA Land, Inc.
Thomas Rockwell, SDSU
Scott Lindvall, Lettis Consultants International, Inc.

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Hogan (Fugro): $9,000
Rockwell (SDSU): $0
Lindvall (LCI): $0

PROPOSAL CATEGORY: **A. Data Gathering and Products**
DICIPLINARY ACTIVITY: **Earthquake Geology**
SCIENCE OBJECTIVES: **2a, 4a, 4b, 4c**

ABSTRACT

We have compiled existing data, drafted trench logs to publication quality, and performed analysis of data including correlation of stratigraphy to nearby trench sites. Based on upward terminations of faults and liquefaction features in the Mexicali trenches, we have identified four events, and are evaluating evidence for a possible fifth event. These trenches document the northern extension of the Cerro Prieto fault, which apparently, steps slip to the southern extension of the Superstition Mountain fault across a broad zone of distributed faulting and liquefaction. Evidence for similar distributed faulting, ground failure, and liquefaction blows was observed across the Colorado Delta Domain during the 2010 El Mayor-Cucapah Mw 7.2 rupture (Fletcher et al., 2014).

TECHNICAL REPORT

This report summarizes progress on our research for SCEC Research Award Number 16084. We used previously collected seismicity and geomorphic data to map the location of the Cerro Prieto-San Jacinto (CPSJ) fault zone northwest from Cerro Prieto volcano and combined these data with paleoseismic observations from trenches across the northwestern extension of the Cerro Prieto fault to study the late Holocene event chronology.

PREVIOUS WORK

As part of a site clearance study for a proposed electricity generation plant, the PIs previously mapped and trenched the northwestern extension of the Cerro Prieto fault approximately 10 km south of the US-Mexico Border near Mexicali (Figure 1, Hogan et al., 2002). Relocated seismicity shows that a seismicity lineament traverses the study area; seismicity also illuminates the Imperial fault (Figure 2) showing that these are separate structural features. A possible connection between the San Jacinto (Superstition Mountain strand) and Cerro Prieto fault zones was previously postulated (Hogan et al., 2002; Magistrale, 2002), and recent geodetic work by Lindsey and Fialko

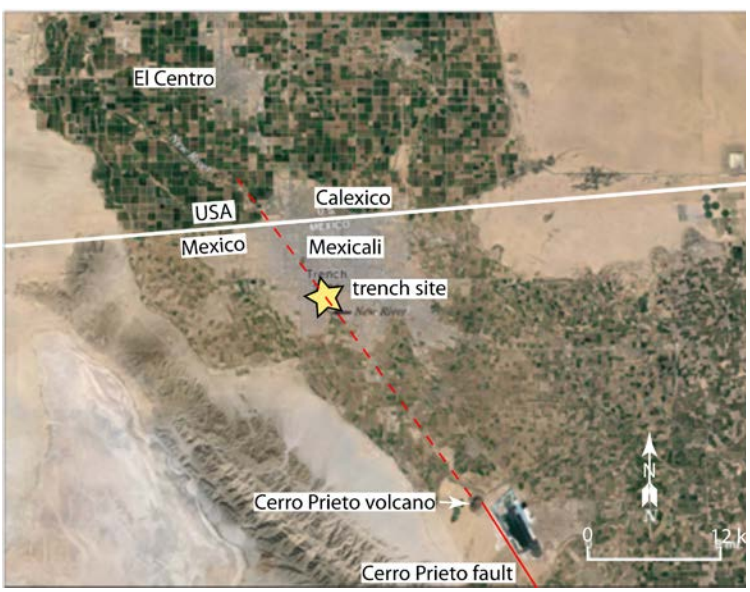

Figure 1. *GoogleEarth image of the Mexicali Valley showing the approximate location of the northwestern extension of the Cerro Prieto fault and trench site.*

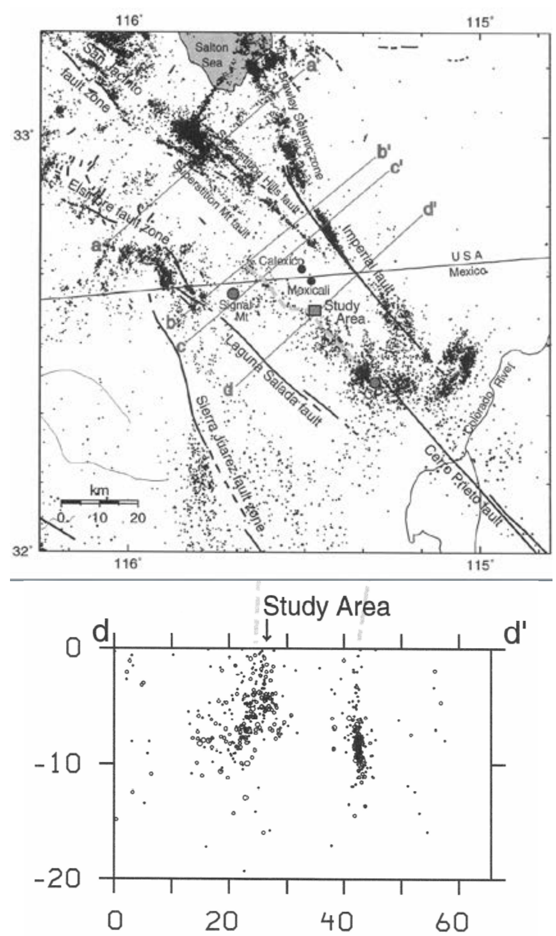

Figure 2. *Seismicity map and cross-profile through the trench site (Hogan et al., 2002).*

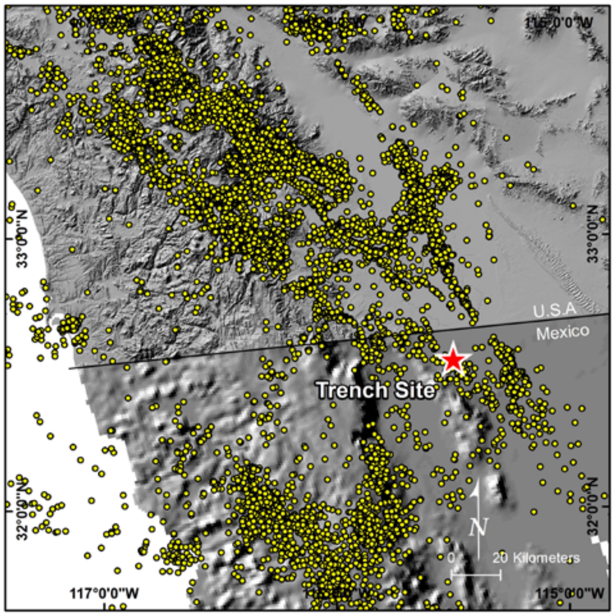

Figure 3. *Seismicity map from relocated seismicity (Hauksson et al., 2012).*

(2015) suggest that an extension of the San Jacinto-Superstition Mountain fault system through the town of El Centro may accommodate a significant portion of the slip previously attributed to the Imperial fault. Missing slip on faults west of the Imperial fault along the Mexican border was previously recognized by Thomas and Rockwell (1996).

Waveform relocated seismicity from 1981 to 2013 (Hauksson et al., 2014) all support connection of the San Jacinto and Cerro Prieto fault zones (Figure 3). The trench sites are located near a right step in the CPSJ fault zone, which parallels the New River from near Cerro Prieto volcano and geothermal field to north of the US-Mexican border (Figure 1). A ~9km wide step-over zone exists between the northern extension of the Cerro Prieto fault and the southern extension of the Superstition Mountain fault (Magistrale, 2002).

As part of the proposed power plant study in 2000, two long trenches were excavated, logged, photographed, and surveyed (Figure 4). These records formed the basis for our research project, with the ultimate goals being to (1) correlate rupture events to the well-dated Lake Cahuilla stratigraphy determined from other trench sites in the region, (2) improve the fault geometries for the CFM database, and publish these results.

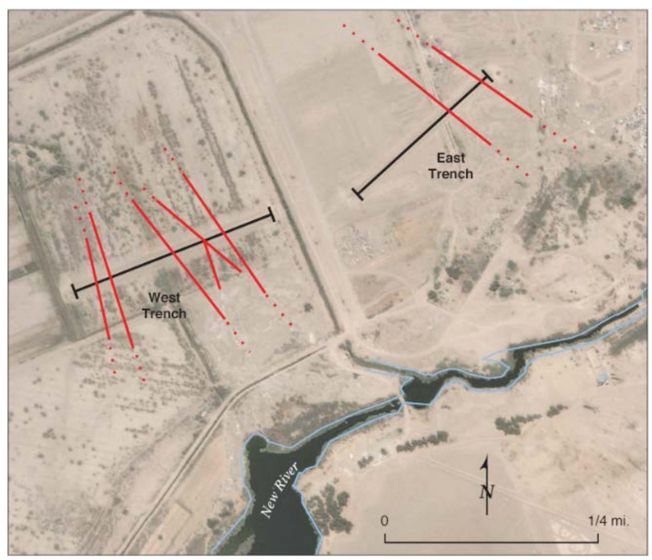

Figure 4. *Location of the trenches and surface projection of the faults exposed in the trenches from the power plant study in 2000.*

PALEOSEISMIC TRENCH RESULTS

The observed stratigraphy in the two AEP Mexicali trenches is nearly identical with that exposed at several nearby trench sites along the Imperial fault (Thomas and Rockwell, 1996; Rockwell et al., 2011; Sharp, 1980; Jerrett, 2015; Wessel, 2015). Of particular significance is that the three lacustrine units exposed in the trenches (Lakes 1, 2 and 3 in Figure 5) almost certainly correlate to the last three major inundations of Lake Cahuilla as documented by Rockwell's group with recent SCEC4 funding. A key red clay marker unit is present in Lake 3 strata at this site, and an identical red clay stratum was found in Lake 3 strata at both Border sites (reinterpreted from Thomas and Rockwell, 1996; & current trench investigation), located several kilometers to the northeast. The stratigraphic units exposed in the trenches are summarized in Table 1.

Table 1: AEP Mexicali Trench Site Stratigraphic unit descriptions.

Unit	Description	Interpretation
10	Blocky silty CLAY with some fine sand.	Plow zone/Lake 1 deposits
100	Massive silty CLAY with few to common shells	Last Lake (#1)
110	Find sand with silt and clay fragments filling vertical fractures/dikes	Liquefaction sand blows and/or faults
120	Fine cross-bedded SAND with few small shells.	Eolian Deposits or recessional shoreline sand
200	Well-bedded silty CLAY	Penultimate Lake (#2)
210	Massive silty fine SAND with angular clay and silt fragments of wall rock filling vertical fractures/dikes	Liquefaction sand blows
220	Well-bedded tan to grey tabular SILT	Deltaic deposits
230	Thin ~6-cm thick RED CLAY layer	Deltaic flood deposit from Colorado River
300	Thinly-bedded Silt and Clay with few small shells. Vertical fractures and tilted blocks in Trench 2.	Lake (#3) deposits
310	Thinly-bedded sands and silts with small shells	Lacustrine or fluvial (?)
320	Find SAND with clay fragments filling vertical fractures/dikes	Liquefaction sands
400	Thinly-bedded SILT and CLAY	Lake (#4) deposits

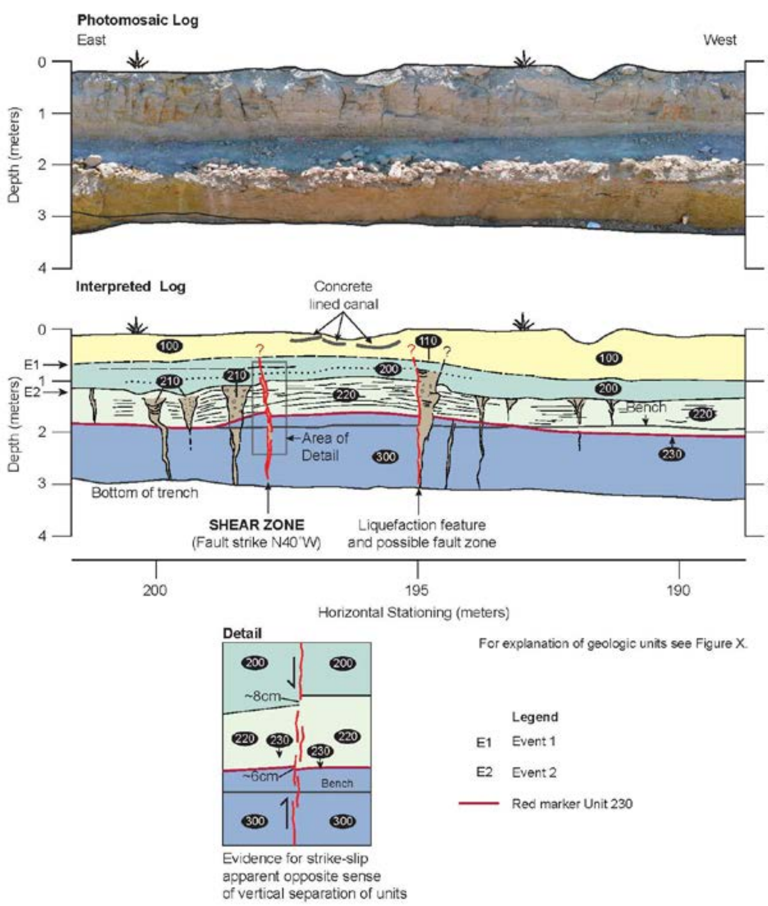

Figure 5. Log and photomosaic of main fault zone in Trench 1.

The trenches exposed evidence for four or five paleoseismic events, with the most recent event rupturing up through Lake 2 and into a well sorted fine sand interpreted to be either recessional beach deposits of Lake 2 or eolian sand deposited between

lakes 1 and 2. A younger, possibly historic event may also be represented. Two fault splays in the eastern trench (Trench 1) have produced a moletrack (Figure 5), whereas a second pair of splays has produced a small depression (Figure 6). These types of features, both transpressive and transtensive, are typical along strike-slip faults.

The penultimate event is documented by many liquefaction features (sand blows and pipes) below Lake 2 deposits in both trenches (Figures 5 and 7), as well as faulted strata in the western trench (Trench 2). The third event is characterized by faulted, offset, and tilted strata in Lake 3 deposits (Figure 7).

A possible fourth event was identified near the base of Trench 4, where liquefaction sands with clay fragments fill vertical fractures/dikes cutting Lake 4, underlying thinly bedded sands and silts of Unit 310. A summary description of the four events and their associated ages is provided in Table 2 below.

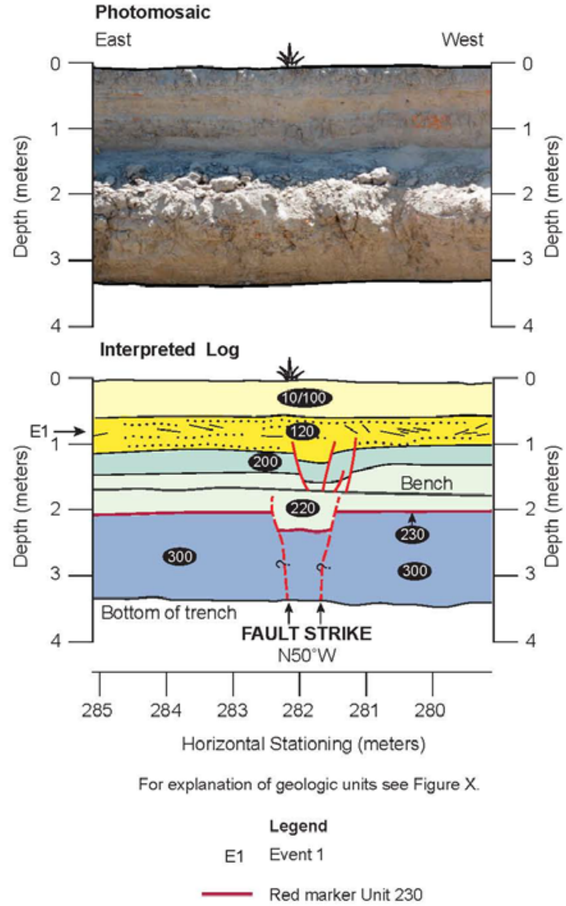

Figure 6. Log and photomosaic of eastern fault zone in Trench 1.

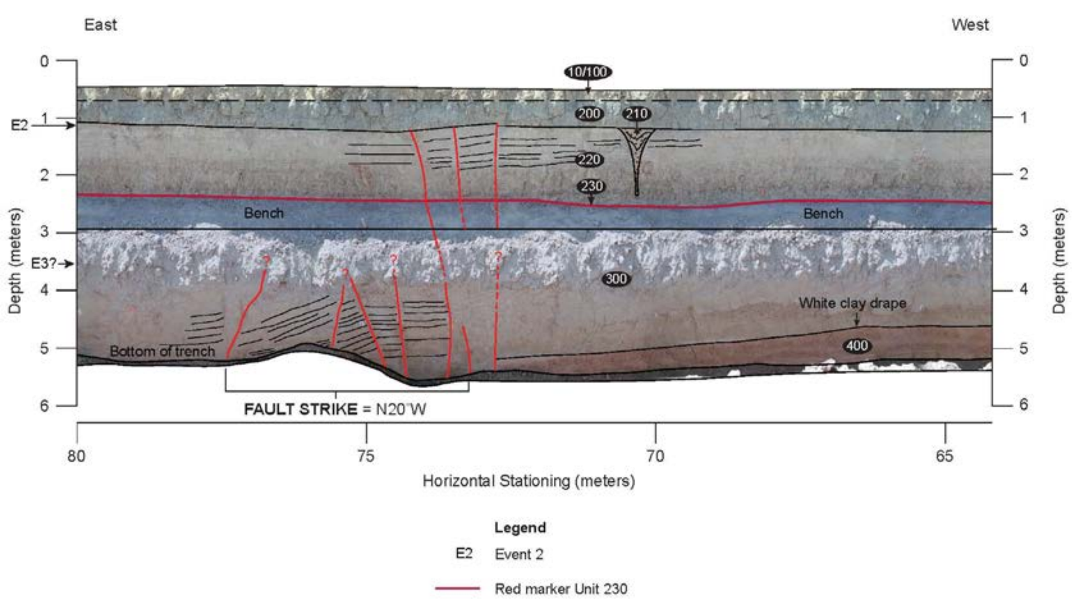

Figure 7. Interpreted photomosaic of western fault in Trench 2.

Table 2: Mexicali Trench Fault Event Summary Descriptions

Event	Description	Stratigraphic Level	OxCal Age Range (95% probability)	Other
1	Most recent fault event demonstrates clear evidence for strike slip offset at multiple locations in trenches 1 (eastern) and 2 (western). Moletrack in eastern trench may be primary fault zone. Concrete Irrigation Canal constructed on top of moletrack is not offset.	Faulting offsets all of lake 2 (Unit 200) deposits. Faulting does not offset Lake 1 (Unit 100) deposits. Where aeolian (Unit 120) deposits are present between Lakes 1 and 2, fault dies out within the aeolian deposits.	1645-1710AD	Interpreted to have ruptured between lakes 1 and 2, or during the regression of lake 2 if the aeolian deposits are actually regressive shore-line sands.
2	Ubiquitous liquefaction features at same horizon within both trenches. Evidence for fault offset (vertical separation) and tilting of strata at (74m) location in Trench 2 (western trench).	Liquefaction pipes extend to top of deltaic Unit 220. Sand boils immediately underlie basal clay of Lake 2 (Unit 200). Faulting terminates at same stratigrahic horizon. Event occurred at the end of deltaic 220 deposition, prior to Lake 2 infilling.	1513-1616AD	Possibly correlative with MRE on Superstition Mountain fault (Gurrola et al., 1996).
3	Fault offset and tilting of lower portion of Lake 3 deposits at (74-77m) location in Trench 2. Liquefaction sands with clay fragments (Unit 320) filling vertical fractures/dikes in Lake 3 deposits observed in other locations.	Faulting terminates approximately midway between bottom and top of Lake 3 (Unit 300).	1456-1501AD	Possibly correlative with MRE on Superstition Mountain fault (Gurrola et al., 1996).
4?	Liquefaction sand blows with clay fragments filling vertical fractures/dikes near base of trench.	Liquefaction pipes cut Lake 4 (Unit 400) deposits and extend to base of Unit 310. Sand boils immediately underlie thin bedded sands and silts of Unit 310. Possible faulting terminates at same stratigrahic horizon.		Liquefaction event. May represent a large earthquake on a nearby fault rather than on this fault. Interpreted to have occurred during the rising stages of Lake 3.

A schematic idealized log summarizing stratigraphic relationships and fault events identified in Trench 1 is illustrated in Figure 8. OxCal age range plots for the last three events are presented in Figures 9a, 9b, and 9c.

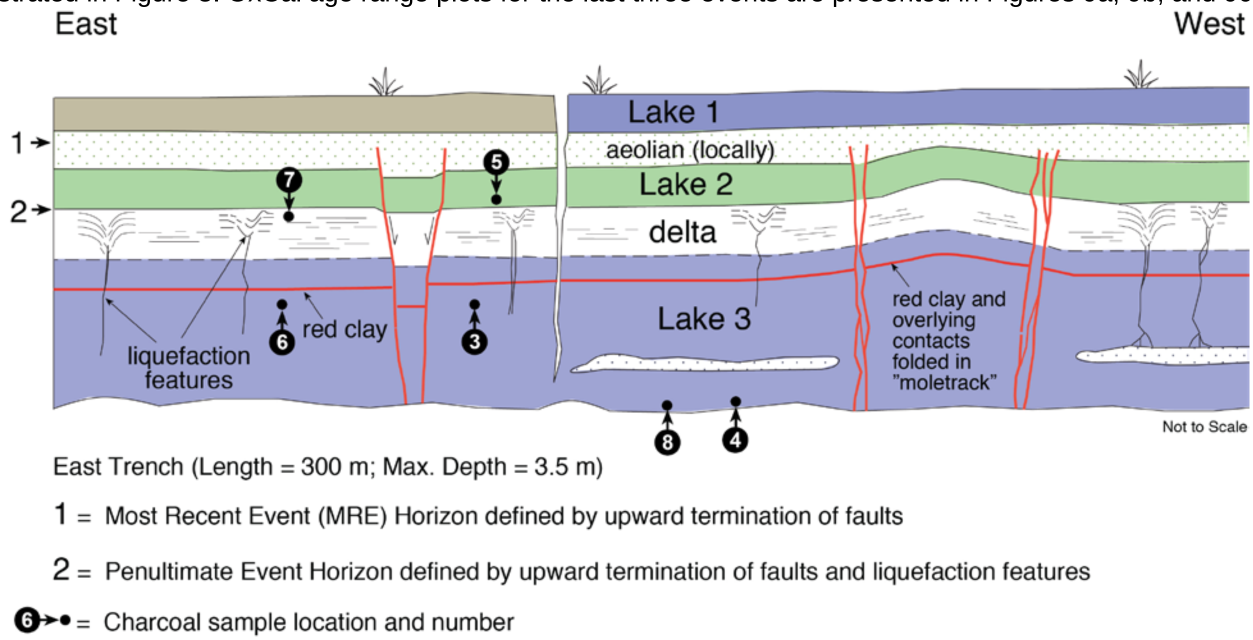

Figure 8. *Schematic log of one trench wall exposure from the power plant study.*

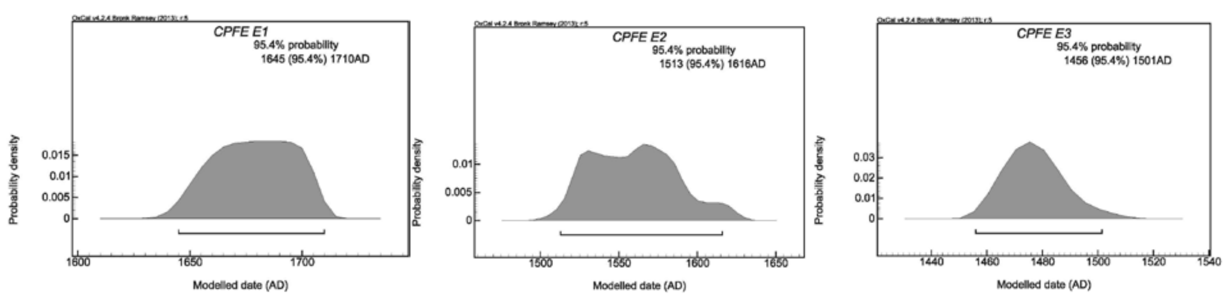

Figure 9a-c. *OxCal plots illustrating age range for Events 1, 2, and 3.*

The OxCal plots suggest that Events 1, 2, and 3 occurred in a 250-year period between about 1460 and 1710. We are still exploring the possibility of a younger event than Event 1 in Trench 2, where two vertical fault splays were logged as cutting units 200 through 400, and possibly extending into Lake 1 (Unit 100) and the plow zone (Figure 10). If this event is confirmed it may represent a historic or prehistoric ground rupture event or, more likely, triggered slip from a nearby large earthquake. This latter interpretation is supported by the observation that it produced only very minor displacement at this site.

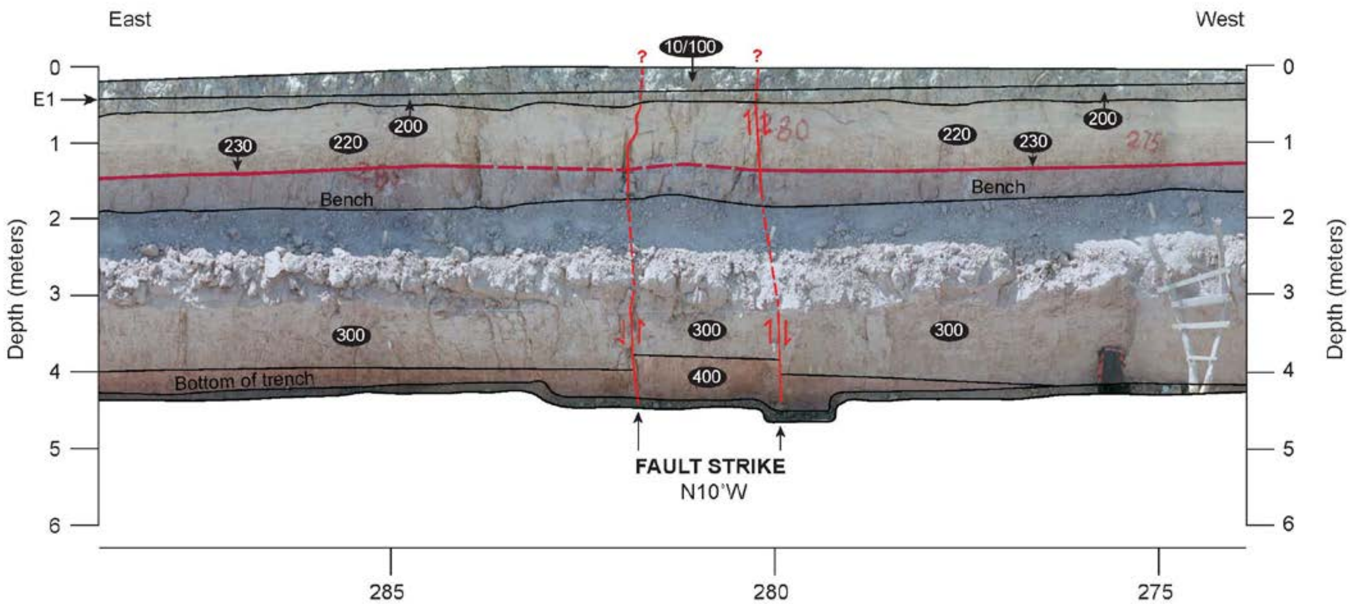

Figure 10. *Recent faulting in Trench 2 expressed by vertical separation of the contact between Units 300 and 400, as well as folding of the red marker unit 230. This may represent Event 1, but could also be indicative of younger faulting or triggered slip.*

CONCLUSIONS, INTELLECTUAL MERIT, AND BROADER IMPACTS

Distributed faulting and liquefaction appears to have affected a broad region in a stepover zone between the northern extension of the Cerro Prieto fault and the southern extension of the Superstition Mountain fault. We have identified four events defined by upward terminations of faults and liquefaction features, and are evaluating evidence for a possible fifth event. Three of these events have displacement associated with them, which argues that they represent earthquakes on this fault strand. Slip rates on the CPSJ connector remain uncertain given the lack of measured offsets in the AEP trenches. However, we plan to publish the results of the current investigation in a peer-reviewed journal, and use this as a springboard for targeting future trench sites north and south of the international border that hold the potential for constraining slip rates and the associated seismic hazard posed by this important fault zone.

This investigation is meaningful because it could help solve the slip deficit across the Salton Trough at the latitude of the US Mexican Border. Additionally, this study further demonstrates the distributed nature of faulting in this region, and the potential for fault and rupture interaction. More importantly, the results could help improve public safety, particularly in the greater metropolitan Mexicali area and border zone region.

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LIST OF PUBLICATIONS SUPPORTED BY SCEC FUNDS

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