Evidence for the most recent rupture of the San Bernardino strand, San Andreas Fault in the 13th to 14th century AD, Burro Flats near Banning, California

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Abstract

The San Bernardino strand of the San Andreas Fault has not ruptured in historic time. A trench site at Burro Flats near Banning, CA shows clear structural and stratigraphic relationships that constrain the most recent event on this fault to have occurred in the 13th to 14th century AD. There was no evidence for younger events. Structural evidence includes truncation and offset of units. Geomorphic and stratigraphic evidence includes a north-facing fault scarp, and an onlap sequence of silt and fine layered (1mm) peat layers. Radiocarbon samples that constrain the age of the event horizon include two samples of peaty soil, and one sample of horizontal plant fibers separated from a peat layer. Calibrated calendar ages constrain the event to have occurred shortly before AD 1225 - 1395. This appears to overlap with the earliest of two events described from the same fault strand at Plunge Creek near San Bernardino, CA (Dergham, 1998).

No evidence exists at Burro Flats for younger ruptures that correspond to either the A.D. 1700 or 1812 events found in the Wrightwood, Pitman Canyon and Pallett Creek areas. Furthermore, evidence of the A.D. 1680 event at Indio does not appear at Burro Flats. The behavior of the San Andreas Fault at Burro Flats therefore appears to be in striking contrast to the fault's behavior to the northwest and southeast, at

Wrightwood and Indio, respectively. Assuming a conservative slip rate of 10mm/year for the San Bernardino strand, the amount of strain accumulated on the fault could exceed 5m since the last event.

Introduction

Paleoseismic study in Burro Flats along the San Bernardino segment provides critical information to scientists trying to determine the frequency of earthquakes and the intensity of ground shaking in this region. The trench site on this segment of the fault shows a dramatically different paleoseismic record from that of sites to the northwest and southeast (Figure 1). My work this summer helped show that the San Bernardino strand of the San Andreas fault has earthquakes _ to _ as often as the San Andreas fault in the Mojave (NW) and Coachella Valley (SE). Information attained in this study will not only be valuable to the scientific community, but to society as well. Determining the frequency of faulting events a well as the motion and size of events will be useful in determining building codes, and safety procedures in this region.

Site Description

Burro Flats exhibits nearly ideal depositional and structural qualities for paleoseismic research. These qualities include an active fault, a high rate of sediment deposition, a yearly supply of carbon to determine the age of the sediment, and little human modification of local geomorphology. At Burro Flats, the active fault is obvious as a set of en echelon fault scarps in Holocene alluvium, the sedimentation rate is high on alluvial fans sourced by the San Bernardino Mountains to the north. The trench site is located in a marsh that provides an annual source of carbon, and there is very little human modification other than a nearby dirt road (Figure 2).

Methods and Procedures

Paleoseismic trenching involves dirt, a lot of it. Every trench site has it's own conditions largely depending on the depositional environment, ranging from wet marshy trenches, to dry desert trenches. Differences between trench conditions require many different methods of trenching. Trenches in unconsolidated sediment often consist of a couple of stepping benches. Some trenches may be narrower, and require shorings to reinforce the trench walls. There are also a few different methods to document trench walls. We used a total surveying station (I will explain later), other methods include use of photologs, and also string grids. A photolog is a collage of pictures of the trench, this creates a map of the trench walls that needs to be drawn in detail. String grids are placed across a vertical cut wall, the grid shows location along the wall, and the trench is mapped box to box.

Excavation of this summer's trench site began on May 17, 1999. A backhoe excavated approximately 3 meters down. Within an hour of digging we reached the water table, from this point to the end of the summer our trench was muddy. Next we began channeling water and moving mud away from the trench walls. As we exposed more sediment it was important to scrape a clean nearly vertical trench surface. We did this while the trench walls were recently exposed so we could preserve a clean surface, and clearly see sediment units and structural features. While the trench walls were freshly scraped, we inserted painted nails of three different colors along layers consisting of peat, sand and gravel. Doing this made it easier to visually follow the layers through a structural deformity such as faulted regions (Figure 3).

A total station was used to survey the location of nails along the trench walls. ArcView software was used to plot the location of the nails using x,y,z coordinates. The nails created a canvas of dots, just waiting to be connected. Putting together a mapboard is the next step, this is done by placing sheets of mylar over the surveying data (nail print out) on to a map board. Mapping both benches of the north and south wall took four of us two and one half weeks to complete. Tools included a mapboard, hard lead pencil, good eraser, measuring tape and a small scraper. Measuring tape is used to measure the thickness of layers as well as the width, length and orientation of medium to large rocks. Small scrapers are used to delicately clean the trench surface, exposing a much clearer stratigraphy.

As we went into the final stages of trench mapping, drafting trench logs quickly consumed our time. In addition to a hand drafted final copy of the trench logs, we also a digitized final draft of the trench logs. Complete field copies of the north and south walls were scanned in to the computer and used in Adobe Photoshop and Adobe Illustrator. Peat samples were collected in the last stages of trench one. Samples were collected from event horizons down to the bottom peat. These samples were used to determine the ages at the event horizon, and also to constrain the ages of other peats. Seven detailed stratigraphic columns of parts of both the north and the south walls were made along both sides of each faulting event, and between the two events.

Cut two of our trench began on July 19th, on July 12th we backfilled the trench and removed the upper bench on the north side with an D8 bulldozer so we could bring in the trackhoe and excavate deeper. However the D8 bulldozer was too large on the soft, and wet sediment and on July 13th it sank approximately 8feet (Figure 5). This was our first serious problem, fortunately it only took a week to remove the bulldozer. It caused soft sediment deformation dateable to 1999! Once again we attacked the trench with shovels and scrapers in hand, all in preparation to begin mapping.

Difficulties

Aside from sinking the bulldozer, other difficulties we have faced this summer seem trivial. We had some difficulty changing the coordinates of the total station information to x,y,z format. While working on final drafts we encountered software difficulties, and software compatibility problems. We also had map board boundary faults, where units one person mapped were shifted, or had slightly different unit descriptions from what another person mapped.

Trench walls are very irregular because of difficulties excavating. It was difficult to dig planar walls because it was soft, wet sediment, and the equipment operator was inexperienced digging for this particular purpose. These irregularities made it difficult to survey in the location of all the nail heads. Photolog mosaics are not an option while constructing our trench logs because of the irregular cut. We did however photograph faults and fissures showing key relationships. We had some problems with theft over the summer, shovels, shade tarps and pic axes were missing.

Field Relations

Burro flats has clear evidence of multiple, faulting events in this region over the last 3,500 years. The focus of my internship is the most recent faulting event (BF-X), current age data suggests occurred sometime in the 13^{th} to 14^{th} century AD (Figure 3). I mapped unfaulted sections of the trench before mapping the fault zone.

Structural evidence of the event includes faults, folds and fissures. Faults show an apparent vertical separation of units toward the northeast. Folds mirror the fault displacement as drag features related to the fault, down on the NE and up on the SW. Fissures are also found to the west of the fault zone. They have a NE orientation suggesting they are en echelon to the fault itself, and they end at the same stratigraphic horizon as the faulting, the top of unit 79a.

Fissures are more numerous than faults in the trench. They are marked by a seam of mixed lithology, of sand, gravel and peat that separates the layered stratigraphy. Size of fissures in our trench typically ranges from 5 to 10cm. They are interpreted as open fractures that have filled with liquefied sediment (sand blows). The upward termination of a fissure is interpreted to approximate the age of an earthquake.

Stratigraphic evidence of event BF-X is provided by finely layered sand, silt, clay and peat that bury the fault scarp. These deposits mark a sudden change in depositional environment, from the coarse deposits below. Suspended load sediments probably accumulated in a small pond depression along the strike of the fault scarp. The pond sequence includes units 80-84, silty clay, fine sand and thin (mm-scale) peat layers and unit 79b, a 5cm thick brown peat (Figure 4). Units 79b-84 overlaps the scarp and gradually pinch out to the east. Pebble and cobble gravel interbedded with uniform peaty soils occur above and below this packet of pond sediments.

Age Constraints

Radiocarbon age data from a shallow trench excavated in 1998 suggests event BF-X occurred between or prior to AD 1415-1465. This age came from a sample collected from the top of a massive amalgamated soil that appeared to be deformed. This summer's trench exposed the fault zone. The AD 1415-1465 soil laterally interfingers with interlaminated silt, clay and thin peat, of the pond sequence described above. To constrain the age of the most recent event we sampled the small (1mm) peat in the lake deposit, and the top of the brown peat below the lake deposits. These samples were sent to Beta Analytic, Inc. in Florida for C13/C14 dating.

Sample 84a, a thin peat at the top of the pond sequence yielded a 2 sigma calibrated calendar age of AD 1420 to 1510. This peat occurs in the same stratigraphic position as the age of the top of the soil from the 1998 trench (AD1415-1465). The soil age and peat 84a overlap within error; therefore the top of the lake is interpreted to have been deposited in the mid 15^{th} century. The middle 1mm peat yields a calibrated calendar age of AD 1105-1185, which is older than the underlying peat, and is therefore disregarded as too old. Note: out of thirteen samples sent in that only one is out of sequence. The top of unit 79b yielded a calibrated calendar age of AD 1255-1395, obtained from horizontal plant fibers separated from the top 1cm of the brown peat layer.

Discussion

Interpreting the event horizon of event BF-X isn't as clear-cut as one might expect. There are two scenarios plausible for the BF-X event horizon. The first possibility is that the event occurred at the boundary between the brown peat, unit 79a, and the lake deposits, unit 80 (Figure 4). This is reasonable because the depositional environment has dramatically changed from an organic marsh to a small lake, some event must have caused this change in environment. Another possibility is that the event horizon is between the brown peat and the black peat. Discoloration of peat, might also suggest a very dramatic difference in depositional environment. Structural evidence supports the latter interpretation. Unit 79a is the uppermost layer truncated by the fault. The boundary between 79a and 79b is therefore the most consistent interpretation of the stratigraphic and structural features in this cut.

Peat accumulation rates of approximately 1mm/yr are known from other paleoseismic sites in similar settings (K. Sieh, personal communication). The base of the brown peat (~5.0cm beneath sample 79b) therefore may have been deposited approximately 50 years before, and shifts the timing of event BF-X between AD 1205 to 1345. However a radiocarbon age from the base of unit 79b will better constrain this estimate.

Timing of the BF-X event at Burro Flats suggests that this segment of the fault ruptures much less frequently than either at Wrightwood and Pallet Creek (northwest) or at Indio (southeast). The 13th to 14th century AD paleoseismic data shows that two events have occurred at Indio on the Coachella Valley segment (Sieh, 1986), and three

(Pallet Creek) to five (Wrightwood) events have occurred on the Mojave segment (Sieh and others, 1998; Fumal and others, 1993). Event BF-X appears to correlate with the earlier of two events seen at Plunge Creek near San Bernardino (McGill and others, 1998), which is another trench on the San Bernardino strand of the San Andreas fault. Burro Flats therefore shows the longest recurrence for the most recent event out of all the paleoseismic sites on the San Andreas fault in Southern California. This suggests that the San Bernardino segment ruptures less frequently than either the Mojave segment (northwest) or the Coachella Valley segment (southeast).

Strain accumulation on the San Bernardino, Palm Springs segment of the SAF is difficult to approximate. Slip rate estimates for this segment of the fault range form 20-25 mm/year (Harden and Matti, 1989). If no earthquake has occurred since the 13th- 14th century (600-700) years, how much strain has accumulated? At these rates strain accumulation could range from 12m to 17.5m on this fault. This would be a very large event even for the San Andreas fault! Several other possibilities are feasible. Either there is a very large event waiting to occur in this region, the slip rate estimation for this strand of the fault is too high, or the strain on this strand of the fault is accommodated by other active faults that in the region. Knowing the slip per event at Burro Flats or knowing a late Holocene slip-rate there will help resolve this problem.

The impact of this study is very important to forecasting the earthquake hazard in the San Bernardino, Palm Springs area. Paleoseismic data from Burro Flats fills a gap in the paleoseismic data set for southern San Andreas Fault. We can now say that in the vicinity of Banning, CA. the San Bernardino segment of the San Andreas Fault does not appear to have ruptured since the 13th to 14th century AD. Extending the paleoseismic record at Burro Flats will help determine whether this means that the region is “over due” for the next earthquake. Seismologists and geophysicists can use this information to estimate the intensity of ground shaking in Southern California. Information such as this can lead to better building codes, and better awareness of the hazard facing Southern California. Previously this type of information about the San Bernardino area wasn’t available, mostly because this is the only segment on the San Andreas Fault that hasn’t ruptured in historic time.

<u>References</u>

Dergham, S., 1998, Paleoseismic Studies of the San Andreas Fault in the San Bernardino Area, 1998 abstract, SCEC Annual Meeting, Palm Springs, CA.

Fumal, T.E., Pezzopane, K.S., Weldon, R.J., and Schwartz, D.P., 1993, A 100-year average recurrence interval for the San Andreas Fault at Wrightwood, California, Science, **259**, 199-203.

Harden, J. W., Matti, J.C., 1989, Holocene and late Pleistocene slip rates on the San Andreas fault in Yucaipa, California, using displaced alluvial-fan deposits and soil chronology: Geological Society of America Bulletin, **101**, p. 1107-1117.

McGill, S., Grant, D., and Wells, S., 1998, Partial Paleoseismic Record of the San Andreas Fault at City Creek, near San Bernardino, California, 1998 abstract, SCEC Annual Meeting, Palm Springs, CA.

Sieh, K., Stuvier, M., and Brillinger, D., 1989, A more precise chronology of earthquakes produced by the San Andreas fault in southern California, *Jour. Geophys. Res.*, **94**: 603-623.

Sieh, K., 1986, Slip rate across the San Andreas fault and prehistoric earthquakes at Indio, California, *EOS Trans. AGU*, **67**, 1200.