Reconstruction of Trench Logs as a Test for Interpreted Paleoseismic Events

SCEC Summer Intern: Natanya Black- UCSB
Mentors: Tom Rockwell and Tim Dawson- SDSU

Abstract

Reconstruction of stratigraphy in a faulted section is a useful technique to test whether initial interpretations of the earthquake history are correct, or whether the section has been over- or under-interpreted. For a composite log from an 8-m-deep trench across the central Garlock fault, I reconstructed the stratigraphy and earthquake history by removing the deformation at each interpreted earthquake event horizon. There were six “well-documented” events that were interpreted in the stratigraphic record exposed at this site. Events W, U, Q, R, K, and F (in order of youngest to oldest) were identified in the field through observations of increasing/decreasing displacement, upward fault terminations, folding, and fissure-fills. These were selected as candidate events to use as a basis for the reconstructions.

The first step was to construct a photomosaic of the trench exposure by rectifying each photograph in Adobe PhotoShop. The photographs were then assembled into a larger photomosaic where important stratigraphic features could be outlined and highlighted. The first reconstruction was of the most recent paleoearthquake, event W. The continuous sediment overlying the event horizon was removed and the faulted units below the event were retrodeformed. The process was repeated for each older event. No obvious mismatches in the stratigraphy could be observed, when the vertical deformation and folding from the four most recent events was removed. This suggests that the events interpreted thus far are correct. The remaining event shows only minimal displacement and folding which suggests that no additional events can be resolved through this retrodeformation technique. I also suggest that not all of the events were of the same magnitude, at least in terms of vertical separation.

Introduction

The Garlock fault is a major transform structure in southern California that expresses 48-64 km of left-lateral slip. The fault intersects the San Andreas in the vicinity of Fort Tejon in the Big Bend region, and extends some 250 km to the northeast to the Death Valley area [Smith, 1962; Smith and Ketner, 1970; Davis and Burchfiel, 1973; Carr et al. 1993]. The fault expresses two, relatively long segments join by a large releasing step-over at Koehn Lake, and is generally more complex towards its eastern terminus.

A trench on the fault near El Paso Peaks has exposed a remarkable section of playa sediments that record an extended sequence of mid-late Holocene earthquakes. McGill and Rockwell (1998) published preliminary work at that site, and this study is a continuation of that earlier work. The primary purposes of my study are to: 1) Extend the record of paleoearthquakes at this site, by identifying additional event horizons in deeper parts of the stratigraphic section; and 2) Reevaluate evidence for paleoearthquakes previously identified in the original trench.

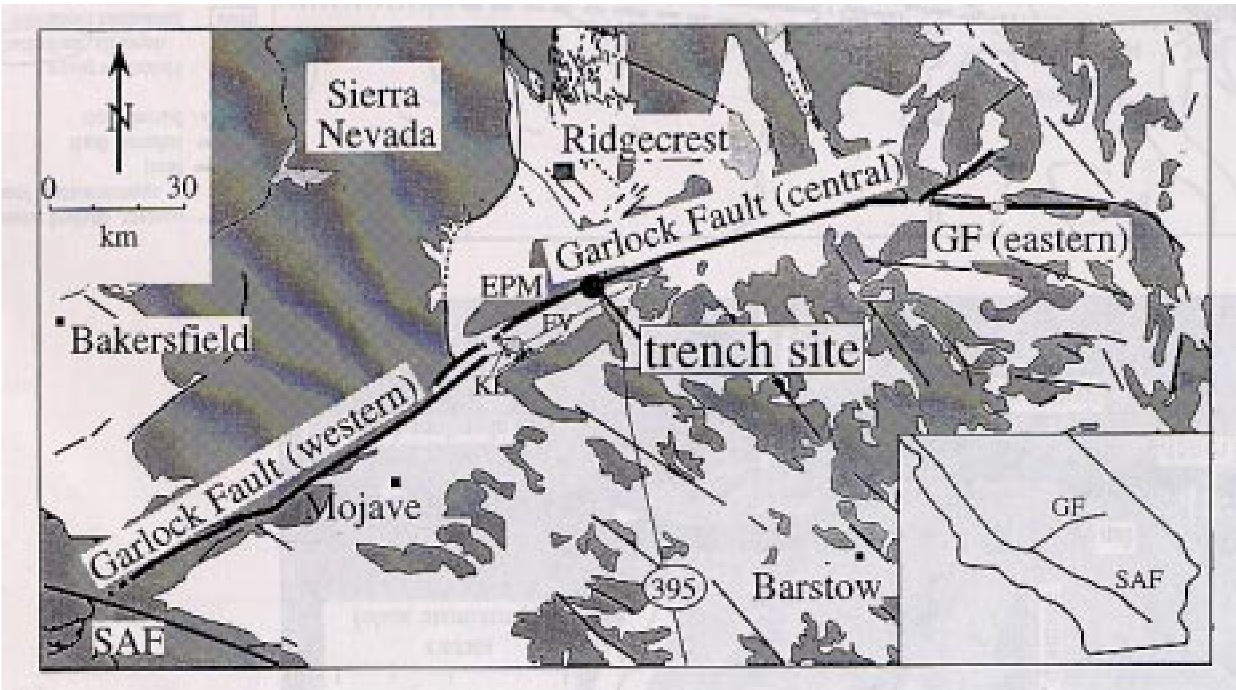
In order to reconstruct the earthquake history of a fault, one common technique is to excavate trenches across the fault in areas that have experienced relatively continuous sedimentation, so that there is both structural and sedimentologic evidence of past surface ruptures. Implicit in this method is the assumption that the stratigraphy and structural relationships can be correctly interpreted. For my summer internship, I tested interpretations of past earthquakes by reconstructing a cross-section of the trench wall. Each event horizon was reconstructed such that any misinterpretations of the paleoseismic record might be discovered if mismatches occur in the stratigraphy.

The basis of this study is to test the interpretations made in the field using logs generated by the fieldwork. This is done through removing the deformation caused in an event by “back slipping” and unfolding or retrodeforming, the stratigraphy affected by each individual event. If the event horizons have been interpreted correctly, then each reconstruction should produce fairly continuous stratigraphy below the reconstructed event horizon, and the next older event should still be easily recognized through it’s expression of additional deformation. If the reconstruction does not produce a reasonable cross-section, then further interpretation is needed to resolve whether the discrepancy is due to changes in unit thickness from lateral slip, or from a misinterpretation of the paleoseismic record, possibly the result of an unidentified paleoearthquake.

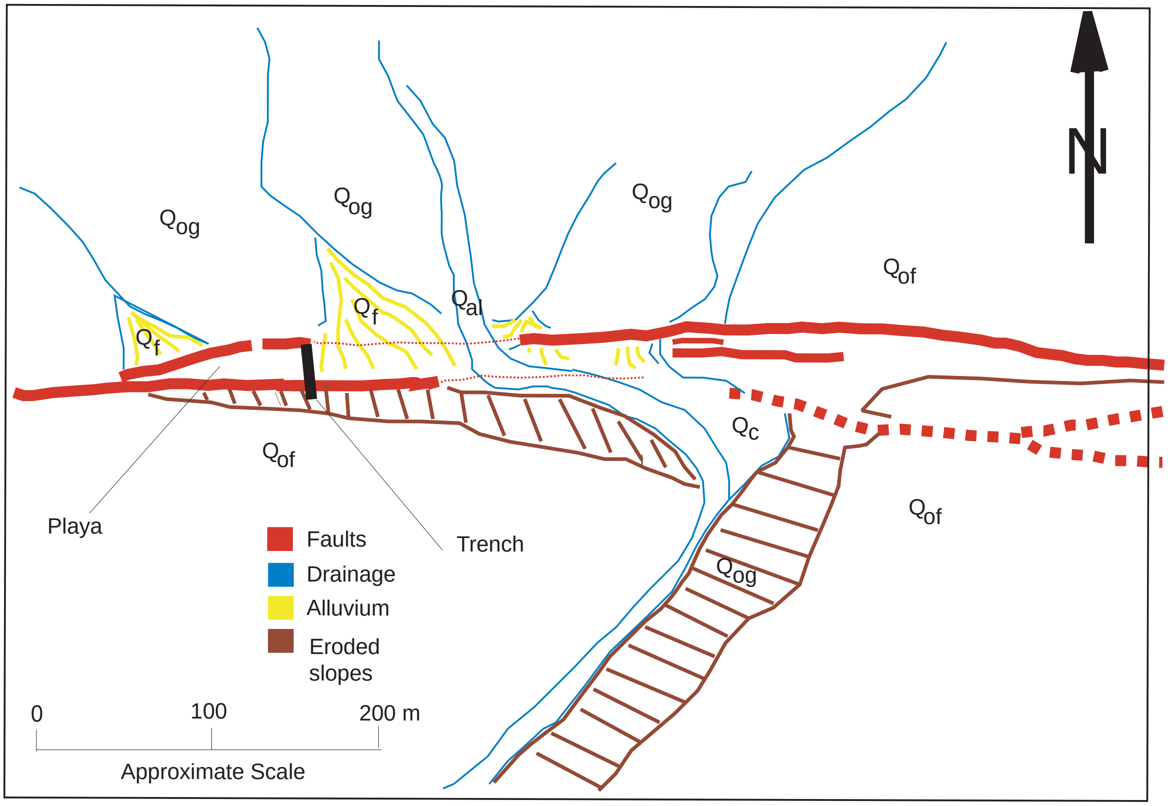
Site Description

The trench is located on the Central Garlock Fault about 2.3 km west of where the fault crosses Highway 395, and east of a 3.5 km wide step over that separates the western Garlock Fault from the central segment. This step over produced a pull-apart basin which resulted in the formation Koehn Lake in Fremont Valley [Clark, 1973; Aydin and Nur, 1982].

Two fault strands run through the area; the trench crosses the southern strand about 100m east of where the north strand joins with the south [McGill and Rockwell, 1998]. The trench was excavated on a playa within a small basin, which is blocked on the northeast by an active alluvial fan. A shutter ridge composed of older alluvial fan gravel blocks the south side of the trench. East of the site, a stream drainage cut into Pleistocene alluvium fan gravel is offset 200-250 m [Clark, 1973].



from: McGill and Rockwell (1998)



Map of the Study Area as Drawn from an Aerial Photograph

Methods

The main methodology is to take trench logs from the Garlock site and remove vertical displacement and folding associated with six events identified in the field. Since these are two-dimensional exposures across a strike slip fault, some units are expected to not match in thickness, due to mass transfer along the fault.

The trench wall was metered using a 50x100-cm grid and then photo logged. The photos from the original unbenched trench were used in the reconstructions, so there would be only one break in the photomosaic where the trench was later benched and dug 2-3m deeper. The photographs were scanned into the computer, and distortion caused by the camera lens and development were removed using Adobe PhotoShop. These photos were pasted together into a large photomosaic that displayed the entire trench wall.

The event horizons identified in the field were used as a basis to begin reconstruction of the photomosaic. The units, faults, and event horizons were drafted on the main photomosaic in an artwork layer. Key units were highlighted so displacements could be followed easily. To begin reconstructing each event, the continuous stratigraphy above the interpreted event horizon was removed. The displacement and deformation caused by the event is removed from the stratigraphy by back slipping the faults and unfolding deformation. The goal is to make stratigraphy continuous and undeformed immediately below the event horizon being reconstructed, but still show deformation below the next oldest event horizon.

To undeform the folded stratigraphy, the defined fold section is removed and adjusted in a workstation. The fold is cut along the inflection points into a series of vertical columns. These columns are then rotated back into the original horizontal position of the stratigraphy. One of the difficulties of this technique is that gaps will open up between columns when sections are rotated. This problem can not be resolved because of the limitations of working with 3-dimensional material in a 2-dimensional space.

Event Reconstruction's

So far, the six well-documented events W, U, Q, R, K, and F (in order of youngest to oldest) are interpreted in the stratigraphic record exposed at this site. The event horizons were selected through evidence present in the field and are used as the premise for the reconstructions.

Event W

The most recent earthquake occurred around A.D. 1600, and is referred to as Event W. In the reconstruction, vertical displacement is removed from the six faults ruptured in this event at stations (S) 7, 8, 12, 18, 22, and 27. Points 22, 17-18, and 11-12 show signs of earthquake related disturbances and each fault was vertically reconstructed by approximately 5 cm. The fault at S22 ruptured below the surface and created a fold in the uppermost sedimentary layers. The fault zone at S11-12 is brecciated from repeated faulting, which has produced a fissure fill. The offset in this disturbed stratigraphy was measured by taking a straight line across the units directly bordering a fissure fill. The fault in S7 is vertically displaced 15 cm, and it bounds a folded area that extends to S12. The fold was confined to the warped stratigraphy above Event K, because sediments below that event had compensated for the shortening by multiple faults and fractures. The section between S26 and 27 was folded in a previous event, and is refaulted in Event W by 10-15 cm of vertical displacement on the northern edge.

Event U

The stratigraphy reconstructed for Event W is removed up to the Event U horizon that ruptured in ca. A.D. 1000. Vertical displacement is observed on faults at S8, 14-15, 18, 22, and 23. The two faults in S21 and 23 display 5 cm of vertical displacement and merge into one fault segment about 2 m below event horizon. Five centimeters of vertical offset is also seen across ruptures at S8 and 14-15. The largest amount of vertical separation caused by event U was 10-15 cm at S18, the offset occurred below the surface and produces a slightly ruptured fold in the overlying stratigraphy.

The two most recent events caused folding in the stratigraphy between S8-12. The folding was localized to the stratigraphy 3 m below the surface, and additional folding from Event U was removed from the region. The folding at S26-27 is confined to a section that is 1.5 m in width, and is highly warped. The deformation is so intense that it could not be remove using the current techniques in Adobe PhotoShop. Some rectification was accomplished in the upper 0.5 m of the fold, but lower units were so completely folded they were unable to be reconstructed.

Event Q/R

Events Q and R both occurred within a short time interval around 160 AD. These two events are treated as a single event in the reconstructions because the earthquake horizon for Event Q/R is the same from stations through sections 2-19. The R event horizon may have been eroded off the fault scarp between sections 2-19, so the horizon is only visible in S19-27. One undisturbed continuous unit that is about 10 cm thick separates the two event horizons where R is still visible. Since there is no deformation or warping in the unit separating Q/R, and the two event horizons are in the same stratigraphic location on most of the east wall, the two events were reconstructed as one event. Most evidence for Event R is apparent on the west wall (not reconstructed here) or has been documented in previous studies of the site (McGill and Rockwell, 1998).

Vertical displacement occurred along four faults at stations 7, 12, 18, and 22. Ruptures at S7 and 12 expressed minor offsets of about 5 cm, whereas displacements of 10 cm or greater occurred on faults at S18 and 22. The large fissure fill at S17-18 may have resulted from the section in S18-22 being folded and uplifted by about 10-15 cm across the fault. The entire section was rotated clockwise and stratigraphy was reconstructed to be horizontal and continuous. A slight incline in the reconstructed stratigraphy remains from the slope of the landscape as it pinches out against the shutter ridge.

Event K

Event K occurred around 3145 BC, and is the oldest event dated. Only 5 cm of vertical slip is observed on the S22 fault, and units pinching up against the alluvial gravel in S7-10 were folded concave up and are highly fractured against the fault. The folding was removed in the unfaulted region of the stratigraphy and the section was slightly rotated in the reconstruction.

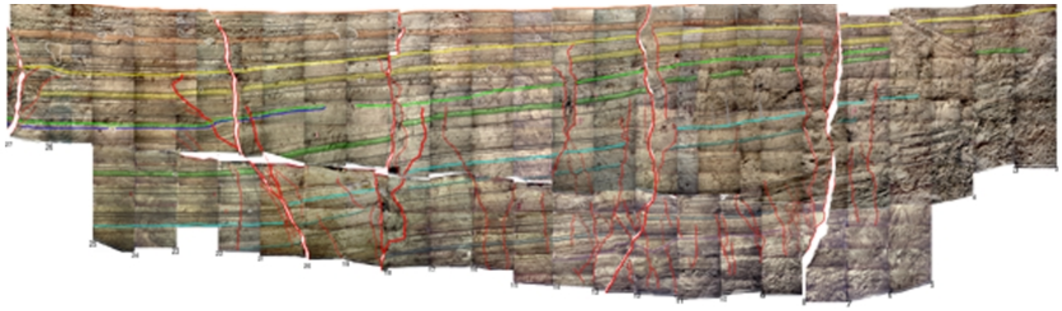
After completing three of the reconstruction's most of the vertical slip was removed from the section, so it appears that event K produced little to no vertical slip and may have been purely lateral. The amount of vertical displacement from event K is so slight that it may be due to multiple fractures along the major faults, micro-faults that did not rupture the surface or stepped over, or from errors made in the first three reconstructions. The vertical displacement observed for Event K occurs in a fault zone that was rupture in the first three earthquakes. The reconstructions only accounted for displacement along the main fault strand, not the smaller faulting directly surrounding the fault zone. Therefore the 5 cm of offset may have occurred in previous event because it is within a heavily fracture fault zone.

<u>Event F</u>

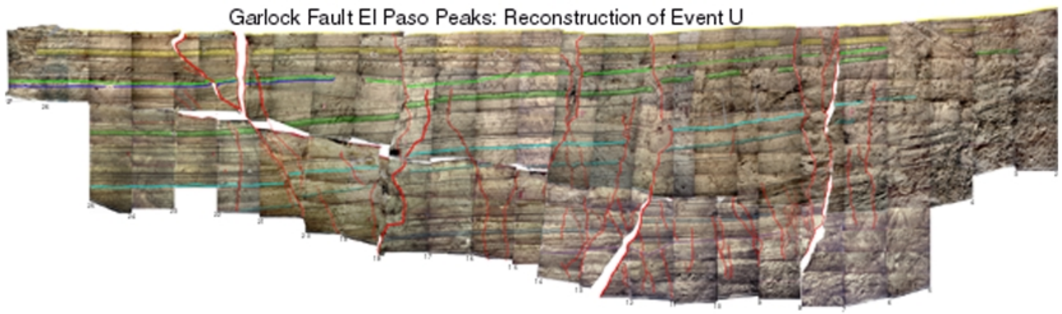
The only observable evidence for Event F is a fissure fill at S1, 2 m from the bottom of the trench. Several events have refaulted the exposed section of event F. No reconstruction was done for the vertical displacement caused in Event F, because the previous four reconstruction's did not reveal any stratigraphical mismatches or need for additional vertical slip reconstruction.

Discussion

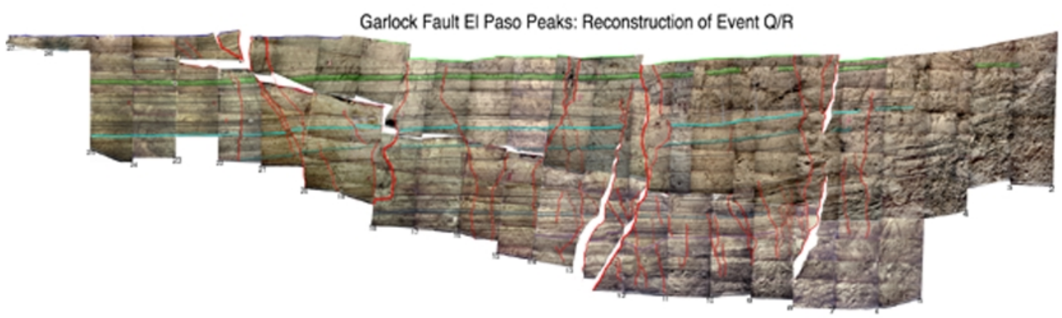
The first three reconstruction's compensated for most vertical displacement in the stratigraphy. This leads to the conclusion that event K did not produce a large amount of vertical slip, but that the event may have been completely lateral. By considering the evolution of the north and south strands we may be able to understand why the fault has begun to display larger amounts of vertical displacement. The vertical displacement is only observed in the three most recent events. This may indicate that the step over in the fault has only recently evolved. If the step over did not exist prior to Event R then large amounts of vertical displacement may not have occurred in previous ruptures. The events prior to the formation of the step over between the north and south strand would only display lateral offset. This may also suggest that other events are hidden in the stratigraphy and are not resolved because of the lack of vertical slip.



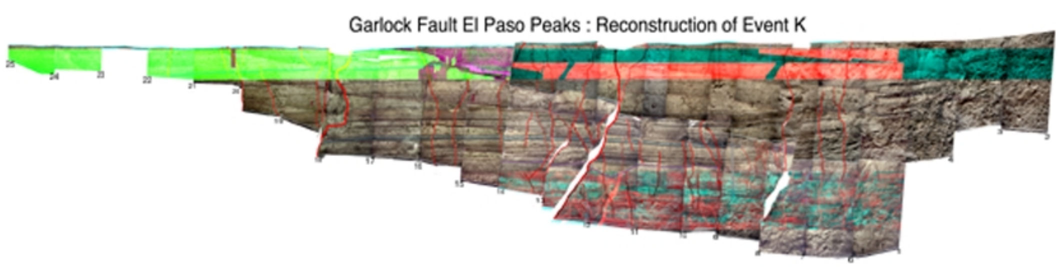
Event W



Event U



Event Q/R



Event K