

A Paleoseismic History of the San Andreas fault in Wrightwood, California: 1000 B.C.-500A.D.

Abstract

The paleoseismic site 4 km northwest of Wrightwood, CA has preserved evidence of seismic events along the southern San Andreas fault for the past ~5000 years. The deformation of late Holocene debris flows and peat layers serve as a record of these past events. Previous trenches in the site have provided evidence for 14 large earthquakes over the past ~1600 years as well as for earthquakes older than 3000 years BP. These trenches have also suggested between 8 and 10 individual earthquakes for the 1500-year period between the younger and older sections. We excavated six trenches to complete the record of earthquakes in the missing period, 1000BC to 500AD.

We found several distinctive structural features including fissures, low angle faults, and anticlines. Although these features provide evidence of tectonic deformation, they do not well demonstrate individual seismic events for the period in question. Deeper excavations may provide a more accurate record of the events during this time.

Introduction

Earthquake hazard analysis necessitates a record of the frequency and intensity of seismic events in various places along a fault. A useful record needs to span both historic and prehistoric time. The study of prehistoric earthquakes can be done accurately in near-surface investigations close to faults. From such studies, we can learn earthquake recurrence intervals and measure fault displacement. The paleoseismic site near Wrightwood, California provides an excellent opportunity to study the history of the southern San Andreas fault. Multiple successions of deformed debris flows and peat layers give evidence of many San Andreas earthquakes since 4800 B.P. From the seismic record in Wrightwood, we seek to further our understanding of the behavior of the San Andreas on a small and large scale. We hope that from this and other paleoseismic studies we may be able to figure out when the next large earthquake may happen as well as its size and location.

Studies at Wrightwood have suggested an average slip rate of 3-4 centimeters/year and an average frequency of 100 years for relatively large seismic events (3-4 meters of slip) along this part of the San Andreas (Fumal *et al.*, 1993). The Wrightwood site gives evidence for 14 of these earthquakes in the past 1500 years (Fumal *et al.*, 2002). The magnitudes of these events cannot be precisely determined; without a record of the ground rupture extent of the prehistoric earthquakes, we can only

estimate the magnitudes using rupture segmentation models. Other paleoseismic studies contribute further information about the behavior of the southern San Andreas beyond what appears in the record at Wrightwood. Here I reference studies cited in Fumal *et al.*, 2002. Studies done at Pallett Creek (Sieh *et al.*, 1989, Biasi *et al.*, 2002) suggest that one or two more earthquakes occurred in the past 1500 years in addition to what has been found in the Wrightwood site. Previous investigations done at Pitman Canyon (Seitz *et al.*, 1997; Seitz, 1999), Burro Flats (Yule and Howland, 2001; Yule *et al.*, 2002) and Thousand Palms (Fumal *et al.*, 2002), together with the seismic history constructed in Wrightwood, reveal rupture lengths of large events to have been at least 100 kilometers long. According to Wells and Coppersmith 1994, the average magnitudes of these events would have been 7.4 or greater. Given that the last major event along the southern San Andreas in the Wrightwood area was the 1857 quake, a large event in this section should be anticipated to happen soon.

Geologic Setting

The Wrightwood paleoseismic site is located where the alluvial fan coming out of Government Canyon enters Swarthout Canyon, 3-4 kilometers northwest of the town of Wrightwood, California (Figure 1). The site contains terrestrial sediments of two different provenances that have been made neighbors by the San Andreas fault. Most sediment deposits are debris flows of Pelona Schist from the southwest on the Pacific plate side. These debris flows are largely schist-derived silt, sand, and gravel but also contain small amounts charcoal and wood. The thickness of these deposits ranges from 1 meter to a few centimeters, often tapering away from the source of Government Canyon. There are also some fluvial deposits from Swarthout Creek near the north and northwest borders of the site. These deposits contain Pelona Schist and quartz diorite gneiss eroded from the North American plate on the northeastern side of Swarthout Canyon. There are also units of mineral-rich peat that separate the debris flows and can be as thick as a few millimeters or up to 20 centimeters. These peats serve as the main tool for the dating of seismic events. At the time of deposition of sand and organic layers, the water table was most likely at the surface. This would allow for the constant accumulation of organic matter sometimes interrupted by debris flows, as well as prevent bioturbation by burrowing animals and plants with deep roots.

The San Andreas fault runs through the site in two major fault zones. These fault zones provide boundaries to the site: the main fault zone to the northeast and the secondary fault zone to the southwest. Within these boundaries, the site is a 150-meter wide structural depression that may be a pull-apart basin and includes 25 meters of

stratigraphy with the oldest deposits more than 6500 years old. Stress from the fault is accommodated in various structural deformations of the stratigraphy: faulting, fissures, folding, and tilting. We used these structures to identify individual seismic events in sediments deposited 3000-1500 years ago.

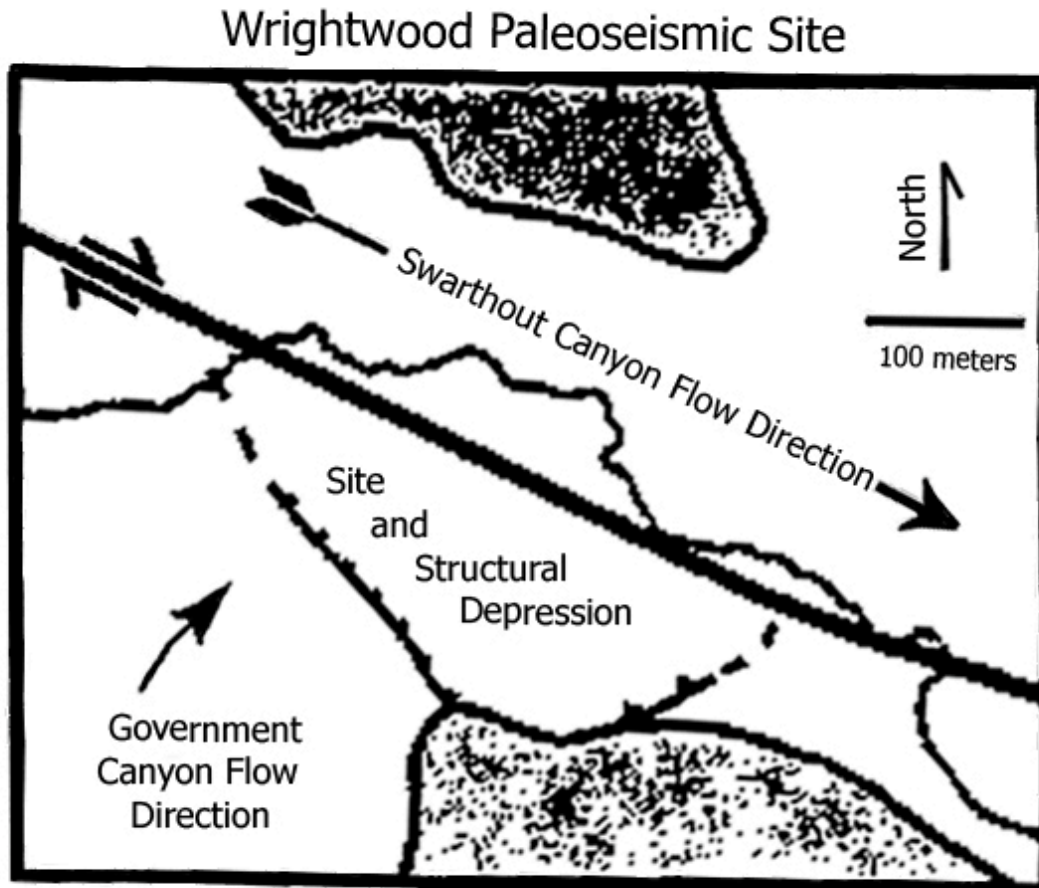


Figure 1: Map of Wrightwood site with outlines of the main and secondary fault zones. Adapted from Weldon et al., 2002.

Methods

Those studying paleoseismic sites will often encounter wearisome problems while trenching. The quality of the Wrightwood site as well as climactic conditions made our investigation to be mostly trouble-free. The surface-level of the water table at the time of sediment deposition prevented bioturbation so the stratigraphy was usually only discontinuous where it was tectonically deformed. Over the past few decades, the site has been cut through and drained by Swarthout Creek, lowering the water table beneath our deepest trenches. With the exception of one day, the weather was warm and sunny. The logging and photographing were easy and quick with the bright sunlight.

We excavated six backhoe trenches to complete the paleoseismic record for a 1500-year gap between two better-researched sections. Two trenches were opened where we could connect trenches from past investigations (trenches 41 and 44 connected to trenches 6, 11 and 21) so they could be better correlated. The other four trenches (42, 43, 45 and 46) were strategically dug in places that were known to have deformed deposits of the correct age (1000B.C.-500A.D.) that could be examined more closely.

After our trenches were dug and the shores were in place, we scraped the trench walls to remove backhoe gouges, make the walls as flat as possible and to get an initial view of the exposed sediments and structures. Next we used nails, string and a meter-level to set up a grid of 1.0 meter horizontal by 0.5-meter vertical rectangles that matched opposite walls. Carefully, so as not to loosen the grid, we went over the trench walls once more to do a finer cleaning so the sedimentary layers and structures could be seen as clearly as possible. We photographed each rectangle as well as the ungridded tops and bottoms with a digital camera attached to a metal frame-box contraption we called the Trench-o-matic to ensure uniform photographs. We then used Adobe Photoshop to rectify the photographs and align them in meter wide columns. We returned to the trenches with print-outs of the columns to map out layer contacts, sedimentary characteristics, faults, and other structures.

We usually had to move the shores at least once to complete the photographs or the logs as they blocked one or two meter wide sections of grid depending on their placement. With the logs complete, we could compare them with photo-mosaics of entire trench walls to finish interpretations of structures and correlate layers from other trenches. Last, we collected samples of peat from several trenches to be sent for radiocarbon analyses to date the section and events we uncovered.

Event Identification

There are several structural features in the stratigraphy that indicate a seismic event. Primarily we look for infilled fissures, upward termination of ruptures folds, and tilted beds. Individual events are best seen in an upward termination of a fault or fissure where a datable peat layer closely overlies the termination.

An example of our technique for event identification is described here. A fissure in Trench 41 provides good evidence for three events and questionable evidence for one additional event. The two most obvious and most recent events can be seen by the offset in the two thin peats seen in Figure 2. Although the upper peat is continuous, it smears out along the fault plane. This indicates that the rupture (W1) occurred when the upper peat had already accumulated but before the upper sand/gravel made a thick deposit in

the depression across the fault zone. The evidence for the second event (W2) can be seen in the sand between the two peats in this section. Right of the fault, this sand is much thicker than the left side; it thins to the right and is thin throughout the rest of trench 41. This indicates a similar sequence of events with W1: peat accumulation interrupted by an earthquake, followed by sand filling in the structural depression, leaving a thicker deposit next to the rupture. Event W4 is represented by the bottom section of the fissure filled by Gravel 1, peat and sand. A thick layer of peat caps this feature, indicating that W4 happened before the peat began accumulating. Once the upper two peats as well as the peat overlying Gravel 1 are dated with radiocarbon analyses, we can constrain the ages for events W1, W2 and W4.

The ambiguous event is represented by the presence of Gravel 2 and the gray sand in the lower part of the fissure. These two units do not match the other deposits seen in this part of the trench. Most likely, lateral movement along a fault transported them (W3). Until their source can be located, this event can only be inferred. This event is also difficult to date as there is no distinct peat layer immediately after the event to give it an age. A parallel trench may reveal more about the source of Gravel 2 and the gray sand as well as the date for W3.

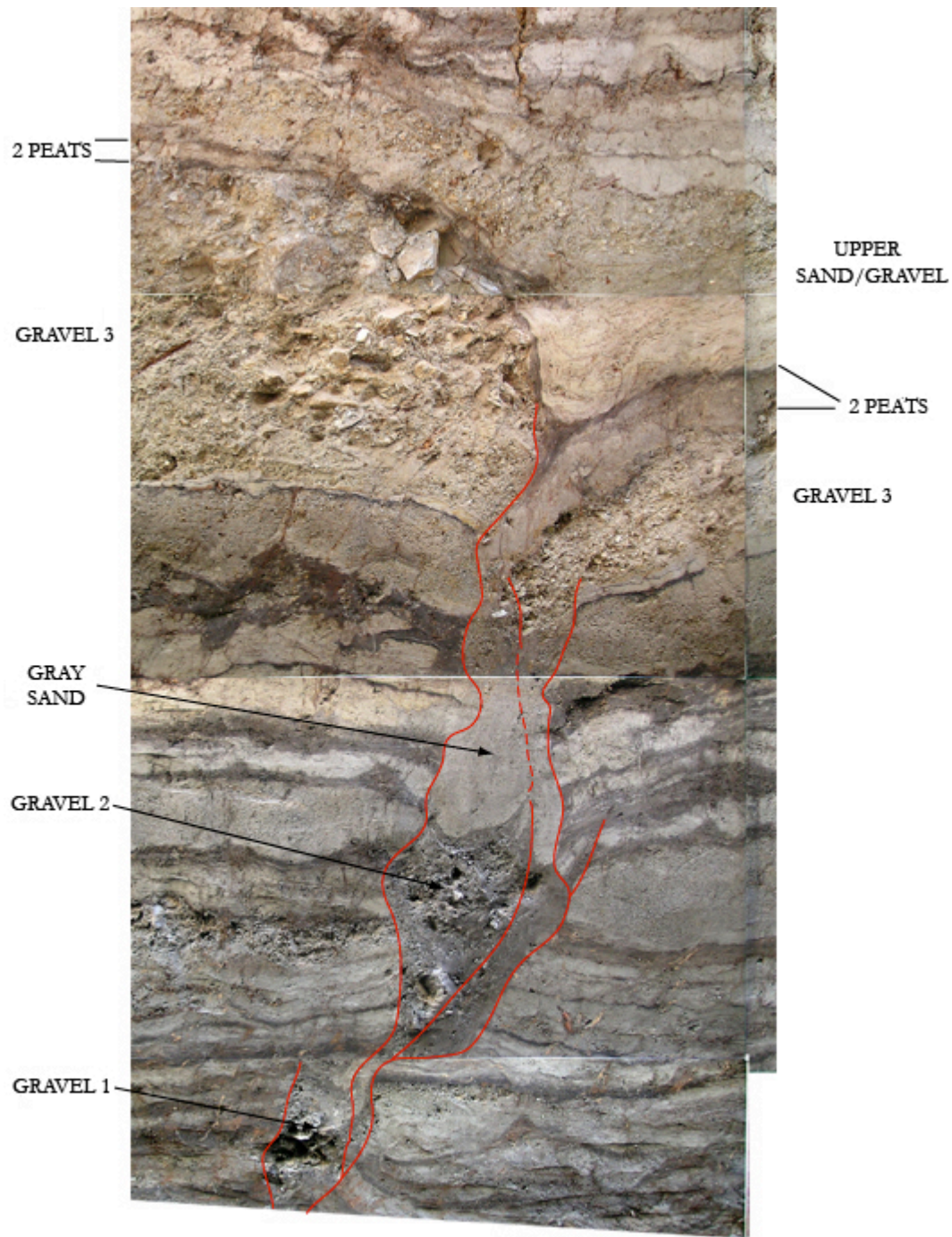


FIGURE 1: fissure in northwest wall of trench 41, red lines trace faults

Discussion

As represented by the ambiguous nature of W3, it is not always easy to interpret individual earthquake events from structural features such as fissures. Although there are three clear events that occur in fissure 41, events represented by less distinct features

without easily datable material make it difficult to get a clear picture of the faults history. To form a complete paleoseismic record for the period 1000BC-500AD, more trenches will need to be excavated. Future work may include deeper excavations of the trenches we opened this summer to get better evidence of events.

There are at least four similar sites similar in topographic seismic structures within 10 kilometers of the Wrightwood site along the SAF. These other sites should be excavated to form an even more complete record of the paleoseismic events of the San Andreas.

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