Reassessment of the 1906 earthquake and paleoseismology of the San Andreas fault, Doda Ranch, northern California

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INTRODUCTION

The great San Francisco earthquake of April 18, 1906 was a result of rupture along the northern San Andreas fault (SAF). Ground rupture occurred on an approximately 435 km-long trace from San Juan Bautista to Point Delgada (Prentice et al., 1999). The 1906 rupture is divided into three segments: North Coast, San Francisco Peninsula, and Santa Cruz Mountains. Although there have been recent subsurface investigations of the SAF on the San Francisco Peninsula and near Point Arena, there is relatively little data on pre-1906 earthquakes and Holocene slip rates on these northern segments of the SAF.

The objective of this project was to excavate a number of trenches at the Doda Ranch on the SAF where it intersects the coastline just south of Fort Ross, California (Figure 1). It was hoped that new paleoseismic data would yield a date for the penultimate earthquake on the northern SAF, and possibly allow for the establishment of a chronology of earthquake events for this segment.

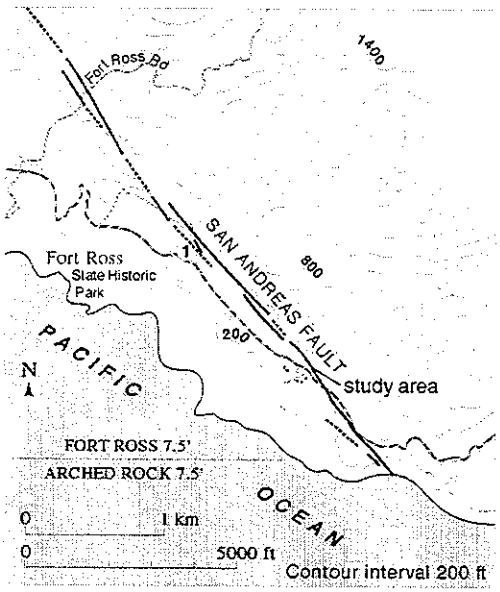

Figure 1. Part of the Fort Ross 7.5 minute quadrangle showing the study area (from Prentice et al, 1991).

HISTORICAL DATA AND SITE SELECTION

Following the 1906 San Francisco earthquake, A.C. Lawson and Francois Matthes completed a detailed survey of the entire length of the fault rupture. This survey involved mapping and measuring fault offset features, and extensive photo documentation of the fault rupture. Matthes, a topographer with the United States Geologic Survey (USGS), made a detailed topographic map (Figure 3), with contours at five foot intervals, of the fault rupture, offset streams and other related features at Doda Ranch.

Figure 2. 1906 SAF offset of Doda Creek. View is southwest towards Doda Ranch and the Pacific Ocean (Lawson, 1908).

An unnamed stream at the Doda Ranch (herein called Doda Creek) was reported by Matthes (in Lawson, 1908) to have been offset about 12 ft (3.7 m) during the 1906 earthquake. Photographs included in Lawson (1908; Plate 37) (Figure 2) show that the offset temporarily dammed Doda Creek, ponding water behind the scarp. Movement on the fault was primarily dextral strike-slip but the photographs reveal a small component of west-side-up dip-slip movement (Lawson, 1908). Although the stream eventually cut through the fault scarp, an offset is still apparent today in the channel of Doda Creek near its intersection with the SAF. Prentice et al., (1991) reported the modern offset of Doda Creek to be 23-26 ft (7-8 m) and suggested that it may have been produced by at least two

earthquakes, one of which was pre-1906. The Doda Ranch area remains relatively unchanged since the 1920's except for the presence of U.S. Highway 1 which now lies approximately 25 m west of the observed offset in Doda Creek.

The Doda Creek site has been noted in a number field trip guides as an exemplary example of an offset stream along the San Andreas fault (Prentice et al., 1991). The fame of the site led to its inclusion in a recent Discovery Channel documentary on the San Andreas fault system. Surprisingly, given the site's notoriety, the historical control provided by Lawson (1908), and the potential of the creek channel as a record of multiple earthquakes, the site has not previously been the subject of a subsurface investigation.

METHODS

Surveying: A total geodetic station and electronic data logger were used to precisely survey key features in the study area. Topographic and man-made features including Doda Creek, U.S. Highway 1, buildings, fences, and the trenches were located. This data was used to create a detailed map of the study area that was then overlaid onto the 1906 map created by Matthes (Lawson, 1908) (Figure 4).

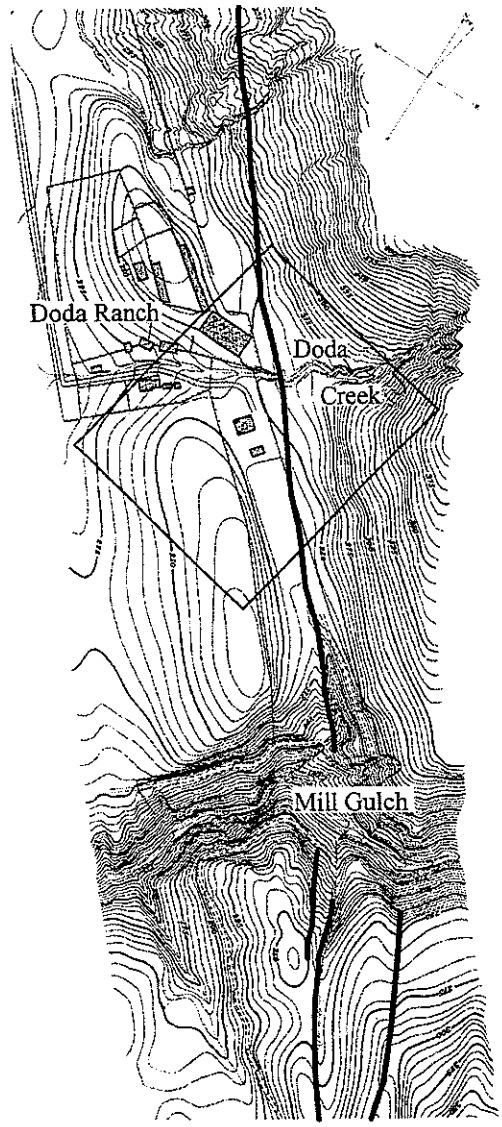

Figure 3. Modified F.E. Matthes map (from Lawson, 1908) showing Doda Ranch, Doda Creek offset and Mill Gulch offset. Heavy lines are 1906 ruptures of the San Andreas fault. Contour interval is 5 ft. The boxed area is shown in detail in figure 4.

Excavation: Three backhoe trenches, two fault-normal and one fault-parallel, were excavated on the southeast side of Doda Creek. The two fault-normal trenches (Trench 1 and 3) were excavated to allow examination of the fault trace in the subsurface while the fault-parallel trench (Trench 2) was constructed in hopes of locating a piercing point with which to constrain the amount of offset. Each trench was approximately 1 m wide and 3-4 m deep. Trench lengths ranged from 6 to 14 m. Trench walls were logged both by hand (Figures 5 and 6) and with trench-o-matic photographic logging equipment.

EXCAVATION RESULTS AND DISCUSSION

Trench excavation revealed a complex stratigraphy consisting of cut and fill channel deposits. Sediment was generally poorly sorted with sizes ranging from silt to cobble. Clasts were sub-angular to angular. Generally, the units were massive and matrix-supported. These characteristics suggest the sediment originated from mass wasting processes. This is consistent with the high gradient of Doda Creek, and the numerous landslide scarps visible on hillsides within the creek's drainage basin. It appears that sediment input was sporadic, with considerable periods of non-deposition during which Doda Creek was able to reestablish its channel. The bottoms of the channel cuts are generally filled with well-sorted, clast-supported fine-grained gravel. Glass fragments found within the upper 1.5 m of the trench exposures suggests that this sediment was deposited during historical time.

The first excavation (Trench 1; Figure 5) provided rather ambiguous results as to the location of the fault. An area of disrupted stratigraphy in the middle, of the lower 1.5 m of the trench suggested fault rupture but many doubts were raised given the lateral continuity of units both above and below the disturbed region. The cut and fill stratigraphy created many difficulties in distinguishing fault-truncated units from units that had been disturbed or terminated by channel incision.

The excavation of Trench 3 was completed in hopes of revealing a stratigraphic section that would be less ambiguous than that of Trench 1. As would be expected, the stratigraphy of Trench 3 (Figure 6) consisted of the same types of channel fill units however, the exposures provided more compelling evidence that the fault was not passing through the trenches. Units in Trench 3 were generally more laterally continuous and the disruptions in stratigraphy that did exist were not continuous from one trench wall to the other as would be

anticipated if they were the result of fault rupture.

REEXAMINATION OF HISTORICAL DATA

Given the rather surprising lack of evidence for fault rupture in the fault-normal excavations, efforts were made to reexamine the historical data presented by Lawson (1908). Previous examination of the 1906 photographs (Lawson, 1908; plate 37) (Figure 2) of the offset in Doda Creek strongly suggested that the current offset is the same as the one documented by Lawson and Matthes in 1906. Difficulties in reoccupying the locations from which the photos were taken however, raised even greater concern that the fault was not located where initially believed.

Utilizing Matthes' map (Lawson, 1908) (Figure 3) as a point of reference, many detailed measurements were made from topographic and cultural features that are assumed to be unchanged in the past 100 years. These measurements revealed that although strikingly similar, the current offset in Doda Creek is not the same one documented in Lawson (1908). By constructing a detailed topographic map of the study area and overlying it onto the 1906 map made by Matthes (Figure 4) we are now confident that the 1906 offset of Doda Creek documented in Lawson (1908) was in fact destroyed during construction of U.S. Highway 1.

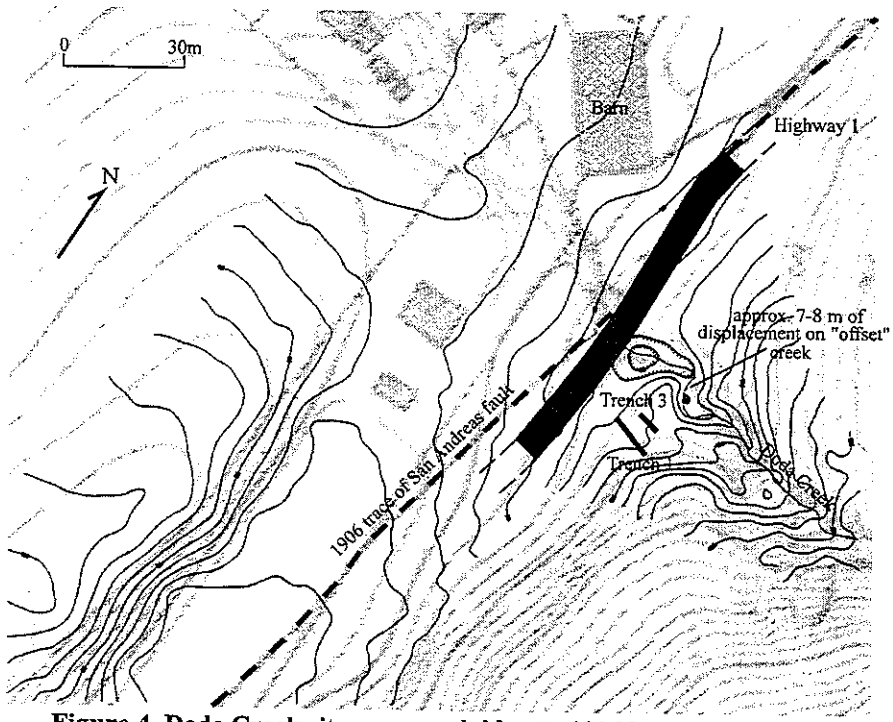

Figure 4. Doda Creek site map overlaid onto 1906 Matthes map of the Doda Ranch and the SAF rupture.

CONCLUSIONS

Given the lack of evidence for fault rupture in the trench exposures, the inconsistencies with the historical data, and the map overlay (Figure 4), it can be confidently concluded that the 23-26 ft (7-8 m) right-jog in Doda Creek is not related to faulting. Although there are striking similarities, the trace of the 1906 fault rupture and the offset of Doda Creek documented in Lawson (1908) are in fact concealed beneath U.S. Highway 1.

The displacement of the channel of Doda Creek initially believed to be the result of movement along the SAF is in fact a stream meander that has been amplified by a post-1906 landslide. Coincidentally, the resulting "offset" of Doda Creek is nearly identical in appearance to the true offset documented by Lawson (1908). Examination of the hillslope directly above the creek revealed a small landslide scarp that may be the origin for the material that diverted Doda Creek.

These findings significantly alter the commonly held belief that the current "offset" of Doda Creek is a result of fault rupture on the San Andreas fault and provide a cautionary note to be considered before conducting any paleoseismic study.

REFERENCES CITED

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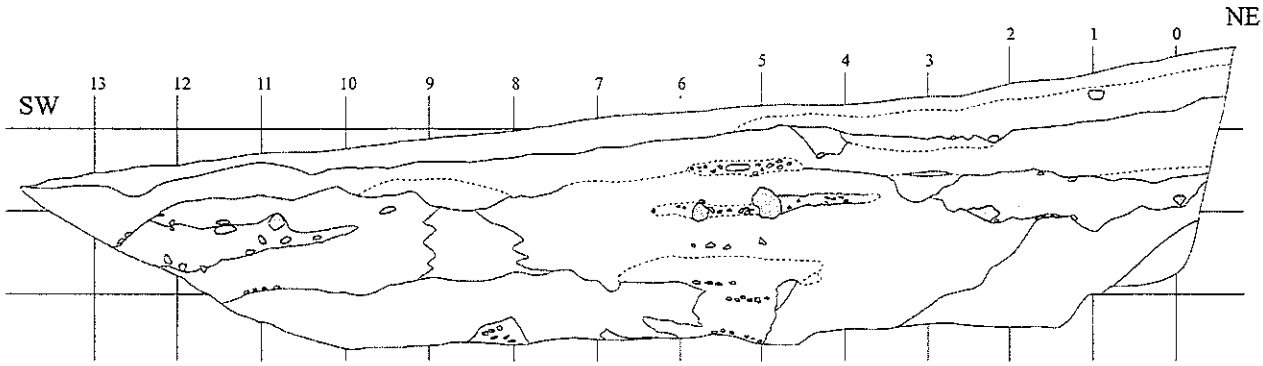

Figure 5. Log for the south wall of Trench 1. Grid spacing is 1 meter.

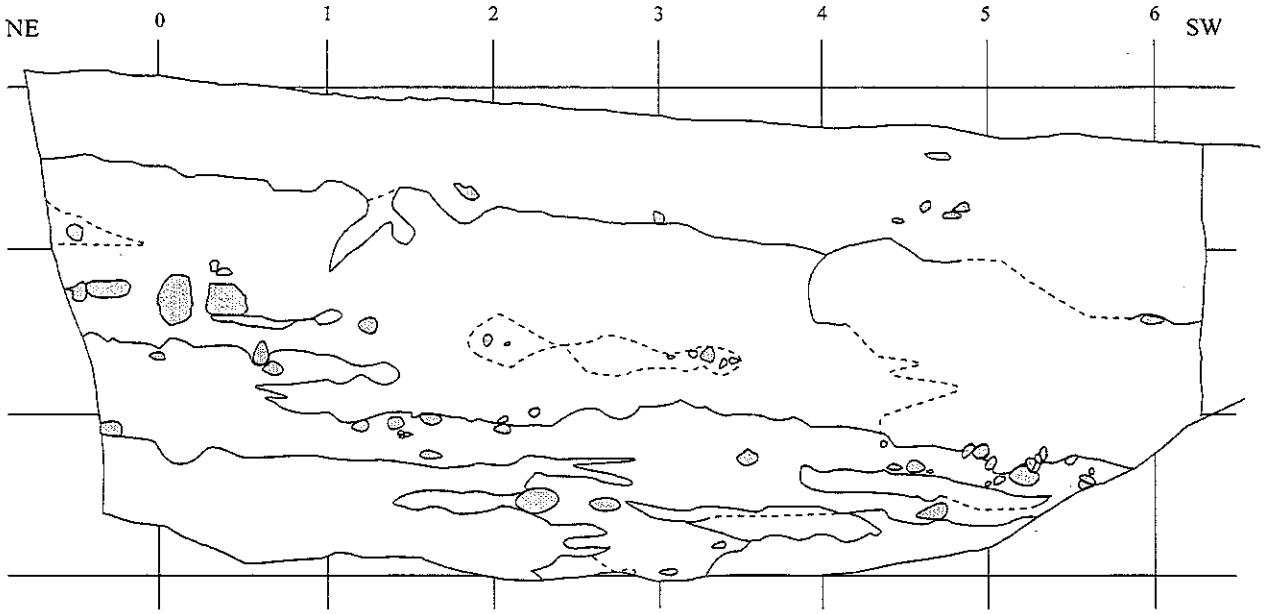

Figure 6. Log for the north wall of Trench 3. Grid spacing is 1 meter.