Statewide California Earthquake Center
Final Technical Report
Project 21136

San Andreas Fault earthquake geology: North Cholame

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Abstract
We present new paleoseismic results from 2 fault perpendicular long trenches along the Cholame segment of the San Andreas Fault. The northwestern site is located south of the Parkfield segment 11 km southeast of Highway 46. Site geomorphology is characterized by linear depressions, several sag ponds, and small offset stream channels. The southeastern site was an additional excavation at the Miller's Well Paleoseismic site in the northwesternmost Carrizo Plain. We were limited in our trenching locations by months of rain in spring 2023 that left our original sites underwater, or the soil moisture too high to prevent trench collapse. Neither site had ideal stratigraphy. The northern site contained clay rich soils and a lack of event horizon evidence but displayed repeating graben-like formations that indicate at least 3 separate rupturing events, numbered E1-E3 by increasing relative age. Supportive evidence for these events include significant vertical soil material change, aligned gravels, and clay filled sags. The southern site had massive thick sand units and lacked variable stratigraphy to determine multiple event horizons for dating. However, the stratigraphy displayed apparent vertical separation of discontinuous large boulder and gravel units.

Intellectual Merit
The Cholame segment of the San Andreas Fault is significant because it records the interaction between the creeping + M6 events of the Parkfield segment to the northwest and the locked Carrizo segment to the southeast. The Cholame segment has poorly characterized rupture history which places significant limitations on evaluating seismic hazard. Large gaps in the paleoearthquake record and various interpretations of past earthquake offset pose problems for modeling past fault behavior.

Broader Impacts
Our understanding of the earthquake history of the Cholame segment of the SAF is incomplete (no maximum likelihood recurrence interval estimate; Biasi, 2013; UCERF3 Appendix H). New paleoseismic data on earthquake recurrence will lead to a better understanding of the transitional rupture behavior between Parkfield and Cholame.

Along with improving our understanding of Southern California's earthquake hazards, our field efforts included a collaboration between Arizona State University and Bates College. We introduced and facilitated training in field geology and paleoseismic investigation for nine undergraduate students, one of which will complete their senior thesis on this project.

Project Publication

Williams, A. M., Arrowsmith, R., Arora, S., Cochran, D., Jansen, E., Pontin, G., & Friedman, C. (2023, 09). Exploring the transition between the Parkfield and Cholame sections of the San Andreas Fault . Poster Presentation at 2023 SCEC Annual Meeting.

Technical Report Narrative

Introduction

Paleoearthquake records are required to develop and test long term earthquake rupture models for the San Andreas Fault (SAF). The ~75 km long Cholame segment of the SAF is particularly interesting because it marks the transition between the locked Carrizo segment to the south, and the creeping Parkfield segment to the north. Despite extensive offset measurements (Lienkaemper, 2001; Sieh, 1978; Zielke et al., 2010, 2012), current rupture models are significantly limited by poorly constrained paleoseismic data, and therefore are insufficient for any maximum likelihood recurrence interval estimation within the UCERF3 exercise (Biasi & Weldon, 2009; Field et al., 2014, 2017).

Due to the poor constraints on the timing of rupture events in Cholame, the details of how the slip deficit is released remains unresolved along with the behavior of ruptures that occur along this important transitional segment of the southern SAF uncertain. The data suggest several possibilities: (1) independent M7 rupture of the separate segments (Parkfield, Cholame, & Carrizo), (2) the reactivation of the 1857 reach (possibly involving, triggered by or anticipated by Parkfield M6 events; (Toke & Arrowsmith, 2006), (3) the occurrence of moderate ruptures in Cholame with minor continuation into the Carrizo and Parkfield segments, and/or (4) aseismic creep. Aseismic creep can likely be ruled out due to the lack of motion measured by a local creepmeter near the study site.

Methodology

We chose candidate sites based on geomorphology using the high resolution topography of the B4 project (Bevis et al., 2005). Our original site locations had to be abandoned due to flooding in the region, and new sites were chosen based on likelihood of saturation, trenches that didn't significantly collapse, and trench safety. The northern third of the Cholame segment is characterized by small ponds, sags and low elevation fields which limited our investigation of the Parkfield/Cholame boundary.

We had a back hoe excavate two fault-perpendicular trenches (Figure 1). The north Cholame site trench was 1m wide, 2 m deep, and 9 m long. The new Miller's Well trench was 1m wide, 2m deep in the fault zone due to collapse, 4m deep on eithr side of the fault zone, and 15 m long. We photographed trench walls and generated structure from motion orthophotographs logging trench stratigraphy. We collected 22 samples of detrital charcoal and organic burn layers for ^{14}C dating as well as 10 samples for Optically Stimulated Luminescence dating. Samples from the northern site will be processed at the UCI Keck AMS lab and funded by Bates College. Samples from the Miller's Well site may not be processed.

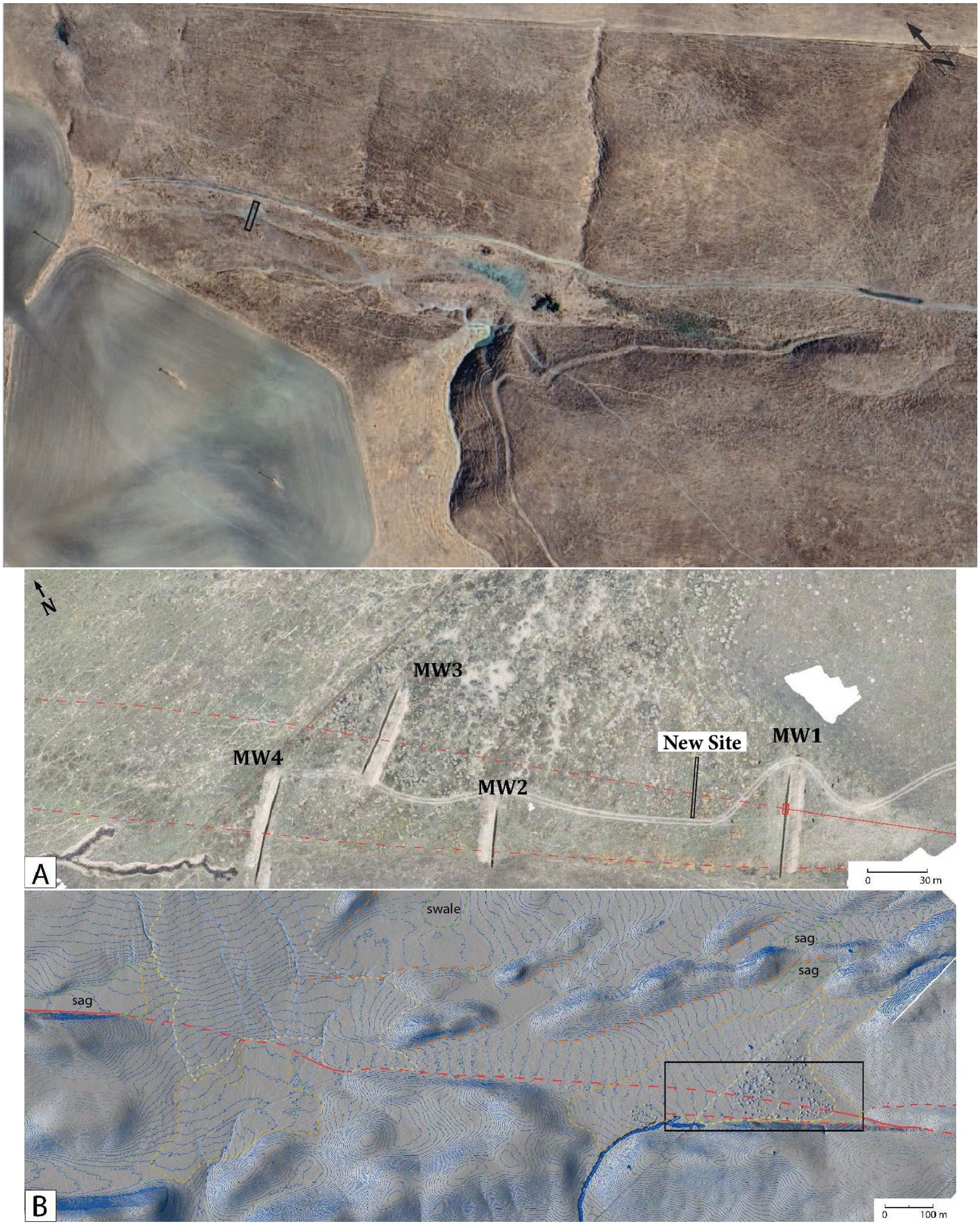

Figure 1. North Cholame site (35°39'25.52"N 120°12'36.74"W, above) and Millers Well site (35°22'47.38"N 119°56'14.46"W, lower two panels A, B). Excavation sites are indicated by small rectangles.

Results—North Cholame

The North Cholame trench has clear evidence for multiple events however the clay content makes it difficult to determine the termination point of the fault splays, fractures are indistinguishable from soil peds and shear fabric is nonexistent (Figures 2 and 3). The fault zone displays aligned pebbles 1-5cm in size, offset channel fill, vertical soil variation from clayey silt to sandy silt and clay. Despite the lack of continuous stratigraphic units, we find evidence for at least 3 events at this site. The regional geomorphology displays a record of extension and fault parallel incision. The fault zone displays 3 stages of graben-like sags with increasing apparent vertical separation. E2 event horizon is above a filled in narrow channel bounded by a more indurated soil on to the east and a clayey silt with higher moisture content west of the channel. These events are consistent with a record of repeated incision followed by a rupturing event resulting in a depression and channel fill for each event.

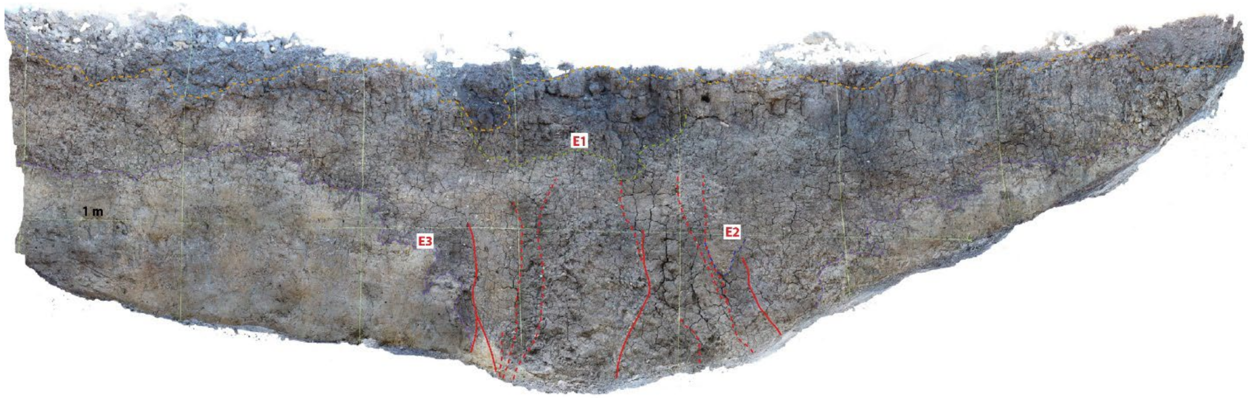

Figure 2. North Cholame trench photomosaic and basic log provides weak evidence for three paleoearthquakes.

Figure 3. Excavation of North Cholame trench.

Results—Miller's Well

The Miller's Well trench (see Figure 1 for location) exposed massive sand units ranging from very fine sand to coarse sand and gravel. The fault zone collapsed in the trench making logging impossible (Figures 4 - 6). Significant but discontinuous unit of large cobbles and boulders with apparent vertical separation drop down as the cross the fault zone from NE to SW towards the ~15m shutter ridge. Lack of discernible fractures and shear fabric, but interpreted fault zone often has finer sand and is less indurated and unstable.

There is minimal evidence for event horizons, however we are confident that there are multiple events along this trace of the fault (Figure 6). E2, the possible penultimate, shows significant facies changes in alluvial fan gravels and cobbles, based on the size of clasts and the thickness of units. There is also a larger apparent vertical separation compared with that of E1. For E1, we have placed in the soil where the apparent vertical separation changes and is capped by a continuous sag. We also see less significant facies changes in the units between E1 and E2. Units are too discontinuous to confidently correlate fans cobbles and gravels and confirm more than 2 events, however the east side of the fault zone is heavily bioturbated and massive which could be indicative of a younger MRE above E1.

Figure 4. Miller's Well trench. See figure 1 for location. Note collapse in fault zone.

Figure 5. Miller's Well trench. See figure 1 for location. Note collapse in fault zone. Bates College undergraduate students at work.

Figure 6. Millers Well Bates College trench log. See text for explanation.

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