Paleoseismology of the central Calaveras fault, Furtado Ranch site, Gilroy, California

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INVESTIGATIONS UNDERTAKEN

The purposes of this one-year research investigation of the central Calaveras fault at the Furtado Ranch site are to:

- Document the locations and rate of historic creep,
- Address the possibility of late Holocene surface-rupture earthquakes, and if present,
- Develop a preliminary rupture-event chronology at the site.

The Calaveras fault plays a major role in accommodating plate-motion slip in the San Francisco Bay region. Geodetic modeling and historical creep data suggest a present-day fault slip rate of about 15 mm/yr on the southern and central sections of the fault. Our previous work at the San Ysidro Creek site, located approximately 3 km northwest of the Furtado Ranch site (Figure 1), provides a preliminary late Holocene slip rate on the central Calaveras fault of 14 $\pm$ 5 mm/yr. Within the uncertainty of the geologic data, this long-term slip rate is consistent with the short-term rate based on aseismic creep and geodetic modeling. However, there is some uncertainty regarding the seismogenic potential and seismic cycle of the central and southern Calaveras fault (i.e., the rate and nature of strain accumulation/ release on the fault). In particular, a critical question is whether or not the central Calaveras fault produces large-magnitude earthquakes, or whether the fault relieves strain by aseismic creep and small to moderate earthquakes. Understanding the maximum size of earthquakes possible along the central Calaveras fault is critical to estimating probabilities of future earthquakes in the San Francisco Bay region.

The primary goals of this proposal are to evaluate the historic creep rate on the central Calaveras fault and consider whether or not the Calaveras fault may produce large magnitude surface-faulting earthquakes. The Furtado Ranch site contains the primary active creeping strand of the fault, as shown by offset cultural features, a series of linear closed depressions, and low-relief topographic swales across a Holocene alluvial fan (Figure 2). Our effort involves surveying the offset cultural features, as well as excavating two paleoseismologic trenches across the main fault strand. First, we surveyed a 29-year-old alignment array installed by the USGS in 1972, in order to provide a historic fault creep rate and identify the exact location(s) of actively creeping fault strands. We surveyed this collection of 15 monuments, which are brass plates set in concrete, on September 26, 2001. Second, we excavated two fault-normal trenches across the prominent closed depression. This effort provides exposures of faulted surficial deposits and of the actively creeping fault, and was designed to address whether large-magnitude earthquakes

have occurred on the fault by determining the presence or absence of deposits or other features that may be related to surface ruptures.

RESULTS

Our survey of the USGS alignment array shows that the creeping fault trace is located at the crest of the west-facing scarp bordering the eastern side of the linear depression. The creeping fault trace is coincident with the primary fault strand exposed in the two trenches at the site. The survey data show that the creeping strand of the fault has right-lateral offset of 400 $\pm$ 30 mm across a well-defined zone less than 5 m wide. These data indicate a 29-year-long creep rate of 14 $\pm$ 1 mm/yr. This rate is consistent with the rate of about 16 mm/yr from the Coyote alignment array and the 14 $\pm$ 5 mm/yr geologic rate from San Ysidro Creek (Kelson and Baldwin, 1999).

Second, we excavated two trenches across the linear depression at the site in order to expose the fault strands and document the presence or absence of diagnostic indicators of surface rupture. We anticipated that the trenches might have exposed upward fault terminations, sediment-filled fissures, or scarp-derived colluvium that could be attributed to coseismic surface rupture. However, none of these features is clearly evident in the trenches. The trenches exposed a well-developed fault zone along the eastern margin of the linear depression, which has a slight east-down net vertical separation. The west-facing scarp along the eastern margin of the depression apparently is a result of uplift and westward tilting of surficial deposits toward the depression. The exposures demonstrate that the creeping fault strand at this site is structurally complex and is about 2 m wide. Fractures extend upward to the ground surface through the youngest surficial deposit, but the number and development of these fractures is far less than the deformation present in lower, older sediments. Adjacent to the main fault strand, sediments are tilted or warped over a width of about 10 m, with the area east of the fault strongly warped and the area west of the fault tilted gently to the west. Radiometric analyses on charcoal from the faulted sediments suggest that all of this creep deformation occurred within the past approximately 2700 years.

Along the western margin of the depression, both trenches exposed a well-developed fault strand along which different facies of the Santa Clara Formation bedrock are juxtaposed. A well-developed soil horizon that formed on the gravelly bedrock and overlying colluvium is warped and faulted with east-down net vertical separation. This zone shows extensive shearing within the bedrock units and warping of the late Quaternary soil, but little or no deformation of younger colluvial deposits shed from the adjacent east-facing hillslope. Thus, this western strand appears to be older than the primary, creeping fault strand at the site. Radiometric analyses on charcoal from the faulted sediments suggest that the deformation along the western fault strand occurred more than 2700 years ago.

NON-TECHNICAL SUMMARY

This research provides geologic data that characterizes the present-day Calaveras fault as an actively creeping fault. This study shows that over the past three decades the fault moved aseismically (without large earthquakes) at an average rate of about 14 mm/yr. This research also exposed strands of the fault in two trench excavations, and shows that the creeping fault strand is complex and about 2 m wide, although the fault also deforms near-surface deposits over a width of about 10 m. There is no definitive evidence exposed in these trenches that the central Calaveras fault has produced a large earthquake within the past two millennia.

REPORTS PUBLISHED

At this time, this research has not resulted in a formal publication. However, a summary of the current interpretations about the Calaveras fault is presently in press:

Kelson, K. I., [in press], Geologic characterization of the Calaveras fault as a potential seismic source, San Francisco Bay area, California: *Engineering Geology Practice in Northern California*, Calif. Div. Mines and Geol. Spec. Publication 212.

We also have submitted an article for scientific publication that concerns the differentiation between deformation produced by aseismic creep and that produced by coseismic rupture. This manuscript currently is under peer review:

Kelson, K. I., and J.N. Baldwin, [in review], Can Paleoseismologic Techniques Differentiate between Aseismic Creep and Coseismic Rupture on Strike-slip Faults?: submitted to *Geology*, September, 2001.

Lastly, we recently led two field trips to sites along the Calaveras fault and other major faults in the San Francisco Bay region, as summarized in the following articles:

Kelson, K.I., Tolhurst, J., and Manaker, D., 1999, Earthquakes on the Calaveras fault: fact or fiction?—The geology, seismology and paleoseismology of the Calaveras fault: California Division of Mines and Geology Special Publication 119: p. 160-173.

Kelson, K.I. (compiler), 2001, Great shakes of the eastern Bay area: A ride through the past to see the future: unpublished field trip guidebook, Seismological Society of America 2001 Annual Meeting, San Francisco, CA; April 21, 2001.

DATA AVAILABILITY

Additional detailed information on the investigation is available from either of the Principal Investigators at the address given above. This information includes a detailed site map, topographic survey data of the alignment array, logs of the trench walls, and results of radiocarbon analyses.

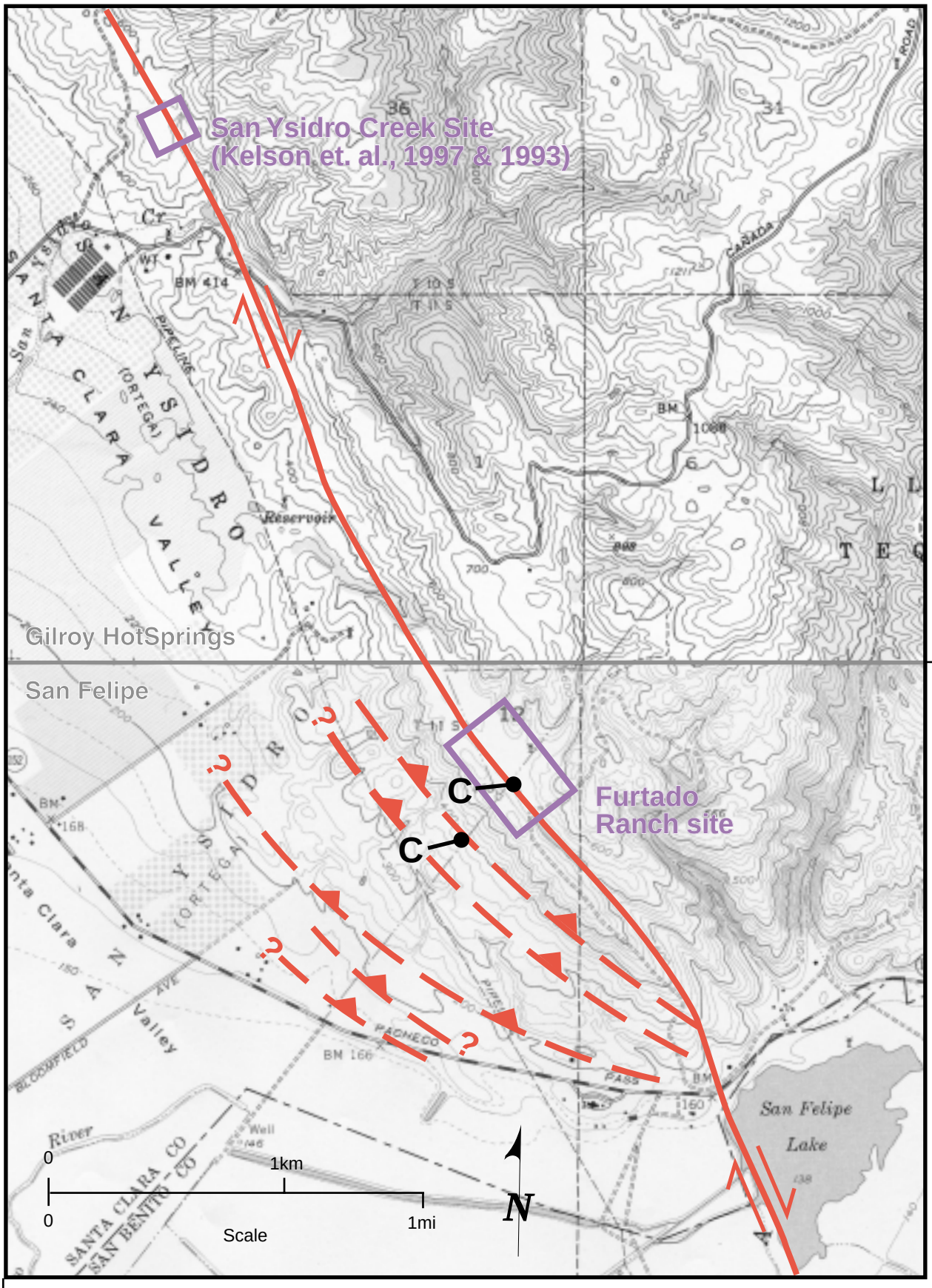

Figure 1. Topographic map showing location of the Furtado Ranch site and the major stands of the Calaveras fault. "C" shows sites of documented fault creep (Armstrong et al., 1980). Fault traces modified form CDMG (1980).

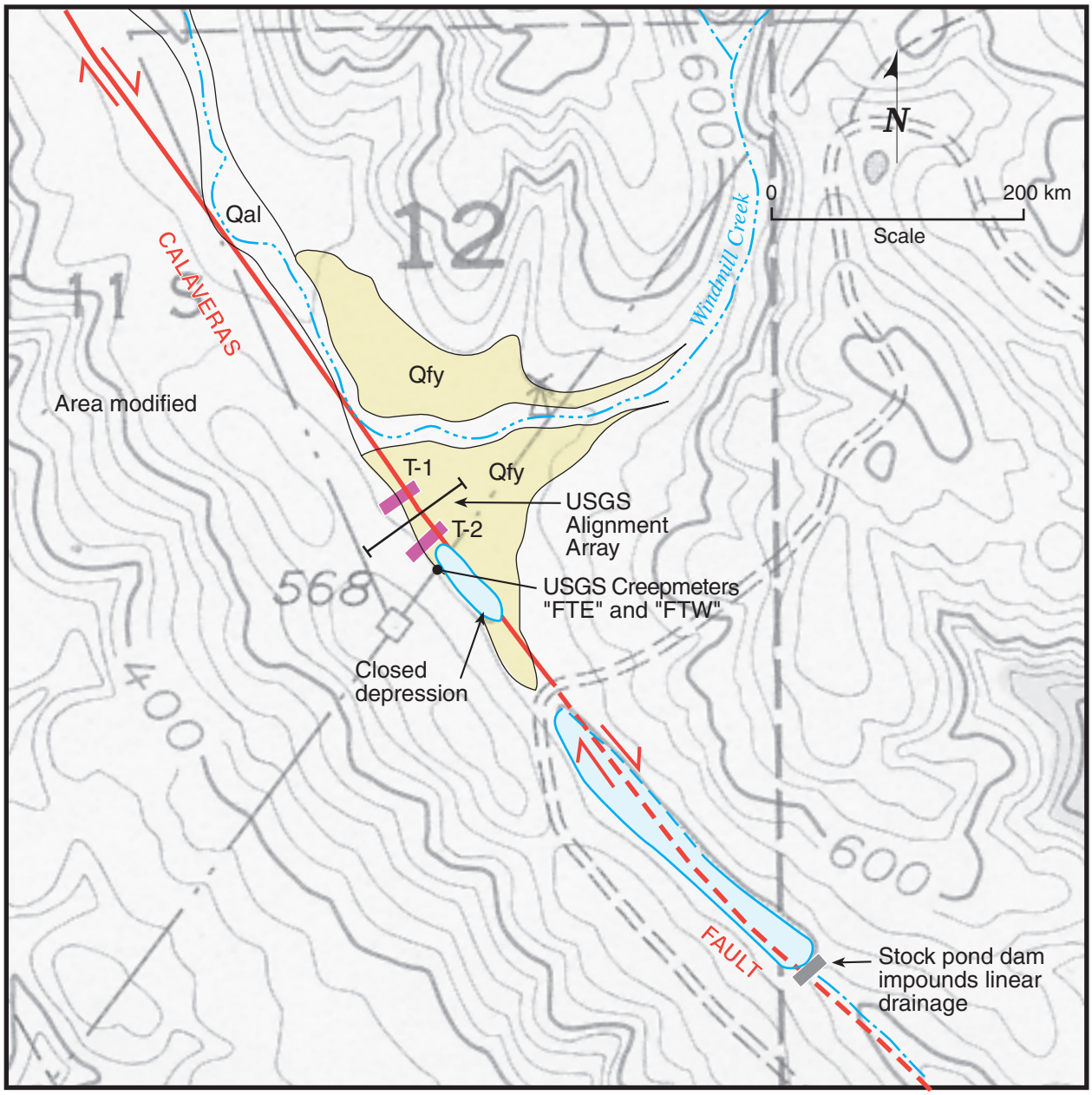

Figure 2. Preliminary map of the Furtado Ranch site, showing the main strand of the Calaveras fault, USGS alignment array, USGS creepmeter (site Furtado Ranch East, "FTE"), and proposed trench localities. Qfy: Holocene alluvial fan; Qal: Holocene alluvium.