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PALEOCLIMATE CONSTRAINTS ON SAN ANDREAS FAULT SLIP RATES AND SLIP PER EVENT IN THE CARRIZO PLAIN, CALIFORNIA

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Overview

We requested funding from SCEC to test the feasibility of using high resolution paleoclimate data to decrease age uncertainty in paleoseismic dates and the short-term slip rate or slip-per-event measurements derived from them. Preliminary work to compile paleoclimate data for the Carrizo Plain had been done by graduate student Gabriela Noriega for unfunded masters thesis research. We requested modest funds to support completion of her thesis and link this work with ongoing research to date paleoearthquakes and measure slip-per-event at the Bidart Fan in the Carrizo Plain. Her thesis was accepted in March 2009. Results of her work were summarized in abstracts (Noriega et al., 2008a,b) for the SCEC Annual Meeting and Fall AGU. Implications of the results, in combination with new dates of earthquakes at Bidart Fan, will be presented at SSA 2009 Annual Meeting (Grant Ludwig et al., 2009). Significance of the work, description of the hypothesis tested, and summary of preliminary results are described below.

Significance of the San Andreas fault in the Carrizo Plain

The Carrizo section of the San Andreas fault (SAF) (Figure 1 Location) has been proposed to rupture only during the largest earthquakes, and thereby to control the occurrence of great "characteristic" earthquakes along the southern San Andreas (Schwartz and Coppersmith, 1984) with centuries-long recurrence times at Wallace Creek (WC) (Sieh and Jahns, 1984). As more data have become available, a more complex picture has emerged (Grant, 1996) with much shorter recurrence times (Akciz et al., 2009 and in prep) comparable to other sections of the fault, and possibly clustered earthquakes (Grant and Sieh, 1994). Measurements of slip per event for the last 5 or 6 earthquakes (Liu et al., 2004; Liu-Zeng et al., 2006), when combined with new dates of earthquakes (Akciz et al., in prep), yield slip rates (up to 50 mm/yr) well above widely accepted values of ~ 35 mm/yr (Sieh and Jahns, 1984; Lisowski et al., 1991; Noriega et al., 2006). The mismatch suggests that either the strain released is not directly proportional to the time between ruptures, thereby casting doubt on time-predictable and slip-predictable elastic strain models, or some of the reported slip-per-event values are actually cumulative slip for multiple events. In either case, resolution of the disparity should yield important insights about the temporal and mechanical characteristics of large SAF earthquakes.

Climate data, channel incision, and earthquakes in the Carrizo Plain

We wanted to test the underlying assumption (e.g., Sieh, 1978; Sieh and Jahns, 1984; Schwartz and Coppersmith, 1984) that channels form and incise on an average decadal frequency which is much more rapid than the centennial earthquake recurrence. This is critical, because if channels are incised less frequently than earthquakes occur, then many channels were offset by more earthquakes than previously reported. If true, it would resolve some slip rate discrepancies and reveal that 1857-type large-slip earthquakes are not "characteristic" of SAF ruptures in the Carrizo Plain.

Figure 1 – Location of the Bidart Fan study site

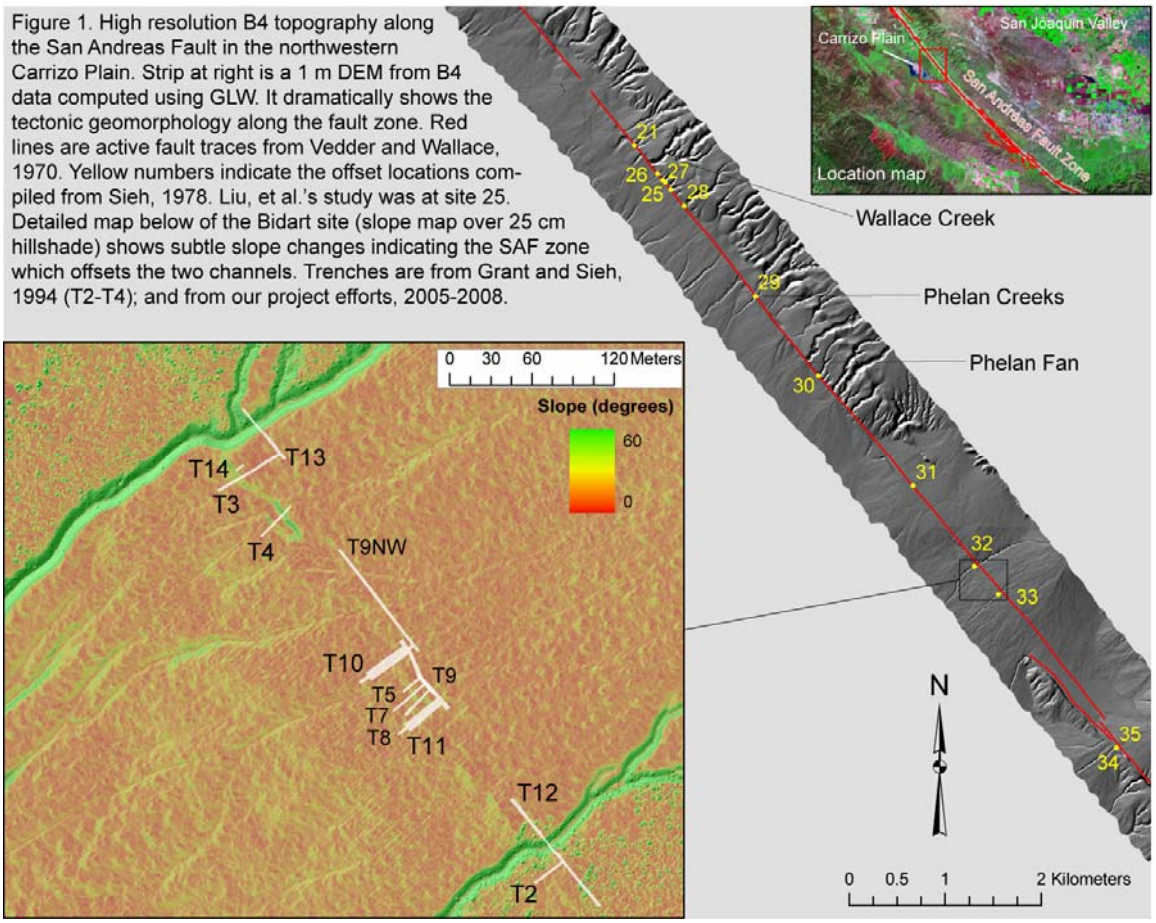

Figure 1. High resolution B4 topography along the San Andreas Fault in the northwestern Carrizo Plain. Strip at right is a 1 m DEM from B4 data computed using GLW. It dramatically shows the tectonic geomorphology along the fault zone. Red lines are active fault traces from Vedder and Wallace, 1970. Yellow numbers indicate the offset locations compiled from Sieh, 1978. Liu, et al.'s study was at site 25. Detailed map below of the Bidart site (slope map over 25 cm hillshade) shows subtle slope changes indicating the SAF zone which offsets the two channels. Trenches are from Grant and Sieh, 1994 (T2-T4); and from our project efforts, 2005-2008.

Methodology

In the Carrizo Plain, streams are incised during major storm events. Rhodes, et al., 2002 and Noriega, in progress, have shown that the geomorphic systems of the Carrizo Plain are linked and typically have synchronous responses to late Holocene climate change: These systems include the offset channel and fan systems (Bidart Fan, Phelan Fan, Phelan Creeks, Wallace Creek) and the playa lake and fringing dune system to which they drain (Soda Lake). Fluvial, aeolian, and lacustrine processes of this closed system show synchronous response to climate change as recorded by channel incisions and dune stability during high lake level and channel stability and dune formation during low lake level. Channel incision events are most likely to occur during a major climatic events. If the stream incision can be related to a known paleoclimate event that is tied to dendrochronology or varve data, then it can be dated with high precision (approx. 1 year). With a few exceptions where trees have been killed by earthquakes (Jacoby et al., 1989) such precise dating of paleo-earthquakes is nearly impossible with conventional dating methods such as C-14, OSL, etc.

Preliminary results

"Paleoclimate constraints on earthquake rupture surface slip for the San Andreas fault in the Carrizo Plain" (Grant Ludwig et al., 2009 SSA abstract)

The Carrizo section of the San Andreas fault (SAF) has been proposed to rupture only in "characteristic" large-slip earthquakes with centuries-long recurrence times. Previous workers assumed that small channels are incised across the SAF more often than they are offset by

earthquakes. Our compilation of paleoclimate and paleoseismic data suggest that perhaps this assumption is false, and several smaller earthquakes could have generated offsets that previously were ascribed to larger single events. We examined paleoclimate data to identify floods and droughts that may be associated with erosion and sedimentation events in the Carrizo over the last millennium. A drought in AD 1468–1580 is coeval with such low sedimentation that 3 ruptures at the Bidart fan site are generally indicated at the same horizon. It is unlikely that these earthquakes are well preserved in the geomorphic record of offset channels. Paleoclimate data combined with Holocene slip rate of the SAF suggest that two prominent channels offset along the SAF in the Bidart fan may have been incised by extreme floods in 1418 $\pm$ 10 AD, and 1605 $\pm$ 5 AD. The smaller channel is offset 7–9 m. If it incised during the 1605 AD extreme flooding event, it has been displaced by both the 1857 earthquake and an earlier rupture. The larger channel to the northwest has been offset 15 – 18 m. This channel may have been incised by the "extraordinary" flood in 1418 AD. If so, according to the most recent and best constrained paleoearthquake chronology, the channel has been displaced by as many as 5 earthquakes, including the relatively large slip 1857 earthquake. Surface slip from several recent earthquakes along the Carrizo section of the SAF was less than previously reported 7 – 9 m slip in 18[redacted]. Slip may have varied temporally such that several smaller-than-1857 ruptures occurred between 1400 and 1857 AD.

Publications partially or completely supported by this project:

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