Final Technical Report for USGS/NEHRP #05HQGR0071 (UofO #238841)

Project Title: From single site records to a 1,200-year rupture sequence for the southern San Andreas fault

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Project Period: Originally January 1, 2005 – December 31, 2005; extended to December 31, 2006 and sub-award issued to Kate Scharer, Appalachian State University

INTRODUCTION

The purpose of this work was to collect paleoseismic data along a 200 km stretch of the southern San Andreas fault between Pallett Creek and sites in the Carrizo Plain (Figure 1). At the writing of the proposal, few sites had been explored along this stretch (Figure 2). For example, the average interval for this stretch of the fault was poorly constrained, bracketed by ~300 years documented at the Carrizo Plain and Frazier Mountain sites (Figure 1; Liu, 2003; Grant and Sieh, 1994; Lindvall et al., 2002), or 120 years documented at Pallett Creek (Sieh et al., 1989; Biasi et al., 2002). The absence of earthquake age and displacement data along this stretch permits several interpretations for rupture histories of the fault (Weldon et al., 2004) and creates uncertainties in models of rupture segmentation (Working Group on California Earthquake Probabilities, 2007).

RESULTS

Activities completed pursuant to the proposal include:

1. Trench excavations, summer 2006

Our original goal was to excavate trenches at Horse Camp Canyon on the Three Points site (Figure 2), and tried to secure access through the Desert Hunt Club, which leases the land. They were interested in the project but after discussions with the landowner, could not allow the project to proceed. Once this was determined, we identified other sites that appeared geomorphically suitable for paleoseismic studies and approached the land owners at four sites: Garden Gulch, Corona del Valle, and the Pine Mountain Club, and Gorman.

Scharer, U.S. Geological Survey colleague Tom Fumal, and Appalachian State University undergraduate student Evan Howell excavated trenches at Garden Gulch (Figure 3). Garden Gulch was originally studied in the 1980's and published by Rust (2005). Rust documented evidence of two 19th century earthquakes, suggesting an 1812 earthquake ruptured the area. Our goal was to confirm these observations and extend the record deeper. Two large, v-shaped trenches were excavated at the site in 2006 (Figure 4). The eastern trench crossed the southern margin of the fault zone and shows evidence for two earthquakes (Figure 5). The event quality was of moderate quality, so we did not date the deposits. Thick deposits (including a single 1.5 m thick debris flow deposit) and a high groundwater table limited deeper excavations. Because the evidence was tentative, and because further work would require extending the trench north across the landowner's access road, we did not pursue additional work at the site.

We also excavated a trench across a trough on the Corona del Valle site in 2006 (Figures 2 and 3). Deposits exposed in the trench was highly bioturbated and not suitable for paleoseismic investigations.

We started the permission process with the Pine Mountain Club in the summer of 2006. The town council granted permission in autumn of 2006. Fumal excavated a trench at the site but the deposits were too coarse and unsuitable for paleoseismic work.

Finally, the Gorman site landowners did not return our letters of inquiry and no phone number is available.

For convenience, we list the latitude and longitude of the sites we have worked at since 2006 below:

Garden Gulch: 34.72879°, -118.61639°

Corona del Vale: 34.74818°, -118.68624°

Pine Mountain Club: 34.85502°, -119.15415°

Cuddy Valley: Norman property, 34.82953°, -119.02882° and 34.82944°, -119.02761°;

Maga property, 34.82849°, 119.02441°

2. Debris flow mapping and fire hazard analysis

Between trenching activities (when waiting for backhoe availability), Scharer and Howell completed a map of debris flow deposits issuing from Horse Camp Canyon, at the Three Points site. We mapped the perimeter of the deposits and dug pits across the deposit to map the shape and thickness of the deposit. Howell used these observations in conjunction with regional soil maps, precipitation and fire intensity data to evaluate the success of a predictive debris flow hazard equation by Cannon (2001). This work became Howell's Senior Honors Thesis (Howell, 2007).

3. Manuscripts and presentations completed during this project:

Peer-reviewed articles

Scharer, K.M., Weldon, R. J. II, Fumal, T. E., Biasi, G. P., 2007. Paleoearthquakes on the southern San Andreas fault, Wrightwood, CA 3000 to 1500 B.C.: a new method for evaluating paleoseismic evidence and earthquake horizons, *Bulletin of the Seismological Society of America.* 97, 1054-1093.

Weldon, R. J, Fumal, T. E., Biasi, G. P., Scharer, K. M., 2005. Past and future earthquakes on the San Andreas fault, *Science*, 308, 966 – 967.

Abstracts:

Howell, E., 2007. Assessing debris flow probability of recently burned basins in the San Gabriel Mountains, CA, *Senior Honors Thesis*, Appalachian State University Department of Geology.

Scharer, K. M., Kashgarian, M., Zermeno, P., Kurdyla, D., 2006. What are we dating? An evaluation of chemical pretreatment methods for AMS 14C dating of peat, *Eos Trans. AGU,* 87(52), Fall Meeting Suppl., Abstract T13B-0507.

Scharer, K. M., Biasi, G. P., Weldon, R. J. II, Fumal, T. E., 2006. How do paleoseismic interpretations affect recurrence parameter estimates? The Wrightwood case study, *SCEC 2006 Annual Meeting*.

Scharer, K. M., Behavior of the San Andreas fault over the last 5000 years: Wrightwood's clues and questions, *International workshop on comparative studies of the North Anatolian Fault and the San Andreas Fault (Southern California)*, Istanbul, 2006.

Scharer, K. M., Biasi, G. P., Weldon, R. J. II, Fumal, T. E., 2006. Reid's elastic rebound theory in light of the long paleoseismic record at Wrightwood, *SSA Annual Meeting*.

Scharer, K. M., Biasi, G. P., Weldon, R. J. II, Fumal, T. E., 2005. Recurrence behavior of the San Andreas fault at Wrightwood, CA, *SCEC 2005 Annual Meeting*.

REFERENCES

Biasi, G.P., Weldon, R.J., Fumal, T.E., and Seitz, G.G., 2002, Paleoseismic event dating and the conditional probability of large earthquakes on the southern San Andreas fault, California: Bulletin of the Seismological Society of America, v. 92, p. 2761-2781.

Cannon, S.H., 2001, Debris-flow generation from recently burned watersheds: Environmental and Engineering Geoscience, v. 7, p. 321–341.

Howell, E., 2007. Assessing debris flow probability of recently burned basins in the San Gabriel Mountains, CA: Senior Honors Thesis, Appalachian State University Department of Geology.

Lindvall, S.C., Rockwell, T.K., Dawson, T.E., Helms, J.G., and Weaver, K.D., 2002, Evidence for two surface ruptures in the past 500 years on the San Andreas fault at Frasier Mountain, CA: Bulletin of the Seismological Society of America, 92, 2689-2703.

Liu, J., Klinger, Y., Sieh, K., and Rubin, C., 2004, Six similar sequential ruptures of the San Andreas fault, Carrizo Plain, California: Geology, v. 32, p. 649-652.

Rust, D., 2005, Palaeoseismology in steep terrain: The Big Bend of the San Andreas fault, Transverse Ranges, California: Tectonophysics, v. 408, p. 193-212.

Scharer, K.M., Weldon, R.J., Fumal, T.E., and Biasi, G.P., 2007, Paleoearthquakes on the southern San Andreas fault, Wrightwood, CA 3000 to 1500 B.C.: a new method for evaluating paleoseismic evidence and earthquake horizons: Bulletin of the Seismological Society of America, v. 97, p. 1054-1093.

Sieh, K., Stuvier, M., and Brillinger, D., 1989, A more precise chronology of earthquakes produced by the San Andreas fault in southern CA: Journal of Geophysical Research., 94, 603-623.

Weldon, R.J., Scharer, K.M., Fumal, T.E., and Biasi, G.P., 2004, Wrightwood and the earthquake cycle: What a long recurrence record tells us about how faults work: GSA Today, v. 14, p. 4-10.

Working Group on California Earthquake Probabilities, 2007, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2), Open-File Report 2007-1437 and California Geological Survey Special Report 203 U.S. Geological Survey.

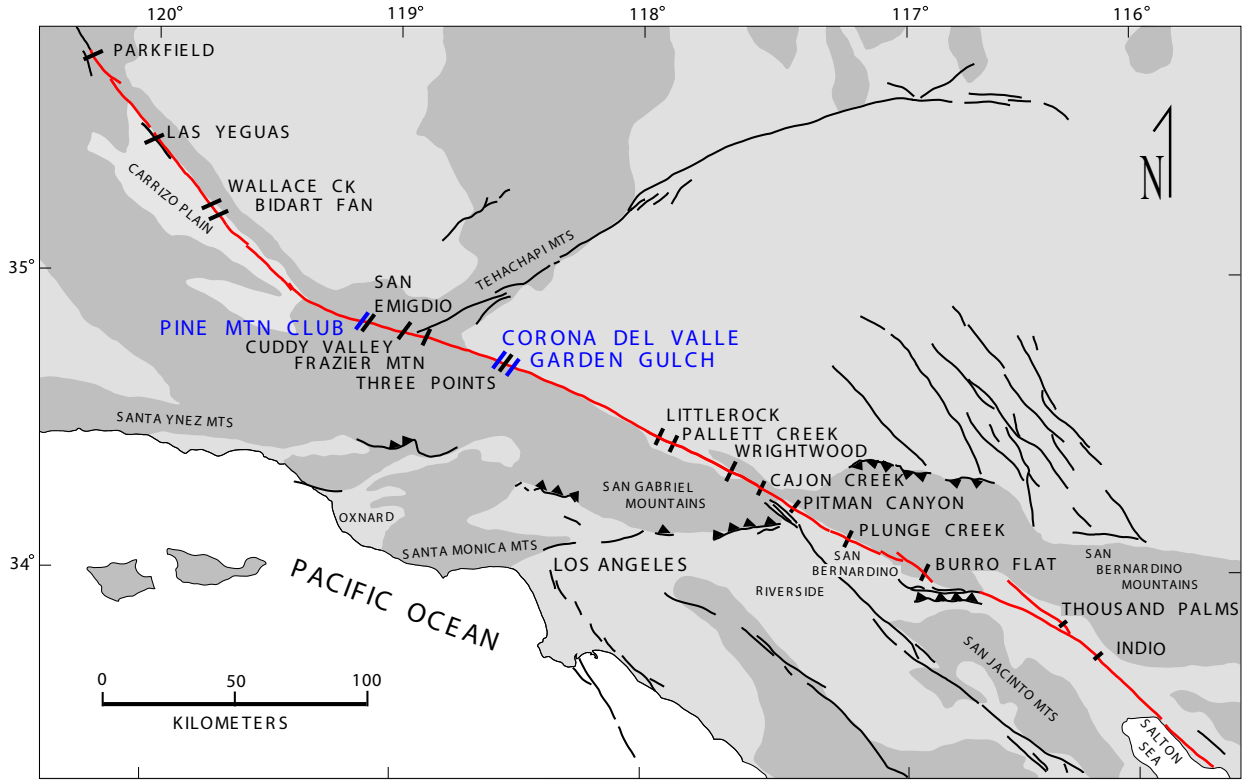

Figure 1. Map of paleoseismic sites along the southern San Andreas fault (red lines). Through funding from NEHRP, SCEC, and USGS, our group has excavated trenches at Garden Gulch, Corona del Valle (the subject of this report), the Pine Mountain Club (near San Emigdio), Cuddy Valley, and Frazier Moutain since 2006. Frazier Mountain is the best site we have explored along the ~200 km stretch of the fault between Littlerock and Bidart Fan.

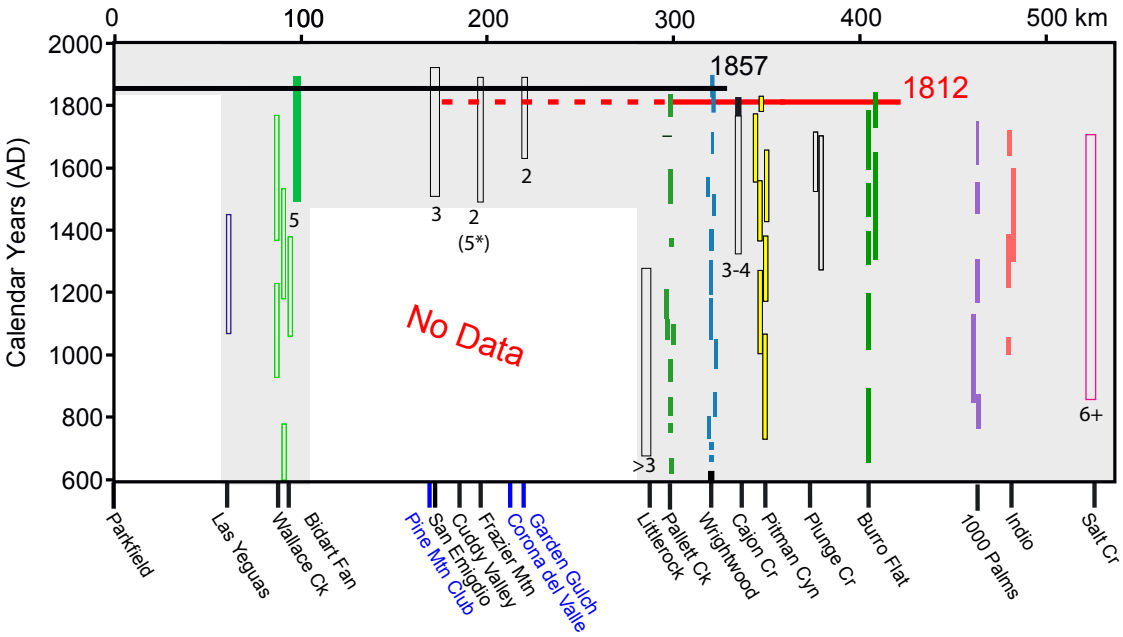

Figure 2. Plot of event ages shows paucity of data on the northern 2/3 of the southern San Andreas fault at the start of this project. Since then, our team has excavated trenches at Garden Gulch, Corona del Valle, Pine Mountain Club (in 2006) and Cuddy Valley (in 2007). None of these sites has stratigraphy suitable for paleoseismic event recognition and dating. *Recent work at Frazier has increased the number of earthquakes in the last 500 years to 5, including the 2 indentified by Lindvall et al. (2002). Solid vertical bars represent ~1 standard deviation of the event age range, open vertical bars represent multiple, undated events or poorly constrained events as noted by numbers below bars. Grey blocks identify areas with moderate to good data. Modified from Weldon et al., (2004); data for Garden Gulch from Rust (2006), Bidart Fan (Ackiz, pers. com), and fieldwork by Scharer and Fumal, 2006.

Figure 3. Google image showing location of Garden Gulch and Corona del Valle sites. The sites are 6.8 km apart and located south of Pine Canyon Road (yellow line).

Figure 4. Google Earth images of Corona del Valle (top) and Garden Gulch (bottom) paleoseismic sites. Locations of 2006 trenches shown with pink bars.

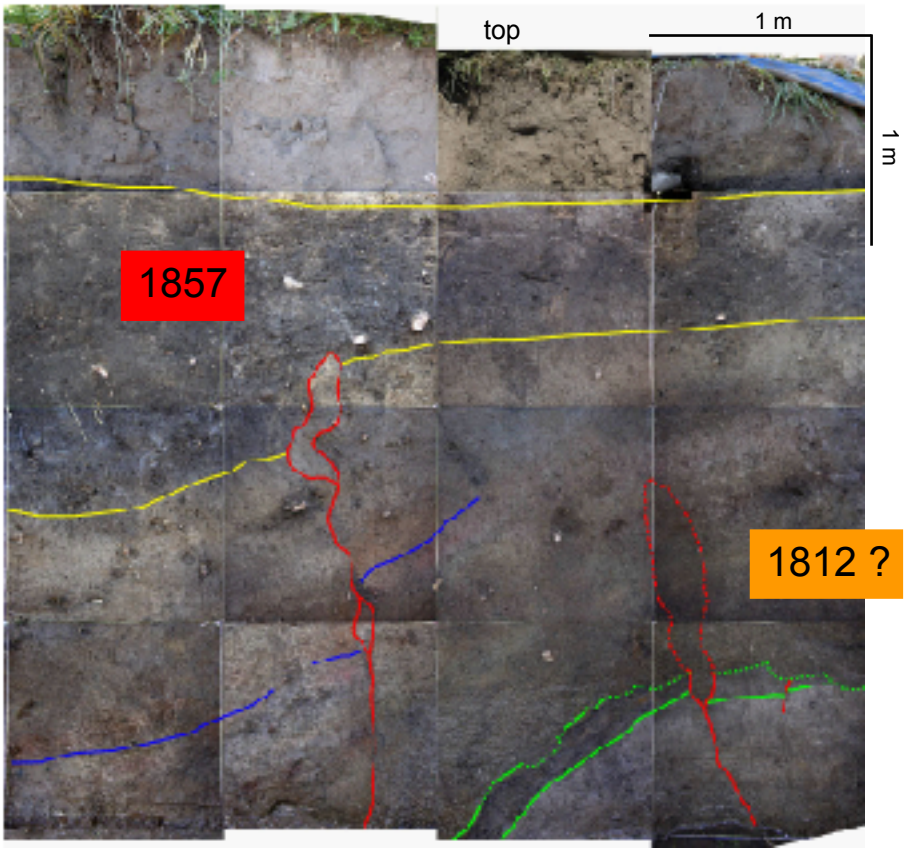

Figure 5. Photomosaic of Garden Gulch, east trench, northwest wall. The most recent faulting extends to the base of a massive debris flow layer, approximately 1.7 m below the ground surface and is likley to be the 1857 earthquake. A fault lower in the section is shown by dashed lines; we were unable to determine if the material between the fault splays is fissure material or has been altered by burrowing animals. This fault could be evidence for the 1812 rupture, based on dating by Rust (2006). Deposits at Garden Gulch can be massive and would require very deep trenches to successfully extend the record here; the upper section includes a debris-flow deposit that is over 1.5 m thick.