2018 SCEC Report:

Paleoseismic Investigation of the Lytle Creek Ridge Fault: Evidence for Linked San Jacinto-San Andreas Earthquake Ruptures

Dr. Michael Oskin, University of California, Davis

Dr. Thomas Rockwell, San Diego State University

Paleoseismic Investigation of the Lytle Creek Ridge Fault: Evidence for Linked San Jacinto-San Andreas Earthquake Ruptures

Abstract: We conducted a paleoseismic and structural investigation of a newly discovered, active, low-angle normal fault located between the San Andreas fault and the northernmost San Jacinto fault. The Lytle Creek Ridge fault (LCRF) strikes west, dips ~30° to the north, and cuts through Lytle Creek Ridge, within the releasing step where the San Jacinto approaches within 3.5 km of the San Andreas fault. The LCRF is uniquely positioned and mechanically favored to record earthquakes that jump this releasing step and breach the Cajon Pass Earthquake Gate. We found evidence for at least two meter-scale coseismic offsets within a hand-excavated, 2.5-meter deep trench across the LCRF. Based on mechanical modeling, these large slip events are probably due to earthquake ruptures that jump from the SAF to the SJF (or visa versa). The trench contains abundant charcoal, and dating is in progress at the writing of this report. The results of this study will provide a critical paleoseismic data set for assessing the rupture behavior of the Cajon Pass Earthquake Gate.

Technical Report: Collectively, the San Andreas fault and San Jacinto fault carry the majority of Pacific-North America plate motion through southern California (e.g. Fialko, 2006, Behr et al., 2010, Blisniuk et al., 2013), and produce frequent, large, surface-rupturing earthquakes (Rockwell et al., 2016). These faults merge in an enigmatic manner within the Cajon Pass, where detailed geologic mapping (Morton and Matti, 1993) shows that their surface traces do not intersect. Instead, the bedrock trace of the San Jacinto fault terminates into a set of cross-cutting, high- and low-angle faults within the eastern San Gabriel Mountains (Figure 1A). Evidently, recent activity on the northernmost San Jacinto fault transfers to the San Andreas across the intervening, 3.5 km-wide step in a releasing configuration. Atypically, rather than subsiding beneath a pull-apart basin, the intervening bedrock is here exposed as a highstanding topographic ridge, with the incongruent name of "Lytle Creek Ridge" on topographic maps. This bedrock exposure is likely a result of regional uplift of the eastern San Gabriel Mountains that exceeds local subsidence. The bedrock lithology of Lytle Creek Ridge consists of greenschist and amphibolite grade Pelona schist, juxtaposed by the inactive Punchbowl strand of the San Andreas fault (Morton et al., 2001).

Hypothetically, earthquake ruptures may jump the 3.5 km wide releasing step between the northern San Jacinto fault and the San Andreas fault. Lozos (2016) showed how the 1812 earthquake, attributed to the San Andreas fault, may have started as a south-to-north rupture on the San Jacinto fault. Evaluating this hypothesis, the possibility of earlier such events (Rockwell et al., 2016), is one of the central goals of the SCEC Earthquake Gates initiative focus on the Cajon Pass. New paleoseismic data, especially from the northernmost San Jacinto fault, is critically needed to assess the fraction of ruptures that may have jumped this barrier. Unfortunately, the alignment of the San Jacinto fault with major river canyons draining the eastern San Gabriel Mountains presents a challenging geomorphic setting for recording earthquake event chronologies.

We conducted a paleoseismic and structural-mechanical investigation of a newly discovered, active Lytle Creek Ridge fault (LCRF), located within the releasing stepover between the northernmost San Jacinto fault and the San Andreas fault. Scarps present along the LCRF are revealed by recently released airborne lidar topography from the County of San Bernardino (Figure 1B). The scarps form a narrow, uphill-facing bench, 1.0 km in length, located on the southwest-facing slope of Lytle Creek Ridge. In the field,

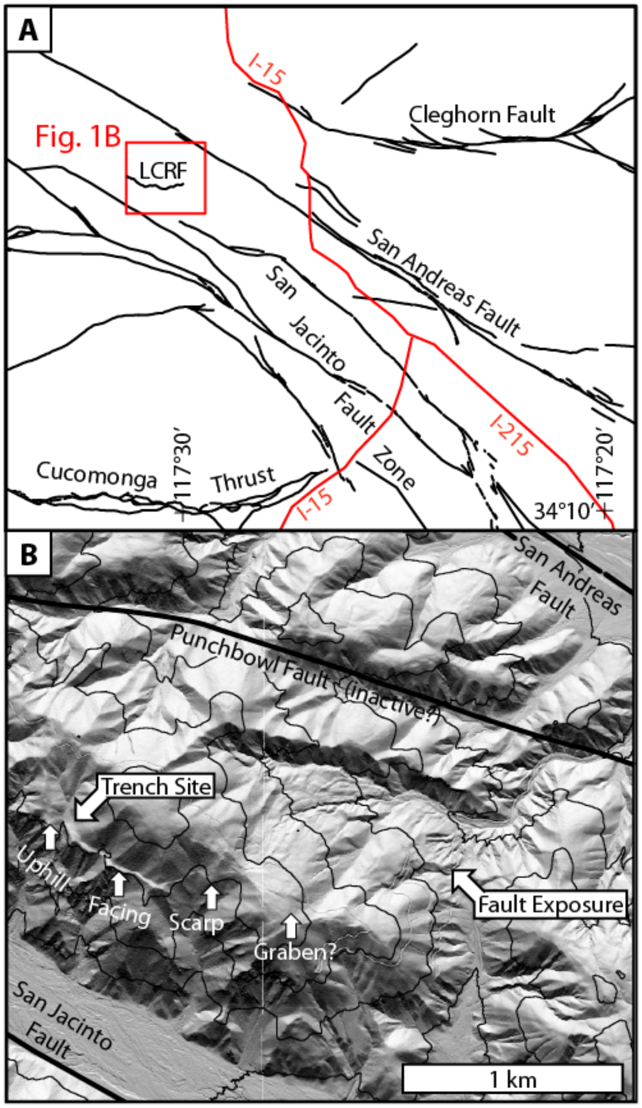

Figure 1. A. Fault map of Cajon Pass region, showing location of Lytle Creek ridge fault (LCRF). B. Lidar hillshade with 100m contours, illustrating features related to slip on the LCRF.

the LCRF footwall froms a bedrock-cored uphill-facing scarp that encloses several topographic depressions in its hanging wall. Our trench site is located in one of these depressions where fine sediments are trapped against the scarp. Field mapping confirms that the LCRF is continuous along strike, dips 27 to 31° to the north, and is in part localized in serpentinite rocks, which are a minor but mechanically weak constituent of the Pelona schist bedrock.

The trench was sited where fine-grained alluvium was ponded against the uphill-facing scarp and where we had previously excavated a small, 1.2 m-deep pit that established the presence of bedded stratigraphy. A 16 x 5 m swath of ground was cleared of vegetation in preparation of the trench excavation. The trench was then excavated with shovels and picks to a depth of 1.5 m for the entire 16 m length of the trench to locate the fault, and then to a depth of about 2.5 m in the fault zone. Wood shoring was emplaced in the deepened portion of the trench to maintain stability.

Figure 2. Photograph of trench excavation, in progress, April 2019. Pink flagging denotes ^{14}C sample locations.

The trench exposed well-bedded layers of gravel, sand and silt punctuated by a couple of thin buried A (topsoil) horizons that represent brief periods of non-deposition. Most of these units were laterally continuous for the length of the trench NE of the fault zone. We differentiated nearly 20 individual stratigraphic units, nearly all of which contained detrital charcoal. We collected over 80 samples for potential radiocarbon dating, with 25 currently in the process of being dated.

At least two, and possibly three ≥2m slip events are revealed in the trench. These large events on a short, linking normal fault, are consistent with the hypothesis that this fault slips only during events that rupture across the stepover between the San Andreas fault and the San Jacinto fault. Based on a Coulomb mechanical model, we find that the conditions necessary for dominantly normal slip on the LCRF occur in the presence of right slip that tapers northward on the San Jacinto fault (Figure 3). Rupture that terminates on the San Andreas fault, without stepping over, induces a stronger component of left slip than normal slip on the LCRF, opposite of that observed.

Because it took over a year to acquire the proper permits to do the trenching, we are still in the field phase and completing the logging and documentation of past ruptures. We anticipate that this field effort will be completed by June, 2019 and presented in full at the annual meeting.

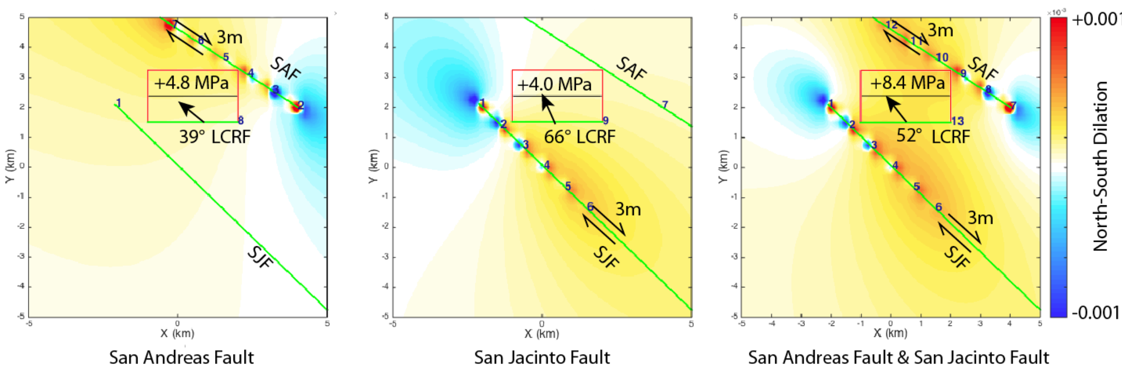

Figure 3. Coulomb models (Lin and Stein, 2004) for stress increase and optimal slip direction on a 30° north-dipping LCRF in response to rupture on the vertical San Andreas fault (left), San Jacinto fault (middle), or both (right). Color corresponds to change in north-south dilational strain. In each case, slip is tapered to simulate constant stress drop of approximately 6 MPa, driving a comparable stress increase on LCRF. Highest stress change, with slip direction consistent with that observed in outcrop, occurs for the case where slip occurs on the San Andreas fault and San Jacinto fault.

References Cited:

Behr, W.M., Rood, D.H., Fletcher, K.E., Guzman, N., Finkel, R., Hanks, T.C., Hudnut, K.W., Kendrick, K.J., Platt, J.P., Sharp, W.D., Weldon, R.J., Yule, J.D., 2010. Uncertainties in slip-rate estimates for the Mission Creek strand of the southern San Andreas fault at Biskra Palms Oasis, southern California. Geological Society of America Bulletin 122, 1360–1377. doi:10.1130/B30020.1

Blisniuk, K., Oskin, M., Mériaux, A.-S., Rockwell, T., Finkel, R.C., Ryerson, F.J., 2013. Stable, rapid rate of slip since inception of the San Jacinto fault, California, Geophysical Research Letters 40, 4209–4213. doi:10.1002/grl.50819

Fialko, Y., 2006. Interseismic strain accumulation and the earthquake potential on the southern San Andreas fault system. Nature 441, 968–971. doi:10.1038/nature04797

Lin, J., Stein, R.S., 2004. Stress triggering in thrust and subduction earthquakes and stress interaction between the southern San Andreas and nearby thrust and strike-slip faults, Journal of Geophysical Research: Solid Earth 109. doi:10.1029/2003JB002607

Lozos, J.C., 2016. A case for historic joint rupture of the San Andreas and San Jacinto faults. Science Advances 2, e1500621–e1500621. doi:10.1126/sciadv.1500621

Morton, D. M., Woodburne, M. O., Foster, J. H., Morton, Gregory, Cossette, P. M., 2001, Geologic map of the Telegraph Peak 7.5' quadrangle, San Bernardino County, California: U.S. Geological Survey Open-File Report 01-293.

Morton, D.M., Matti, J.C., 1993. Extension and contraction within an evolving divergent strike-slip fault complex: The San Andreas and San Jacinto fault zones at their convergence in southern California, in: Powell, R.E., Weldon, I., R.J., Matti, J.C. (Eds.), San Andreas Fault System: Displacement, Palinspastic Reconstruction, and Geologic Evolution, Geological Society of America Memoir 178.

Rockwell, T., Scharer, K., Dawson, T., 2016 Earthquake Geology and Paleoseismology of Major Strands of the San Andreas Fault System, in: Anderson, R., Ferriz, H. (Eds.), Applied Geology in California. Association of Engineering Geologists, pp. 1–35.