SCEC 2005 – 2006 Progress Report:

A high-resolution geomorphic and chronologic record of the dynamic evolution of a seismogenic strike-slip fault

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Summary

This project seeks to empirically determine if a relationship exists between the evolution of a nascent fault zone and its slip rate through time. The study site chosen to test this relationship is the northern Lenwood fault, located in the Mojave Desert portion of the Eastern California shear zone. Reconnaissance studies by Oskin and UNC M.S. student, Mike Strane, discovered evidence that the fault has very little slip (~2 km), but appears to be one of the most active structures in the shear zone over the Late Quaternary. Our initial study is part of a larger, NSF-funded project to determine fault slip rates across the Eastern California shear zone. Additional funds from SCEC enhanced this research through support of additional geochronology and expanded mapping efforts. Preliminary results include multiple age-dates on Quaternary surfaces deformed by faulting and detailed mapping that from which we will develop kinematic models of fault evolution. Further mapping, to be completed this February, will be required to test if the fault has undergone acceleration in the Late Quaternary in response to development of linkage zones between individual fault strands.

Introduction

Understanding the origination and development of active faults is a fundamental component of deciphering how continental transform fault systems function. Although major strike-slip faults with tens to hundreds of kilometers of cumulative slip carry the majority of active strain accumulation in these systems, fault splays and linkages provide paths for rupture propagation that may influence the ultimate size of individual earthquakes and significantly affect seismic hazard (Ben-Zion and Rice, 1995; Harris and Day, 1999). Fault segmentation can also limit rupture propagation, leaving behind high residual stresses that may nucleate subsequent earthquakes (Stein, 1999). Over longer time scales, origination and reactivation of faults can significantly alter the pattern of strain accumulation within a plate boundary (Roy and Royden, 2000a, 2000b).

For 2005, we proposed to document a high-resolution record of the development of a youthful strike-slip fault: the Lenwood fault of the Eastern California shear zone. We seek test the hypothesis that fault slip rate increases as fault linkage zones develop and smooth out the fault plane through time. The Lenwood fault is an advantageous target for this research for three reasons: (1) it has low (~2 km) total slip and a discontinuous, complex trace as expected for a nascent fault, (2) it has a relatively high slip rate (at least 1.5 mm/yr) so that growth of fault linkage and secondary structures is evident in the geomorphic record (ca. 300 kyr), and (3) the fault is very well exposed in the field and in an airborne LIDAR survey (Fig. 1).

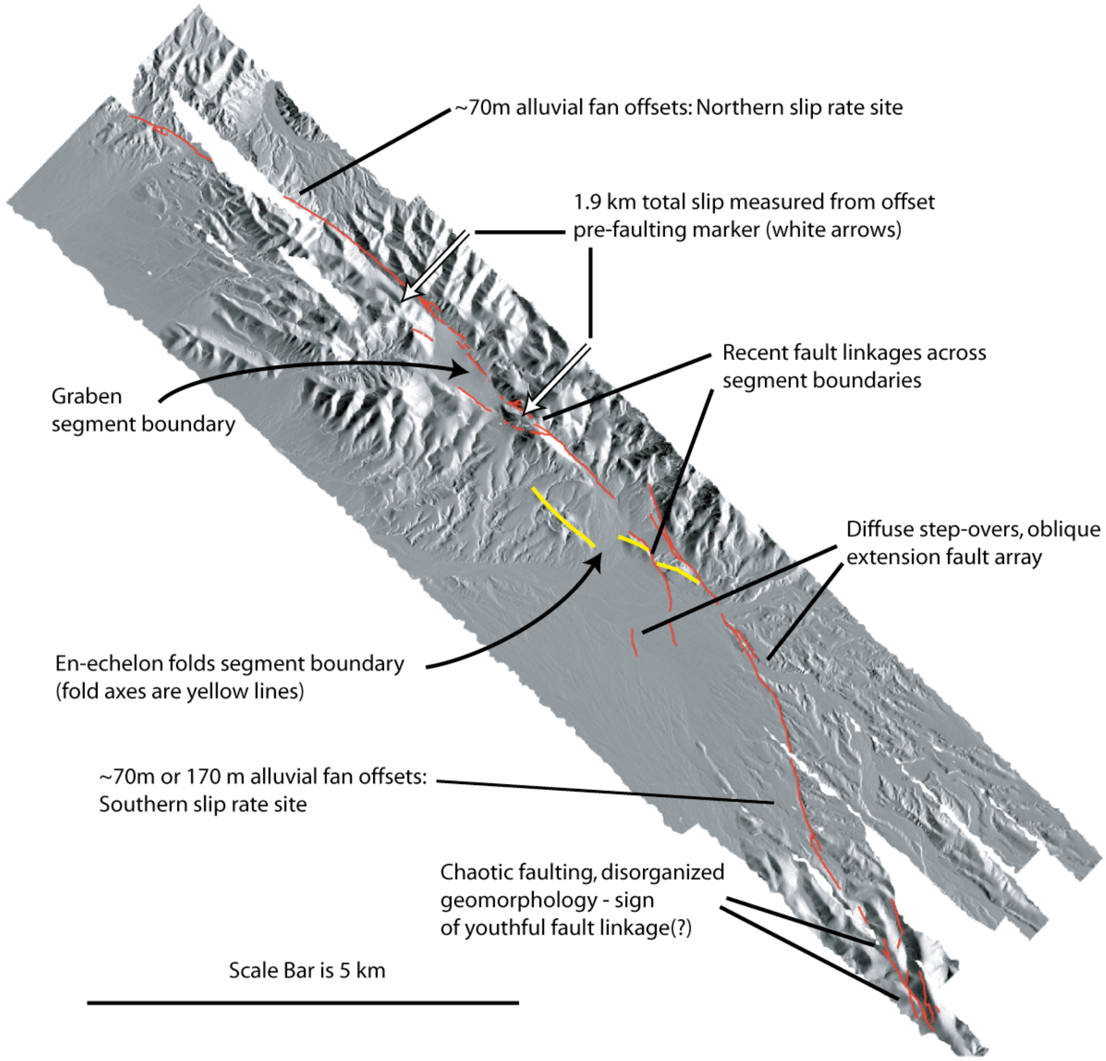

Figure 1. Airborne laser swath map overview map of part of the Lenwood fault. Note variety of fault linkage zones in this area. Two active grabens separated by a zone of en echelon folding occur along the fault over a distance of ~5 km.

Results

Dating of geomorphic surfaces

In order to test if fault slip rate is changing over the late Quaternary, a dated chronosequence of geomorphic markers is required. We have identified two principal Late Pleistocene geomorphic surfaces displaced by the Lenwood fault that are useful for this test. Cosmogenic depth profile ^{10}Be dating of quartz deposited in the younger, Tk surface indicates an age of roughly 45 ± 0.5 ka once the significant cosmogenic inheritance is removed from the results (Fig. 2). These results are duplicated by independent measurements of amalgamated quartz clasts and quartzose sand. Interestingly, inheritance measured in modern stream samples varies by 50% in these two sample sites – a result probably indicative of enhanced transport of sand in the modern stream. We also attempted a profile age of the older Tf surface. Unfortunately, the results yielded evidence of a buried, older surface that complicates its interpretation. However, its minimum age probably greater than 150 ka. An additional dating effort is planned to refine the Tf age from a different site along the Lenwood fault.

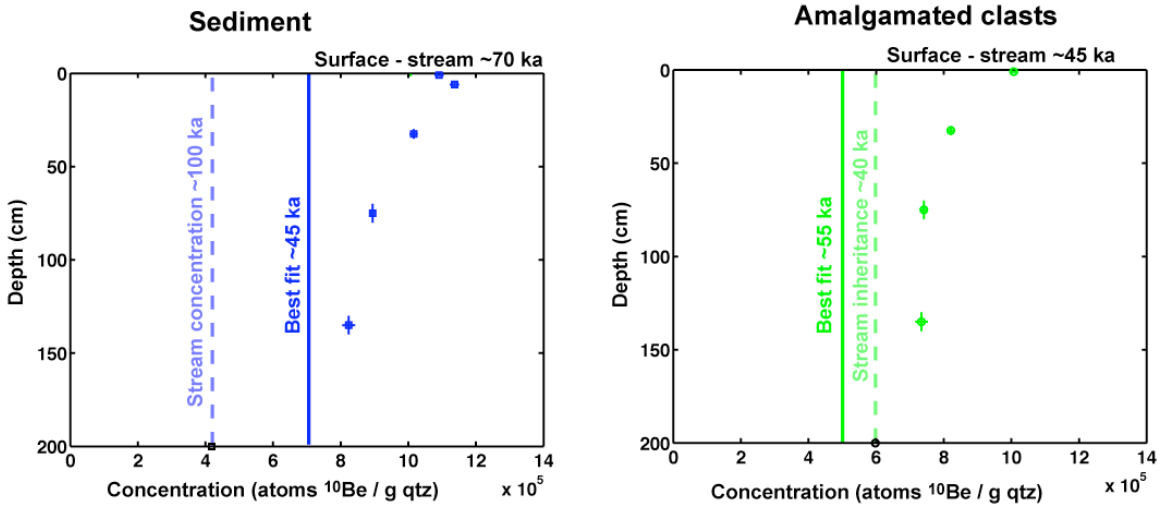

Figure 2. Concentration of cosmogenic ^{10}Be in depth profiles sampled from the Tk surface adjacent to the Lenwood fault (area of Fig. 4). Both bulk sand and amalgamated quartz coarse gravel give consistent results with expected exponential decay with depth. Modern stream samples yield ages high inherited concentrations, as does the excess cosmogenic component at depth. Excepting the anomalously low inheritance value of modern stream sand, all samples yield similar ages of 40 to 50 ka when corrected for inheritance.

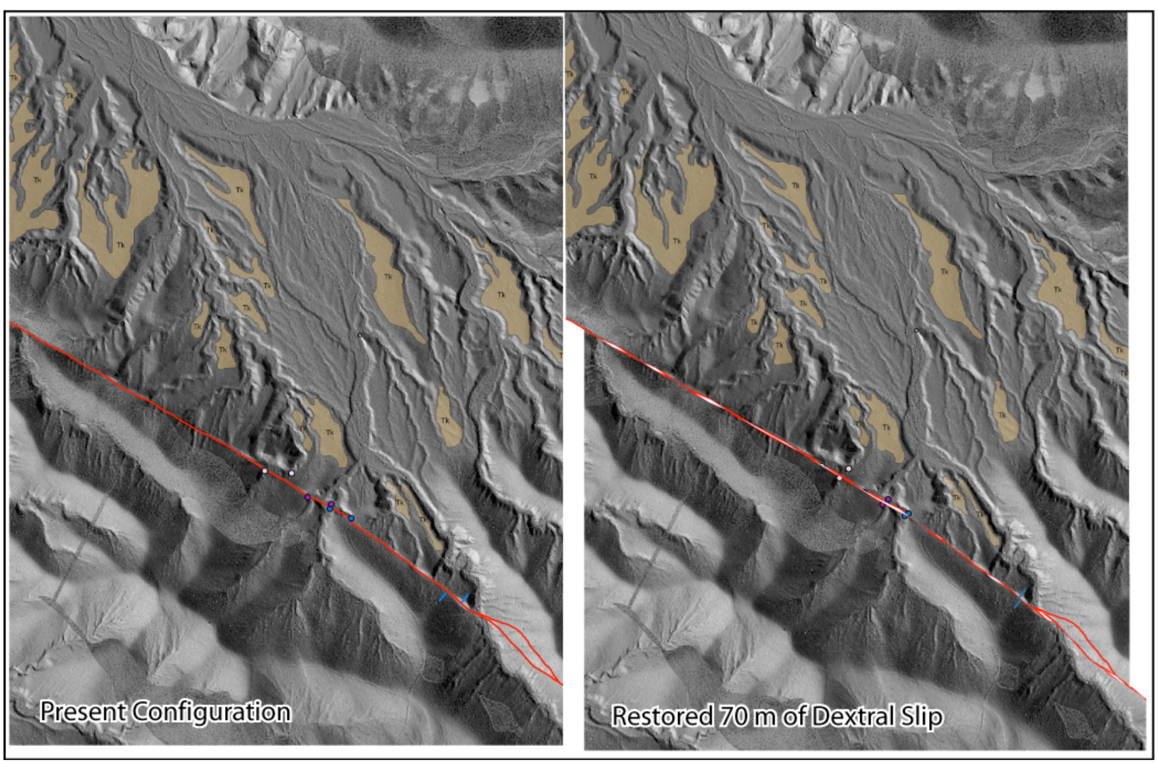

Figure 3. Map of Tk alluvial fan surfaces, northern slip rate site. Displaced canyons cut into Tk surface restore with ~70 meters of dextral slip removed.

Present slip rate of the Lenwood fault

We have significantly refined the total slip and slip rate of the Lenwood fault. Previous estimates of total slip have varied from 1 to 3 km. Detailed mapping has confirmed total slip lies between these values at 1.9 ± 0.1 km (Fig. 1). Published estimates of slip rate for the Lenwood fault are ca. 1mm/yr or less, based on its low total offset (Dokka and Travis, 1990) and its low rate of paleoseismicity (Rockwell et al. 2000). Our initial assessment of stream deflections around outcrops of the Tk surface indicated in excess of 300 meters of offset and a commensurably rapid slip rate. Subsequent mapping deemed this offset as unsupported by other evidence and thus we have sought alternative reconstructions. Several stream offsets in the north and south part of the fault indicate ~70 m of offset post-emplacment of the Tk fan. This offset would yield a slip rate of 1.5 ± 0.3 mm/yr (Fig. 3). An alternative reconstruction of up to 170 m on the southern part of the fault and a corresponding slip rate of 3.8 ± 0.6 mm/yr remains under consideration until additional mapping is completed early next year.

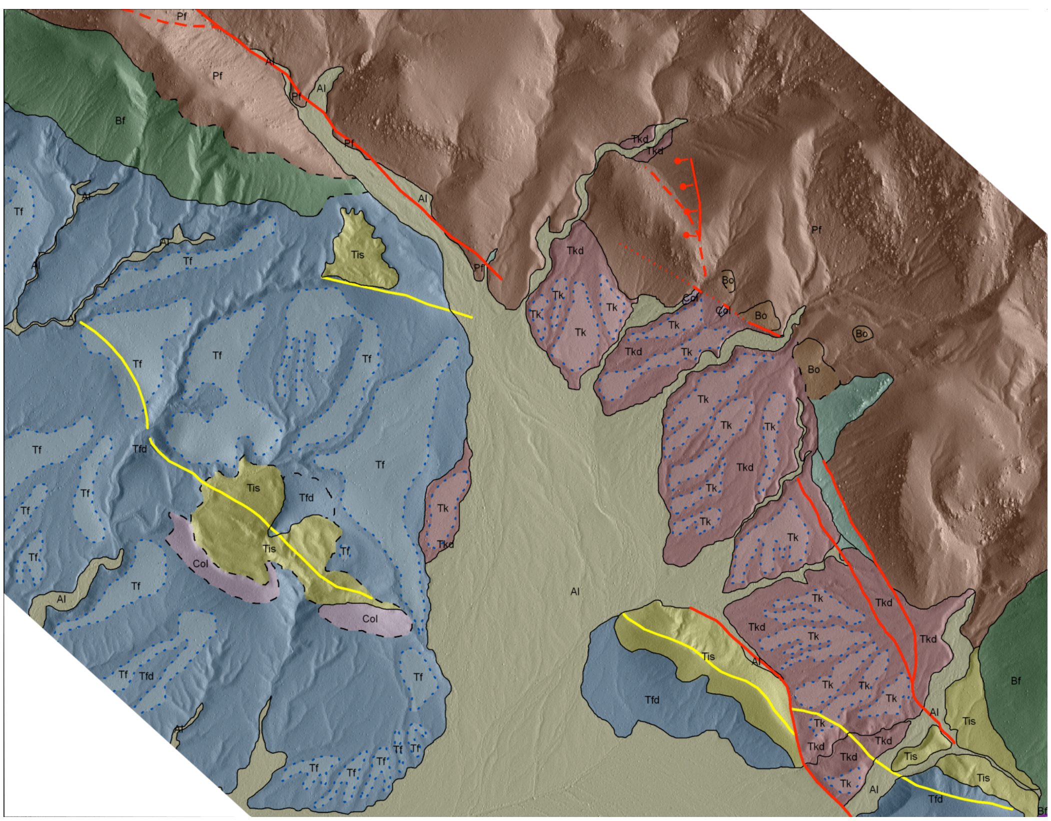

Figure 4. Geomorphic and geologic map of the en echelon folds linkage zone. Both folds deform the Tf surface (blue) and underling lacustrine deposits of the Barstow Fm. (yellow). Tk surfaces (purple) are deformed where deposited across the axis of the southeastern fold. Total fault displacement of ~ 2km supported by displacement of the basal contact of the lower Barstow Formation conglomerates (Bf, green) above Pickhandle formation megabreccia (Pf).

Kinematic evolution of fault linkage zones

Mapping and dating efforts, when completed, will permit reconstruction of the development of linkage zones between segments of the Lenwood fault and testing for an increase of fault slip-rate as linkage zones mature. Preliminary mapping confirms that fold growth in one of the linkage zones has persisted from before emplacement of Tf through Tk and probably to the present (Fig. 4). Additional age data on the Tf surface is required to link the fault slip rate to fold development. New mapping also supports that both the northern and southern grabens continue to subside despite development of newer fault strands that bypass all of these linkage zone structures.

Future Work

Sufficient support remains in our present SCEC budget to complete our study of the development of Lenwood fault. This will require additional field mapping that is planned for the months of February and March of 2006. Mapping will completely document the internal structure of the en echelon folds linkage zone, extend the chaotic faulting linkage zone south of the LiDAR swath to connect to the next segment of the Lenwood fault, and confirm the magnitude of the southern offset. We will also locate an additional site to collect a Tf depth profile in order to refine the age of this critical surface. A paper describing our slip rate measurement, based on the Tk surface offset, is in preparation. This paper will be submitted for publication following confirmation of the Tk offset during our planned fieldwork. Submission for publication of results of our studies of the development and reconstruction of linkage zones is planned for the summer of 2006.

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