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Characterization of Earthquake Slip Distribution on the Northern Coyote Creek Strand of the San Jacinto Fault Using LiDAR and Field Mapping

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The Coyote Creek fault (CCF) is the second longest strand of the San Jacinto Fault (SJF) Zone in southern California (Figure 1), but the size of earthquakes that typically occur along this fault is unknown. A portion of the CCF ruptured in the 1968 M6.5 Borrego Mountain earthquake, and produced a maximum displacement of about 50 cm between Borrego Mountain and the Ocotillo Badlands (Clark et al., 1972), but it is not known if this was typical for the CCF, or whether larger events also occur. In contrast, the Superstition Mountain fault (SMF), which is the southern continuation of the CCF, experienced a large

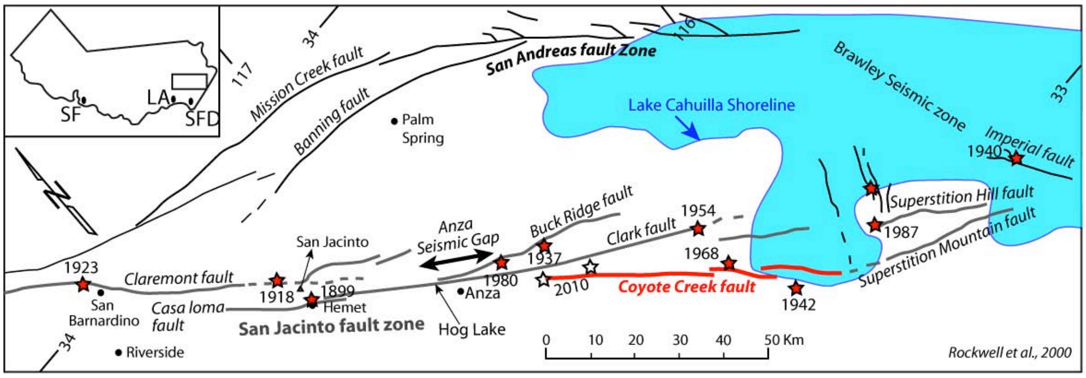

Figure 1. *Map of the central and southern San Jacinto fault zone with historical earthquakes. Note that the southern segment of the Coyote Creek fault ruptured during the 1968 M6.5 Borrego Mountain earthquake. Seismicity after the 2010 M7.3 El Mayor-Cucapah earthquake sequence, with aftershocks of M 4.9 and M5.4 along the northern CCF (open stars), suggests that the northern segment is stressed.*

earthquake in ca 1500 AD with 2-4 m of displacement (Rockwell et al., 2000; Ragona, 2003; Faneros, 2005; Verdugo et al., 2005; Verdugo, 2010). Paleoseismic work suggests that large earthquakes on the SMF may propagate onto the CCF, potentially rupturing as much as 90 km of the southern SJF (Rockwell et al., 2000). Such a signal should be represented by larger displacements (>1m) along the northern portion of the CCF where

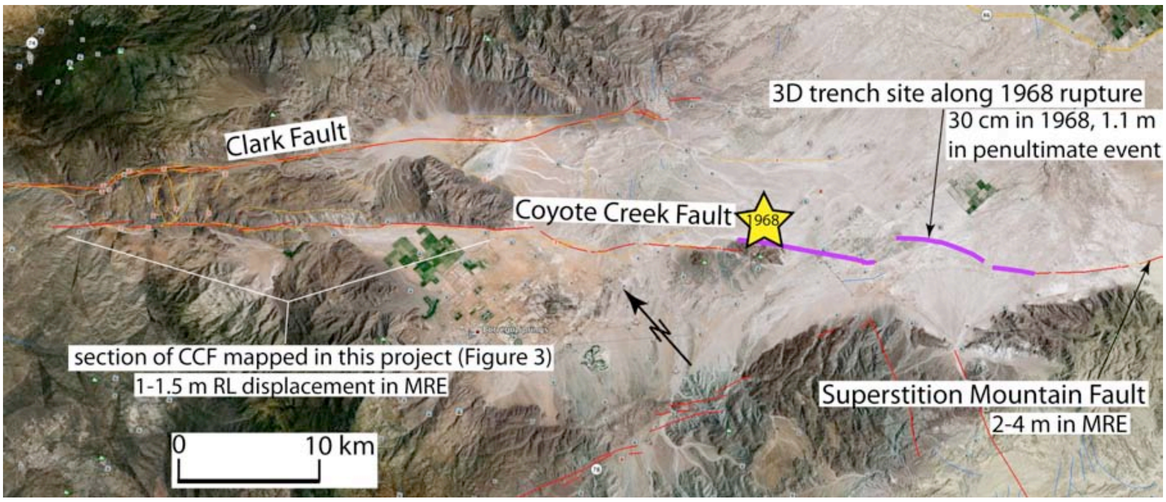

Figure 2. *Detail of mapped area on GoogleEarth base image. The slip distribution interpreted from our mapping is shown in figure 3. The results of the 3D trenching are shown in figure 4*

there is preservation of small offsets. The purpose of this project was to use LiDAR and field mapping to quantify the numerous small offsets along the northern CCF and to test whether they are likely the result of many small displacements or fewer, larger displacments.

Results

We downloaded and processed the B4 LiDAR dataset (opentopography.org) and produced 0.25 m DEMs for the northern Coyote Creek fault using ESRI software (Fig. 3). Using GoogleEarth Pro and the LiDAR shaded hillside relief maps as a base, we mapped the location of all recognizable fault strands and identified areas where small offsets are likely to be preserved. We then walked the entire Coyote Creek fault north of County Highway S22 and identified, mapped, and measured small offsets in the field.

We focused on small channel features that could be reliably measured with a steel tape measure. Larger offsets could be measured fro the LiDAR dataset, but we found that most offsets of young channel deposits (late Holocene channel bars, thalwegs, channel margins; age determined by the surface morphology and absence of a significant soil profile) were too small to identify in the LiDAR data.

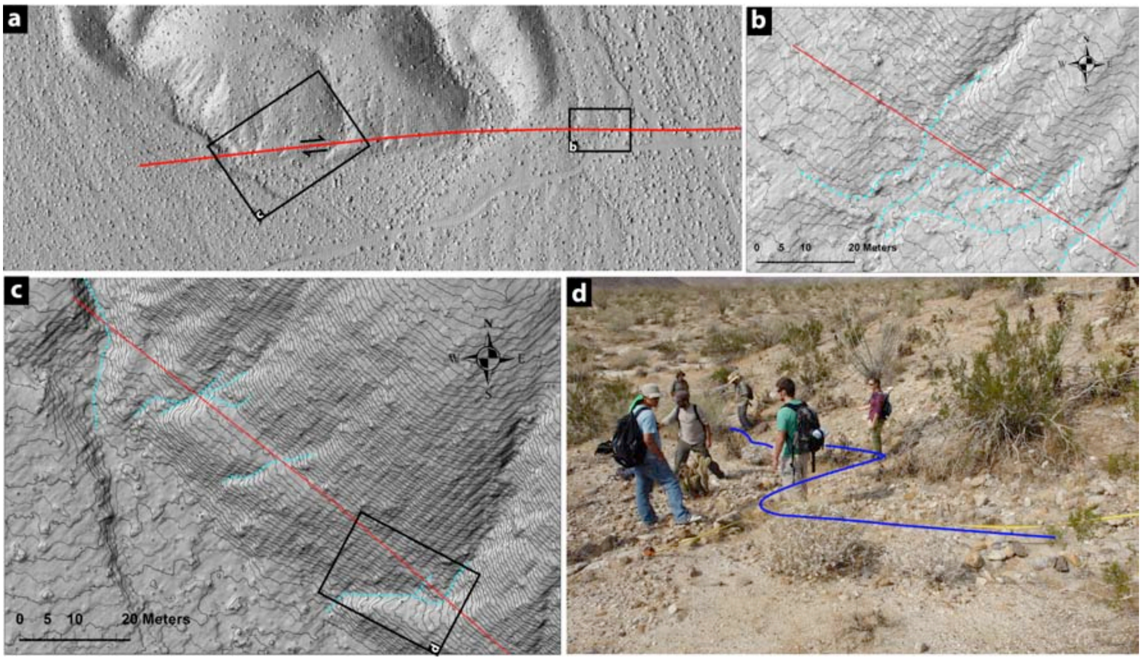

Figure 3. *a) LiDAR DEM near Desert Garden. Boxes show the location of b) and c), where several small drainages are deflected or offset. The box in c) shows the location of d), where we measured a rill offset about 90±40 cm, and a beheaded channel offset 235±50 cm. Note that displacements of 1-2 m cannot be well resolved in the LiDAR, thus requiring measurement of all displaced features in the field.*

Figure 3 shows an example of a small offset drainage along the CCF near Desert Garden. Here, slip is localized in a narrow zone and the channel thalweg is offset about 90±40 cm. Along this 150 m section of fault, the smallest offsets and deflections we measured are: 90±30 cm, 140±40 cm, 105±40, and 120±40, with a mean of about 115 cm. We also measured two offset channels at 230±40 and 235±40, which is roughly double the smaller values, so we attributed these offsets to slip in the past two events. Larger offsets of 3.9±40 and 5.0±1 m are also present along this short stretch of fault.

Similar features were mapped and measured along the northern ~30 km of the Coyote Creek fault, and each feature was ranked in terms of its clarity of expression, narrowness of the displacement zone and other qualities that affect the overall quality of the measured offset. The best offsets, that is, those that are most convincing and where the fault is very clearly expressed, are shown in Figure 4. The offsets were binned in 1 km segments and plotted as a function of the distance from the northwest end of the Coyote Creek fault near Horse Canyon (see figure 4). We interpret the smallest offsets along a stretch of the fault to represent displacement in the most recent event (MRE). If small displacements (<0.5 m as occurred in 1968 farther southeast) are typical for most earthquakes, we expected to observe a broad spectrum in the amount of offset of preserved small channels and bars, with no particular groupings or clusters. In contrast, if the northern CCF typically fails with larger displacements, we expect to see clusters of displacements along strike of the fault, similar to what we documented for the Clark strand of the San Jacinto Fault (Salisbury et al., 2012). Figure 4 shows distinct clustering of offsets, which we interpret to represent slip in past earthquakes.

We connected larger offsets that have about twice the amount of displacement as that interpreted for the MRE to reflect displacement in the past two events, and three times the MRE as representing slip in three events. Surprisingly, the amount of lateral slip appears fairly characteristic (self-similar slip distribution from event to event), at least for the past three interpreted ruptures. These observations suggest that the northern ~30 km of the Coyote Creek fault fails with displacement in the 1-1.5 m per event range. Furthermore, displacement is generally increasing to the southeast, which suggests that the rupture in these past events extended considerably farther than the 30 km that we could document north of County Highway S22.

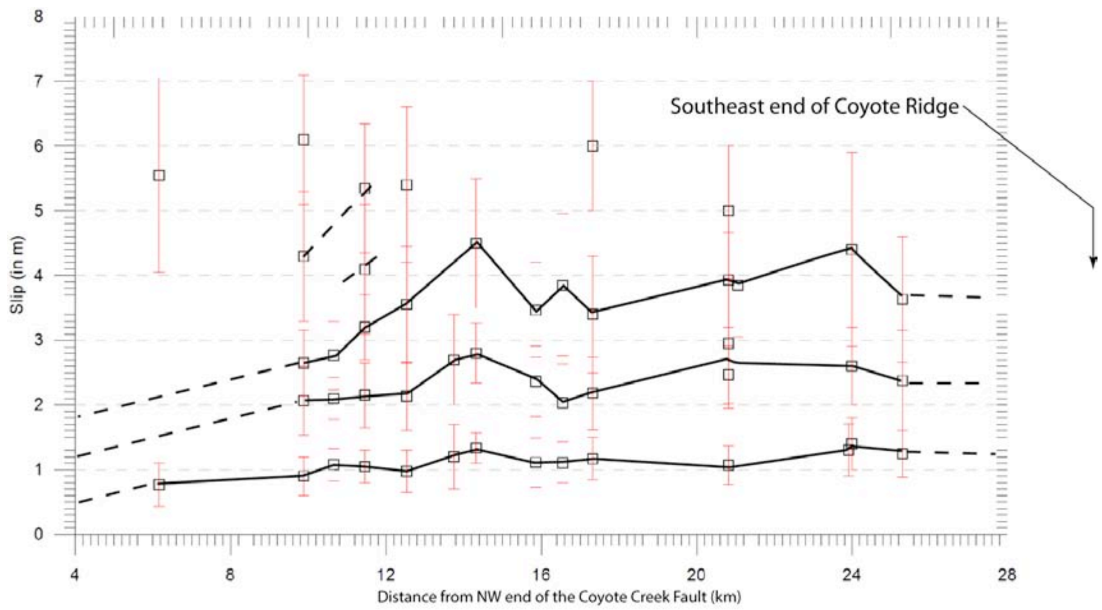

Figure 4. *Slip distribution determined from the reliable offsets (quality ranking based on narrowness of fault zone, distinctness of measured features, certainty in location of the fault) for the northern ~28 km of the Coyote Creek fault. Uncertainties indicated by the error bars. Note that offset amounts tend to cluster, suggesting rather characteristic behavior for the past several northern CCF events.*

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