3D Images of Faults Within the Crafton Hills Fault Zone From the June 16th, 2005, Yucaipa, California, Earthquake: Implications for the Geometry of the San Andreas Fault.

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Introduction

A magnitude 4.9 earthquake occurred near Yucaipa, SE of San Bernardino, on June 16th, 2005, followed by over 100 aftershocks, one of which reached magnitude 3.9 (fig. 1a). The June 16th event had an oblique thrust focal mechanism, while the largest aftershock, which occurred on June 27th, showed a left-lateral strike-slip mechanism (http://www.scsn.org/2005yucaipa.html).

Most of the aftershocks were confined to depths below 10 km. We relocated the aftershocks using the double-difference hypocenter location method of Waldhauser & Ellsworth 2000 (fig. 1b) in an attempt to define the geometry of the faults involved.

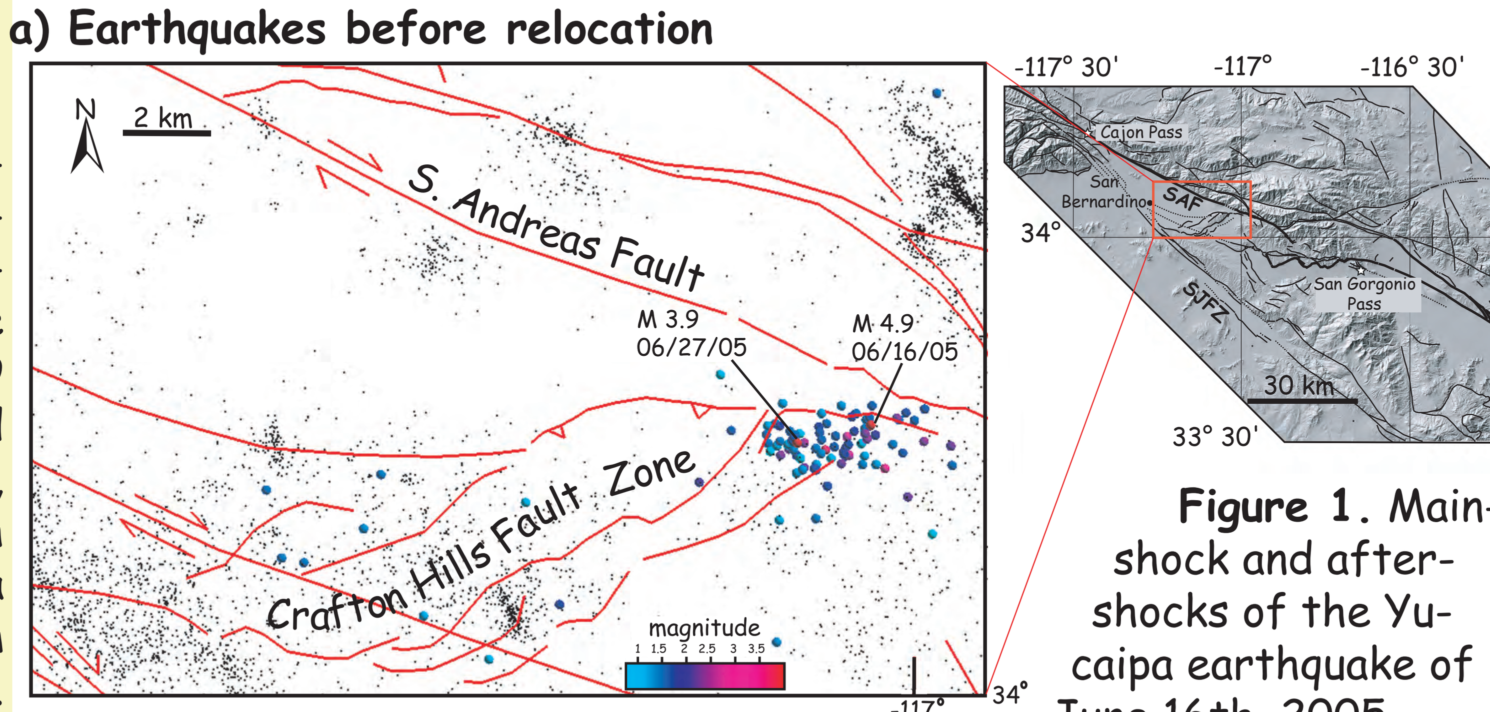
Earthquake clusters and imaged faults:

I) The Crafton Hills Fault Zone

The relocated events delineate two dense, separate clusters, one of which contains the main shock (06/16/05), the other the largest aftershock (06/27/05). These clusters outline two ENE trending, nearly vertical, sub-parallel faults about 500 m apart (fig 1b).

The up dip projection of these faults reaches the Earth's surface in the vicinity of several fault traces attributed to the Crafton Hills fault zone (fig. 2), though they do not match any mapped fault trace. Several other faults related to this fault zone can be imaged from the relocated events of Richards-Dinger & Shearer (2000) (fig. 2). Six out of a total of eight faults seem to be seismogenic only below about 10 km depth, they also all dip slightly to the NW and are located at the SE boundary of the CHFZ.

a) Earthquakes before relocation



b) After double-difference relocation

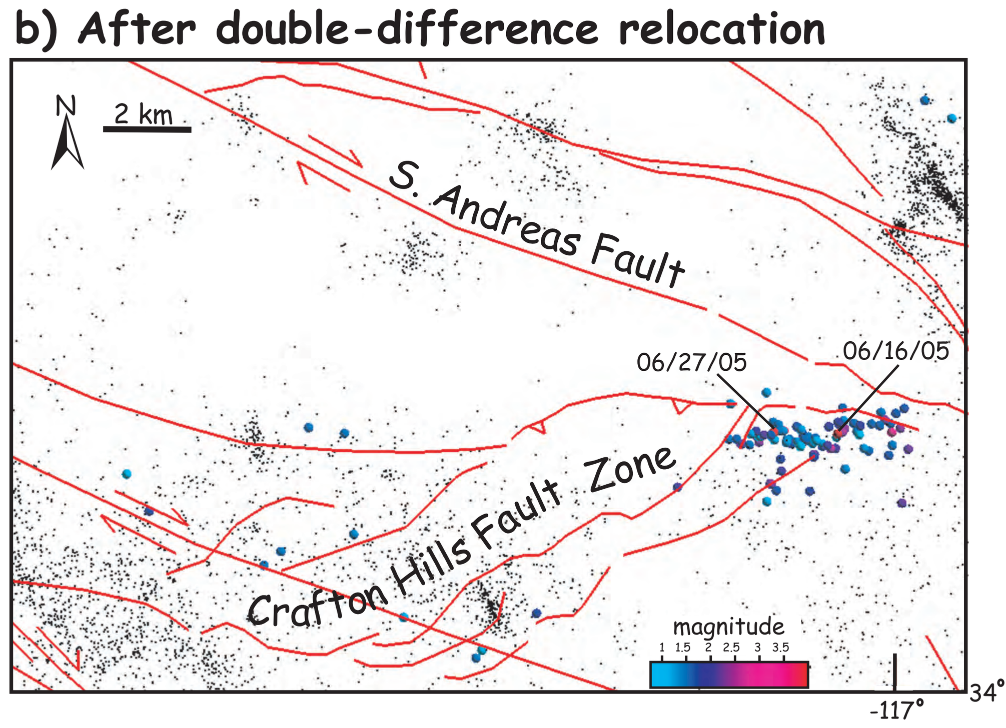
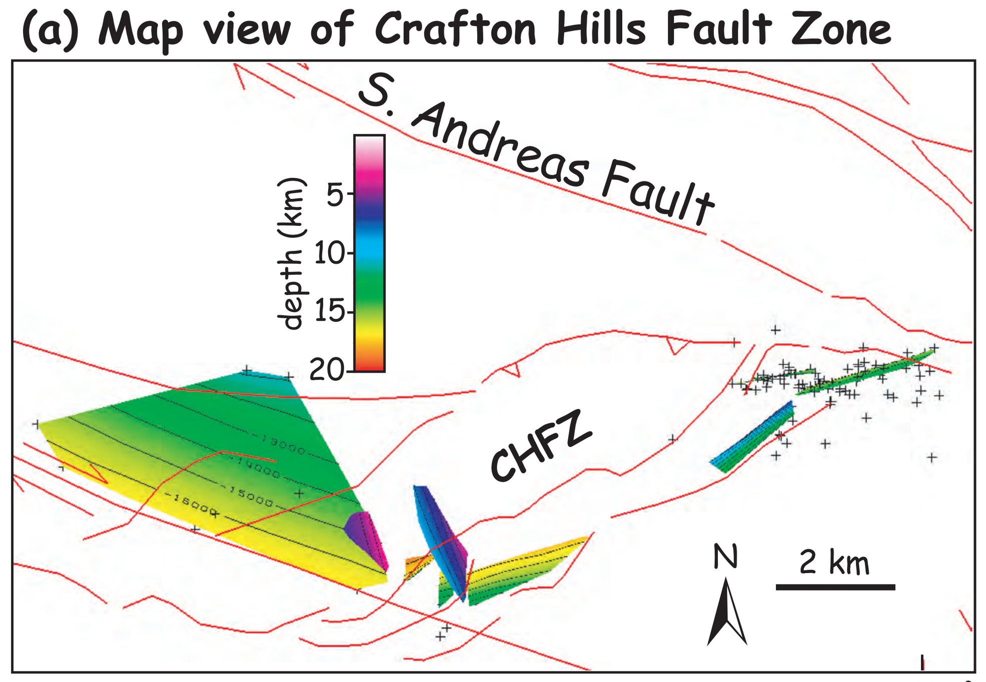


Figure 1. Mainshock and aftershocks of the Yucaipa earthquake of June 16th, 2005, before (a) and after (b) relocation using the double-difference method. Background seismicity (black dots) from Richards-Dinger and Shearer (2000). SAF = San Andreas Fault; SJFZ = San Jacinto Fault Zone.

(a) Map view of Crafton Hills Fault Zone



(b) Perpsective views

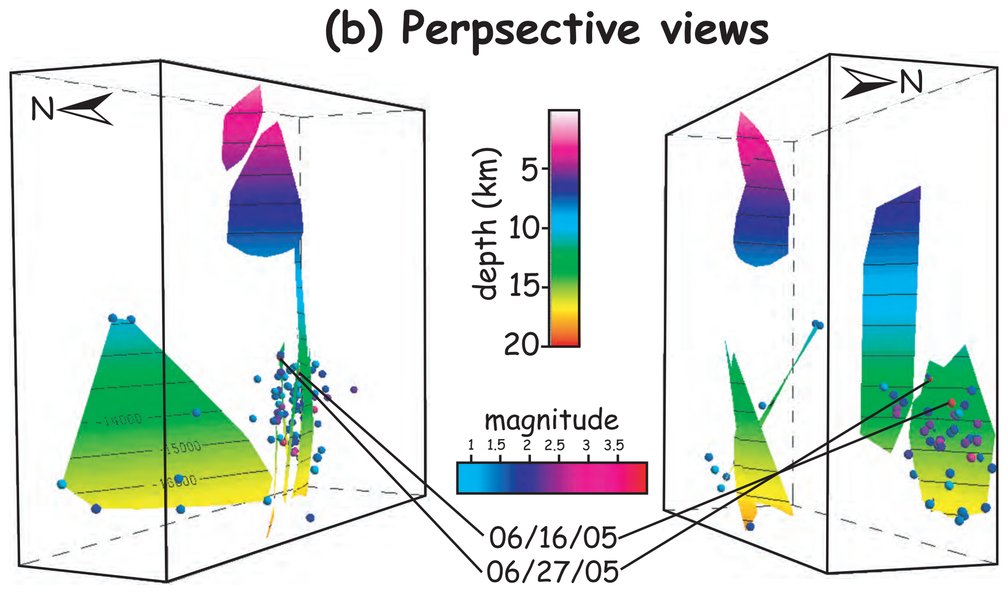


Figure 2. (a) Map view of fault surfaces in the Crafton Hills Fault Zone (CHFZ) imaged from earthquake clusters. (b) Two different perspectives of the same faults shown in (a).
The fault located in the lower left corner of the map, dipping to the SW, projects upwards to the San Andreas Fault trace. This fault was imaged from the earthquakes shown in fig. 3 (circled in purple). It can be imaged directly from eartquakes only below a depth of 10 km.

Events aligned with San Andreas trace

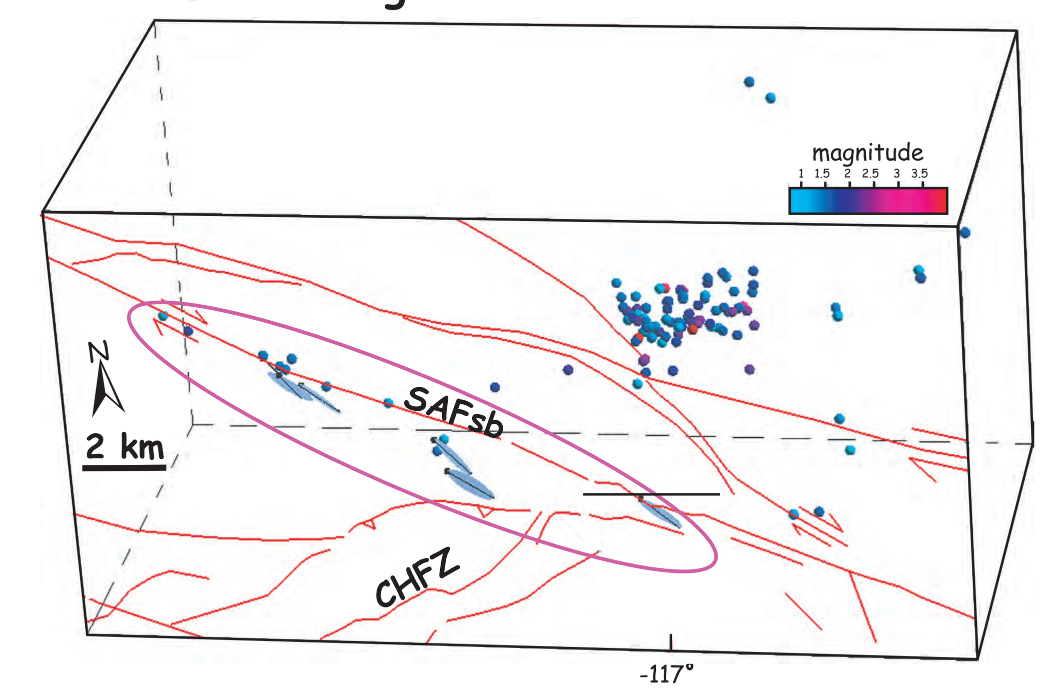


Figure 3. Perspective view of the relocated aftershocks. Circled in purple are those events that align with the surface trace of the San Bernardino strand of the San Andreas Fault (SAFsb), together with nodal planes (light blue ellipses) and slip vectors (black lines on nodal planes with dot in slip direction) of events in the vicinity that show compatible motion (from Hauksson 2000).

Imaged fault and selected nodal planes

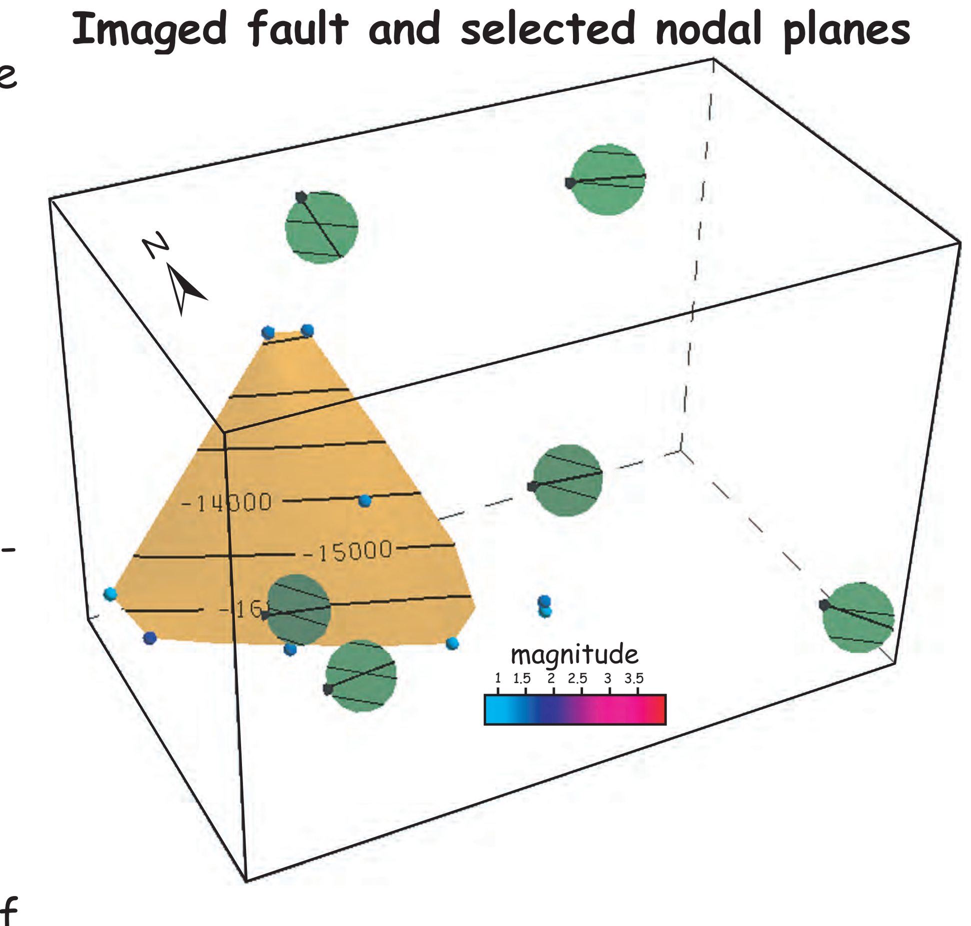
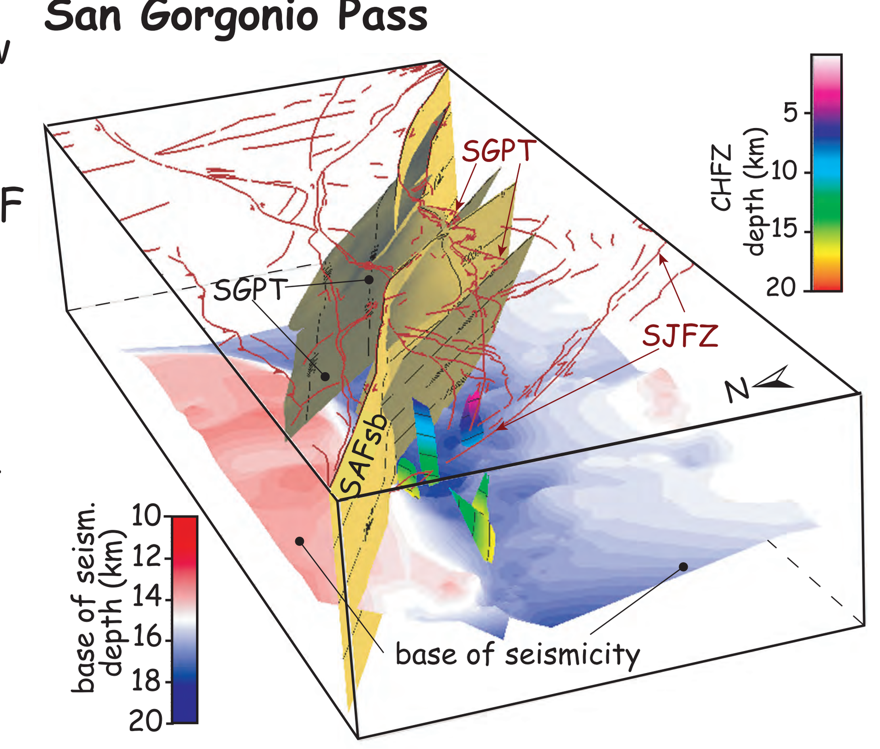


Figure 4. Perspective view, perpendicular to the fault surface itself, of the fault imaged from the events in fig. 3. Contour lines are 1000 m apart on the fault surface.
The green circles are selected nodal planes of other events (Hauksson 2000) in the vicinity. All planes dip to the SW. Contour lines on nodal planes are indicated to show the horizontal. All vectors (black line on plane with dot in the direction of motion) indicate a strong right-lateral component of motion.

3D fault model between Cajon Pass and San Gorgonio Pass



SGPT = San Gorgonio Pass Thrust; SAFsb = San Bernardino strand of San Andreas Fault; SJFZ = San Jacinto Fault Zone (red = fault traces, black = 3D surfaces).

Figure 5. The faults previously imaged (rainbow color map for depth) viewed in the context of a possible model for the SAF between Cajon Pass and San Gorgonio Pass (model from Carena et al., 2004). Faults of the CHFZ below 10 km depth stop at a vertical SAF, but a SW dipping SAF would also be geometrically compatible, as it would pass between deep and shallow faults of the CHFZ without intersecting any other fault.

II) SW-dipping fault

A third, less dense alignment of events within the aftershock cloud delineates at depth a fault with a ~60 degrees dip to the SW (fig. 2) whose up dip projection emerges very close to the trace of the San Bernardino segment of the San Andeas fault (SAFsb) (fig. 3).

The few focal mechanisms (Hauksson 2000) available for events in the vicinity of this fault are all oblique and show a right-lateral component of slip on a SW dipping plane (fig. 4). The dip-slip component is normal for some mechanisms and reverse for some others, but mostly smaller than the strike-slip component.

A regional view

In the context of the San Andreas Fault geometry between Cajon Pass and San Gorgonio Pass (Yule and Sieh, 2003; Carena et al., 2004), both a vertical and a SW dipping SAFsb are possible. In fact, faults of the CHFZ below 10 km depth stop exactly where a vertical SAF would be. A SW dipping SAFsb would also be geometrically compatible, as it would pass between deep and shallow faults of the CHFZ. However, a vertical SAFsb is easier to connect to the other faults through San Gorgonio Pass. Further data is therefore needed to constrain the geometry of the San Bernardino segment of the San Andreas Fault.

References

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Hauksson, E., 2000 - JGR 105, 13,875-13,903.
Richards-Dinger, K., and P.M. Shearer, 2000 - JGR, 105 (5), 10939-10960.
Waldhauser, F., and W.L. Ellsworth, 2000 - BSSA, 90 (6), 1353-1368.
Yule D. and K. Sieh, 2003 - JGR, 108 (B11), 2548, doi:10.1029/2001JB000451.