3-D Mapping of Active Faults in Southern California: Eastern Ventura Basin and San Gorgonio Pass—San Bernardino Regions.

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Investigations

We used the catalog of 43,500 relocated 1975-1998 earthquakes of Richards-Dinger and Shearer (2000). A clustering algorithm was applied to the relocated earthquakes in order to obtain tighter earthquake clouds and thus better-defined fault surfaces (fig. 1a). The earthquakes were then imported into Gocad, a 3D modeling software that allowed us to separate earthquakes into coplanar clusters associated with different faults and fault strands and to fit optimized surfaces to them (figs. 1b, 2a). We also used the catalog of 13,000 focal mechanisms of Hauksson (2000) to confirm the nature of the mapped faults. The focal mechanisms were imported into Gocad as 3D objects (fig. 2b). The comparison between earthquake hypocenter distribution and focal mechanisms in 3D allowed us to [1] distinguish between principal and auxiliary nodal planes, [2] identify and map faults which have only a few events associated with them, [3] determine the slip direction on most faults.

Results

So far we have mapped 70 faults and fault segments (figs. 1b, 2a). A comparison between modeled fault surface and selected nodal planes is shown in fig. 3. Here the fault plane is modeled from the aftershocks of the Palm Springs earthquake.
Examples of our results are as follows: [1] The major San Jacinto strike-slip fault is offset by an east-dipping thrust fault near Anza at a depth of 11-15 km (figs. 4-6). [2] We do not see any clear seismic illumination of an active through-going San Andreas fault at depth in the San Gorgonio Pass area, but we can place several constraints on its possible location and geometry on the basis of the 3-D geometry and distribution of other faults. Between 5 and 20 km depth, this area is dominated by closely spaced faults trending SE-NW, which in map view occupy a triangle delimited by the Mission Creek fault to the N, the San Jacinto fault zone to the W, and the San Jacinto Mountains to the S (figs. 1b, 2). To the E, some of these faults terminate northward against an E-W trending fault. These faults do not show any sign of having been displaced by an intersecting fault. At the latitude of San Bernardino, there is a stretch of about 35

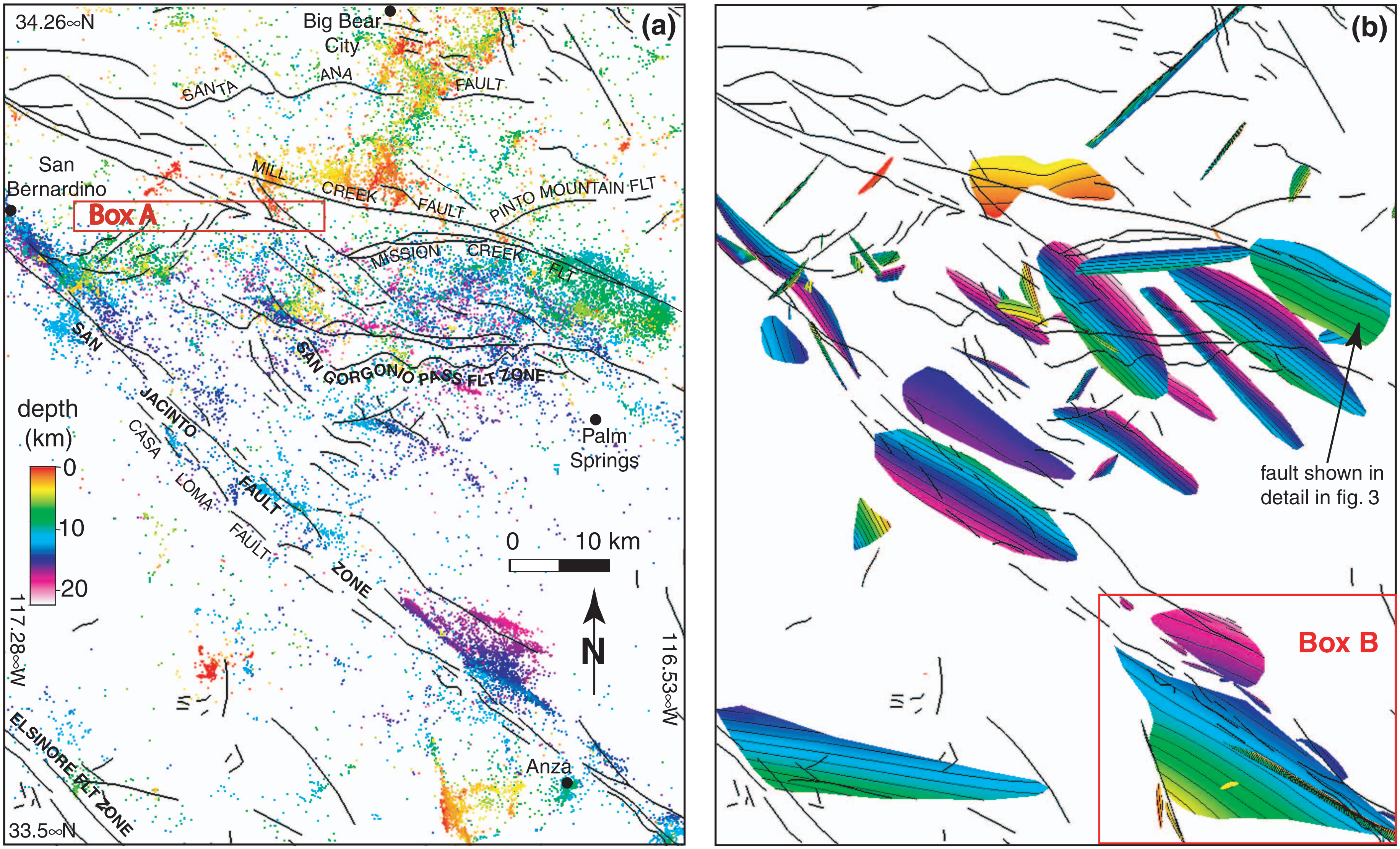

Figure 1. San Bernardino-San Gorgonio Pass area. Map showing 43,400 events recorded between 1975 and 1998 (Richards-Dinger and Shearer, 2000) after clustering (a). Map of the 70 fault surfaces we have modeled so far (b); horizontal and vertical scales are the same as in (a).

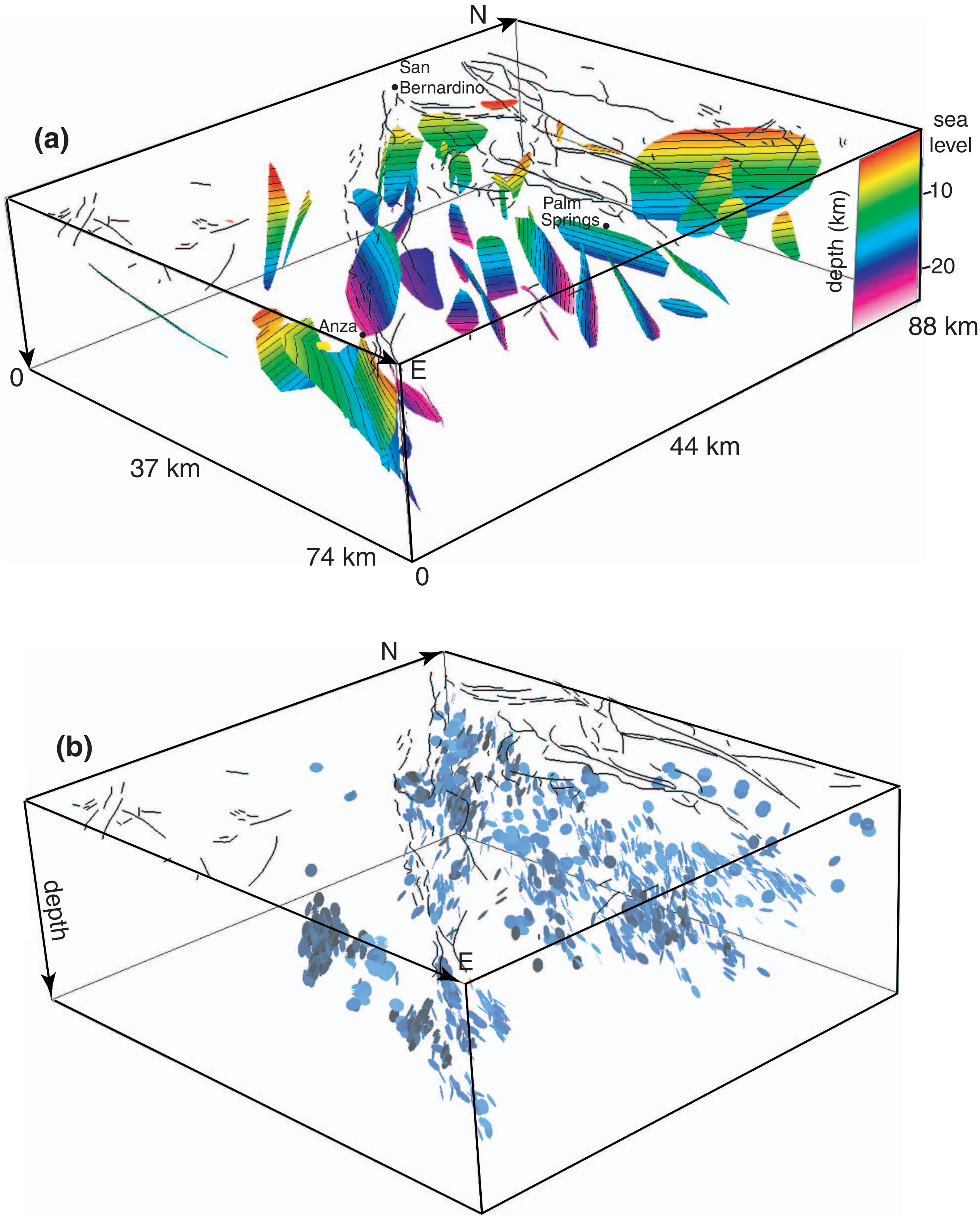

Figure 2. Perspective view of the faults shown in fig. 1b (a), and same view of the 1539 nodal planes we have been able to select so far (b).

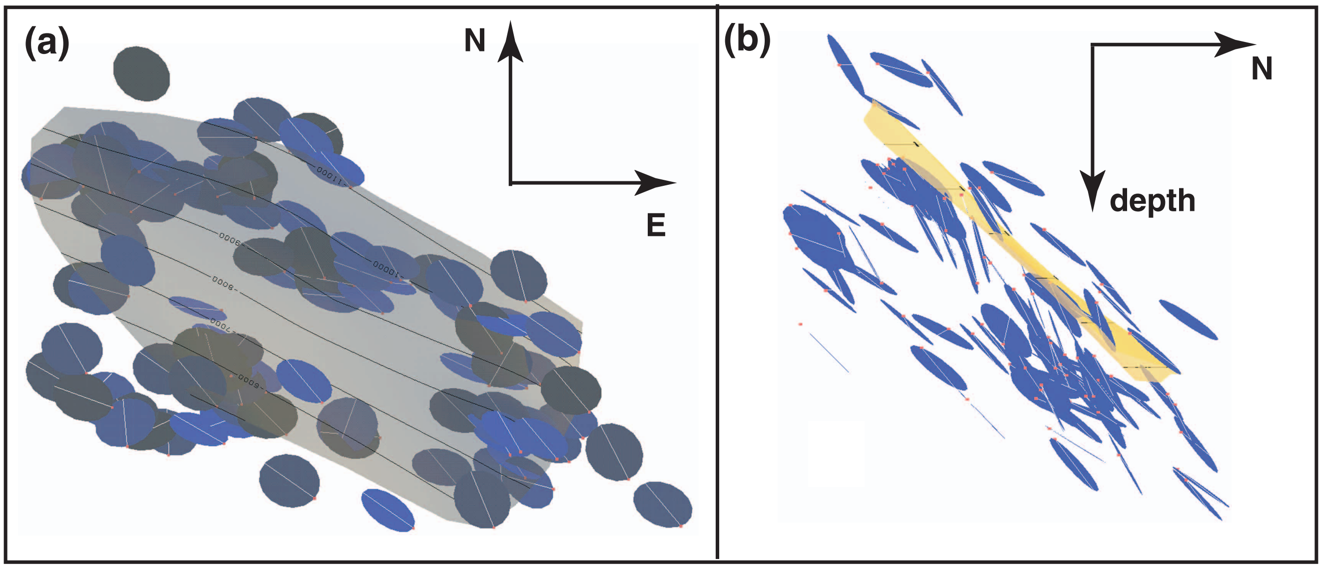

Figure 3. Map view of a modeled fault and its associated nodal planes (a), and view parallel to strike of the same (b). The location of this fault is marked on fig. 1b. The fault has an oblique slip with right-lateral and reverse components. If this fault were to be extended (with constant dip) to the topographic surface, it would intersect the latter just on the south-eastern side of the San Gorgonio Pass fault zone.

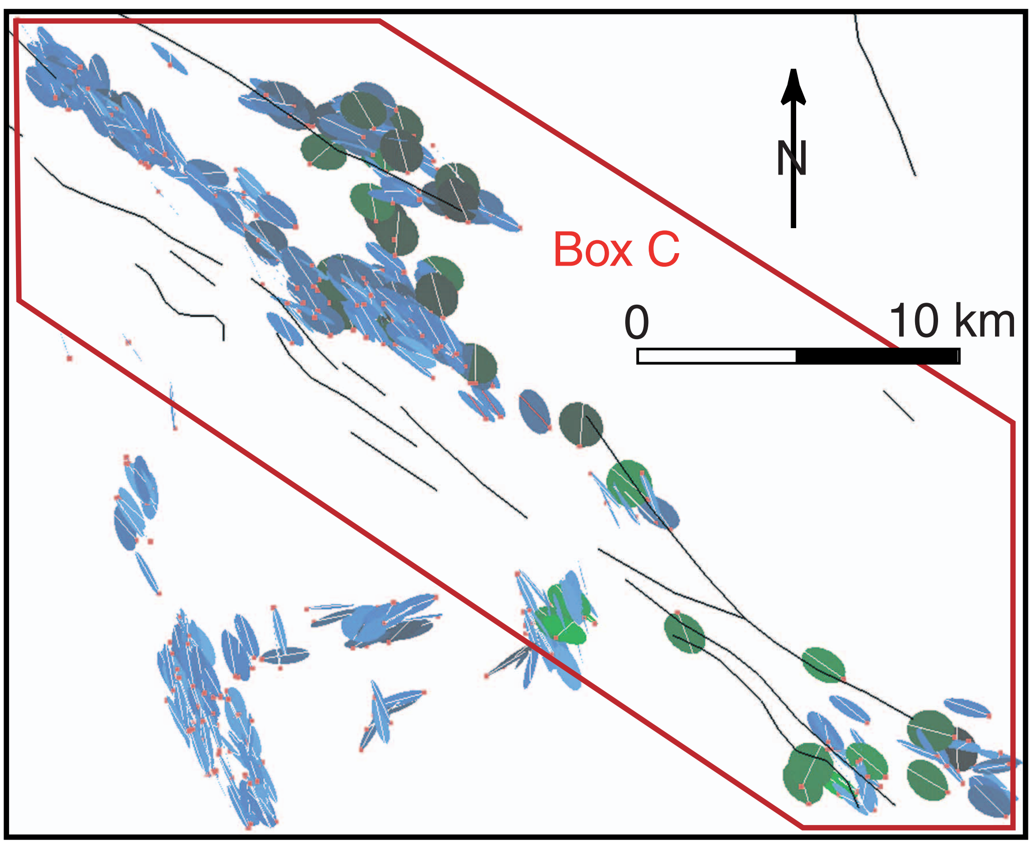

Figure 4. Map view of the selected nodal planes and slip vectors in box B, fig. 1b. All planes have a default diameter of 1600 m. Most planes shown here dip toward the NE. The sense of slip of the hanging block is indicated by the red dot at the end of the slip vector. Planes in blue represent high-angle faults, mostly right-lateral strike-slip. The green planes represent 2 faults (A and B in figs. 5 and 6) with a 40-45 degrees dip and mostly reverse oblique slip with strong right-lateral component.

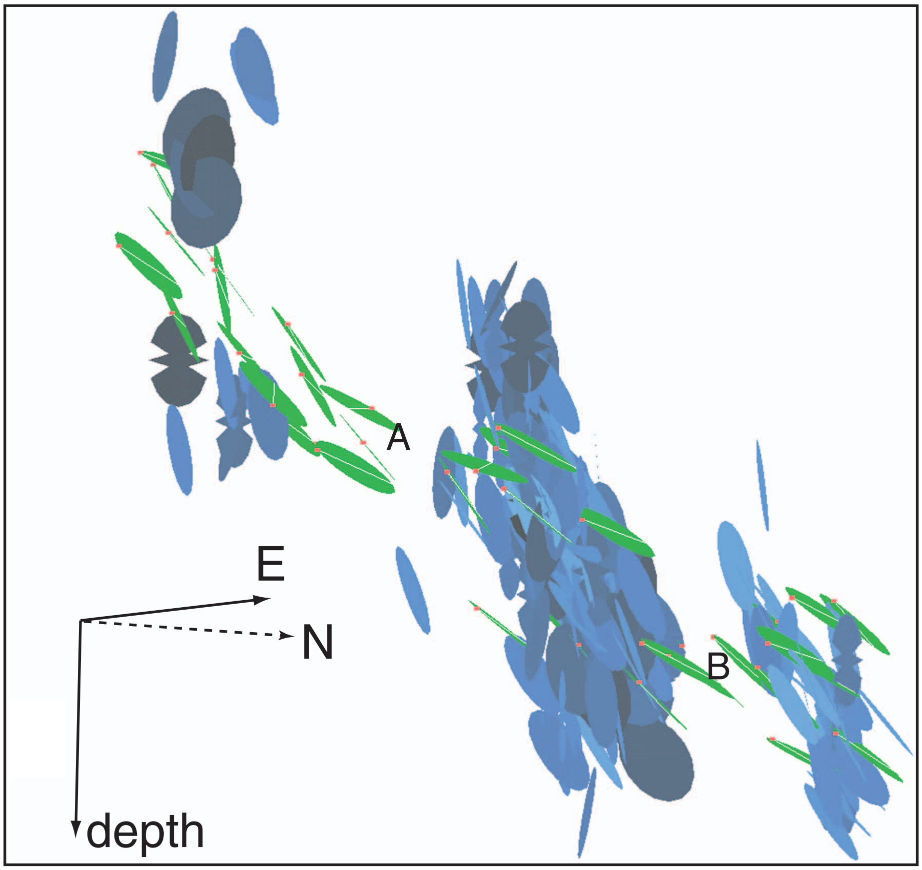

Figure 5. View parallel to strike of the nodal planes in box C, fig. 4. The view angle is approximately the same as fig. 6. For clarity, only the slip vectors of the shallow-dipping planes (A and B) are shown.

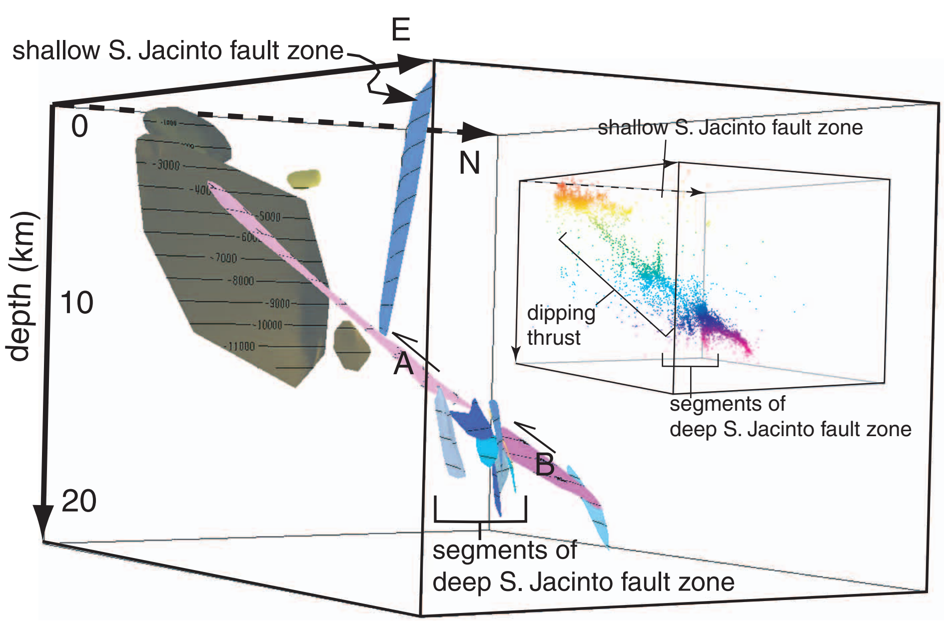

Figure 6. Close-up perspective view of the area in box B, Fig. 1b, showing both 3-D fault models and the seismicity used to obtain them (smaller cube). It shows the displacement of part of the San Jacinto Fault Zone due to the presence of a thrust fault. Faults A and B correspond to A and B faults in fig. 5.

km E-W where there are 7 nearly-vertical nodal planes with an E-W average trend (location in fig. 1, box 1A). Five of these are nearly pure strike-slip, although only three are right-lateral. The other two are mainly reverse, with a small left-lateral component. We could not find similarly oriented nodal planes further to the east.

Some of the faults we imaged have a surface area comparable to the size of the rupture on the Northridge thrust. In fact, 6 of the faults imaged so far have a surface area between 200 and 300 km^2. Thus, besides the San Andreas, other faults capable of producing damaging earthquakes exist here.

Non-technical Summary

We imaged and mapped in 3-D 70 active faults in the San Gorgonio Pass region using earthquake locations and focal mechanisms. The majority of these faults are previously unknown or unnamed. The 3-D fault maps better define the active structure of this complex region marked by profound uncertainties over the fundamental structural framework, including the subsurface continuity and geometry of the first-order San Andreas and San Jacinto faults, as well as the existence and role of major blind faults, some of which are as large as the rupture area of the Northridge earthquake.

Reports published

Carena S., and Suppe J., 3-D Imaging of Active Structures Using Earthquake Aftershocks: the Northridge Thrust, California. *J. Struct. Geol.*, in press.

Data availability

The original earthquake hypocenter locations and focal mechanisms are available from the Southern California Earthquake Center database (http://www.scecdc.scec.org/catalogs.html). ASCII files of the clustered locations and all the Gocad files (earthquake hypocenters, focal mechanisms, and fault surfaces) are available from Sara Carena (scarena@princeton.edu).