The south-central San Andreas Fault system: a natural laboratory for Earthscope

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Introduction

At a global scale, the San Andreas Fault (SAF) system has been a narrow boundary along which steady shearing has occurred between the North American and Pacific plates for at least 5 Myr. However, when one looks closer, the deformation varies in space and time within the one hundred to several hundred km wide shear zone. Such variation is a manifestation of the geometric and mechanical development of the structures (faults, folds, and distributed rock fabrics) and rocks within the shear zone including exacerbation and smoothing of fault bends and steps and fault strength and lithospheric rheologic variation. The distribution of this deformation over the Quaternary and Holocene time scales in particular and over the spatial extent of the shear zone in south-central California (Figures 1 and 2) can provide an important focus for EARTHSCOPE research. The geometry of the major faults and lithospheric blocks can be an emphasis of USARRAY, the motions along the faults and of the blocks a focus of PBO and INSAR, and the mechanics of deformation along the San Andreas Fault surface and surroundings is the target of SAFOD.

Problems: geometry, motions, and mechanics of fault systems

The geology of central California (e.g., Figure 1) records events largely associated with the Mesozoic convergent margin and overprinted by Cenozoic tectonics associated with the SAF (e.g., Page, 1981). This record is well preserved and studied, but questions remain with regard to the geometric significance of Mesozoic and early Tertiary structures and blocks for subsequent structural development and to the geometric relationship between the major thrust and strike-slip faults (e.g., Namson and Davis, 1988). To unravel the mechanisms of the interactions between these major crustal structures, we must know the motions of the blocks which they bound over time scales varying from the integrated view of the Quaternary geology to the much shorter geodetic and seismologic timescales (Figures 1 and 2). In addition, these structures may represent earthquake hazards; thus studies of them have an applied component. Finally, the mechanics of faulting along major faults such as the SAF are well studied in this area (SAFOD will be located in the extreme northwest end of the area shown in Figure 2). An integrated geologic, geomorphic, and geophysical study of not only the partially creeping and partially locked Parkfield segment but the entire range of the south-central SAF and the adjacent structures—which may be significantly different from a strength standpoint—will provide a valuable natural laboratory in which we can work to improve our knowledge of the geometry, kinematics, and mechanics of fault systems.
Preliminary research plan

In order to address the research problems identified above, I suggest the following research plan for further thematic development:

USARRAY—Hierarchical approach to imaging lithospheric and crustal structure with increasing resolution applied to strike-slip and thrust structures in both complex and simple geometric settings. Improve velocity model and network sensitivity for seismicity studies (note variations shown in Figure 2).

PBO/INSAR—Improve density of geodetic monitoring in order to identify variations in deeper/broader loading rates and enhance imaging of fault slip in the northwestern transition zone (Parkfield) and along the base of the brittle portion of major faults.

SAFOD—Borehole investigations as planned, but include geologic, geomorphic, and geophysical studies as identified below and above to improve framework understanding.

The three major components of EARTHSCOPE identified above must be supplemented by geologic/geomorphic studies and a digital data infrastructure:

GEOLGY—Geological information must be available and well understood for the interpretation of EARTHSCOPE data. In addition, some questions require information about the activity of structures over time scales longer than that of the geodesy and seismology. Those data can come from tectonic geomorphology studies of the landscape responses to active deformation (e.g., Figure 2 topography). Quaternary geologic timing constraints on activation and cessation of motion along certain structures (includes stratigraphic and geochronologic information), and earthquake geologic characterization of the timing, extent, and magnitude ranges of pre-instrumental earthquakes along the major structures of the fault system.

GEOINFORMATICS—Along with the large quantities of data to be collected by EARTHSCOPE and related activities, major but so far poorly associated geospatial datasets such as imagery, digital topography, geophysical observations and models, and geologic map data should be gathered and integrated so that all researchers can easily interact with relevant data. Metadata (data about the data) should be maintained for the databases. Establishment of such a data system will be valuable, but also very expensive and will require coordination among various related groups (e.g., http://www.geoinformaticsnetwork.org/).

References


Figure 1. A) Areas of contrasting behavior along the San Andreas Fault (SAF; modified from Allen, 1968). One of the first order features of the active SAF system is the contrast between seismically quiet and active areas (which include active fault creep in central and southern California). B) The south-central SAF is a zone of transition from fully creeping (to the north off the map) and fully locked (Carrizo Plain area in the center of the figure). In addition, this area is notable for evidence of SAF-normal maximum horizontal compression (e.g., Zoback, et al., 1987) and active thrust faulting and folding adjacent to the SAF. This region represents a prime location to study the geometry, the motions, and the mechanics of the SAF and its surrounding crustal environment. See also figure 2 for the optimal extent of the study area. The map is a portion of the California State Geologic Map (modified from Jennings, et al., 1977). Dallas Rhodes helped generate this figure.
Figure 2. Seismicity and topography along the south-central San Andreas Fault system of California. The only major historic rupture along the San Andreas Fault here was the great 1857 earthquake (Sieh, 1978). Numerous moderate Parkfield earthquakes have ruptured the northwestern portion of the SAF shown in this figure, and an expected repetition of a Parkfield earthquake may be captured during EARTHSCOPE operations. Such an event may also rupture or trigger an event further southeast along the Cholame segment. Seismicity in central California is concentrated along the southeastern portion of the Parkfield segment in the northwest and the southern Great Valley (events associated with the M7.7 1952 Kern County earthquake) in the southeast. The topography and Quaternary geology (see Figure 1) indicate active deformation not only along the SAF but also in the adjacent ranges and basins. The red line is the trace of the San Andreas fault. Segmentation along the SAF is indicated by white lines separating the Parkfield, Cholame, and Carrizo segments. The transition to the Mojave segment occurs in the southeasternmost portion of the figure. Abbreviations used in the figure: GV, Great Valley; TR, Temblor Range; CP, Carrizo Plain; CR, Caliente Range; and SM, Sierra Madre Mountains. Seismicity data come from the CNSS Worldwide Earthquake Catalog and the topography is from the USGS 1:250,000 scale DEMs. The topographic data were preliminarily processed by George Hilley. I plotted this figure using GMT (Wessel and Smith, 1995).