Investigation of Slip Localization in Large-Displacement Faults for Application to Laboratory Fault Modeling

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Investigation

Models which seek to explain the state of stress and the mechanics of slip on the San Andreas Fault are based on assumptions about stress conditions in the fault, pore fluid pressures and sources, thickness of the fault zone, and physical properties of the brecciated layer such as fracture density, grain size distribution and permeability. Although realistic fault models require such detailed knowledge of the mechanical properties of the material within the zone, many of these assumptions are not verified through direct or geophysical observations. Moreover, extrapolation of laboratory friction data to natural faults requires a thorough understanding of strain accommodating mechanisms in fault zones which at present is limited. Therefore, we have begun a structural study of deformation across the width of the San Andreas and San Gabriel faults in order to characterize fault zone morphology, mineralogic alteration, and the distribution and range of grain size structures. Samples are being analyzed using optical, scanning and backscattered electron microscopy and x-ray diffraction. Particle size distribution, texture, and petrofabric of localized shear features will be documented and related to the overall structure of the fault. We will use this information to improve mechanical models of seismogenic faults.

Results

We have completed collection of a suite of samples from across the width of the North Branch of the San Gabriel Fault. The San Gabriel Fault is an ancient trace of the San Andreas Fault and is considered an analogue of the modern San Andreas at depth (Anderson et al., 1983). We chose exposures of the faults at Devils Canyon and Bear Creek as our initial sample sites. On the north side of the fault at Devils Canyon is a Precambrian gneiss while the south side of the fault consist of a granodiorite and amphibolite dike complex. One of the principal surfaces of the North Branch at this locality is well-defined by the juxtaposition of the two rock units along a continuous layer of ultracataclasite. The samples from this locality were examined using X-RD, optical and scanning electron microscopy and the following preliminary observations can be made.

These results will be presented at the Spring session of the American Geophysical Union (Biegel et al., 1991).

1. At a distance of 63 meters from the core of the fault, the amphibolite host consist of almost equal amounts of pyroxene and amphibole with small amounts of epidote and clay. The pyroxene/amphibole grains are highly fractured along cleavage planes which have been chemically altered and weakened. The granodiorite host rock consist of nearly equal amounts of quartz and plagioclase (many times partially altered to clay), with large numbers of intragranular and transgranular cracks. Many of the plagioclase grains contain quartz inclusions. These observations suggest that the damage zone of the fault at depth extends at least to this distance from the fault surface.

2. At a distance of 10 meters from the fault core, the granodiorite has undergone a high degree of localized grain size reduction and possesses a cataclastic fabric. Grain size reduction occurred mainly in anastomosing bands within plagioclase grains. Dense networks of extension and shear fractures in plagioclase occur along chemically altered cleavage planes. The fluids necessary to alter the plagioclase seem to reach the grains along pre-existing fractures. This grain size reduction mechanism operates in addition to the tensile failure mechanism due to loading of the grains in compression at the poles observed in both simulated and natural fault gouge by Sammis et al. (1987), Biegel et al. (1989). The amphibolite is completely crushed and largely altered to clays

3. At a distance of 2.7 m from the fault the granodiorite is highly comminuted and contains clay alteration products. X-ray diffraction analysis has confirmed the presence of smectite and illite. The grain size distribution in this sample ranges from a diameter of approx. 1 mm down to the submicron scale. The larger grains contain high numbers of intragranular cracks, while the smallest grains appear to lack any significant crack population.

4. Samples from the ultracataclasite zone are composed almost entirely of clay (illite, montmorillinite) and zeolite (laumotite) alteration products. The presence of folded, broken and comminuted veins and the preferred orientation of clay within the ultracataclasite suggests that alteration of feldspars to laumontite and clays occurred primarily at depth during displacement on the fault. The only porphyroclast observed within the ultracataclasite are quartz particles less than ~50 microns diam.

5. We conclude that the mechanisms leading to fault rock structure are primarily cataclastic particle size reduction in the damaged zone with a transition to mineralogic alteration of the finest particles within the core of the fault. Both mineralogic alteration and slip appear to be extremely localized in the zone.

References

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