Influence of phyllosilicate mineral assemblages, fabrics, and fluids on the behavior of the Punchbowl fault, southern California

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[1] The Punchbowl fault is an ancient segment of the San Andreas System that was active between 1 and 4 Ma and exhumed from a depth of 2–4 km, thereby providing the opportunity to study processes along the top of the seismogenic zone of today's San Andreas fault. X-ray diffraction, X-ray texture goniometry, and scanning and transmission electron microscopy data characterize the detailed microstructural and chemical changes that occurred along the Punchbowl fault and address the importance of mineral transformations, rock fabric, and fluid activity on the hydromechanical behavior of the fault zone. On the basis of bulk and clay fraction X-ray analyses, the fault rocks have mineral assemblages that are distinct from the protolith, indicating that mineral reactions have occurred. However, microstructural observations show that many of the changes in mineral assemblages occurred after the cessation of faulting. Moreover, measures of phyllosilicate fabrics across the Punchbowl fault from X-ray goniometry are uniformly weak, and so phyllosilicate-induced permeability anisotropy in the zone was small. This absence of fabrics limits the effectiveness of fluid focusing along the fault, although some anisotropy may have been imparted by compartmentalization of the fault zone by occasional clay shears. Together these observations indicate that neither clay growth nor fabric-imposed fluid focusing appeared to have played a significant role during strike-slip faulting and cataclasite formation, which suggests that fault-weakening mechanisms that rely on clay growth and elevated fluid pressure cannot be applied to the Punchbowl fault. *INDEX TERMS:* 3625 Mineralogy and Petrology: Descriptive mineralogy; 8159 Tectonophysics: Rheology—crust and lithosphere; 8030 Structural Geology: Microstructures; 7209 Seismology: Earthquake dynamics and mechanics; *KEYWORDS:* San Andreas fault system, Punchbowl fault, phyllosilicates, fault behavior, overprinting

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1. Introduction

[2] The Punchbowl fault, located on the northeastern side of the San Gabriel Mountains in southern California (Figure 1), was an active strand of the San Andreas system from 1 to 4 Ma. The fault accommodated ~40 km of right-lateral displacement [*Dibblee*, 1987] and was exhumed from a loosely constrained depth of 2–4 km, based on the thickness of the stratigraphic sequence overlying the faulted Punchbowl formation [*Chester and Logan*, 1986; *Dibblee*, 1968]. The Punchbowl fault also accommodated some amount of dip slip associated with the uplift of the San Gabriel Mountains as indicated by fault-related folds in the Tertiary Punchbowl Formation adjacent to the fault [*Dibblee*, 1987]. As such it provides the opportunity to study rocks that were involved in faulting at depth, and may serve as an analog for the modern San Andreas fault at shallow depths (above 4 km). Assuming a geothermal gradient of 30°C/km (similar to the value reported for the Cajon Pass borehole by *Lachenbruch and Sass* [1988]) and a bulk density of 2400 kg/m^3 (the value used by *Vincent and Ehlig* [1988] for Cajon Pass) the temperature was between 60 and 120°C, and the lithostatic pressure was ~45–95 MPa (0.45–0.95 kbar). The protolith in the study area is composed of Precambrian gneissic rocks and Mesozoic intrusives to the southwest of the fault and Tertiary sandstones and conglomerates (The Punchbowl and San Francisquito Formations) to the northeast (Figures 1 and 2).

[3] Similar to previous studies in the region, the fault zone at this location consists of ultracataclasite bound by less intensely deformed cataclasite. The Precambrian and Mesozoic protolith grades into an ~0.5-m-thick zone of green rock with cataclasite bands and a foliation that

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