Micro-mechanical processes from the San Andreas Fault Observatory at Depth (SAFOD) Phase 3 cores

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Microstructural development in core retrieved from SAFOD Phase 3 drilling has been examined in three locations utilizing light, scanning electron (SEM), and transmission electron microscopy (TEM): (1) within the Salinian terrane near its contact with the presumed Great Valley sequence (Hole E-Run 1-Section 4 and 6); (2) proximal to the Southwest Deformation Zone (SDZ) with which are associated casing deformation and seismic aftershocks indicative of active faulting (Hole G-Run-1-Section 2 and Hole G-Run 2-Section 3); and (3) within the Central Deformation Zone (CDZ) in the centre of the damage zone identified in Phase 2 drilling (Hole G-Run 4-Section 2). The sampling locations translate to an across-strike distance from outside the damage zone to its centre of approximately 125 m, and a change in current measured depth from 2610 m to 2685 m. Common to all cores are: (1) a significant fractional volume (<1 um) of very fine-grained material, both primary grains and tectonized particles; (2) evidence of extensive fluid flux in the form of stress-induced dissolution seams (pressure solution), grain precipitation, and veining; and (3) complex, non-systematically varying phyllosilicate intergrowths (illite, muscovite, phengite, and chlorite).

The Salinian terrane material (E14 and E16) comprises coarse-grained quartz and perthitic feldspar clasts that locally form slightly foliated cataclasite. The matrix is commonly chloritic with very fine-grained aggregates and zones of quartz and/or feldspar. Microbrecciation is ubiquitous. There are both fluid-corroded clasts, particularly of quartz, and globular infillings of calcite with sutured contacts. Quartz and feldspar grains are coated by chlorite. Amorphous silica and secondary Ti-Fe oxides occur within cataclasite. Foliated siltstone-shale cataclasites (G12 and G23) at the edge of the damage zone close to the SDZ exhibit brecciation and cataclasis at different scales. Deformation is episodic as there are distinct overprinting relationships. The fine-grained matrix exhibits a strong SPO of phyllosilicates and cryptocrystalline quartz (<5 mm). The quartz is introduced as fine stringer veins that are progressively incorporated into the overall fabric. Similar thin calcite veins form parallel to the cataclastic foliation, suggestive of fault parallel hydraulic fracture. Coarser grained phyllosilicate zones develop C-S type fabrics with dextral displacement sense. Deformation bands can exhibit well-rounded clasts separated by thin foliae of a pressure solution foliation. Sheared siltstone/sandstone (G42) from within the central portion of the damage zone, approximately 7 m across strike from the CDZ, exhibit extensive evidence of fluid-rock interaction. Grains commonly have overgrowths, and there are well-developed pressure solution foliae. Quartz grains commonly 'float' in a calcite matrix. The fine-grained matrix itself has a strong foliation. The most unique feature is the occurrence of calcite veins at a high angle to the tectonic foliation. Collectively, microstructures indicate repeated cycles of cataclasis, with rapid strength recovery (interseismic?) by fluid-enhanced healing with significant aseismic strain accumulation.

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