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Do swelling clays influence the behavior of the San Andreas Fault? New results from the San Andreas Fault Observatory at Depth (SAFOD) drill hole

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Swelling clays are considered to be common in shallow fault rocks, but their properties and the role these minerals play in influencing the mechanical and hydrological behavior of active fault systems remain a subject of debate. Based on new mineralogical (XRD, TEM) and chemical (ICP-OES) analytical data, hydrated clays in faulted, clay-rich rock samples of the SAFOD mud-rocks were studied for their mineralogic characteristics, mass transfer, hydration behavior, and fabric and textural relationships. Several clay mineral phases are present in the matrix and on fracture surfaces at 3064 and 3436 m depths, which is a segment of recent creep and faulting, containing detrital grains of chlorite and biotite, along with a range of authigenic illite, illite-smectite, chlorite, chlorite-smectite and smectite phases. The dominant authigenic clay minerals in the rock chips are illite and chlorite. The illite, 20-30 nm in thickness, is mainly of a $1M_d$ polytype. The illite in the shallower part constitutes $\sim$75% of the illite-smectite mixed-layer particles, with a long-range ordering ($R \geq 3$). The illite at greater depths shows less ordering and a higher proportion of smectite in the mixed-layer particles. These authigenic mineral phases were likely formed during the movement of aqueous fluids along permeable fractures and veins by dissolution-precipitation reactions, and partly at the expense of larger ($\sim$150 nm thick), deformed, detrital packets. Differential thermal analysis (DTA) and heat flow results from a whole rock mudstone indicate a loss of $\sim$6% of total volatiles ($\sim$2% interlayer water, $\sim$4% crystalline water), latter would occur during the dehydroxylation of clays (at 400-600˚C). Based on textural observation the timing of authigenic mineral growth in the matrix assemblages is coeval or older than mineralization along polished fractures and grain boundaries

that are common in these samples. Hand-plucked fracture grains are notably smectite rich and show high element mobility and mass transfer, indicating circulation of low temperature fluids of varying composition and more extensive dissolution of detrital components. The alignment and widespread occurrence of these coating along microscopic displacement surfaces indicate a direct relationship between slip and mineral formation. The physical properties of these coatings, therefore, will significantly affect the fault properties at these shallow depths.