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Mineralogical changes in the active creeping section of the SAFOD borehole in Parkfield/California, and its influence in fault zone weakening processes

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A detailed mineralogical investigation from two actively creeping sections of the San Andreas Fault Observatory at Depth (SAFOD) borehole at 3194 m and 3301 m measured depth is presented. Both damage zones show relatively high U/Th values compared to the adjacent wall rock samples representing average crustal U/Th ratios. These elevated U/Th values are due to enhanced, localized U precipitation as a result of change in fluid chemistry to reducing conditions.

X-ray diffraction results show illite and illite-smectite (I-S) and chlorite minerals dominating at 3186.7 m to 3196.3 m, and 3294.9 m to 3297 m measured depth. Abundant chlorite-smectite (C-S) and corrensite (50:50 C-S) minerals are mostly restricted to well-defined intervals in the center of the two fault strands between 3196.3 m to 3198.1 m, and 3297.5 to $\sim$3305 m. The high U/Th values and the presence of corrensite and chlorite-smectite are both independent tracers suggesting reducing conditions during mineral formation, compared to more oxygenated adjacent rocks along the drill cores.

TEM analyses in the two fault intervals reveal altered chlorite minerals into C-S and corrensite with both straight and irregular crystal boundaries, whereas numerous C-S minerals surround the serpentine minerals (chrysotile) especially in the fault centers at 3196.8 m and at 3297.5 m depth. Chemical analyses show chlorite and C-S with a high Mg content, which indicates that their crystallization may have involved the destabilization of serpentine, providing Fe and Mg, whereas leaching of mica, feldspar and quartz from the wall-rock, is the probable source of Si and Al. This temporal sequence of reaction weakening suggests that distinct changes in the fluid chemistry are responsible for progressive dissolution and subsequent precipitation events along displacement surfaces. Localized reaction of strained Mg-Fe minerals to weak mixed-layered clay phases is proposed as a possible cause of fault weakening at the Parkfield location.