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Footwall Refrigeration in the Whipple Mountains Metamorphic Core Complex, CA

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Metamorphic core complexes of the western US formed during profound Cenozoic crustal extension and their characteristic regionally extensive detachment faults have accommodated large lateral displacements of the crust. Quantitative constraints on the rates and angles at which these faults slip are derived primarily from thermochronologic data ($^{40}Ar/^{39}Ar$ spectra and fission tracks). Most of these studies document rapid cooling and are based upon the assumption of conductive cooling in response to denudation. Oxygen isotope compositions in the footwall of the Whipple Mountains core complex of SE California are interpreted to indicate that rapid cooling may be the result of advective removal of heat from the footwall by flowing surface-derived fluids. If this is an important mechanism of heat removal, then thermochronologic studies may have overestimated the role of tectonic denudation.

The detachment fault in the Whipple Mountains core complex is underlain by chloritic breccias that vary in thickness from a few meters up to ~300 m. Chloritic breccias document the brittle deformation and fluid flow that accompanied detachment faulting. In Bowman's Wash an 89 ±3 Ma tonalite underlies the aphanitic cataclasite below the fault and is increasingly brecciated and altered upwards towards the fault. Neoblastic growth of epidote + chlorite + muscovite ±quartz ±hematite ±calcite, alteration of feldspar and biotite, and brittle deformation characterize the chloritic breccia. Major element variations are consistent with silicification in the 10 m below the fault.

Adjacent quartz and epidote grains in samples collected at distances of 12, 25, 40 and 50 m below the fault have been analyzed for $\delta^{18}O$. Five discrete Quartz-Epidote pairs were analyzed by laser microprobe in each sample. Epidote $\delta^{18}O$ values range from 5.45 to 2.21 per mil and quartz values range from 10.03 to 8.25 per mil. Average $\Delta_{Qtz\text{-}Ep}$ values range from 4.54±0.46 per mil to 5.81±0.52 per mil and increase systematically towards the fault. Average Quartz-Epidote temperatures systematically decrease from 432ºC at 50 m below the fault to 350ºC 12 m below the fault. Ambient pre-detachment temperatures were estimated using two feldspar thermometry to be 458 ±35ºC. The systematic decrease in temperature is consistent with greenschist and sub-greenschist mineralogical and textural variations. If the temperatures are time synchronous, they result in a temperature gradient of ~82ºC/38 m (or ~2160ºC/km). This gradient is too large to result from conductive cooling alone and is instead interpreted to result from the advective removal of heat by circulating, surface-derived fluids during faulting. Fluid $\delta^{18}O$ values were ~2 per mil at the fault surface and are interpreted to document exchange with relatively cold, surface-derived basinal brines which circulated down through high angle normal faults in the upper plate. As the fluid flowed through the upper portions of the footwall, heat was advectively removed causing rapid cooling of the lower plate. This advective removal of heat has important implications for models of brittle behavior, thermal models of core complex evolution, and thermochronologic studies of extended terranes.