Hematite textures and (U-Th)/He thermochronometry inform seismic and aseismic fault zone processes

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Hematite-coated slip surfaces in fault damage zones record thermal and mechanical processes operative within fault systems. Hematite is amenable to (U-Th)/He (hematite He) thermochronometry and accurate interpretation of hematite He data requires hematite textural characterization, grain-size distribution data, and constraints on the ambient thermal conditions during and after hematite formation from apatite (U-Th)/He (apatite He) thermochronometry. Here, we present examples of this workflow from hematite-coated fault surfaces in two exhumed, seismogenic basement-hosted fault damage zone systems. Data from the Wasatch fault, Utah, and Mecca Hills fault damage zones, California reveal evidence for seismic and aseismic deformation processes, respectively.

A network of high gloss, light reflective hematite "fault mirrors" in the exhumed Wasatch fault zone preserve textural and thermochronometric evidence for elevated temperatures during fault slip. Polygonal hematite crystal morphology, coupled with hematite He data patterns from these surfaces and host rock apatite He data, are best explained by friction-generated heat, hematite recrystallization, and attendant He loss (thermal resetting) at geometric asperities. Models of asperity flash heating and coupled fractional hematite He loss yield temperatures of ~>1200 °C and 85-100% He loss at fault surfaces. Results imply asperity flash heating and dynamic weakening promoted nano- to milli-earthquakes on these surfaces <4.5 Ma. In the Mecca Hills, adjacent to the southernmost San Andreas Fault, damage zone faults cut Plio-Pleistocene sedimentary rocks and underlying crystalline basement. In the Painted Canyon fault damage zone, hematite-coated slip surfaces comprise thin, high aspect ratio, shingled, hematite platelets in anastomosing patterns akin to "scaly fabrics" in clay slip surfaces. Reproducible mean hematite He dates from these surfaces range from ~0.7-0.4 Ma and are younger than ~1.2 Ma apatite He dates from adjacent crystalline basement host rock. Hematite textures and thermochronometric data collectively imply Late Pleistocene episodes syn-kinematic hematite mineralization via cyclic crack-seal and creep processes.