Direct dating of brittle deformation with hematite (U-Th)/He chronology

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Dating brittle fault slip is a research frontier integral for characterizing numerous upper crustal processes, yet few radioisotopic methods exist to do so. Hematite, common in fault zones, presents a new target for directly dating brittle deformation. The hematite (U-Th)/He method can directly date fault slip events if dates record syntectonic hematite formation or rapid cooling from hot fluids or frictional heating during fault slip. Results from two pilot studies demonstrate the application of this method to young and old faults. Hematite He dates from polished, iridescent minor fault surfaces in the Wasatch fault footwall damage zone yield highly reproducible ~4-5 Ma dates. Results overlap with new apatite (U-Th)/He and fission-track data. However, hematite from two samples with the same closure temperature separated by 20 cm on the same fault surface yield dates of 2.5 ± 0.2 Ma and 4.0 ± 0.1 Ma (mean ± 1σ sd). X-ray photoelectron spectroscopy reveals the presence of reduced Fe on these iridescent surfaces, requiring elevated temperatures. This is strong evidence against simple ambient cooling during footwall exhumation and instead argues for hematite He resetting from shear heating during localized seismic slip events. Hematite from fissure fills cutting Mississippian limestone on the Gower peninsula, South Wales yield consistent ~140 Ma He dates. Independent geologic constraints and fluid inclusion data indicating formation temperatures below the hematite He closure temperature, imply that these dates record hematite formation. Because mineralization was structurally controlled by fault activity, the Early Cretaceous hematite He dates directly constrain faulting episodes, consistent with regional extension due to incipient opening of the North Atlantic Ocean.