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**Fluid+Thermal History Reconstruction of Basins and Fault Zones, from Combined Fluid-Inclusion and (U-Th)/He Analyses Applied to Hematite**

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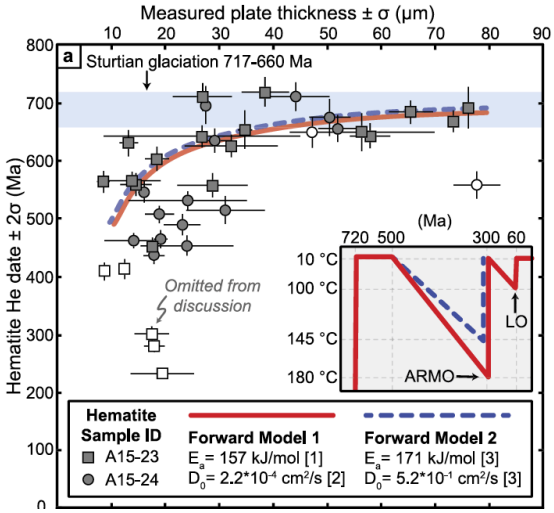
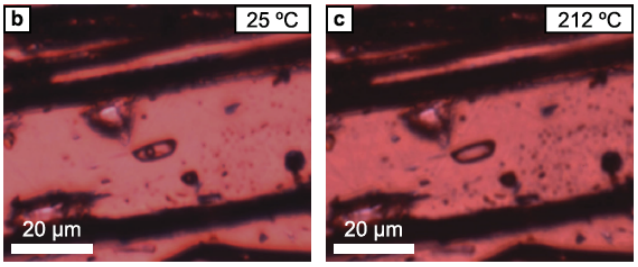
The goal of this project was to explore temporal constraints on fluid flow through basinal rocks and fault zones, coupled with the properties of fluids circulated, by combining thermochrological and fluid-inclusion studies on hematite. The specific field areas targeted in this research included the Tavakaiv clastic dykes in Colorado, the Buckskin-Rawhide detachment zone in western Arizona, and the Rheingraben rift in southwest Germany. Through the duration of the project, one graduate and two undergraduate students were supported by this project and participated in this research, along with several unfunded collaborators from various institutions. So far, one peer-reviewed journal article (Jensen et al., 2018, *Earth and Planetary Science Letters*, v. 500, p. 145-155) has resulted from this work, with two others in preparation.

The research conducted in this project represents a fundamentally new approach to understanding fluid circulation through basins and fault zones, both in terms of timing, temperature and chemistry. Hematite is a very common mineral in such settings, but has been targeted for fluid-inclusion studies only rarely, owing to being opaque to visible light. In this project, we used infrared light microscopy to study fluid inclusions in hematite. Combining this approach with (U-Th)/He thermochronology provides excellent time-temperature constraints that are complementary to the data obtained from fluid inclusions. Our approach, highlighted in our *EPSL* paper, has wide ranging applications in geosciences, from petrology to petroleum migration.

Our published paper in *EPSL* describes our new approach in the context of studying the enigmatic Tavakaiv sandstones, which are basement-penetrating clastic dykes hosted in Proterozoic rocks of Colorado. Our results indicate that the dykes were emplaced during the Sturtian glaciation around 720 Ma, and accompanied by circulation of hot basinal brines (see the Figure). These results suggest that Neoproterozoic breakup of Rodinia, coupled with overlying glacial ice, created unique conditions that permitted injection of sediment and advection of fluids into a basement-hosted fracture array. Thus, the sedimentary dykes and associated hematite mineralization record unique conditions resulting from supercontinent breakup and snowball Earth.




Results and interpretations presented by Jensen et al. (2018, *Earth and Planetary Science Letters*, v. 500, p. 145-155). Left: Thermochronology of the Tavakaiv dykes by (U-Th)/He dating of hematite. These results indicate emplacement at approximately 720 Ma. Above: A fluid inclusion in hematite, showing homogenization at 212 °C, the minimum temperature of formation. The liquid is a salty brine, ~23 wt% salt.

By allowing the development, testing and application of a new approach, this project has significantly benefited my career and research prospects, because this work has led to important discoveries like the ones highlighted in our EPSL paper and the approach will permit many future studies of other geologic processes. Moreover, the work has generated fruitful collaborations with several colleagues, which will continue beyond the duration of this project.

The three students who have participated in this work have all benefited tremendously. The graduate student published his first article in the prestigious journal *EPSL*, and as a result of the experience and expertise he gained during this work he was awarded a prestigious doctoral fellowship and has accepted a position in the petroleum industry. Of the two undergraduate students who participated in this work, one accepted in industry position upon graduation, and the other has started an MS program. All three of these students continue to use the skills and expertise gained during this project in their current positions.