Jordan Jensen - Project Profile

2023 AGeS-Grad awardee

Project Title: Developing a new approach to date <1 Ma fault slip using paired U-series disequilibrium and (U-Th)/He analyses of hematite

Lab: The University of Kansas Isotope Geochemistry Laboratory

Lab Mentors: Dr. Noah McLean, Dr. Andreas Möller

What scientific question(s) does your research address and what motivates this work?

Hematite, a secondary Fe oxide, is common in shallow fault zones and capable of recording deformation during different stages of the earthquake cycle. Reconstructing fault slip histories and bridging them to geophysical observations of deformation at depth requires accurate geochronology, but few geochronometers are applicable to young (~0.1-1 Ma) fault rocks. (U-Th)/He geochronology of hematite can help fill this critical data gap in fault zones. Hematite that formed <1 Ma may be impacted by U-series disequilibrium, which affects He ingrowth and violates assumptions made by the standard (U-Th)/He age equation. My AGeS-Grad research overcame this limitation by incorporating direct measurements of U-series isotopes (^{234}U, ^{230}Th) into the derivation of hematite (U-Th)/He dates from fault surfaces in the southern San Andreas fault (SSAF) system. Extending the (U-Th)/He system to young fault surfaces has the potential to inform the timing and depths of fault damage creation in the SSAF and other seismogenic fault systems.

Figure 1. Due to intense heat waves in southern California, I collected some of my hematite samples early in the morning before sunrise!

What chronometric tool did you employ and why?

I combined elements from the U-series and (U-Th)/He chronometers to enhance the versatility and temporal range of these dating systems, particularly to young (<1 Ma) fault damage zones with abundant hematite mineralization.

Secondary hematite may be prone to initial radiochemical disequilibrium because the parent aqueous fluids from which it precipitates can exhibit variable amounts of dissolved ^{234}U and ^{230}Th. I accounted for the effects of variable U-series disequilibrium by incorporating direct measurements of ^{234}U and ^{230}Th into routine hematite (U-Th)/He analyses. I then input He and U-series measurements into a numerical model to calculate new, refined hematite (U-Th)/He dates. This approach is fundamentally different from standard (U-Th)/He and U-series methods, which either assume secular equilibrium or require assumptions about the initial abundances of ^{234}U and/or ^{230}Th.

What were some of the key takeaways of your research?

1. Hematite aliquots display ^{234}U and ^{230}Th abundances that are not in equilibrium with ^{238}U. These results suggest open-system behavior (e.g., U loss) in some aliquots and/or the adsorption of excess ^{230}Th from percolating fluids.
2. Our findings yield insight into the geochemical nature of fluid-rock interactions in exhumed fault damage zones in crystalline basement. Adsorption of excess ^{230}Th onto Fe oxides can result in conventional (U-Th)/He dates that far exceed the “true” age of the sample.
3. New U-series-based hematite (U-Th)/He dates are consistent with hematite formation and fault slip during a more restricted time and thus depth interval (~400-650 ka) than previously recognized.

What new experiences, opportunities, and collaborations did you gain as an AGeS-Grad awardee?

My AGeS-Grad research gave me invaluable laboratory experience that I otherwise would not have received during my graduate studies. My new collaboration with Dr. McLean and the Isotope Geochemistry Lab provided hands-on experience in a clean lab, which involved acid dissolutions and column separation techniques, followed by isotope dilution ICP-MS analysis. I feel a stronger connection to this component of my PhD because I was involved at every step of the process of acquiring geochronologic data, from field sampling to the final processing and interpretation of the isotopic data. Additionally, I built valuable relationships with my cohort and other colleagues associated with AGeS.

What is one piece of advice you have for future AGeS-Grad award applicants or awardees?

Your lab visit may not go as planned or take longer than you envisioned, so prepare by establishing good communication channels with your lab mentors and by doing as much preparatory work as possible at your home institution.