Payton McCain - Project Profile

2023 AGeS-Grad awardee

Project Title: Thermal History of the Western Cordilleran Fold-Thrust Belt, southern Peru: implications for incision of one of Earth's deepest canyons

Lab: *Helium Analysis Laboratory, University of Illinois Urbana-Champaign*

Lab Mentors: *Dr. William Guenthner*

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

The relationship between climate, crustal deformation, and geodynamic processes and their relative roles in shaping topography remain a topic of debate. Orogenic plateau uplift and fold-thrust belt deformation occur at major orogens and impart first order controls on interactions between the geosphere, atmosphere, and hydrosphere. The nature of continental drainage patterns and subsequent canyon incision are major symptoms of these interactions and reflect the relative contribution of such processes. The Altiplano-Puna Plateau in the Central Andes is the second most elevated orogenic plateau on Earth, and in southern Peru, the Altiplano is bounded by the Eastern and Western cordilleras. In the Western Cordillera of southern Peru, Colca Canyon is a deeply incised canyon with high relief (>3 km) and drains to the Nazca trench (Figure 1). The rate and magnitude of Colca Canyon incision has been variably ascribed to climate or geodynamic uplift, but the role of fold-thrust belt deformation, or

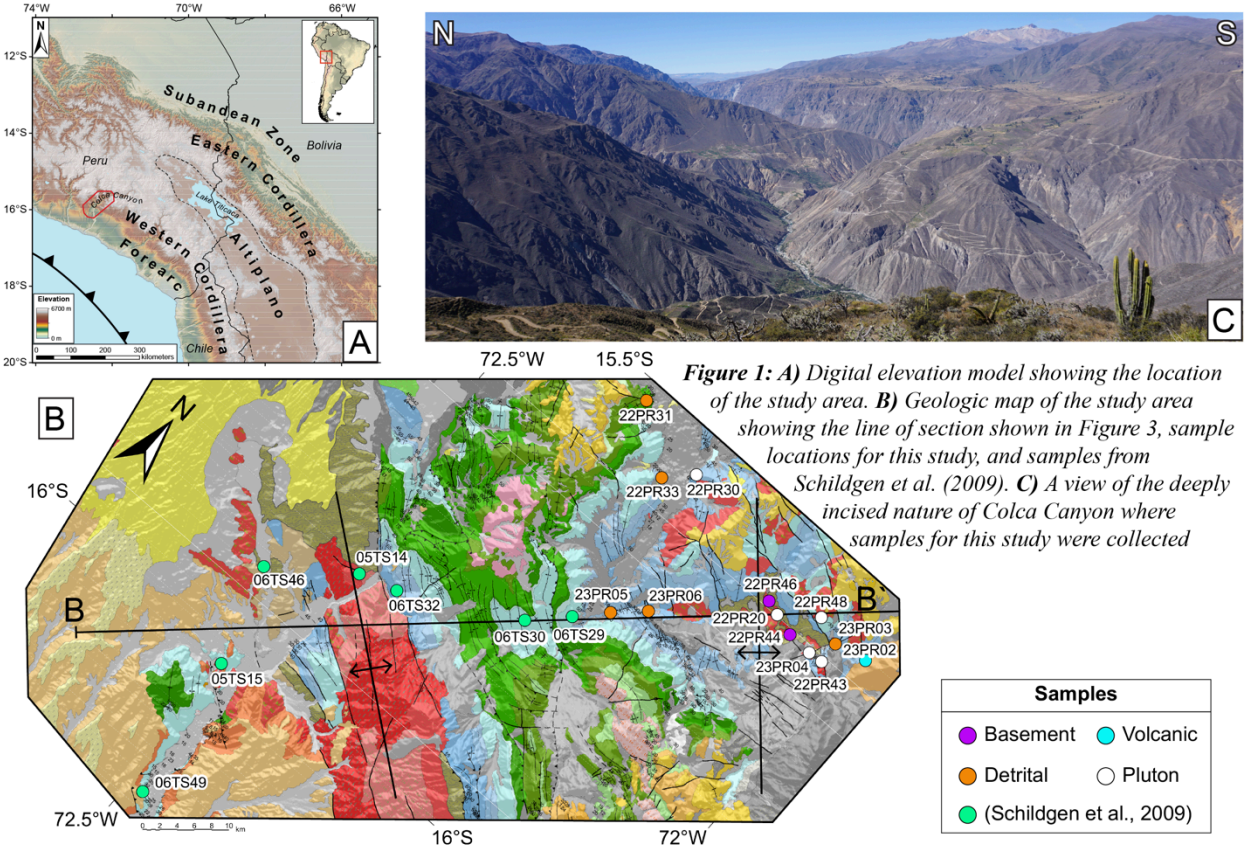

Figure 1: A) *Digital elevation model showing the location of the study area.* ***B)*** *Geologic map of the study area showing the line of section shown in Figure 3, sample locations for this study, and samples from Schildgen et al. (2009).* ***C)*** *A view of the deeply incised nature of Colca Canyon where samples for this study were collected*

integrated contribution of such processes remain unresolved. This work aims to resolve the interaction between different drivers of Colca Canyon incision and how that relates to deformation in the Central Andes. The results have implications for the sequence of deformation in the Central Andes and the current models of Cordilleran systems.

What chronometric tool did you employ and why?

This work investigates the timing and drivers of Colca Canyon incision using apatite and zircon (U-Th)/He thermochronometers. The results of such analyses can be used as a proxy for testing competing or combined structural and geodynamic rock uplift processes in concert with canyon incision (Figure 2). Cordilleran systems form along convergent margins and fold-thrust belts are common within these systems. Thrust faulting and associated folding results in shortening and subsequent thickening of continental crust. Inherent in this deformation is uplift along thrust ramps resulting in vertical and lateral variation in the local thermal field and development of topography and attendant erosion. The combination of these processes results in upward advection of isotherms and allows certain minerals to cool through a specific closure temperature depending on the isotopic system. In this context, thermochronometric data will have discrete graphical expressions when plotted in time-distance space. Such distributions are powerful tools for interpreting the relationship between geodynamic, structural, and/or climatic drivers of canyon incision.

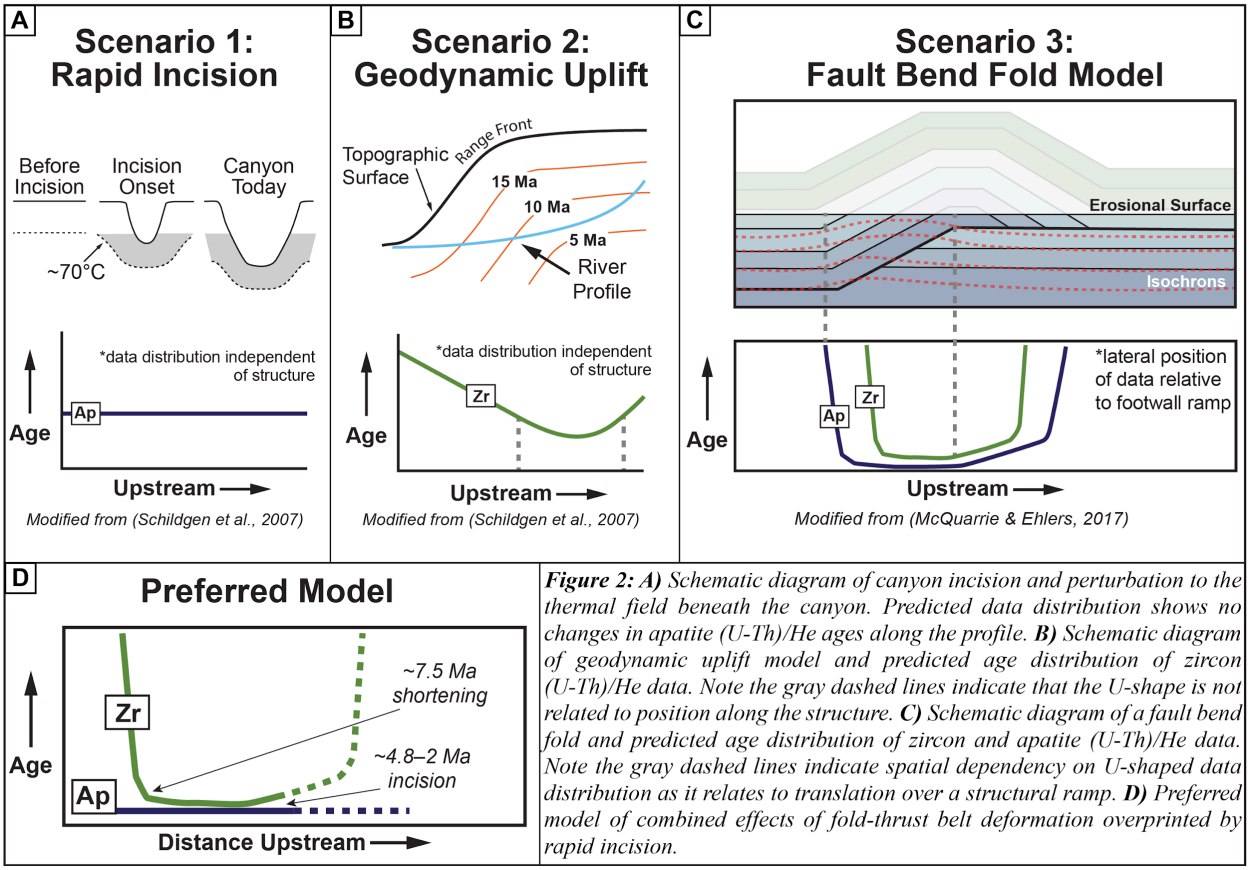

Figure 2: A) *Schematic diagram of canyon incision and perturbation to the thermal field beneath the canyon. Predicted data distribution shows no changes in apatite (U-Th)/He ages along the profile.* ***B)*** *Schematic diagram of geodynamic uplift model and predicted age distribution of zircon (U-Th)/He data. Note the gray dashed lines indicate that the U-shape is not related to position along the structure.* ***C)*** *Schematic diagram of a fault bend fold and predicted age distribution of zircon and apatite (U-Th)/He data. Note the gray dashed lines indicate spatial dependency on U-shaped data distribution as it relates to translation over a structural ramp.* ***D)*** *Preferred model of combined effects of fold-thrust belt deformation overprinted by rapid incision.*

What were some of the key takeaways of your research?

- The (U-Th)/He data distribution for the across-structure transect reveals competing drivers between canyon incision and structurally driven uplift in the third deepest canyon on Earth (Figures 2 & 3).
- Results indicate that Late Miocene basement-involved structural uplift occurred out-of-sequence in the Western Cordillera of southern Peru while deformation was ongoing in the modern foreland.
- Such results have implications for the kinematics of basement-involved structures in the Andes and structural styles in Cordilleran systems.

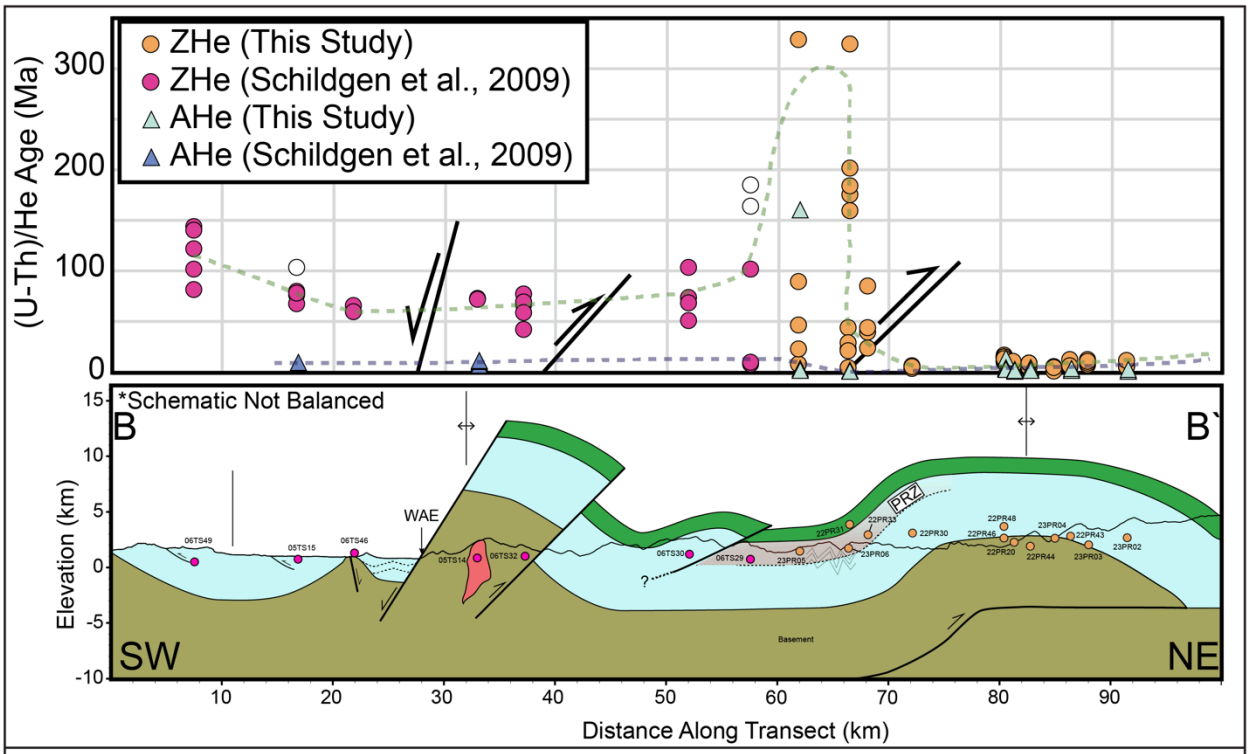

Figure 3: (TOP) *Individual AHe and ZHe grains plotted along transect (SW–NE) from this study and Schildgen et al. (2009). Sample locations were projected perpendicular to the line of section. Note locations of major faults.* ***(BOTTOM)*** *Schematic (unbalanced) cross-section showing distribution of samples plotted as elevation vs. distance along transect. Note location of partial retention zone (PRZ) derived from data.*

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

This was a brand-new collaboration for all parties in this study. Throughout the course of this project, I gained new hands-on experience in helium extraction methods, and learned about the dissolution processes and data acquisition for apatite and zircon (U-Th)/He thermochronology. Prior to commencement of this project, I knew very little about the methodology of helium extraction and subsequent processes up to data acquisition and reduction. The host lab was

very helpful in sampling strategy and managing expectations regarding data resolution and the greater implications for the results. This work would not have been possible without funding from the AgeS-GRAD program. I have gained new insights and invaluable experiences through this collaboration; for that, I will forever be grateful.

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

Take advantage of the access to expertise from your host lab mentors; this is a fundamental focus of the program. In this context, discuss sampling strategies, limitations of the methods, and data reduction throughout the course of the project.