Reconstructing the evolution of the Pamir lower crust: Zircon U-Pb and trace-element petrochronology of Pamir xenoliths

Madeline Shaffer, M.S. candidate, Department of Earth Science
Advisor: Bradley Hacker

The Pamir are part of Earth’s largest continental collision zone, the Cenozoic India-Eurasia orogenic belt, characterized by extreme uplift and shortening of the Asian plate overriding the subducting Indian plate (Fig. 1). This 55 m.y.a. collision zone is an archetype for continental convergent boundaries, and has a complex history of subduction, accretion, and exhumation. However, limited information has been put forward to describe the nature and history of deep crustal recycling along this tectonic boundary. Understanding these crustal recycling processes is necessary if we are to comprehend the compositional evolution of Earth’s crust versus its mantle; how this evolution effects velocity structure, density, thickness, radioactive heat production, and thermal profiles; the implication of density-driven crustal foundering concerning plate movement; and parameters that govern crustal thickness. One avenue of collecting this information is through analysis of xenoliths transported to the surface in erupted lavas.

Fortunately, a suite of lower crustal xenoliths was collected from an ultrapotassic pipe belt in the southeastern Pamir. The suite includes crustal-derived, eclogite- and granulite-facies rocks of sedimentary and igneous origin, and is unique in this regard. The xenoliths reached equilibration with (near) ultra-high pressure (UHP) and ultra-high temperature (UHT) conditions during a crustal recycling event (via gravitationally unstable lithosphere) of the Pamir lower crust (Hacker et al., 2005). These rocks currently provide the only known xenolith record of crustal recycling. Thus, we have an excellent opportunity to construct a model for how continental crust evolves during foundering into the mantle, leading to a more detailed understanding of these recycling processes. Zircon, an accessory phase well-known for its interaction with major phases such as garnet and plagioclase, is analyzed in this study to acquire the pressure-temperature-time (P-T-t) path of the xenoliths before and during crustal foundering. Ultimately, this interpretation could be used as a model for foundering in general.

Over the summer of 2016, U-Pb and trace-element data was collected for zircon from 30 xenolith samples using laser-ablation split-stream (LASS). This data is crucial in determining the P-T-t path of the xenoliths during crustal foundering. Pressure evolution indicators from zircon include i) depletion of heavy rare-earth elements (HREEs; described as Lu/Gd ratios) as garnet begins to grow, and ii) observed changes in Europium anomaly (Eu/Eu*) that indicate breakdown of plagioclase (Rubatto, 2001). Temperature was calculated using Ti-in-zircon thermometry (Ferry and Watson, 2007), and time was determined using concordant ages from the U-Pb decay system. Overall, the data revealed initial zircon crystallization during the Cretaceous; a “quiet” period through the Paleogene with no apparent increase or decrease in pressure or temperature; onset of eclogite facies at 20 Ma as the Pamir lower crust began to thicken (Fig. 2, 3); a brief period of UHT near 13-12 Ma (Fig. 4); and eruption at 10 Ma. The unstable lithosphere may have formed over ~9 Myr and foundered due to gravitational instability in the last 1 Myr. Future work for the xenoliths involves creating P-T models using Perple_X software and determining instability size through thermal diffusivity and pressure calculations.
 References:


Figure 1. a) Google earth image of Asia and India, with the Pamir highlighted by the red box. b) Expanded image of the Pamir Mountains, indicating the locale of the Dunkeldik ultrapotassic magmatic suite (pink box) in the southeastern Pamir. Modified after Gordon et al (2012).
Figure 2. Decreases in HREEs of up to two orders of magnitude constrain the timing of the garnet growth to ~20 Ma (dashed line). Cretaceous values were normalized to 1.

Figure 3. Eu anomalies decrease in magnitude at ~20 Ma (dashed line), compatible with the breakdown of plagioclase.

Figure 4. Ti concentrations in zircon indicate temperature increases to 950-1075°C just prior to eruption.