Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.21959

Classifying complex igneous rocks from zircon depth profiling using multivariate approaches

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Zircon ($ZrSiO_4$), an accessory phase in almost all felsic igneous rocks, is an invaluable tool for investigating the timing and process of petrogenesis. Past efforts utilized zircon chemistry from various magmatic settings to develop frameworks for interpreting the crystallization history. This has been useful in determining the formation of Hadean[1] and lunar[2] magmas. While useful for determining likely source magmas, the interpretations are limited to general crystallization trends of these complex early Earth and extraterrestrial samples. To refine the interpretative framework for the magmatic evolution of these types of samples, we propose building a machine-learning classification system utilizing laser ablation depth profiling, capturing unique crystallization histories recorded by zircon geochemical trajectories.

We have made progress on a preliminary classification model for terrestrial granitoids using a broad sample selection across magmatic and tectonic environments utilizing depth profile data. These efforts aim to establish a framework to interpret the geochemical trajectory of zircons from complex or unknown settings, enhancing current classification systems. Initial results from zircon depth profiling suggest that the late-stage crystallization history of granitoids is influenced by source composition, co-crystallizing assemblage, and P-T conditions of the magma body. These defining characteristics can be interpreted from the depth profile data.

Using an unconventional routine for split stream mass spectrometry, we collected Ti, trace element, and U/Pb geochemistry from various samples, including Archean TTG, impact melts, and typical tectonic settings. Comparison of this sample suite was performed by using standard bivariate ratios, principal components analysis, and supervised clustering. The additional dimensionality of depth profiling data captures unique magma variability across the sample selections, improving upon past classification efforts. Future application of this supervised classification to Hadean and extraterrestrial zircon analyses will yield an interpretative framework for magma evolution in complex settings from analogous systems.

[1] Reimink, Chacko, Stern & Heaman (2014) *Nat. Geosci.* 7, 529–533.

[2] Crow, McKeegan & Moser (2017) *Geochim. Cosmochim. Acta* 202, 264–284 .