Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.23436

Exploring terrestrial habitability by applying experimental results to ancient geological materials

DUSTIN TRAIL[1], WRIJU CHOWDHURY[1], NICHOLAS TAILBY[2], MICHAEL ACKERSON[3] AND IAN SZUMILA[4]

[1]University of Rochester

[2]University of New England (UNE)

[3]Smithsonian National Museum of Natural History

[4]Carnegie Institution for Science

Presenting Author: dtrail@ur.rochester.edu

The chemistry preserved in the oldest-known remnants of terrestrial crust is a crucial window into the geodynamics of the crust and mantle. This chemistry has led to new models for the composition and volume of the continental crust, the existence and extent of subaerial landmasses, and the properties of high temperature "hydrothermal" water-rock interactions [1]. Constraining these chemical/environmental characteristics is crucial to evaluating realistic models for the origin of life, but this relies on a limited set of extant minerals/materials that exist from the early Earth. [2]. Here we present new research which covers two broad themes.

The first theme reports preliminary results to infer how silica activity is recorded in zircon chemistry from ancient systems. This method utilizes the Ti coordination ratio across the two sites in zircon ([VIII]Zr4+ and [IV]Si4+), as quantified by X-ray absorption near edge structure (XANES). We compare Ti coordination in experimental zircons crystallized at different silica activities to detrital Hadean zircons. We show that Hadean zircons likely crystallized in the presence of quartz. These data help infer geodynamic and geochemical regimes, including the density/buoyancy (and potentially long term survivability) of a rock. We also explore commonly used trace element discrimination diagrams used to infer ancient tectonic regimes [e.g. 3], with revisions, from support vector machine (SVM) classification.

The second theme presents our progress to explore physico-chemical interactions between high-T fluids and the lithosphere. High-T fluids represent a key messenger for chemical exchange between the Earth's interior and the surface, with redox state exerting significant control on the nature of those interactions. We explore ancient fluids using zircon/rutile-fluid partitioning of redox-sensitive elements (Ce, V, Sn) under oxygen fugacity buffered conditions, coupled with measurement of natural zircon and rutile of subsolidus origins. We use this information to model the effect of redox gradients of fluids in surface-interfacing systems; i.e., at a location attractive for prebiotic molecular synthesis or sustained microbial activity [4].

[1] Harrison, T.M. (2020) doi.org/10.1007/978-3-030-46687-9_1

[2] Benner, S.A. et al. (2020) doi.org/10.1002/syst.201900035

[3] Grimes, C.B. et al. (2007) doi.org/10.1130/G23603A.1

[4] Trail and McCollom (2023) doi:10.1126/science.adc8751