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Isotope Tracers and the Secrets of Vestrahorn

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There is no singular thread that explains the early Earth's evolution, but modern proxies such as Iceland's plutonic complexes help weave a narrative. The formation and alteration of silicic crust in an Iceland-like setting are a proxy for early Earth and planetary differentiation. The Vestrahorn intrusion, part of a series of plutons in southeast Iceland, represents a unique case for studying weathering processes in a basalt-dominated environment. Previous studies have utilized isotopic systems, particularly oxygen isotopes, to trace hydrothermal alteration in the region, linking granitic magmatism to partial melting of altered basalt. Work on oxygen isotope variations of zircons (e.g., 1,2) have shown isotopic shifts indicative of hydrothermal influence, while whole-rock geochemical studies have demonstrated evidence of open-system processes affecting the granitoid compositions.

The recent study by Law et al (2024) was able to use Vestrahorn silicic rock samples to trace their formation through partial melting of crustal basalts. This implies intracrustal melting is insufficient to generate TTG-like compositions. Our study expands on the Law et al study by employing Zn and Mg isotopes on a suite of Vestrahorn samples. This allows us to determine the range of fractionation in the setting, utilizing novel isotopic proxies to assess the extent and effects of weathering, with a focus on differentiating surficial alteration from magmatic processes. These data provide insights to various environmental conditions, including hydrothermal alteration, mineral transformation, and oxidative weathering. Zinc can trace fluid-rock interactions and transition metal mobility, while Mg provides constraints on silicate weathering and secondary mineral formation. By integrating these systems, they can reflect the different pathways of element mobility.

This ability to differentiate between weathering type signatures in the absence of subduction is applicable to not just the early Earth, but planets such as Mars and Venus. These data allow us to refine models for planetary crustal development, offering new perspectives on the interplay between magmatism and surface alteration in ancient environments.

- Padilla et al 2016, Contributions Mineralogy Petrology; (2) Martin & Sigmarsson 2010, Lithos; (3) Law et al 2024, Nature Communications