Zr Stable Isotope Fractionation During Magmatic Processes

MAURICIO IBANEZ-MEJIA[1*] AND FRANÇOIS L.H. TISSOT[2]

[1]Dept. of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627, USA (*corr: ibanezm@rochester.edu)
[2]Dept. of EAPS, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Despite decades of work on zirconium (Zr) isotope anomalies in early Earth, early Solar System and other planetary materials [1, 2], Zr stable isotope systematics remain virtually unknown. A refractory and moderately incompatible lithophile element, Zr is a geochemically important tracer that can yield insights into processes of silicate differentiation [3], and whose budget in rocks and melts exerts a major control on the presence and abundance of zircon and baddeleyite in planetary igneous systems. Crystallization of Zr-rich phases from silicate magmas involve important transitions in the local bonding environment of dissolved tetravalent Zr ions [4], which, according to first-principles of stable isotope theory, suggests fractionations can be induced during zircon and/or baddeleyite crystallization. Yet, investigation of the occurrence and extent of Zr stable isotope fractionation is still lacking, and, in fact, the analytical methodologies and materials necessary to perform high-precision Zr stable isotope analyses have yet to be developed.

Here, we present results demonstrating that stable Zr isotope fractionation does occur amongst co-existing natural Zr-rich accessory phases. Single-zircon and baddeleyite crystals from a Duluth Complex anorthositic gabbro (FC-1 locality) exhibit δ^{94}Zr [i.e., $((^{94}\mathrm{Zr}/^{90}\mathrm{Zr})_{\mathrm{sample}}\ /\ (^{94}\mathrm{Zr}/^{90}\mathrm{Zr})_{\mathrm{Std}}-1)*1000$] inter- and intra-mineral differences of up to 0.60‰ (*i.e.*, 0.15 ‰/amu), thus indicating that resolvable Zr stable isotope fractionation can be induced by igneous differentiation processes on Earth and potentially other planetary bodies.

Proper understanding of the causes of theses variations, however, requires a systematic assessment of the direction and magnitude of the Zr stable isotope fractionation factors (Δ^{94}Zr) between Zr-rich accessory phases and silicate melts. Measurements of the δ^{94}Zr of whole-rock FC-1, as well as that of other zircon, baddeleyite, and bulk-rock samples, is currently underway. These data will allow us to build a framework for interpreting natural Zr stable isotope variations and deepen our understanding of the Zr cycle on Earth.

[1] Minster and Allègre (1982), GCA, 46, 567-573. [2] Iizuka *et al*. (2016), EPSL, 439, 172-181. [3] Weyer *et al*. (2002), Chem. Geol., 187, 295-313. [4] Louvel *et al*. (2013), GCA, 104, 281-299.