

Fe-Mg inter-diffusion drives the isotope fractionation in basalt

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Both iron and magnesium are major constituents of the mantle, but the isotopic fractionation of these elements during melting is still poorly understood. Modeling calculations suggest up to ~0.1‰ Mg isotope ($\delta^{26}\text{Mg}$) fractionation during mantle partial melting [1], although such large differences are not typically observed between basalts and mantle peridotites. Similarly, analyses of the Fe isotope ratios in oceanic basalts show $\delta^{57}\text{Fe}$ ~0.15‰ heavier than in peridotite (e.g., [2],[3]) but the fractionation mechanism is also not fully explained (e.g., [4], [5]).

We employed a critical mixture double-spiking method for measuring $\delta^{26}\text{Mg}$ in a wide-range of mid-ocean ridge basalts (MORB) from the Pacific, Atlantic, and Indian. We found the MORB samples have variable $\delta^{26}\text{Mg}$, from ~-0.2‰ to ~-0.3‰. We further analysed the Fe isotope ratio of these MORB samples (by sample-standard bracketing) and found their $\delta^{57}\text{Fe}$ ratios also show a wide range from ~0.1‰ to ~0.25‰ that are negatively correlated with $\delta^{26}\text{Mg}$.

This interesting observation cannot be simply explained by either partial melting or magma differentiation. Instead, we argue it is the Fe-Mg inter-diffusion process between mantle olivines and migrating melt. Interaction between deeper, relatively Fe-rich melts from the melting column and depleted Fe-poor harzburgite at the top of the melting regime will decrease the Fe/Mg of the melts. If this process is diffusionally limited, it will increase the $\delta^{57}\text{Fe}$ and decrease the $\delta^{26}\text{Mg}$ in the melts since light isotopes move faster. Model calculations show such a process can reproduce the correlation between Mg and Fe isotope ratios, and the magnitude of isotope fractionations we observed. It explains some of the anomalously high $\delta^{57}\text{Fe}$ value in oceanic basalt and the inconsistency between modeling and empirical analysis of Mg isotopes. Such diffusion process may also explain some of the unexpected isotope fractionation of other elements in natural samples (e.g., Ca, Cr and etc.) [6]

[1] Liu *et al.* (2023) *GCA Under Review*. [2] Craddock *et al.* (2013). *EPSL* **365**, 63-76. [3] Gleeson *et al.* (2020). *EPSL* **535**, 116114. [4] Soderman *et al.* (2021) *GCA* **292**, 309-332. [5] Sossi *et al.* (2016) *EPSL* **452**, 295-308. [6] Soderman *et al.* (2022) *GCA* **318**, 388-414.