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Characterization of Nitrogen Isotopes in Oceanic Basalts

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The large concentration contrast between nitrogen (N) in Earth's atmosphere (78%) and mantle materials (ppm) makes it a sensitive tracer of interactions between these reservoirs. To understand the origin and evolution of N in the mantle, we investigate two families of oceanic basalts: mid-ocean ridge basalts (MORB) and high $^{3}He/^{4}He$ plume-influenced basalts. The high ^{3}He signal in plume-influenced basalts is thought to be derived from an undegassed primordial component in the plume's mantle source [1].

We determine $\delta^{15}N$ for MORB samples from the Central Indian Ridge (CIR), Alarcon Rise, and Mid-Atlantic Ridge (MAR), as well as plume-influenced samples from Iceland, Lau, and Manus. Iceland and CIR data are in excellent agreement with previous studies [2,3]. In addition, we present 45 new N isotope measurements, nearly doubling the published global data set for oceanic basalts (Fig. 1). Average MORB $\delta^{15}N$ values range from -1 to -5‰ (relative to air = 0‰), with each locality representing a distinct portion (CIR=-1±1‰; Alarcon=-2.3±1.3‰; MAR=-4.3±1.2‰). Plume-influenced samples, in contrast, have distinctly positive $\delta^{15}N$ values: Manus=+0.3±0.9‰; Iceland=+1.4±0.9‰; and Lau=+1.6±0.8‰.

The source of variation between MORB sample localities remains enigmatic but may be related to the proximity of plume-influenced basalts (CIR) and subduction zones (Alarcon). Iceland and Lau, on the other hand, are nearly identical. Notably, they are also marked by extremely high $^{3}He/^{4}He$ values (>20 R_A) [1,4,5]. The correlation of high $^{3}He/^{4}He$ values with positive $\delta^{15}N$ suggests that positive N isotope anomalies are also derived from the primordial deep mantle (Fig. 2). Such anomalies could either be: 1) introduced by subduction of sediments with $\delta^{15}N$=+5‰ [3,7,8], or 2) a remnant of N isotope fractionation during core formation [8,9].

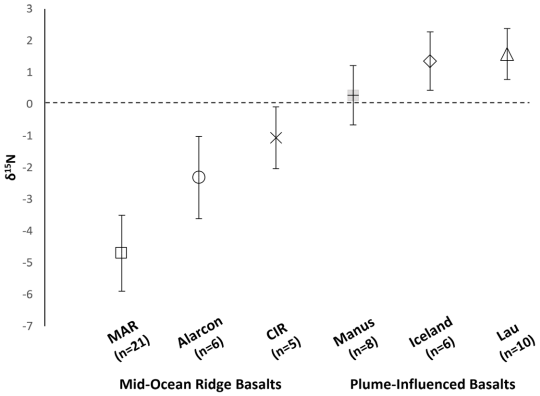

Fig. 1: N isotope results of crushing experiments for MORB and high $^{3}He/^{4}He$ plume-influenced basalt. samples. Analytical uncertainty is 0.7‰, error bars are one-sigma.

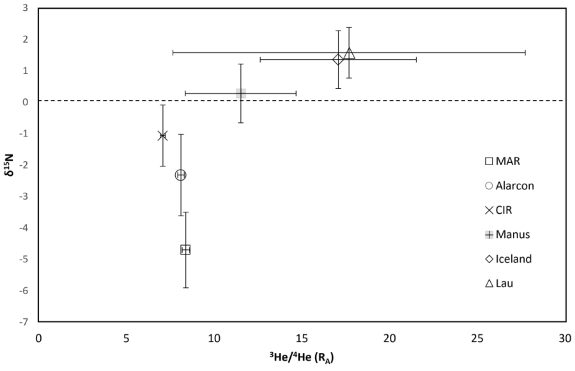

Fig. 2: N isotope data vs. published $^{3}He/^{4}He$.

[1] Jackson et al., 2017. [2] Halldórsson et al., 2016. [3] Barry and Hilton, 2016. [4] Parai et al., 2019. [5] Hilton et al., 1993. [6] Barry and Broadley, 2021. [7] Marty and Dauphas, 2003. [8] Dauphas and Marty, 1999. [9] Dalou et al., 2019.