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Deep recycling of nitrogen to the plume mantle sources: Insights from plume-ridge interaction at Reykjanes Ridge to plume-slab interaction at Rochambeau Bank

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The question of how efficiently N can be subducted into Earth's mantle is a hotly debated subject in the geochemical community [1,2]. Nitrogen isotope systematics of mantle-plume influenced materials provide a unique opportunity to better constrain Earth's deep N cycle. Here, we present new N isotope data for two suites of high $^{3}He/^{4}He$, plume-influenced basaltic glasses from Reykjanes Ridge (RR; up to 18 R_A; R_A is the atmospheric $^{3}He/^{4}He$ ratio of 1.4×10^{-6}) in Iceland and Rochambeau Bank (RB; up to 23 R_A) at the Lau Back-arc Basin. Our results show that RR (-2.2‰ to +0.1‰) and RB (-0.1‰ to +2.8‰) samples are all characterized by $\delta^{15}N$ values (where $\delta^{15}N = [(^{15}N^{14}N/^{14}N^{14}N)sample/(^{15}N^{14}N/^{14}N^{14}N)air - 1] \times 1000$) greater than the depleted mantle (i.e., DM; -5±2‰). Additionally, we employ the $(La/Sm)_N/(Ba/Nb)$ ratio as an index for the relative contributions of plume and subduction components. We find a negative correlation between $(La/Sm)_N/(Ba/Nb)$ and $\delta^{15}N$ values for RB samples, suggesting the existence of both a Samoan plume component and a subduction component – likely from the Pacific slab subducting in Tonga – in the RB mantle source. The subduction component likely has a higher $\delta^{15}N$ value than the plume component. Three-endmember mixing between air, DM and plume component indicates a contribution from a plume component with a $\delta^{15}N$ of ~+1‰, which is consistent with the range of $\delta^{15}N$ values (~0‰ to ~+6‰) observed in Iceland [3]. Notably, RB sample D9-9 appears to be heavily influenced by N from a component with a $\delta^{15}N$ value of ~+6‰ and extremely low $(La/Sm)_N/(Ba/Nb)$, compatible with a subduction origin. Further the ^{3}He-rich plume sources for RR and RB samples are characterized by positive $\delta^{15}N$ values. Combined with elevated $N_2/^{3}He$ ratios relative to DM, these new N isotope data consistently indicate the subduction of ^{15}N-rich surficial material into Earth's deep mantle. The combination of high $^{3}He/^{4}He$ ratios and the inferred subduction influences on N of plume sources can be reconciled with large variability of $N_2/^{3}He$ ratios in the source endmembers.

[1] Labidi, 2022. [2] Bekaert et al., 2020. [3] Halldórsson et al. 2016.