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The origin of nitrogen in Earth's mantle constrained by $^{15}N^{15}N$ measurements

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Nitrogen in Earth's mantle may be surface-derived. Signatures inherited from Earth's accretion and differentiation would have been erased by billions of years of volatile subduction. Constraining $\delta^{15}N$ and $N_2/^3He$ ratios of various mantle sources may help quantify nitrogen subduction. We present $^{15}N^{15}N$ data on hydrothermal gases that provide a window into plume and arc sources, where fresh glasses are often absent. Measurements of $^{15}N^{15}N$ in natural samples allows tracing the provenance of nitrogen in gas mixtures. The approach is based on the recent finding that atmospheric N_2 has an enrichment in $^{15}N^{15}N$ of nearly 20‰ relative to any other source of N_2. This is particularly useful for the study of hydrothermal gases, where air-derived N_2 is unavoidable.

Important findings include that the $\delta^{15}N$ tracer, used alone or in conjunction with N_2/Ar and N_2/He ratios, can be surprisingly deceiving. Isotope fractionation of atmospheric nitrogen occurs within hydrothermal systems, resulting in negative $\delta^{15}N$ values similar to estimates for mantle values, yet with $^{15}N^{15}N$ values that preclude a mantle origin. The $^{15}N^{15}N$ data show that the true $\delta^{15}N$ of volcanic components is positive in arcs, consistent with a contribution of subducted nitrogen. The $\delta^{15}N$ of hydrothermal nitrogen in the Yellowstone plume is near-zero. This is similar to published $\delta^{15}N$ data on plume basalts from other locations, with values between –2 and 0‰, only marginally higher than MORB.

With $^{15}N^{15}N$, we also determine the true, uncontaminated $N_2/^3He$ of volcanic components in hydrothermal systems. Arc volcanic endmembers show elevated $N_2/^3He$ by two orders of magnitude compared to MORB, consistent with sub-arc sources being overwhelmed by near-quantitative slab devolatilization. In contrast, the Yellowstone plume source shows a MORB-like $N_2/^3He$ ratio. Literature data on plume basalts also tend to indicate MORB-like $N_2/^3He$ ratio. This is not consistent with the addition of recycled nitrogen in plume sources. Instead, published data seem to indicate that N recycling has an overall more limited impact on mantle nitrogen than previously thought. The new data allow the possibility that $\delta^{15}N \sim 0$ for plumes reflect a primordial feature of undegassed mantle reservoirs, rather than a signature inherited from subducted nitrogen.