Nitrogen budget of Earth: Insights into volatile cycling in the deeper planet

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The N content of the Bulk Silicate Earth (BSE) has been difficult to determine. We present an updated, comprehensive estimate based on literature compilation of N analyses from rocks and minerals as well as N-Ar measurements. The BSE contains the majority of the planetary budget of N, with $27\pm16\times10^{18}$ kg N, equivalent to 7±4 present atmospheric masses of N (PAN, 4×10^{18} kg N). This estimate negates the need for a reservoir of "missing" N when compared to chondrite abundance.

Geochemical similarity of N and Ar allows whole mantle N mass calculation given a calculated Ar [1]. We identify two distinct reservoirs of N in the mantle from N-Ar systematics: a low-N reservoir with low, constant, $N_2/^{40}Ar$ (~120), composed of mid-ocean ridge basalts (MORB), some ocean island basalts (OIB), and depleted xenoliths, coined "MORB-source like" (MSL); and a high-N reservoir, defined by high N concentration and high $N_2/^{40}Ar$ (~9300), composed of some OIB and fertile xenoliths. Not only are these reservoirs distinct in N mass, they also appear to be different ages and are distinct isotopically.

Determining the proportion of each mantle type is crucial to estimate mantle N mass. Based on K/U ratios, the mantle is 80% MORB-source and 20% OIB-source [2]. Of this 20% OIB-source, we suggest that 15% is high-N, which corresponds to 3% of the total mantle. Therefore, we estimate MSL contains ~2 PAN and high-N mantle contains ~4 PAN.

Other proxies corroborate large mantle N mass. Comparison to chondritic sources suggests BSE N mass of 4 to 8 PAN, consistent with terrestrial analyses. Experimental results and measurements from other primary mantle melts (lamproites/lamprophyres) are indicative of large N mass in the mantle.

The existence of a large reservoir of N in the BSE has a number of implications for the evolution of the Earth system. The N in the mantle carries the signature of crustal/surface material, even in the MORB-source. While recent estimates of paleoatmospheric pressure suggest atmospheric mass is in steady-state over time [3], the evolution of the atmosphere-mantle system is poorly constrained, and should be a target for future research.

[1] Marty, B (1995), *Nature* **377**, 326-329. [2] Arevalo, McDonough, and Luong (2009), *EPSL* **278**, 361-369. [3] Marty *et al*. (2013), *Science* **342**, 101-104.