Nitrogen in minerals and atmospheres – a sign of life?

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All living cells require nitrogen to build proteins and DNA, and this biological demand is probably as old as life itself. It is therefore conceivable that the biosphere has significantly altered geological and atmospheric nitrogen reservoirs over Earth's history [1,2]. To evaluate this idea, we first test the null hypothesis that abiotic processes on their own can sustain a dynamic nitrogen cycle. Several abiotic pathways have been proposed that can transform atmospheric N_2 – the major surface reservoir – into NH_4^+, which could adsorb to mineral surfaces and become incorporated in the rock record. However, a quantitative model of such an abiotic nitrogen cycle reveals that realistic N concentrations in sediments would be less than a few ppm, compared to several 10s to 1,000s of ppm in biomass-rich mudrocks [3]. In the absence of life on Earth, the flux of nitrogen from the atmosphere to the lithosphere would thus be significantly smaller. We then place this information into a multi-box model of geological nitrogen reservoirs, including the mantle, continental crust, shelf and pelagic sediments and the atmosphere. Our results show that a large Archean biosphere could potentially have drawn down atmospheric pN_2 to about half modern levels [4]. Most of this nitrogen would have been stored in sedimentary rocks on the continents. The onset of oxidative continental weathering with the rise of biogenic O_2 may have restored atmospheric pN_2 to the modern 0.8 bar. Our results suggest that the concurrently high abundances of O_2 and N_2 in our atmosphere may be a sign of life.

[1] Zerkle, AL and S Mikhail (2017) Geobiology DOI: 10.1111/gbi.12228. [2] Johnson, B and C Goldblatt (2015) Earth Science Reviews 148: 150-173. [3] Stüeken, EE (2016) Astrobiology 16: 730-735. [4] Stüeken, EE, et al. (2016) Astrobiology 16: 949-963.