Evidence for the deep Archean nitrogen cycle from >3 Ga diamonds

SMART, K.A.[1], TAPPE, S.[2], STERN, R.A.[3]

[1]University of the Witwatersrand, Johannesburg, South Africa; katie.smart2@wits.ac.za
[2]University of Johannesburg, Auckland Park, South Africa
[3]CCIM, University of Alberta, Edmonton, Canada

The nitrogen isotope contrast between the ^{15}N-enriched crust and ^{15}N-depleted mantle allows for effective tracking of volatile cycles between the surface and interior of Earth. It has been suggested that the Archean mantle was much more ^{15}N-depleted (δ^{15}N ~ -40‰) compared to the modern mantle (-5‰), where subduction recycling of crustal material over Gyr timescales led to the modern mantle δ^{15}N value [1]. Diamonds, containing appreciable nitrogen impurities, provide one of the few constraints on the deep extension of the nitrogen cycle betweeen Earth's surface and interior.

In order to investigate Archean volatile cycles and evaluate its bearing on early Earth processes, we conducted a SIMS isotopic study of placer Archean diamonds from the ca. 3.1 – 2.7 Ga Witwatersrand Supergroup (Kaapvaal craton, South Africa). Nitrogen aggregation states of the Wits diamonds are low to moderate (6–64 %B), corresponding to mantle residence times of up to 400 Myr, which places diamond formation at 3.5-3.1 Ga. Thus, these diamonds provide some of the earliest mantle record of Earth's deep volatile cycle.

δ^{15}N values of the Wits diamonds range between -0.5 and +2.7 ‰, significantly more enriched than the isotopically depleted ancient and modern mantle. Based on positive δ^{15}N values for >3 Ga Kaapvaal craton sediments [2], we interpret that the positive δ^{15}N values of the Wits-diamonds require involvement of nitrogen from Earth's surface that was transferred into the mantle via subduction tectonics during Kaapvaal continent formation. The Wits diamonds demonstrate that by 3.5 Ga, and possibly much earlier, surficial nitrogen was present within a mantle wedge environment above a subduction zone [3].

[1] Cartigny & Marty (2013) Elements 9: 359-366.
[2] Thomazo & Papineau (2013) Elements 9: 345-351.
[3] Smart et al. (2016) Nature Geoscience10.1038/ngeo2628