Release of Nitrogen during Planetary Accretion Explains Missing Nitrogen in Earth's Mantle

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Nitrogen and carbon are essential elements for life on Earth, and their relative abundances in planetary bodies (C/N ratios) are important for understanding planetary evolution and habitability[1,2]. However, the high C/N ratio in the bulk silicate Earth relative to CI chondrites and other volatile-rich chondrites is difficult to explain with partitioning behavior between silicate and metallic liquid or solubility in silicate melt, and has thus been a major unsolved problem in geochemistry[1-5]. Because core formation does not explain nitrogen depletion in the mantle, another process is required to match the observed BSE C/N ratio, such as devolatilization of metallic liquid. Previous studies have examined the Fe-C phase diagram extensively (e.g. ref. 6, 7), but very limited melting data is available for the Fe-N system[8]. Here we examine melting relations for four Fe-N-C compositions with 1-7 wt% nitrogen up to 7 GPa and 2200 K in the Paris-Edinburgh press by a combination of *in-situ* X-ray radiography, X-ray diffraction and *ex-situ* electron microprobe techniques. In striking contrast to the Fe-C system, near-surface melting in all compositions in the Fe-N-C system entails release of nitrogen fluid and depletion of nitrogen from the liquid alloy. This could provide a pathway for nitrogen to escape the magma ocean in the accretion stage while carbon is retained. On the basis of our experimental results, we propose a new quantitative model of mantle nitrogen evolution during the core formation stage to explain the high BSE C/N ratios and resolve the paradox of missing mantle nitrogen[1-5]. Although nitrogen itself is not a greenhouse gas, the nitrogen released to the atmosphere from metallic melt early in Earth's history could amplify the greenhouse effect through collision-enhanced absorption[9,10], which may help to explain warm surface temperatures during the Hadean and Archean eras on Earth when the solar luminosity was 25-30% lower than the present[11].

References

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