Nebular and chondritic volatiles in the Earth's mantle

SUJOY MUKHOPADHYAY[1] AND CURTIS D. WILLIAMS[1]

[1]Dept. of Earth and Planetary Sciences, University of California Davis, CA 95616, USA (sujoy@ucdavis.edu)

The capture of nebular gases by planetary interiors places important constraints on planet formation models including accretion timescales, volatile compositions, and redox states. For example, presence of nebular gases in planetary interiors requires growing planets to reach sufficient mass in the presence of nebular gas, which demands a short accretionary timescales. Likewise, acquisition of nebular gas during accretion produces an H_2-dominated atmosphere that influences magma ocean solidification timescales[e.g.,1,2] and sets the initial conditions for mantle volatile contents and fugacities[e.g.,3]. However, evidence for nebular gases in the mantle remains controversial[e.g.,4-7].

We will show that high precision neon isotopic measurements in mantle plumes from the South Atlantic document the presence of nebular gases in the present day deep mantle. Neon isotopic composition of mantle-derived basalts, along with ratios of primordial argon to neon and primordial xenon to neon, indicate that mantle noble gases are a two-component mixture of nebular and chondritic gases. While mantle neon is dominated by the nebular component, primordial argon and xenon are dominated by a chondritic component. The nebular component, best preserved in the neon isotopic ratios, is present in significantly higher proportion in the deep mantle plume source compared to the shallower MORB source. The presence of nebular neon in the Earth's mantle requires proto-Earth to have reached a sufficient mass within a few million years so as to capture and dissolve nebular volatiles in a magma ocean. Embryos in the terrestrial planet forming region can grow to 0.3 Earth masses within 2 million years[8], suggesting that capture of nebular gases, could have been a common feature of terrestrial embryos. Furthermore, the preservation of distinct reservoirs of primordial noble gases in the present day mantle signifies limited interaction between the plume and MORB sources since Earth's accretion and place constraints on long-term mixing of the mantle.

[1] Matsui T. and Abe Y. Nature 319, 1986. [2] Elkins-Tanton T. L. EPSL 271, 2008. [3] Hirschmann M. M. et al., EPSL 345-348, 2012. [4] Yokochi R. and Marty B. EPSL, 225, 2004. [5] Mukhopadhyay S. 486, Nature 2012. [6] Moreira M. and Charnoz S. EPSL 433, 2016. [7] Peron et al. Geochem. Perspect. Lett. 3, 2017. [8] Levison H. F. et al., PNAS 112, 2015.