

DELIVERY OF CARBON, NITROGEN AND SULFUR TO THE SILICATE EARTH BY A GIANT IMPACT. Damanveer S. Grewal*, Rajdeep Dasgupta, Chenguang Sun, Kyusei Tsuno and Gelu Costin. Department of Earth, Environmental and Planetary Sciences, Rice University, Houston, TX. (*correspondence: dsg10@rice.edu).

Introduction: Constraining the origin, distribution and evolution of volatiles such as carbon (C), nitrogen (N) and sulfur (S) in terrestrial planets is essential to understand planetary differentiation, habitability and comparative planetology [1]. C/N ratio of Bulk Silicate Earth (BSE) is superchondritic (40 ± 8), while C/S ratio is nearly chondritic (0.49 ± 0.14) [2]. Accretion, core formation, and magma ocean (MO) crystallization are the key processes that could have set the relative budgets of C, N and S in different planetary reservoirs [3]. However, high P-T alloy-silicate partitioning experiments using either C-N or C-S-bearing systems have shown that C is more siderophile than N and S, consequently core formation would have left behind subchondritic C/N and C/S ratios in BSE [4-6]. Accretion of extremely C-rich bodies during core formation or/and as a late veneer along with an early atmospheric blow-off are amongst the scenarios that have been suggested to explain C/N ratio, while the addition of a differentiated body with a C-rich mantle has been suggested to explain C/S ratio in BSE [4-6]. However, no internally consistent explanations exist on the origin of all the volatile elements.

Methodology: We performed piston cylinder and multi-anvil experiments, using Fe-Ni-N-C±S alloy with variable amounts of S and mafic-ultramafic silicate mixtures in graphite saturated conditions at 1-7 GPa, 1600-1800 °C, and f_{O_2} ranging from ΔIW of -0.5 to -1.5. EPMA and SIMS were used to determine major elements and volatile abundances in the coexisting alloy and silicate melt phases, while the speciation of the volatiles was determined using Raman spectroscopy.

Results: Our experimental data reveals that $D_N^{alloy/silicate}$ ($D_i^{alloy/silicate}$ = concentration of element i in alloy/concentration of element i in silicate) does not change significantly (Fig. 1a), while $D_C^{alloy/silicate}$ decreases monotonically with increase in S content in the alloy melt (Fig. 1b). Moreover, C solubility in the alloy also drops in the presence of N and S. Therefore, C becomes less siderophile in the presence of N and S during core-mantle differentiation involving an S-rich alloy.

Using $\sim 10^9$ inverse Monte-Carlo simulations, we test the hypothesis whether the unique volatile budget of BSE can be satisfied via the merger of a volatile-bearing planetary embryo to a volatile-depleted proto-Earth. Our simulations predict that a disequilibrium merger of a Mars-sized planetary embryo with a C-saturated, S-rich core to a volatile-depleted proto-Earth

(Fig. 2) during the main stage of accretion could have simultaneously satisfied C-N-S abundances and ratios in BSE along with setting up the stage of for the presence of NH_3 and HCN in the Earth's early atmosphere via MO degassing.

[1] Zahnle et al. (2007) Space Sci. Rev. [2] Marty (2012) EPSL. [3] Dasgupta et al. (2013) GCA. [4] Hirschmann (2016) AM. [5] Dalou et al. (2017) EPSL. [6] Li et al. (2016) Nat. Geosci.

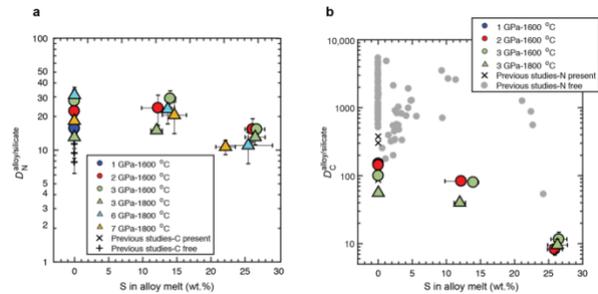


Fig 1: a) $D_N^{alloy/silicate}$ and b) $D_C^{alloy/silicate}$ as function of S content in the alloy melt.

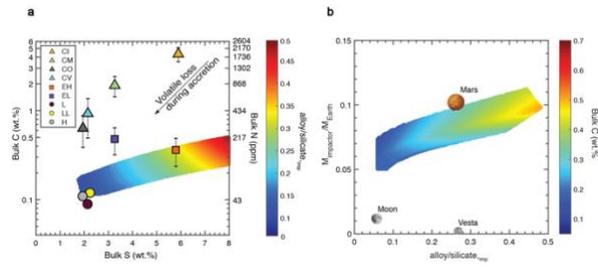


Fig 2: a) Composition of the volatile-bearing impactor relative to various types of chondrites and b) mass of the impactor relative to present-day mass of the Earth.

