Origin and timing of volatile (N, H) delivery to the angrite parent body

C. Deligny[1], E. Füri[1], and E. Deloule[1]. [1]Centre de Recherches Pétrographiques et Géochimiques, CNRS-UL, 54501 Vandoeuvre-les-Nancy, France. E-mail: cecile.deligny@univ-lorraine.fr.

Introduction: The volcanic angrites D'Orbigny and Sahara 99555 are two of the oldest meteorites known, with ages of 4563.51 ± 0.8 and 4564.07 ± 0.43 Ma, respectively [1]. They are derived from the differentiated angrite parent body (APB), which was accreted ~1.5 Myrs after CAIs [2] inside Jupiter's orbit, as indicated by the isotopic signatures of ^{50}Ti and ^{54}Cr [3]. Previous studies have revealed a non-neglibible amount of H, C, and N in D'Orbigny [4, 5]. The goal of this study was to determine the content and isotopic signature of N and H in the primitive and more evolved melt from which the two angrites were formed. To this end, we measured, for the first time, the N content and isotopic ratio (^{15}N/^{14}N) of glass inclusions (in anorthite, pyroxene, and olivines), interstitial glasses, and silicate minerals – in four polished sections of D'Orbigny and one polished section of Sahara 99555 – by *in-situ* high-resolution secondary ionization mass spectrometry [6]. The new data allow us to better constrain the source(s) and timing of volatile delivery to planetary bodies in the inner Solar System.

Results: Glass in D'Orbigny contains 15.4 ± 2.1 to 655.3 ± 189.1 ppm N with isotopic ratios (δ^{15}N corrected for cosmogenic ^{15}N) from 0.6 ± 29.7 to 1068.2 ± 174.2 ‰. The nitrogen content of all minerals is below 1 ppm. Sahara 99555 contains very little N (≤ 23 ± 1 ppm), precluding δ^{15}N measurements. The water content in D'Orbigny glass ranges from 81.1 ± 2 ppm to 5.49 ± 0.44 wt.% and H isotope ratios (δD corrected for cosmogenic D) from -346.7 ± 19.1 to +146.7 ± 69.7 ‰. For Sahara 99555, the water concentration ranges from 475 ± 60 ppm to 1.25 ± 0.06 wt.% and the δD value varies from -178.1 ± 79.5 to +254.7 ± 62.9 ‰. Compared to D'Orbigny, Sahara 99555 is enriched in deuterium and contains less water and nitrogen, indicating that it samples a more degassed melt.

Discussion: The most primitive melt, trapped in Mg-rich olivines, is characterized by a δ^{15}N value between 0.2 ± 25 and 82.2 ± 54.9 ‰. This value is similar to that of the terrestrial mantle or CM chondrites [7]. Similarly, the H isotope signature of inclusions in Mg-rich olivines is comparable to that of OIBs [8]. During its evolution, the melt is expected to experience degassing and/or mixing. However, open-system degassing of N_2 or NH_3 cannot explain the highest δ^{15}N values observed in D'Orbigny. Instead, mixing between two components with distinct ^{15}N/^{14}N ratios has to be considered. According to this scenario, the δ^{15}N signature of the more evolved melt, trapped in inclusions with low a Mg-number, is consistent with a cometary contribution (δ^{15}N ≈ +1000 ‰; [7]). Therefore, given the very old age of the two angrites, volatile-rich CM-like and cometary materials must have been delivered from the outer Solar System to the terrestrial planet-forming region within the first ~4 Myrs after CAI formation. Jupiter is thought to have prevented the influx of volatile-rich material to the inner Solar System for at least 3 to 4 Myrs [9]. Once the nebular gas started to disperse, CM-like and cometary objects could have been scattered inward, due to the growth/migration of Jupiter [10]. Thus, angrites may record the earliest delivery of outer Solar System volatiles. These results imply that a cometary volatile contribution to the building blocks of the terrestrial planets cannot be ruled out.

[1] Tissot, F.L. et al. (2017) *GCA*, 213, 593-617. [2] Kleine, T. et al. (2012) *GCA*, 84,186-203. [3] Warren, P.H. (2011) *EPSL*, 311(1-2), 93-100. [4] Sarafian, A.R et al. (2017) *Phil. Trans. R. Soc. A* 375: 20160209. [5] Varela, M.E. et al. (2003) *GCA* **67**(24), 5027-5046. [6] Füri, E. et al. (2018) *Chem. Geol.*, 493, 327-337. [7] Alexander, C.M.O.D. (2017) *Phil. Trans. R. Soc. A375*: 20150384. [8] Deloule, E. et al. (1991) *EPSL 105*(4), 543-553. [9] Kruijer, T.S. et al., (2017) *Proceedings of the National Academy of Sciences*, *114*(26), 6712-6716. [10] Raymond, S.N. and Izidoro, A. (2017) *Icarus*, *297*, 134-148.