

DISTRIBUTION OF VOLATILE ELEMENTS IN ENSTATITE CHONDRITES

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Volatile and moderately volatile elements such as hydrogen, nitrogen, carbon, or sulfur are essential for life. The question of the origin of these elements on our planet and more generally on the rocky planets of the solar system is fundamental for understanding our origins. Primitive chondrites are key witnesses for deciphering the conditions that prevailed in the early solar system and the nature of planet building blocks. They contain variable and sometimes high concentrations of volatile elements [1].

Enstatite chondrites (ECs) are of particular interest because they share isotopic similarities with Earth and could be analogues of the Earth's building blocks (e.g., [2-3]). As ECs do not contain hydrated minerals or traces of aqueous alteration [4], they are generally considered to be dry, i.e., without water and poor in volatile elements. Moreover, by comparison with asteroid types and thermodynamical conditions in the disk, it is considered that the EC parent bodies formed in the inner solar system [5]. Conversely, carbonaceous chondrites (CCs) are enriched in volatile elements (especially H) and are thus thought to have formed further away from the Sun, beyond the snowline.

In a previous study, high hydrogen contents (up to 1.2 wt.% H₂O; [6]) were measured in the chondrule glassy mesostases of the least altered EC Sahara 97096, although no specific H-bearing phase was reported. In the continuity of this study, we perform analyses for determining the H and other volatile contents of two primitive enstatite chondrites (Sahara 97096 and Sahara 97116, paired with Sahara 97096). The aims of these analyses are to understand the dispersion of volatile elements, the nature of their bearing phases and the distribution of volatile elements in the inner solar system.

Methods: Images and point analyses of volatile elements in ECs were obtained with a SIMS IMS1270-E7 at CRPG using a Cs⁺ primary beam of 10 kV. We first collected ion images of 50 x 50 μm² with a primary current of 70 pA for a spatial resolution of ~0.5 μm. ¹²C, ¹⁶OH, ¹⁸O, ¹⁹F, ¹⁸OH, ³⁰Si, ¹⁴N¹⁶O, ³²S, ³⁵Cl, ²³Na¹⁶O, ²⁴Mg¹⁶O ions were collected on the axial electron multiplier (EM). A 1-nA beam was used for point analyses and the ¹²C, ¹⁶OH, ¹⁸O, ¹⁹F, ²⁷Al, ³⁰Si, ³²S, ³⁵Cl ions were collected on the axial (EM) and Faraday cup equipped with a 10⁻¹² ohm resistor [7]. Finally, ¹⁶OH, ¹⁸O, ¹⁶OD, ²⁷Al, ³⁰Si ions were measured with a primary current of 2 nA for estimating the D/H ratios of chondrule mesostases. Additional analyses were realized using Raman spectroscopy at GeoRessources and with an EPMA at CamParis.

Results & discussion: The areas of interest (with no cracks and showing the highest/lowest concentrations) for quantitative point analyses were chosen according to the visible heterogeneities in the ion images. Mesostases contain (in wt. ppm): 600 < H₂O < 7400, 2600 < S < 8200, 120 < C < 5300, 1800 < Cl < 14 300 and, 60 < F < 580 and have a mean isotopic composition of δD = -114 ± 55 ‰ (2σ, standard deviation). H₂O in enstatite pyroxenes is generally below 200 wt. ppm. The higher hydrogen concentration and the lower D/H isotope ratio in the EC chondrule mesostasis are consistent with [6]. Moreover, the distribution of C, S, Cl is heterogeneous in the different zones of mesostasis with high concentrations. Conversely, the F content is rather low (~113 ppm) and looks homogeneous. However, for all the other elements, and in particular for C and S, hot-spots are visible on the ion probe images and could correspond to local exsolutions in the mesostasis.

The concentration of H is only correlated with the amount of S. This association between hydrogen and sulfur might be favored by the low Fe content of the mesostasis [8] resulting from the very reducing conditions of formation of enstatite chondrites. In this talk, we will discuss the nature of H speciation in chondrule mesostasis and the implication for the EC chondrule formation conditions.

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