ASUKA 12325: EXPANDING THE CHEMICAL VARIETY OF THE MARTIAN MANTLE SAMPLED BY SHERGOTTITES.

V. Debaille[1], J. Roland[1,2], S. Goderis[2], G. Hublet[1], H. Pourkhorsandi[1], [1]Laboratoire G-Time, Université Libre de Bruxelles, Brussels, Belgium (vinciane.debaille@ulb.be), [2]AMGC, Vrije Universiteit Brussel, Brussels, Belgium

Introduction: Besides their mineralogical and textural classification (see recent summary in [1]), shergottites, a subgroup of martian meteorites, have also been divided in 3 categories according to their content in rare earth elements (REE) (e.g. [2]). As such, shergottites that are depleted in the most incompatible REE, the light REE (LREE), are called the depleted shergottites, with a progressive enrichment in LREE observed in the intermediate shergottites and then the enriched shergottites showing a relatively flat CI-normalized REE pattern in REE. Interestingly, the mineralogical and chemical classifications do not match, as the geochemical range encompasses all mineralogical categories [1], as well as several ejection events (e.g. [3]). The chemical variation between depleted and enriched shergottites has been attributed to contamination of the magma by the martian crust (e.g. [4]) or contamination by enriched cumulates resulting from the solidification of the martian magma ocean [2, 5]. In any case, while the enriched shergottites clearly contain a contribution from an enriched endmember, the depleted shergottites are thought to be representative of the depleted martian mantle [2, 6, 7], hence providing important information about the geological evolution of Mars and the martian interior. As such, they are particularly important within the shergottite compositional continuum.

During the Belgian-Japanese field expedition on the Nansen Blue Ice field in 2012-2013, a greenish stone was collected and later identified as a shergottite (NIPR-RBINS Meteorite Newsletter April 26 2018). The stone weights 28 g and is devoid of any fusion crust (Fig. 1). Geochemical investigation has been performed at the Laboratoire G-Time (Université Libre de Bruxelles) in order to constrain the geochemical affinities of Asuka 12325 and shed new light on the geological evolution of Mars.

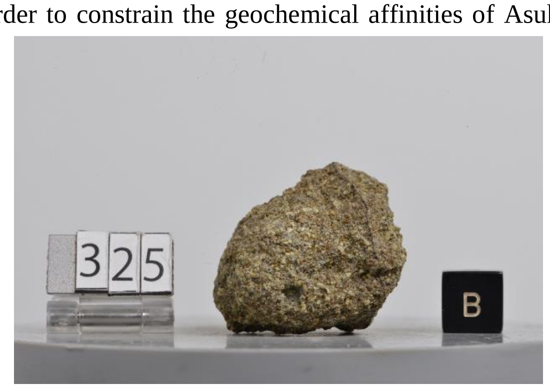

Figure 1: Picture of Asuka 12325, scale is 1 cm. © NIPR

Method: Around 50 mg of samples has been dissolved by alkaline fusion for major and trace elements content. Major elements were measured on the iCAP ICP-AES at ULB using Y as internal standard. Overall, the total reproducibility estimated using USGS rock standards is better than 2%. Trace elements were measured on the Agilent 7700 ICP-MS at ULB, using In as internal standard. The total reproducibility estimated using multiple USGS rock standards is better than 10%. For isotope analyzes, around 0.8 g of sample was gently crushed and sieved, and minerals separation was performed using heavy liquids and Frantz magnetic separator. After dissolution using 3:1 mixture of HNO_3:HF, and then HCl, a small aliquot was removed for Lu-Hf and Sm-Nd spiking. Hafnium and rare earth elements (REE) were purified first using a cationic resin and 2N HCl and 6N HCl respectively. Hafnium was subsequently purified first on an anionic column to eliminate Fe and then on a HDEHP column, where Ti was removed and Hf eluted with 4N HF. On the other hand, REE were purified on HDEHP resin. The Nd cut of the whole rock was then further purified to remove Ce because of the isobaric interference column [5] and the Na introduced during this column chemistry was finally removed using a small cationic column. All spiked and unspiked cuts for Lu-Hf and Sm-Nd have been measured using the Nu II HR-MC-ICP-MS at ULB using an Aridus 2 desolvating nebulizer, while, the bulk rock Nd fraction has been measured on the ThermoScientific Triton Plus at ULB.

Results and discussion: According to the REE pattern (Fig. 2), Asuka 12325 is a depleted shergottite, showing a clear depletion in LREE. However, it also shows a marked depletion in HREE relative to the average depleted shergottites. The bulk Mg# is 0.42, comparable to that of mafic shergottites, according to the classification introduced by [8]. However, the CaO conten of 4.1 %wt is unusually low for mafic shergottites, resembling the permafic or even the ultramafic shergottites. The Lu-Hf and Sm-Nd geochronological systems yield ages 231 ± 27 Ma and 286 ± 120 Ma respectively (Fig. 3).

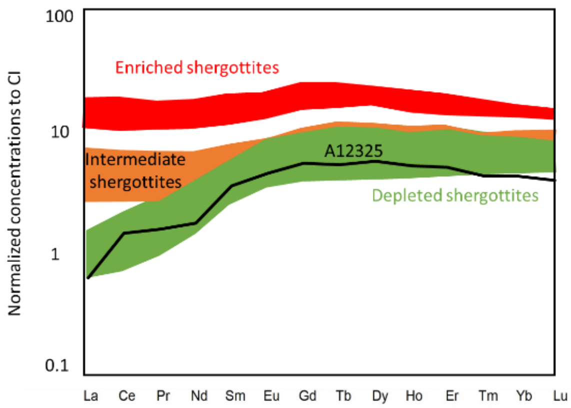

Figure 2: REE pattern normalized to CI chondrites, of Asuka 12325, compared to literature data for shergottites.

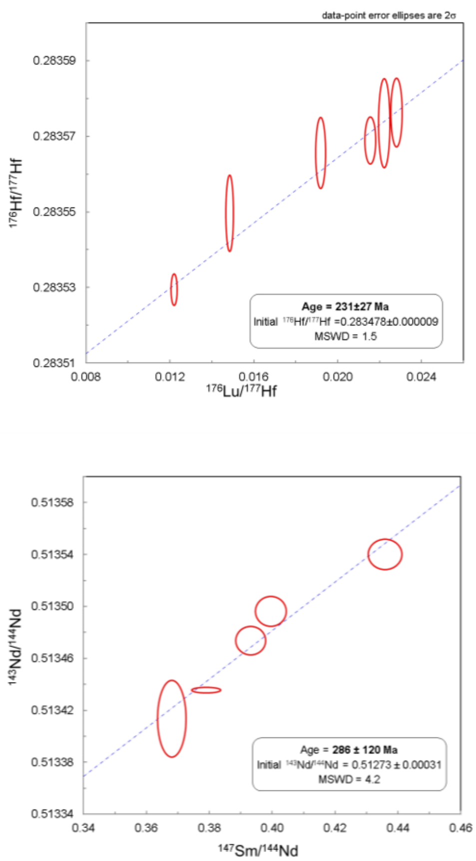

Figure 3: Lu-Hf and Sm-Nd isochrons for Asuka 12325.

The initial ε-values obtained on the isochrons are $\varepsilon_i{}^{143}$Nd of +9.0 ± 6.1 and $\varepsilon_i{}^{176}$Hf of +30.1 ± 0.3. Those values do not correspond to the depleted shergottites range ($\varepsilon_i{}^{143}$Nd from ~+36 to +39; and $\varepsilon_i{}^{176}$Hf from ~+46 to +50) (e.g. [7]). As such, Asuka 12325 might represent a new flavor in the shergottite continuum.

A similar observation can be made when working with the ^{142}Nd value of Asuka 12325. Indeed, while all shergottites plot on the same continuum between a depleted and an enriched endmembers [2, 5, 6, 9, 10], Asuka 12325 is set apart from that mixing line. This implies that even though being classified as a shergottite, it evolved independently from the shergottite continuum since at least 4 billion years. Interestingly, a two-stage modeling cannot provide a simple and satisfactory answer on the source evolution of Asuka 12325. This unique meteorite clearly expands the chemical variability of the martian mantle as sampled by shergottites.

References:

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