

**TRACE ELEMENT ABUNDANCES OF OLIVINE-HOSTED MELT INCLUSIONS IN SHERGOTTITES NORTHWEST AFRICA 7397 AND ROBERT MASSIF 04262.** J. Ferdous<sup>1</sup>, A.D. Brandon<sup>1</sup>, M. Humayun<sup>2</sup> and A.H. Peslier<sup>3</sup>. <sup>1</sup>University of Houston, Houston TX 77204, USA, [jferdous@uh.edu](mailto:jferdous@uh.edu); <sup>2</sup>Florida State University, Tallahassee FL 32310, USA; <sup>3</sup>Jacobs, NASA-Johnson Space Center, Mail Code X13, Houston TX 77058, USA.

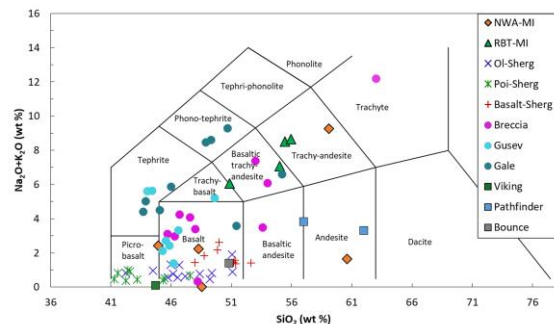
**Introduction:** Olivine-hosted melt inclusions (MIs) may retain trapped parent magma compositions as well as record progressive differentiation while magmas crystallize and ascend towards the surface [1,2 and references therein]. Major element compositions of the MIs, especially Fe and Mg, can be affected by post-entrapment re-equilibration with their host olivine [1,2]. Therefore, Fe/Mg ratio correction is required to obtain MI bulk compositions following equilibrium with their host olivine. Partition coefficients of most of the trace elements in olivine are very low (i.e.  $D_{OL/melt} < 0.001$ ). Thus, ratios of trace elements of olivine-hosted MIs are unlikely to be affected by post-entrapment re-equilibration and no correction is necessary [2]. Hence, tracking trace element behavior in MIs may constrain the composition of the parent magma and its evolution yielding insights on magma differentiation of shergottites. However, analyzing MIs for chemical compositions is a challenging task due to their low abundances and small sizes. Using a highly sensitive and precise micro-beam technique is essential to examine olivine-hosted MIs in order to measure trace element abundances. For this purpose, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) is an excellent tool due to its wide range of laser spot sizes (1-150  $\mu\text{m}$ ), ability to obtain raster analysis (several  $\text{mm}^2$ ) and lower detection limits (0.1 ppb) [3].

In this study, olivine-hosted MIs of 2 incompatible trace element-enriched poikilitic (also known as lherzolitic) shergottites, Northwest Africa (NWA) 7397 and Robert Massif (RBT) 04262, were analyzed for 60 major, minor and trace elements using LA-ICP-MS. Major element analyses of the MIs in NWA 7397 and RBT 04262 using electron microprobe (EMP) along with their corrected primary trapped magma compositions were presented in [4,5]. The goal of this work is to determine whether these MIs are derived from crystallization of the host parent magmas for these two shergottites or instead reflect crustal contamination during shergottite magma ascent through the crust.

**Analytical Techniques:** The same thick-sections of NWA 7397 and RBT 04262 used for EMP analyses were analyzed using an Electro Scientific Instruments (ESI) New Wave™ UP 193FX ArF excimer (193 nm) laser ablation system coupled to a Thermo Element XR™ ICP-MS at the National High Magnetic Field Laboratory at Florida State University. Olivine-hosted

MIs and major phases (olivine, pyroxene, maskelynite, phosphate, and chromite) were analyzed using different laser spot sizes (25, 50, 75 and 100  $\mu\text{m}$ ) depending on the size and depth of the analyzing phases at 50 Hz repetition rate with varying dwell time from 5-20 seconds. Elemental concentrations were obtained using relative sensitivity factors (RSFs) collected from multiple reference glasses i.e. BCR-2g, BHVO-2g, BIR-1g and NIST SRM 610 [3]. From both sections, 5 MIs in NWA 7397 and 4 MIs in RBT 04262 were selected. Some MIs were analyzed in the poikilitic lithology within RBT 04262, which turned out to be plagioclase grains only and are not discussed further, here.

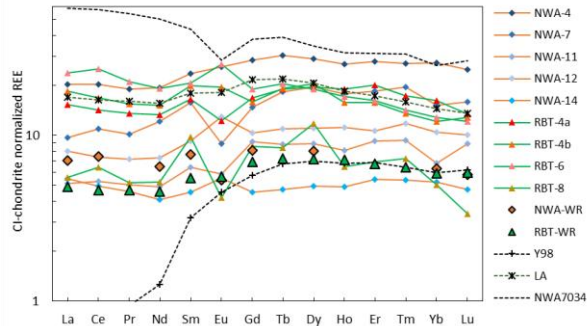
**Results and Discussion:** The  $\text{SiO}_2$  contents of the MIs vary from 45-60 wt% and that of their host olivines ( $F_{0.56-6.3}$ ) vary from 34-36 wt%. With the exception of one MI,  $\text{CaO}/\text{Al}_2\text{O}_3$  is super-chondritic ( $\geq 0.8$  [6]) in NWA-MIs with lower alkalis (<2.5 wt%, except one MI with ~9 wt%), whereas, RBT-MIs have sub-chondritic  $\text{CaO}/\text{Al}_2\text{O}_3$  (0.2-0.3) ratios with higher alkalis ( $\geq 6$  wt%). The feldspar phase in RBT 04262 is more Na-rich than NWA 7397 feldspar, justifying such variation in  $\text{CaO}/\text{Al}_2\text{O}_3$  ratios in their MIs. In Fig. 1, the compositions of MIs from these two shergottites are plotted on a total alkalis vs.  $\text{SiO}_2$  (TAS)- diagram together with literature data for bulk shergottites and martian surface rock samples. Melt inclusions from RBT 04262 plot in the trachybasalt-trachyandesite field, while MIs from NWA 7397 plot in the basalt-andesite fields.



**Fig. 1:** Total alkalis vs. silica diagram of MIs in NWA 7397 and RBT 04262 with shergottites and Martian surface rocks. Breccia= NWA 7034 and NWA 7533 [13,14,15].

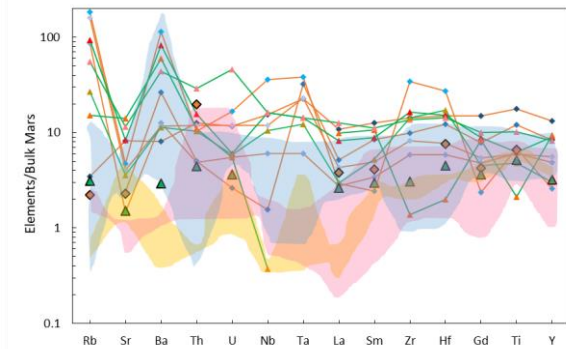
The CI-chondrite normalized REE patterns of almost all the MIs overlap with and are within an order of magnitude higher than their respective whole-rock (WR) compositions (Fig. 2). The  $(\text{La}/\text{Lu})_N$  ratio varies

from 0.58 to 1.16 in NWA-MIs and from 1.14 to 1.96 in RBT-MIs whereas these ratios are 1.23 and 0.82 for the WRs, respectively. The La/Sm ratio varies from 0.61 to 1.2 in NWA-MIs and from 0.57 to 1.14 in RBT-MIs, consistent with their WR-ratios (i.e. 0.92 and 0.89 for NWA 7397 and RBT 04262, respectively). Martian regolith breccia NWA 7034 has LREE abundances that are ~2 times higher than the most enriched MIs (NWA-4 and RBT-6). The Ce-anomaly is negligible (i.e. 0.97-1.2) in all MIs indicative of minimal terrestrial alteration [11].



**Fig. 2:** CI-chondrite normalized REE concentrations of the MI compositions of NWA 7397 and RBT 04262 compared to their WR compositions. NWA 7034 (crustal breccia), Yamato 980459 (Y98, most primitive shergottite) and Los Angeles (LA, most evolved shergottite) are shown for reference [7,8,9,10,11].

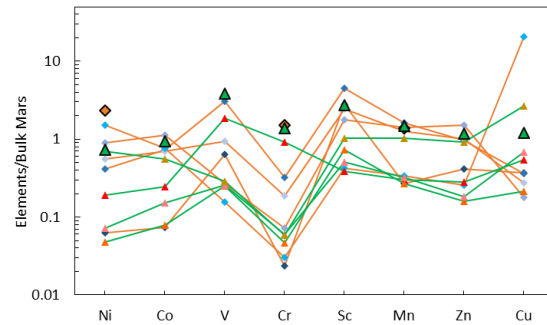
Bulk silicate Mars normalized LILE (Rb, Sr, Ba) and HFSE profiles are plotted in Fig. 3. The LILE in the MIs are higher in concentrations by as much as an order of magnitude compared to their respective WRs, an observation consistent with their REE compositions (Fig. 2). The HFSE in the MIs plot above and below their respective WR compositions.



**Fig. 3:** Bulk silicate Mars normalized spider-diagram of the MI compositions in NWA 7397 and RBT 04262. Symbols are same as Fig. 2. Yellow, pink and blue shaded areas are depleted, intermediate and enriched shergottite fields, respectively [3].

Nickel and Co concentrations, compatible in olivine [12], are lower in MIs compared to their respective host olivine as well as WR compositions consistent with olivine removal (Fig. 4). Similarly, Cr

and Sc concentrations, compatible in pyroxene [12], are also lower in the MIs compared to their respective primary pyroxenes and WR compositions (Fig. 4), suggesting MI entrapment after the onset of pyroxene crystallization. Note that NWA-MIs have higher Ni, Co and Cr abundances than RBT-MIs.



**Fig. 4:** Bulk silicate Mars normalized transition elements of the MI compositions in NWA 7397 and RBT 04262. Symbols are same as Fig. 2.

Nearly parallel REE-profiles of MIs are reflecting closed system crystal fractionation. The increasing abundances in MI-REEs indicate melt entrapment throughout the crystallization sequence. The lower abundances of Ni, Co, Cr and Sc in MIs compared to the WR compositions indicate that none of them are representative of parent melt from which olivine crystallized and that the MIs were trapped after the initiation of pyroxene crystallization. This finding is in agreement with the corrected Mg# (32-36) of MIs in Fe-rich host-olivine (Fo<sub>56-63</sub>).

**Conclusions:** The combination of major and trace element abundances in the MIs indicate that their compositions are more evolved than their host rocks. They are likely evolved melts derived from crystallization of their respective WRs and no evidence of exogenous addition of material via crustal contamination is present in NWA-MIs. Additional evaluation of crystallization and mixing models will be conducted to better evaluate RBT-MIs.

**References:** [1] Goodrich (2003) *GCA*, 67, 3735-3771. [2] Basu Sarbadhikari et al. (2011) *GCA*, 75, 6803-6820 [3] Yang et al. (2015) *MAPS*, 50, 691-714. [4] Ferdous et al. (2018) *LPSC XLIX*, Abs.#1033. [5] Potter et al. (2015) *LPSC XLVI*, Abs.#2945. [6] Agee & Draper (2004) *EPSL*, 224, 415-429. [7] Irving (personal communication). [8] Anand et al. (2008) *LPSC XXXIX*, Abs.#2173. [9] Agee et al. (2013) *Science*, 339, 780-785. [10] Shirai & Ebihara (2004) *Ant. Met. Res.* 17, 55-67. [11] Jambon et al. (2002) *MAPS*, 37, 1147-1164. [12] Rollinson (1993). [13] Agee et al. (2013) *Science*, 339, 780-785. [14] Humayun et al. (2013) *Nature*, 503, 513-516. [15] Santos et al. (2015) *GCA*, 157, 56-85.