NICKEL IN OLIVINE AND CONSTRAINING MANTLE RESERVOIRS FOR SHERGOTTITE METEORITES. Geoffrey H. Howarth[1] and Arya Udry[2], [1]Department of Geological Sciences, University of Cape Town, Rondebosch 7701, South Africa (ghhowarth@gmail.com), [2]Department of Geoscience, University of Nevada, Las Vegas, Las Vegas NV, USA.

Introduction: Shergottite meteorites represent the dominant martian meteorite group and, as such, are central in our understanding of martian volcanism and constraining mantle reservoirs. Three distinct martian mantle reservoirs have been defined for the shergottite meteorites, which are primarily based on radiogenic isotope variations and Light Rare Earth Element (LREE) enrichment: 1) depleted, 2) intermediate, and 3) enriched reservoirs [1]. The exact nature of these mantle reservoirs, however, is still much debated. In this study, we use olivine chemistry to better constrain the nature of the shergottite magma sources.

Olivine is the first mineral to crystallize from shergottite parent magmas and thus provides insight into the composition of parent melts as well as their mantle source chemistry. On Earth, olivine chemistry is a growing field of study where correlations between major, minor, and trace elements have allowed for the discrimination of mantle source components [2, 3], relative depth of melting [4], redox conditions [2], etc.

Several processes can explain Ni variations in olivines. 1) Ni concentrations in some primitive olivines from basaltic magmas on Earth (e.g., Hawaii) have extreme Ni enrichment relative to primitive olivine from mid-ocean ridge basalts (MORB) (Fig. 1a) [2]. Nickel is compatible in olivine, thus, in the source, it would buffer Ni concentrations producing melts in equilibrium with source olivine Ni contents: i.e., MORB magmas. For olivine-free lithologies, Ni more freely enters the melt phase (e.g., Hawaii; Fig. 1a) producing more Ni-rich melts and resultant Ni-rich olivine at a given Fo content. Therefore, the Ni enrichment was suggested to be related to an olivine-free pyroxenitic source component formed through the interaction of eclogite-derived melts and peridotite in an ascending mantle plume. 2) Olivine-melt Ni partitioning has been shown to be affected by temperature whereby melting at greater depths and at relatively high temperatures results in lower Ni olivine-melt partition coefficients than crystallization at lower temperatures at the surface. This has the effect of olivines crystallizing with higher Ni contents relative to their source [4]. These authors suggested that elevated Ni in Hawaiian olivines was more likely the result of formation under thickened lithosphere relative to MORB. 3) A third model for Ni enrichment in olivine suggests that Ni enriched parental magmas were derived from Ni-rich lithologies at the core-mantle boundary on Earth [5].

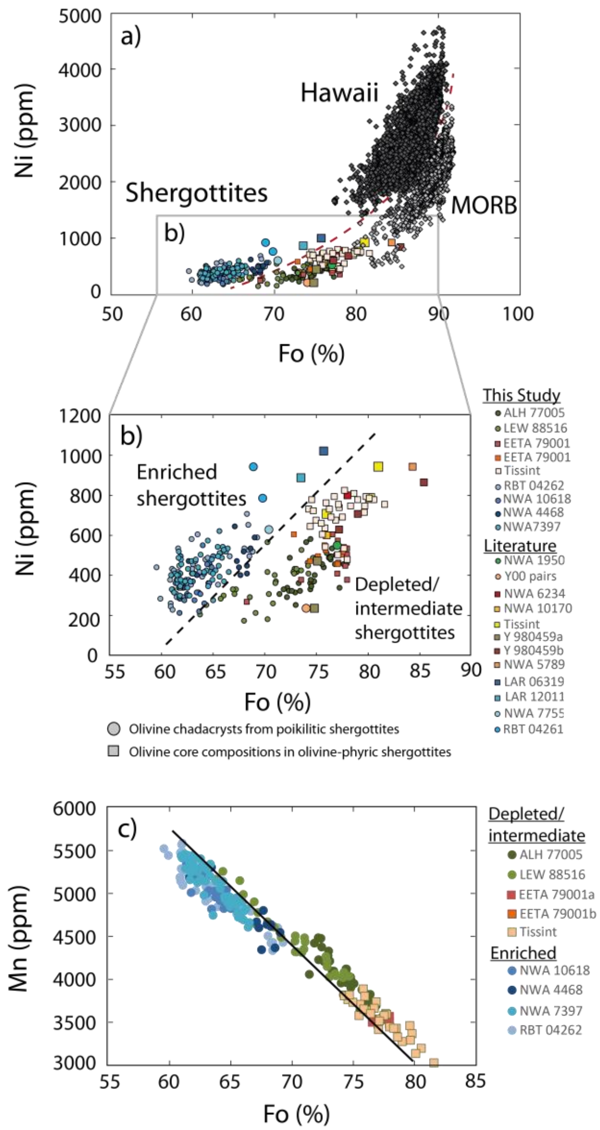

Fig 1. Olivine chemistry for shergottites. a) Olivine chemistry for shergottites analyzed in this study along with data compiled from the literature in comparison with terrestrial MORB and Hawaii data. b) Fo versus Ni contents for olivines from this study and compiled data. Data from references [6-17]. c) Fo versus Mn concentrations for olivines analyzed in this study.

In this contribution, we present detailed high precision electron microprobe (EMP) data for olivine from shergottites in order to evaluate the potential for Ni in olivine to constrain mantle source reservoirs on Mars.

Analytical techniques: Olivines were analyzed using the EMP at the University of Nevada, Las Vegas with a high-beam current of 60 nA, 15 kV, 3 μm beam, and long counting times: e.g., 60 s for Ni and most other minor elements. Detection limits for minor elements; e.g., Ni were <40 ppm.

Results: We present results for olivines analyzed from poikilitic shergottites sourced from the enriched mantle reservoir (NWA 7397; NWA 4468; RBT 04262; NWA 10618) and from the intermediate reservoir (ALH 77001; LEW 88516). All of the measured olivines analyzed represent primitive chadacryst olivine enclosed in coarse-grained pyroxene oikocrysts. In addition, olivine megacryst data for olivine-phyric shergottites EETA 79001A (intermediate) and Tissint (depleted) are presented. An additional five olivine-phyric shergottites have been acquired but not yet analyzed for this study. A compilation of literature data of the most primitive olivine from various other shergottites is also presented in Fig. 1.

The olivine from ALH and LEW are more Mg-rich with Fo contents up to Fo_{78} whereas the enriched poikilitic shergottites are more Fe-rich with Fo up to Fo_{69} (Fig. 1). The Ni contents overlap for both groups (200-750 ppm); however, the enriched shergottites are characterized by Ni enrichment at a given Fo content (Fig. 1b). The olivine-phyric shergottites analyzed have more Mg-rich olivines with Fo contents up to 81. Both the EETA and Tissint samples analyzed overlap with the intermediate poikilitic shergottites (Fig. 1b). Literature data are consistent with the observations in this study, in that, the enriched shergottites have Ni-rich olivine at a given Fo content relative to olivine from the intermediate and depleted groups (Fig. 1b). For example, enriched olivine-phyric shergottites LAR 12011 and LAR 06319 have high-Ni (~900-1000 ppm) relative to olivines at the same Fo content for the depleted shergottites such as Tissint (~700 ppm) (Fig. 1b). The shergottite groups are also distinct when plotting Fo versus Mn (Fig. 1c), where the enriched shergottites have lower relative Mn contents. This is also observed in the Mn/Fe ratios where the enriched shergottites have lower 100Mn/Fe ratios (<2.1) relative to the intermediate/depleted groups (>2.1). The Ca contents overlap completely for the different shergottite groups.

Discussion:

Comparison with terrestrial olivines: Martian olivines are Fe-rich and Ni-poor relative to terrestrial equivalents (Fig. 1a). This is a function of the Fe-rich nature of Mars and low-Ni contents of the mantle due to a significant proportion of the Ni being held in the core [18]. However, the Ni-enrichment observed for enriched versus depleted/intermediate shergottites is similar to that observed between Hawaii versus MORB basalts. The trend for terrestrial olivines extends to the martian olivine, where depleted/intermediate olivine are similar to MORB and enriched olivines are similar to Hawaii (Fig. 1a). This may suggest a similar control on Ni contents in olivine to that observed for terrestrial populations, and that olivine chemistry may reveal key clues to the origin of mantle reservoirs on Mars.

Implications for mantle source components on Mars: The key discriminators for the hypotheses discussed earlier is not the Ni contents, but rather the Mn and Ca contents of the olivines. Melts generated from a pyroxenitic source are expected to have lower Mn and Ca as a result of higher bulk partition coefficients of the pyroxene and garnet residua [2]. No variation in trace elements would be observed for a P-T control on the Ni partitioning [5]. The enriched shergottite olivines have lower Mn contents as would be expected, but the Ca contents are similar for both the enriched and depleted/intermediate olivine groups. Recently, it was shown that Ca-in-olivine may be used as a hygrometer and that Ca olivine-melt partitioning may be a function of magmatic water contents [19]. Therefore, chemistry is somewhat ambiguous, but we tentatively suggest here that the chemistry of olivines in shergottites are indicating the presence of a pyroxenitic component in the plume source for the enriched shergottites. Recent geodynamic models predict the formation of dense eclogite at the late stages of magma ocean crystallization on Mars, which sink down to the core mantle boundary [20]. If this eclogite was subsequently entrained by an ascending plume it would preferentially melt and these melts would interact with the surrounding peridotitic mantle consuming olivine and producing a pyroxenitic component. Regardless of the interpretation, the variation in Ni enrichment for the enriched versus depleted/intermediate shergottite olivine is providing a clue to mantle source components on Mars. Further work on olivine chemistry in shergottites has been planned to further constrain the implications discussed here.

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