CONSTRAINTS ON MARS MANTLE EVOLUTION FROM SM-ND AND LU-HF ISOTOPE COMPOSITIONS OF SHERGOTTITES AND ALH 84001

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Introduction: Calculated Lu-Hf and Sm-Nd initial isotope compositions of shergottites and ALH 84001 indicate a hybridized upper-mantle is a likely source of these materials. The hybridized mantle formed during crystallization of a Mars magma ocean where cumulates with depleted Sm/Nd and Lu/Hf ratios and late-stage residual liquids with enriched Sm/Nd and Lu/Hf ratios represent the depleted and enriched mantle end-member compositions, respectively [1-3].

Discussion: Shergottites span a range in source ^{176}Lu/^{177}Hf and ^{147}Sm/^{144}Nd ratios of 0.028 – 0.052 and 0.18 – 0.28, respectively. Source ^{176}Lu/^{177}Hf and ^{147}Sm/^{144}Nd compositions of ALH 84001 (ALH), calculated for the measured Lu-Hf age of 4.091 Ga, are 0.018 and 0.172, respectively [2]. Although ALH is distinct both in age and lithology, its source compositions are consistent with mixtures of depleted and enriched mantle end-member components that describe the Lu-Hf and Sm-Nd mixing array of shergottites (Figure 1). Furthermore, calculated source compositions of ALH indicate that it is derived from a source that has the highest proportion of the enriched component relative to recognized shergottites.

Modeling of a crystallizing 2000 km thick magma ocean by Debaille et al. [3,4] provides a data set of mantle reservoir Sm-Nd and Lu-Hf compositions we have tested for compatibility with the observed source variation of shergottites. An upper mantle (200 - 750 km) assemblage consisting of olivine, CPX, OPX, and garnet (with a majorite component) cumulates and trapped residual liquid in equilibrium with the cumulates [3] is consistent with the inferred depth of mantle partial melting (250 – 400 km [5]). Furthermore, mixing of the cumulates and trapped liquid in this upper-mantle assemblage can describe the Lu-Hf and Sm-Nd source characteristics of shergottites and ALH (Figure 1). This upper mantle assemblage formed during magma ocean crystallization of the remaining ~35 – 7% liquid [3]. The calculated ^{147}Sm/^{144}Nd and ^{176}Lu/^{177}Hf ratios of the very late stage residual liquid after ~ 98% magma ocean crystallization are < 0.16 and < 0.017 [3], respectively. Although the ^{176}Lu/^{177}Hf composition of this very late stage liquid is compatible (within uncertainty) with the model, the ^{147}Sm/^{144}Nd ratio is too low to be a major component of the enriched end-member [2]. In light of both enriched shergottite and ALH source data, Lu-Hf and

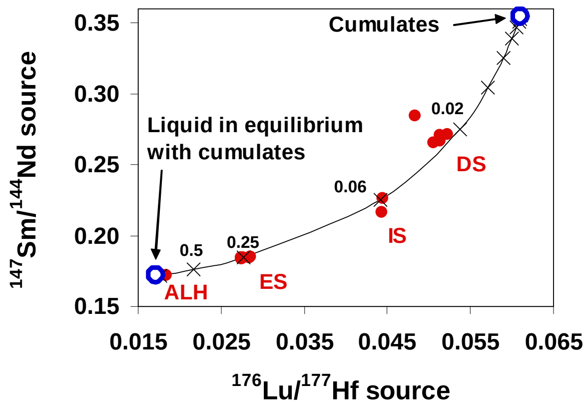

Figure 1. Mixing diagram for shergottites and ALH ^{147}Sm/^{144}Nd and ^{176}Lu/^{177}Hf source compositions. Red dots are shergottites; DS = depleted shergottites; IS – intermediate shergottites; ES = enriched shergottites; ALH = ALH 84001. The black binary mixing line is based on source compositions of cumulates and liquids in equilibrium with the cumulates in the upper mantle assemblage (UM1) of [3] produced in a 2000 – 1350 km deep MO. Isotope data used for the source calculations of shergottites come from [2-12]. Labeled mixing proportions (black symbols) are based on the fractions of residual trapped liquid.

Sm-Nd compositions of very late stage residual liquids and associated cumulates are not consistent with the enriched component of shergottites sources.

The shergottites and ALH do not appear to sample highly incompatible element enriched source material reflective of a late stage residual liquid after >98% magma ocean crystallization [2]. If this is the case, this material was removed during impact processing or it was not uniformly distributed such that it did not develop near the volcanic centers and influence shergottite compositions.

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