CONSTRAINTS ON THE ISOTOPIC COMPOSITION OF THE SHERGOTTITE MANTLE SOURCES—FROM OBSERVATIONS BASED ON THE EXPANDING ROCK RECORD. R. Andreasen[1], T. J. Lapen[1], M. Righter[1], and A. J. Irving[2], [1]Department of Earth and Atmospheric Sciences, University of Houston, 312 Science & Research Building 1, Houston TX 77204, USA (randreas@central.uh.edu, [2]Department of Earth & Space Sciences, University of Washington, Seattle, WA 98195.

Introduction: The number of recognized Martian meteorites is rapidly increasing, particularly the population of shergottites is growing. With the increase of radiogenic isotopic data, the systematics of the mantle source compositions of the shergottites are becoming better constrained. It has been recognized [1,2] that the source composition of shergottites (depleted DS, intermediate IS, and enriched ES) can be linked by mixing of depleted and enriched mantle end-members, formed as a result of crystallization of a Martian magma ocean. This has been modeled in terms of mineralogy [3] and isotopic characteristics [4].

Here the source composition of the oldest and most depleted shergotitte, NWA 7635 [5], is put into context with the existing dataset of source compositions for shergottites and associated rocks and some inferences on the isotopic composition of the depleted mantle end-member are made.

Discussion: In figure 1 the calculated $^{87}Rb/^{87}Sr$ ratios of source magma versus the calculated $^{147}Sm/^{144}Nd$ ratio of source magma (calculated using equations given in [6]) for shergottites and ALH 84001 are plotted. The shergottites define a tight mixing hyperbola as noted by [1] with the intermediate shergotitte EETA 79001 the only outlier, likely due to crustal contamination. Rb-Sr is unique among the commonly used radioactive chronometers in that Rb the parent, is strongly incompatible during magmatic differentiation. This lead the earliest formed cumulates to have very low Rb/Sr ratios. Importantly the Rb/Sr ratio of the depleted end-member cannot be lower than zero, where the maximum $^{147}Sm/^{144}Nd$ of the mixing hyperbola is 0.324. The distinct and tight clustering of the DS, IS, and ES gives a high degree of confidence in the curvature of the mixing hyperbola and especially the position of the IS preclude the involvement of a depleted end-member with a $^{147}Sm/^{144}Nd$ ratio higher than 0.324 in the generation of the shergottite mantle sources.

A mixing hyperbola for the Lu/Hf and Sm/Nd source ratios of shergottites has been successfully modeled by [2,4], there is now enough data to suggest that the scatter in Lu/Hf and Sm/Nd source compositions among IS and DS is not analytical, but point to three component mixing. With a depleted reservoir with high Sm/Nd and high Lu/Hf (garnet signature) ratios, a depleted reservoir with high Sm/Nd and low Lu/Hf ratios (shallower, no or limited garnet signature)

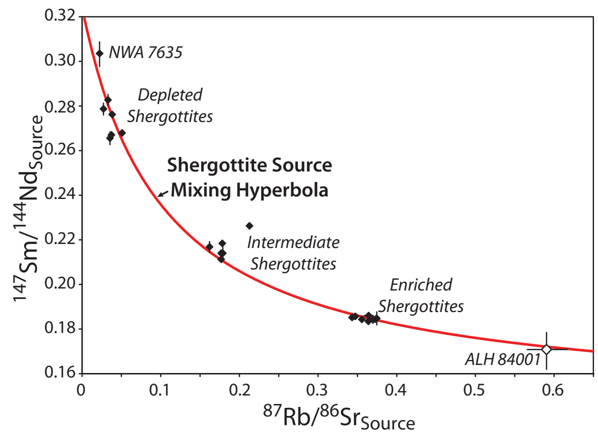

Figure 1: Mixing Hyperbola for Rb/Sr and Sm/Nd source compositions of depleted, intermediate, and enriched shergottites. The shergottite data define a 2-component mixing hyperbola with an $^{147}Sm/^{144}Sm$ intercept value of 0.324 at $^{87}Rb/^{87}Sr=0$ and an enriched end-member with a composition similar to that of ALH 84001 (not used in regression). Shergottite and data compiled from sources listed in [7], ALH 84001 source data from [8], NWA 7635 this study.

and an enriched mantle reservoir with low Sm/Nd and Lu/Hf ratios. Figure 2 shows Lu/Hf and Sm/Nd source systematics using the end-members and nomenclature of [4]. Volumetrically the depleted high Sm/Nd, high Lu/Hf reservoir (UM1 or UM2) is dominating with up to a few percent of SUM for DS, IS, and ES and ~1-25% of the enriched reservoir added to form the DS, IS, and ES sources, respectively.

The exact mixing proprortions hinges on the calculated composition of the mantle end-members and all the depleted high Lu/Hf end-members calculated by [a] have too high $^{147}Sm/^{144}Nd$ ratios to fit the Rb/Sr-Sm/Nd correlation in Fig 1. The Rb/Sr-Sm/Nd data preclude the involvement of end-members with a composition within the grey shaded region of Fig 2. The yellow oval indicate a likely composition of the high Lu/Hf, high Sm/Nd end-member, mixing hyperbolas from this end-member will have to encompass the source compositions of the IS and DS samples to the right of the mixing array, where very little involvement of a shallow depleted is indicated.

As maximum $^{147}Sm/^{144}Nd$ value for the depleted end-member of ~0.324 means that NWA 7635 with a

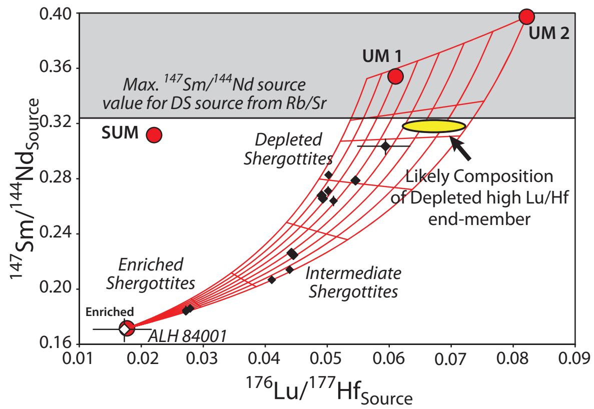

Figure 2: Mixing array for Lu/Hf and Sm/Nd source compositions of depleted, intermediate, and enriched shergottites. Variations within all three shergottite groups require 3-component mixing, explained by variable components of a depleted end-member with high Sm/Nd and high Lu/Hf, a shallow depleted end-menber with high Sm/Nd and low Lu/Hf, and an enriched end-member with low Sm/Nd and low Lu/Hf. The mixing array is calculated from end-member compositions and nomenclature from [4] despite the deeper depleted end-members have too high Sm/Nd ratios. Shergottite and ALH 84001 data compiled from sources listed in [7], NWA 7635 this study.

^{147}Sm/^{144}Nd source ratio of 0.304±6 is close in its Sm/Nd composition to the depleted end-member. Unfortunately, the old age of NWA 7635, and the absence of a Lu/Hf isochron with a well defined initial means that its source Lu/Hf is not constrained well enough to pin the composition of the depleted end-member in Lu-Hf space.

As both the high Lu/Hf and low Lu/Hf depleted end-members are expected to have very low Rb/Sr ratios, they cannot be resolved in Rb/Sr-Sm/Nd space (fig. 1), so the two depleted components appear to be near identical in terms of their Rb/Sr and Sm/Nd ratios. This is further evidence that the ^{147}Sm/^{144}Nd ratios of the depleted end-members have to be similar, in effect forming a horizontal mixing line in figure 2.

The location of the source composition of ALH 84001 is within error of the enriched end-member in Lu/Hf and Sm/Nd as noted by [2], this suggest that the composition of the enriched end-member is also within error of that of ALH 84001 in Rb/Sr-Sm/Nd space (Fig. 1).

The coupled ^{142}Nd-^{143}Nd systematics of NWA 7635 is shown in figure 3. With its more depleted source characteristics NWA 7635 is expected to have a larger positive anomaly which with a μ^{142}Nd value of +91.4 ± 7.7 it does. NWA 7635 falls on the shergottite mixing line in coupled radiogenic Nd isotope space further

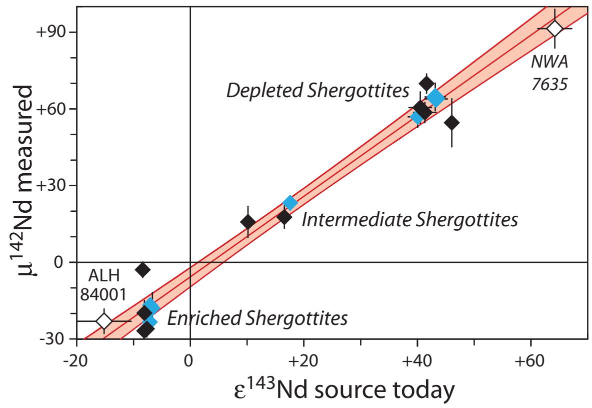

Figure 3: Mixing line for long- and short-lived Sm-Nd for shergottites. Black data points from [9], Blue datapoints [4], ALH 84001 data point from [10], NWA 7635 data this study. All data points except ALH 84001 are used in the regression. The ε^{143}Nd of the depleted end-member today is around +74.

confirming a genetic relationship between these samples and ALH 84001 despite their wide range in crystallization ages.

Conclusions: With the growing rock record of Matian meteorites firmer constraints can be placed on the their composition and evolution of their sources for future models of Martian magma ocean solidification. The existing shergottite record now encompass close to the extremes in terms of source isotopic compositions in what still appears to be a three group punctuated record of depleted, intermediate, and enriched shergottites.

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