A MARTIAN MANTLE DERIVED BY DISSECTION OF THE DEPLETED SHERGOTTITES. J. H. Jones[1] and J. I. Simon[2], [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (humejones@protonmail.com); [2]ARES, NASA/JSC, Houston, TX 77058 (justin.i.simon@NASA.gov).

Introduction: Although seemingly trivial, classification remains a basic necessity for scientific enquiry. A difficulty with the shergottite clan of the martian (SNC) meteorite suite is that samples become shergottites by exclusion. If a SNC is not obviously a nakhlite or chassignite, it becomes a shergottite by default.

Different schemes have been devised to sub-divide the shergottites into more coherent sub-groups. We begin with the traditional geochemical classification, which is based on initial isotopic ratios and incompatible trace element geochemistry, such that groupings are: enriched, intermediate, and depleted with respect to incompatible elements [e.g., 1].

Here we explore further subdivisions of the depleted shergottites in terms of this classification. In this discussion we neglect the ~2400 Ma, depleted shergottites, NWA 7635 and NWA 8159, which are clearly in a category unto themselves [2].

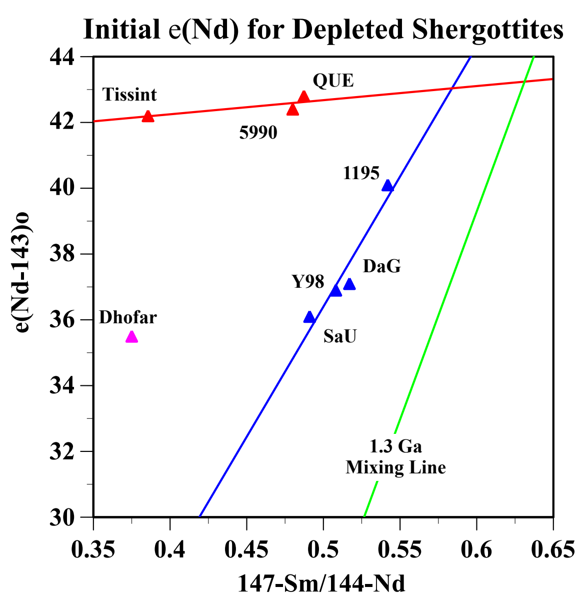

Figure 1. Summary of Sm-Nd for Depleted shergottites. We subdivide the depleted shergottites into Depleted (SaU, Y98, DaG, 1195) and Highly Depleted (Tissint, 5990, QUE), leaving Dhofar ungrouped. For comparison, the 1.3 Ga mixing line of [3] is shown. Data from the literature.

Sm-Nd of Depleted Shergottites: Figure 1 shows a modified conventional Sm-Nd isochron diagram, plotting $\varepsilon(^{143}Nd)_o$ vs. bulk rock $^{147}Sm/^{144}Nd$. This type of diagram eliminates post-solidification effects and facilitates inter-laboratory comparison. The data do not appear to plot randomly. The depleted shergottites DaG 476 (DaG), NWA 1195, SaU 005 (SaU), and Y-980459 (Y98) appear to define a trend, as do the more depleted shergottites NWA 5990 (5990), QUE 94201 (QUE), and Tissint. For the moment, we assign Dhofar 019 (Dhofar) to neither trend and regard it an outlier. Because both the "Depleted" and "Highly Depleted" trends contain members having different internal isochron ages, we assign no age significance to them; and we regard them as possibly being mixing lines. But clearly, attempts to discern geochemical regularity in a selection of (for example) Dhofar, DaG, and NWA 5990 could be problematic.

Discussion: With this subdivision of the depleted shergottites as a guide, we may now look for other correlations and relationships.

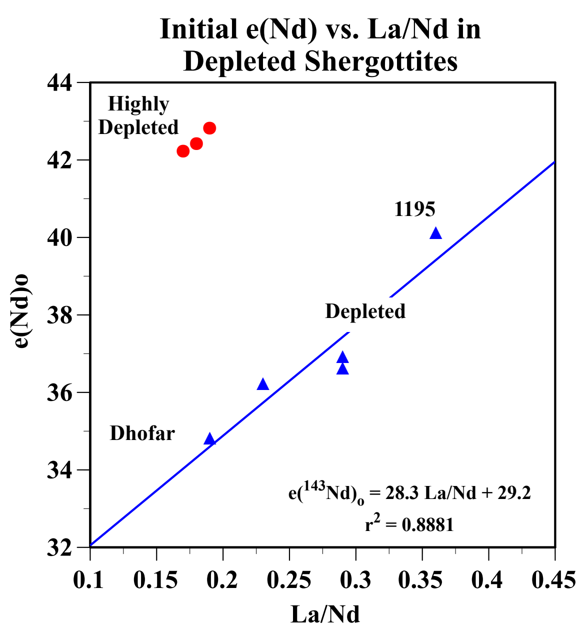

Figure 2. Initial ε(Nd) vs. La/Nd. Only the Depleted shergottite subgroup (and Dhofar) shows a significant correlation with La/Nd (see text). Although we have included Dhofar in the regression, there would be a similar trend without that sample. Data from the literature.

ε(Nd)$_o$ vs. La/Nd. Figure 2 shows initial ε(Nd) vs. La/Nd for both the Depleted and Highly Depleted shergottites. The Highly Depleted shergottites show little, if any, variation. However, the Depleted shergottites (and Dhofar) show a good, positive correlation. We use La/Nd as a measure of the influence of a LREE-enriched component on the Sm-Nd system. Several of the Depleted shergottites have either a flat LREE pattern or a turn-up at La [4]. The abrupt changes of LREE slope seen in these shergottites suggest that this component was acquired late.

Note that the slope of the trend in Fig. 2 is *opposite* to what would be expected. Figure 2 indicates that a parameter of LREE enrichment (La/Nd) correlates positively with a parameter of LREE depletion [ε(Nd)]. One possible explanation is that there was mixing with a very small degree partial melt (high La/Nd) from a source that was long-term LREE-depleted [large, positive ε(Nd)], as previously invoked for the nakhlites [5].

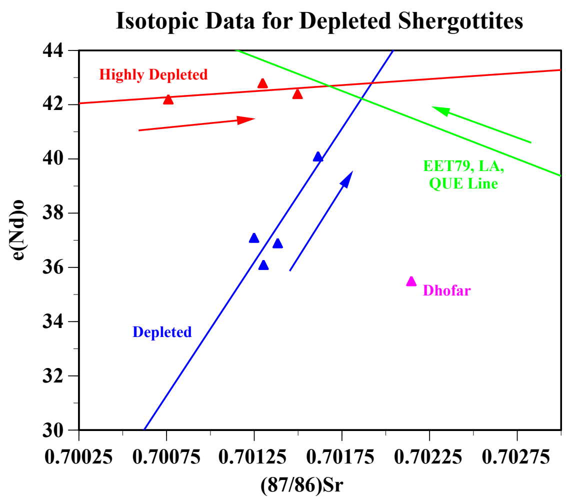

Figure 3. $\varepsilon(Nd)_o$ vs. $^{87}Sr/^{86}Sr$. With the exception of Dhofar, the style of Figure 3 mimics that of Figure 1. Also shown is a regression through QUE, EET79, and Los Angeles (LA) (i.e., a version of the 1.3 Ga mixing line). The close intersection of the three trends suggests a communal reservoir that acted as a component for all shergottites (see text). Data from the literature.

Neodymium vs. Strontium. Figure 3 is reminiscent of Figure 1, in terms of the Depleted and Highly Depleted subgroups. As in Figure 2, an incompatible element depletion signature [ε(Nd)] positively correlates with an incompatible-element enrichment signature (time-integrated Rb/Sr). But unlike Fig. 2, it is not obvious that the non-intuitive correlation of Fig. 3 can be explained away by a chemical fractionation penecontemporaneous with shergottite genesis. This is because both $\varepsilon(Nd)_o$ and $^{87}Sr/^{86}Sr$ are time-integrated signatures.

A Common Mantle Source for the Shergottites? It is clear from Figs. 1-3 that there are complexities associated with shergottite petrogenesis that remain unexplained. But so far these complexities only concern the Depleted and Highly Depleted shergottites. The Intermediate and Enriched shergottites have not yet been addressed.

In this vein, it has not escaped our attention that both Figure 1 and Figure 3 hint at the possibility that there could be a three-way intersection between the Depleted shergottites, the Highly Depleted shergottites, and the original 1.3 Ga mixing line of [3]. Since the 1.3 Ga trend was defined using Intermediate and Enriched shergottites only [e.g., EET 79001 (EET79) & Los Angeles (LA)], an intersection of these three trends would provide a linkage between all these groups. This postulated intersection point has the time-integrated properties (at the time of shergottite genesis 200-600 Ma ago): $^{147}Sm/^{144}Nd$ = ~0.625; $\varepsilon(^{143}Nd)$ = ~43; and $^{87}Sr/^{86}Sr$ = ~0.702. This value of $^{147}Sm/^{144}Nd$ approaches the maximum that could be produced from a chondritic source in a single stage of differentiation.

Missing Melts? In the past, we and others have called upon missing melts (or other phases) that depleted the shergottite source region in LREE just prior to shergottite genesis [e.g., 6]. This is because the time-integrated Sm/Nd ratios necessary to produce shergottite $\varepsilon(Nd)_o$ are always less than the Sm/Nd of the sample. However, we note that if melts generated in our proposed communal reservoir mixed with rock lying along the martian Sm-Nd geochron (Fig. 1), missing melts may no longer be required. Even so, this only partially addresses the issue of Sm/Nd fractionations relating to the shergottites. Our communal reservoir does not lie on the geochron and must therefore represent some younger differentiation event. Simply stated, the origin of the communal reservoir has yet to be explored.

Local Martian Geology. Others have noted that the depleted shergottites all have extremely similar cosmic ray exposure ages [e.g., 2]. This is highly suggestive of liberation from Mars by a single cratering event. And in turn, this suggests that the depleted shergottites were from proximal locations. But if our analysis is correct, depleted martian basalts interacted with at least two very different lithologies *en route* — one with ε(Nd) ~+40 and another with ε(Nd) possibly as low as ~+15.

The geological interpretation of this observation is unclear. First, "proximal" in this case, means within a crater diameter, which could be a significant distance. Second, it is possible that the crater could be located at the boundary of two or more geologic terrains, at least in terms of basement or lithospheric geology. Perhaps the depleted shergottite locality is analogous to our Hawaii, with its proximal Mona Loa and Mona Kea isotopic signatures, which must originate in the sub-Hawaiian mantle, but presumably from a single plume.

References: [1] Borg L.E. et al. (2003) *GCA* **67**, 3519-3536. [2] Lapen T.J. et al. (2017) *Sci. Adv.* **3**, e1600922. [3] Shih C.-Y. et al. (1982) *GCA* **46**, 2323–2344. [4] Peters T.J. et al. (2015) *E.P.S.L.* **418**, 91-102. [5] Shih C.-Y. et al. (2010) *LPSC XLI*, Abstract #1367. [6] Jones J.H. (2003) *MAPS* **38**, 1807-1814.