Rb-Sr AND Sm-Nd ISOTOPIC STUDIES OF MARTIAN DEPLETED SHERGOTTITES SaU 094/005. C.-Y. Shih[1], L. E. Nyquist[2], and Y. Reese[3], [1]Mail Code JE-23, ESCG/Jacobs Sverdrup, P.O. Box 58477, Houston, TX 77258-8477, chi-yu.shih-1@nasa.gov; [2]Mail Code KR, NASA Johnson Space Center, Houston, TX 77058-3696, laurence.e.nyquist@nasa.gov; [3]Mail Code JE-23, ESCG/Muniz Engineering, Houston, TX 77058, young.reese-1@nasa.gov.

Introduction: Sayh al Uhaymir (SaU) 094 and SaU 005 are olivine-phyric shergottites from the Oman desert and are considered as pairs. [*e.g.*, 1]. They are very similar to the Libyan desert shergottite Dar al Gani (DaG) 476 in petrology, chemistry and ejection age [2-6]. This group of shergottites, also recognized as depleted shergottites [e.g. 7] has been strongly shocked and contains very low abundances of light rare earth elements (REE). In addition, terrestrial contaminants are commonly present in meteorites found in desert environments. Age-dating these samples is very challenging, but lower calcite contents in the SaU meteorites suggest that they have been subjected to less severe desert weathering than their DaG counterparts [3-4]. In this report, we present Rb-Sr and Sm-Nd isotopic results for SaU 094 and SaU 005, discuss the correlation of their ages with those of other similar shergottites, and discuss their petrogenesis.

Samples and Analytical Procedures: The SaU samples were kindly provided by Dr. Beda A. Hofmann. A large chip of SaU 005, weighing ~0.6 g was picked out and initially processed in 2001. The sample was further crushed gently to pass a nylon sieve of opening size <149 µm. About 100 mg was taken as the bulk rock sample (WR). The rest of the sample was sieved into 149-74 µm and 74-44 µm size fractions. Minerals (Plag and Px) in both size fractions were separated by Franz magnetic separator following the procedure used for DaG 476 [8]. We processed the SaU 094 slab in 2006, initially chipping off fusion crusts. The sample is extremely compact and great efforts were needed to break and pulverize it. Interior chips totaling 685 mg were picked out for this study. The bulk rock sample (WR) of 139 mg was taken from the <149 µm size fraction prior to finer sieving. Minerals were separated by densities using heavy liquids. At density fraction <2.85 g/cm^3, we obtained the plagioclase (Plag). In the density fraction (2.85-3.32 g/cm^3), we obtained the plagioclase-pyroxene mixture (Im Plag). The pyroxenes (Px1 and Px2) were separated in the slightly higher density fraction (3.32-3.45 g/cm^3). An olivine sample (Ol) was separated with a heavier liquid of density 3.45 g/cm^3. In addition, the bulk rock and all mineral samples were washed with 1N HCl (for Plag, Im Plag, Ol), 2N HCl (for Px, Px1, Px rej) and 3N HF (for Px2) in an ultrasonic bath for 10 minutes to eliminate possible post-crystallization, pre- or terrestrial, contamination. Both the WR residues (r) and WR leaches (l) of these samples were analyzed. The acid washes from all minerals (Leach) were combined and also analyzed.

Rb-Sr isotopic results: The ^{87}Rb/^{86}Sr and ^{87}Sr/^{86}Sr data for seven SaU 005 (squares) and nine SaU 094 (circles) samples are shown in Fig 1. As for DaG 476 [8], the Rb-Sr isotopic data are so scattered that no Rb-Sr isochron, and thus, no age information can be obtained from these sixteen unwashed and washed samples. The two acid leachates, WR(l) and Leach, plot close to the present-day sea water value of ^{87}Sr/^{86}Sr =~0.709, indicating that all the samples, even those washed with acids, still contain significant amounts of desert contaminants. The SaU 094 samples plot closer toward the sea water ^{87}Sr/^{86}Sr value, and are probably more severely altered than the SaU 005 samples. An estimate of the initial ^{87}Sr/^{86}Sr =0.701303±15 ($\lambda(^{87}$Rb) =0.01402 Ga^{-1}) for SaU005/094 can be made using the SaU 005 Plag(r) datum and the Sm-Nd age of 445 Ga (shown in Fig. 2). This value is slightly higher than the DaG 476 value [8], but close to that of Y980459 [7]. A higher initial ^{87}Sr/^{86}Sr estimate of 0.702272±12 is obtained from the Plag(r) of SaU 094. A two-stage model calculation indicates that the time-averaged ^{87}Rb/^{86}Sr for the SaU source region is ~0.04-0.05.

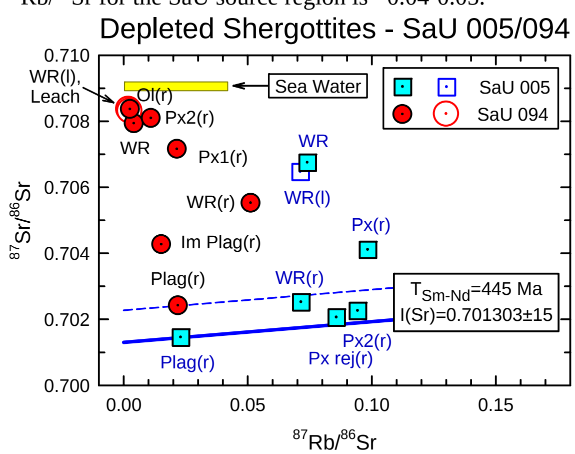

Figure 1. Rb-Sr data of SaU 005/094.

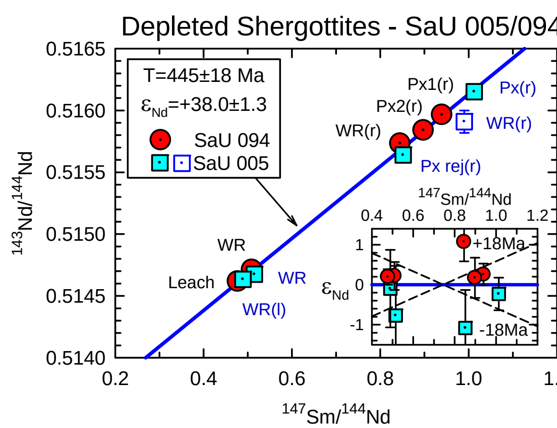

Figure 2. Sm-Nd data of SaU 005/094.

Sm-Nd isotopic results: Fig. 2 shows ^{147}Sm/^{144}Nd and ^{143}Nd/^{144}Nd data of ten SaU samples. Unlike the Rb-Sr data, the Sm-Nd data form a linear array. Using the Isoplot regression routines [9], four SaU 005 samples (solid squares) consisting of WR, WR leachate and two washed Px, yield an age of 446±13 Ma for $\lambda(^{147}$Sm)=0.00654 Ga^{-1} and an initial ε_{Nd}=+37.4±1.2. One small WR(r) sample having only 0.3 ng Nd (open square), plots off the isochron and may contain a significant portion of desert alteration products. The similar SaU 094 WR-Leach-Px assemblage yields an almost identical age of 448±21 Ma and initial ε_{Nd} =+38.1±1.4. All the other samples have too small amounts of Sm and Nd (<1 ng) and did not run well. Since SaU 005 and SaU 094 are likely paired meteorites [1], we regressed all nine SaU samples to obtain an age of 445±18 Ma and initial ε_{Nd}=+38.0±1.3, representing the SaU igneous event.

Recently, we reported the Sm-Nd age of 472±27 Ma and the initial ε_{Nd} =+36.9±2.2 for Y980459 [7]. These age and isotopic data are indistinguishable from the 474±11 Ma age and the +36.6±0.8 initial ε_{Nd} obtained for DaG 476 in [8]. In addition, both meteorites have essentially the same young exposure age of ~1.2 Ma [5,10]. All these data suggest that they both could come from the same magma flow during a single impact-ejection event. In this case, Y980459 probably represents a sample from the rapidly cooling outermost portion of the flow and DaG 476 from the slower cooling interior portion of the flow. An Isoplot [9] regression of ten Sm-Nd data, 7 from Y980459 and 4 from DaG 476, yields an age of 470±12 Ma and initial ε_{Nd} =+37.0±0.7. This age probably best defines the time of the DaG/Y98 magmatic event.

Petrogenetic implications: The ε_{Nd}-values and ages of two depleted shergottite pairs, SaU 005/094 and DaG/Y98, are summarized in Fig. 3. The two parallelograms, defined by their respective age and ε_{Nd}-value uncertainties, do not overlap, showing that the pairs represent two different co-magmatic flows. These flows probably extruded contemporaneously ~460 Ma ago in the same igneous complex, as suggested by their similar petrology, chemistry and ejection age [3-6,10]. Based on two-stage model calculations, the time-averaged source $^{147}Sm/^{144}Nd$ ratio for these shergottite pairs could be 0.268 and 0.266, respectively. These high values suggest they were derived from strongly LREE-depleted mantle sources. To produce even more LREE-depleted melts of $^{147}Sm/^{144}Nd$ ~0.51 found in the SaU/DaG/Y98 shergottites by a partial melting event at ~460 Ma is not straightforward. It could have involved multiple episodes of remelting of residues at ~460 Ma, as suggested for the genesis of depleted shergottite QUE 94201 [11].

Alternatively, these depleted shergottites (DS) could have been produced by processes with three major stages, as shown in Fig. 4. This model starts with the formation of a DS source precursor at ~4.553 Ga, soon after martian core formation, and while the short-lived nuclides ^{146}Sm (most) and ^{182}Hf (some) were still alive [12-15]. This source precursor could have been a garnet-bearing peridotitic cumulate crystallized during the early martian mantle differentiation. The model cumulate had nakhlite-like $^{147}Sm/^{144}Nd$ = ~0.235, but un-nakhlite-like low $^{87}Rb/^{86}Sr$ =~0.04 . It evolved until ~925 Ma, when partial melting produced nakhlite-like LREE-enriched melts and their corresponding highly LREE-depleted residues. These residues became the direct DS sources, from which SaU/DaG/Y98 DS finally were produced by large degree melting ~460 Ma ago. This three-stage model can also explain the nakhlite-like positive ^{142}Nd anomalies (~+0.6 ε) of DS [e.g. 13, 15]. The Sm and Nd abundances of DS Y980459 were reproduced by this model in [7]. The model suggests that we should have more martain meteorites of the Hesperian era, corresponding to LREE-enriched nakhlite-like melts produced between ~925 Ma and ~1.38 Ga, and associated with the production of DS sources. The ages of these basalt melts, although not so far sampled, would support the wide distribution of Hesperian volcanic materials on the martian surface implied by the revised crater-frequency curve of [16].

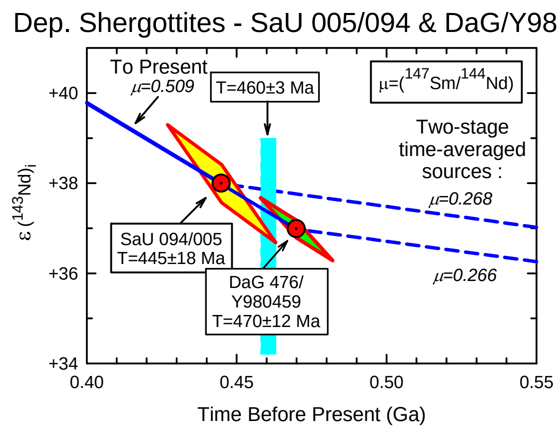

Figure 3. ε_{Nd} vs. T(age) of SaU 005/094 and DaG/Y980459.

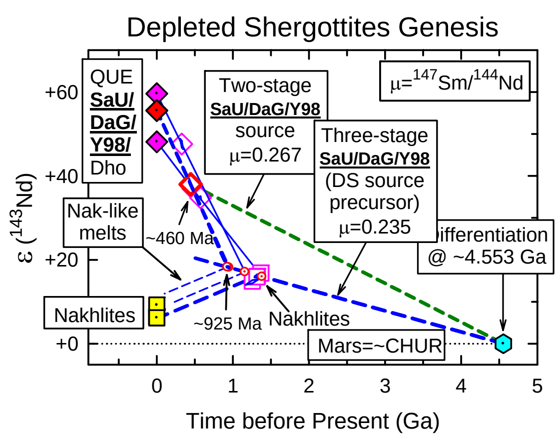

Figure 4. ε_{Nd} vs. T(age) of dep. shergottites & nakhlites.

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