PRELIMINARY AGE OF MARTIAN METEORITE NORTHWEST AFRICA 4468 AND ITS RELATIONSHIP TO THE OTHER INCOMPATIBLE-ELEMENT-ENRICHED SHERGOTTITES. L. E Borg[1], A. M. Gaffney[1], and D. DePaolo[2]. [1]Institute of Geophysics & Planetary Physics, Lawrence Livermore National Laboratory, 7000 East Ave. L-231 Livermore CA 94550 (borg5@llnl.gov), [2]Center for Isotope Geochemistry, University of California, Berkeley.

Introduction: The martian meteorite suite contains a wide variety of rock types, such as basalts and lherzolites (shergottites), clinopyroxenites (nakhlites), dunites (chassignites), and an orthopyroxenite. The most numerous of these are the shergottites. These samples exhibit a variety of mineralogies ranging from olivine-bearing primitive basalts and lherzolites (e.g., Y98405, DaG 476, NWA 1068/1110) to significantly more evolved pyroxene-plagioclase bearing basalts (e.g., QUE 94201, Los Angeles, and Shergotty). In addition, the shergottites fall into three groups based on their trace element and isotopic compositions. One group is defined by samples with light REE-depleted patterns and low initial Sr and high initial Nd isotopic compositions (e.g., QUE 94201), whereas another group is defined by samples with light REE-enriched patterns and high initial Sr and low Nd isotopic compositions (e.g., NWA 1068/1110) [1-3]. The third group has characteristics that are intermediate between the other groups.

There are two general scenarios to account for the mineralogical, geochemical, and isotopic variability observed in the shergottite suite. In the first scenario, the compositional variability is attributed to a combination of compositional heterogeneity in the mantle sources and variable degrees of fractional crystallization experienced by the mantle melts once leaving their source regions [1-3]. In the second, it is attributed to assimilation fractional crystallization (AFC) of differentiated crustal rocks [4-5]. In order to constrain the mechanisms responsible for the observed compositional diversity in the shergottite suite, we have begun Rb-Sr and Sm-Nd isotopic analyses on the primitive enriched olivine-bearing shergottite NWA 4468. By investigating how this relatively primitive and unfractionated meteorite obtained its enriched incompatible element signature, we hope to constrain the mechanism by which incompatible element variability is produced in the shergottite suite.

Petrology and geochemistry of NWA 4468: Northwest Africa 4468 has been classified as an olivine basaltic shergottite [6]. In addition to containing ~35% Fo_{59-71} olivine, NWA 4468 contains ~30% clinopyroxene, ~25% maskelynite, and minor abundances of chromite, ilmenite, and phosphate. The REE pattern and whole rock Sr and Nd isotopic systematics are very similar to NWA 1068/1110 and are consistent with either derivation from an enriched source (mantle heterogenity scenario) or interaction with an enriched crustal source during its petrogenesis (AFC scenario).

Sm-Nd and Rb-Sr Isotopic Analyses: A 51 mg whole rock fraction of NWA 4468 was crushed, washed in 18 mΩ water, and then progressively leached in 2N HCl and 4N HCl for 15 minutes each at 45 °C. Rubidium, Sr and REEs were separated using cation exchange columns in 2N and 6N HCl. Samarium and Nd were purified using pressurized 2-hydroxyisobutyric acid columns. Rubidium and strontium were run on the VG Sector 54 multi-collector thermal ionization mass spectrometer, whereas Sm and Nd were run on the Triton thermal ionization mass spectrometer at the University of California, Berkeley.

Preliminary Sm-Nd isotopic analyses on the whole rock residue (Wr-1 R) and 2N HCl leachate (Wr-2L) yield an age of 150 ± 29 Ma and an initial ε_{Nd} value of -6.9 ± 0.3 (Fig. 1). Analyses of numerous other shergottites demonstrate that igneous phosphates are easily dissolved in 2N HCl and that this fraction commonly lies on the Sm-Nd isochron defined by maskelynite, pyroxene, and/or olivine [2,3,7]. As a consequence, the Sm-Nd tie-line is interpreted to represent the crystallization age of the meteorite. The data from NWA 4468 lie within error of the Sm-Nd isochron defined for NWA 1068 and suggest that these samples are closely related [6,7].

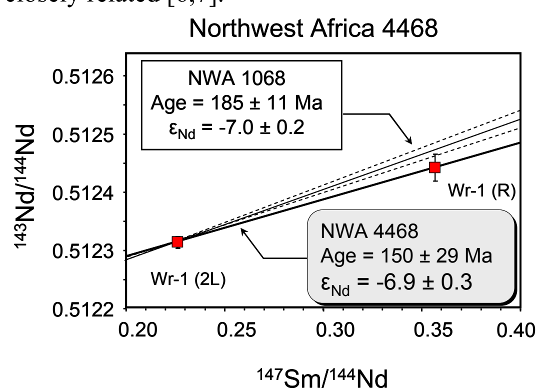

Figure 1. Sm-Nd leachate-residue tie-line for NWA 4468 yielding an age of 150 ± 29 Ma. Isochron reference line for NWA 1068 calculated from data presented in [7]. The Sm-Nd ages and isotopic systematics of these samples are indistinguishable.

The Rb-Sr isotopic systematics of the Wr-1 R, Wr-2L, and 4N HCl leachate are disturbed. This is commonly observed in martian meteorites that are found in desert environments because terrestrial alteration often adds high-Sr phases, such as calcite, to the samples

[3,7]. However, leached residue mineral fractions typically lie on or near isochrons that are concordant with the Sm-Nd isochrons (e.g., [7]). Consequently, an initial Sr isotopic composition of NWA 4468 can be estimated from the Rb-Sr isotopic systematics of the Wr-1 R fraction using the Sm-Nd age. This calculation yields an initial $^{87}Sr/^{86}Sr$ ratio of 0.72258 ± 14. Note that the initial Sr calculated for NWA 4468 represents a maximum value because it assummes an age of only 150 ± 29 Ma and is extrapolated from the Wr-1 R data point which might contain a small amount of alteration products. Nevertheless, the result is in good agreement with the initial Sr isotopic composition of NWA 1068 of 0.72230 ± 3 calculated by [7] and further suggests that these two rock are closely related to one another.

Relationship of NWA 4468 to other shergottites: Northwest Africa 4468 shares many trace element and isotopic characteristics with other martian meteorites. Like Shergotty, Zagami, Los Angeles (LA), and NWA 1068/1110, NWA 4468 is enriched in incompatible elements, has a flat REE pattern, and has initial Sr and Nd isotopic compositions that indicate derivation from an enriched source. Thus, this sample contains a relatively large proportion of the enriched component that is present in the shergottite meteorite suite. At the same time, NWA 4468 is an olivine-bearing shergottite with a fairly mafic major element composition. These observations lead to the question of whether shergottites, such as NWA 4468 and NWA 1068/1110, can be produced by AFC processes and still maintain their magnesium-rich compositions.

The MELTS algorithm [10] is used to assess whether magnesium-rich, incompatible element-rich shergottites, such as NWA 1068/1110 and NWA 4468, can be produced by AFC from a more magnesian parent. The parent is assumed to have a composition of Y980459 [8] and is assumed to assimilate a basaltic crustal rock represented by the composition of LA [9]. Los Angeles was choosen as the assimilant because it is strongly enriched in incompatible elements and represents the most evolved (Fe-rich) martian meteorite. Y980459 was choosen as the parent because it is the only unambigious mantle melt in the meteorite collection. The models were run assuming the system was at 1 kbar pressure and isenthalpic, and that the starting temperature of the assimilant is 100 ºC and the starting temperature of the host magma (Y980459) is 1400 ºC. The major element composition of NWA 4468 has not been determined so NWA 1068 composition is modeled instead. It has been noted that NWA 1068 may have accumulated olivine because the most magnesian olivine (Fo_{72}) is not in equilibrium with the Mg-rich bulk composition [10]. Consequently, the NWA 1068 bulk compostion has been corrected for olivine accumulation by subtracting ~30% Fo_{72} olivine from the bulk rock until the composition is in equilibrium with Fo_{72} olivine.

The results of the MELTS calculations are presented in Fig. 2. The liquid evolution paths of AFC are represented by the orange/yellow lines on this diagram and do not intersect either the bulk rock or olivine-free compositions of NWA 1068, indicating that this sample is not produced from Y980459 by AFC of LA under the modeled conditions. Partial melts of LA (green lines) have Ca/Al ratios that are too low, indicating these cannot serve as the assimilants either. Instead, either an assimilant that is compositionally different from LA or a parental melt with a higher CaO/Al_2O_3 ratio is requred. Note that NWA 1068 cannot be produced by fractional crystallization (light blue line) of Y980459 either. Interestingly, the major element composition of LA can be produced from fractional crystallization of the olivine-free NWA 1068 composition (dark pink line). This is consistent with the observation that these samples have similar REE patterns and initial Sr-Nd isotopic compositions. Further, this supports the suggestion of [1] that the trace element and isotopic systmatics of the shergottites are derived from their mantle sources, and their major element compositions reflect fractional crystallization of the parental melts upon leaving the mantle.

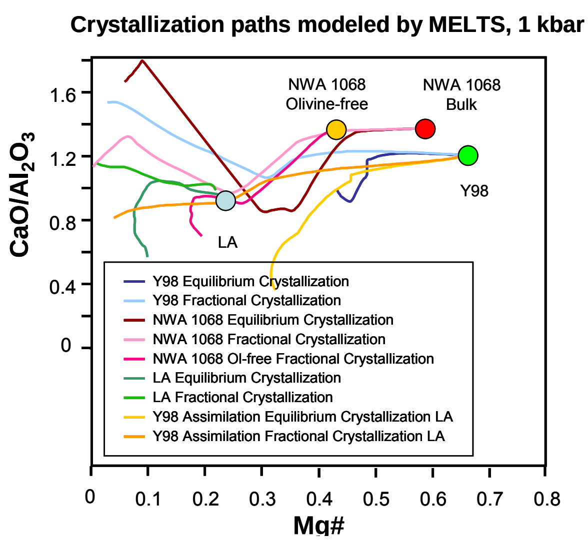

Figure 2. Compositional evolution of liquids during crystallization as modeled by MELTS.

References: [1] Symes S. et al. (in press) *GCA*; [2] Borg L. et al. (2005) *GCA* **69,** 5819-5830, [3] Borg L. et al., (2003) *GCA* **67,** 3519-3536; [4] Jones J. (1989) *19th PLPSC* 465-47; [5] Herd C. et al. (2002) *GCA* **66,** 2025-2036; [6] Irving A. et al., (2007) LPSC XXXVIII, Abstr.# 1526; [7] Shih C. -Y. et al. (2003) LPSC XXXIV, Abstr.# 1439; [8] Shirai N. & Ebihara M. (2004) *Ant. Met. Res.* 17, 55-67; [9] Rubin A. E. et al. (2000) *Geol.* **28**, 1011-1014; [10] Ghiorso M. & Sack R. (1995) *CMP* **119**, 197-212. This work performed under the auspices of the U.S. DOE by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.