SM-ND AND LU-HF ISOTOPIC SYSTEMATICS OF SHOCK-MELTED INTERMEDIATE OLIVINE GABBROIC SHERGOTTITE NORTHWEST AFRICA 11509. M. Righter[1], T. J. Lapen[1] and A. J. Irving[2] [1]Dept. of Earth & Atmospheric Sciences, University of Houston, TX, USA (mrighter@uh.edu), [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA, USA.

Introduction: Northwest Africa 11509, a fresh 500 gram stone found in Mali, is a relatively coarse grained olivine gabbroic shergottite containing shock-melted intercumulus zones [1]. It consists of relatively equant grains of clinopyroxene and olivine with vesicular, plagioclase-rich interstitial regions (Fig. 1). The mineral mode (in vol.%) is 50.5 clinopyroxene, 20.1 plagioclase, 17.1 olivine, 11.1 vesicles, 1.0 oxides (chromite+ilmenite) and 0.2 pyrrhotite. Clinopyroxene and olivine exhibit rather limited compositional zoning, and olivine has been recrystallized into aggregates of ultra-fine grained polygonal subgrains. Some plagioclase (birefringent and *not* maskelynite) has a curved lath-like habit, and has experienced essentially complete melting and vesiculation during ejection shock [1]. Among the 127 unpaired Martian meteorites now recognized [2], only a few (e.g., NWA 6342) exhibit such extreme shock features.

The REE abundances of NWA 11509 are similar to those of intermediate shergottites (Fig. 2). The cosmic ray exposure age [2.7 Myr (^{3}He), 3.0 Myr (^{21}Ne)] is in the same range as for other intermediate shergottites and some enriched shergottites [1]. However, NWA 11509 has a previously unrecognized radiogenic isotopic signature which is different from those for both intermediate and enriched shergottites.

Here we present Sm-Nd and Lu-Hf isotopic results for NWA 11509, and place these new data in the context of existing data for shergottites with the aim of identifying similarities and potential source affinities.

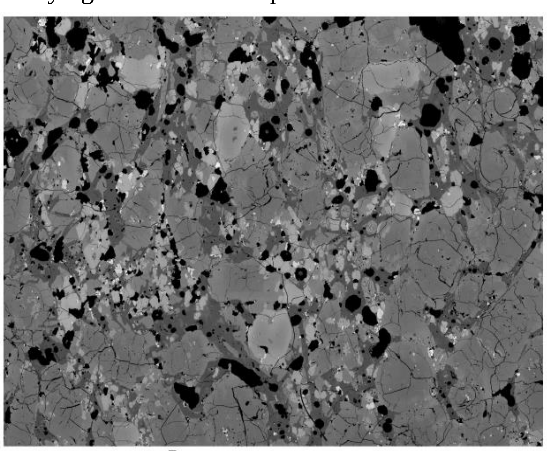

Figure 1. Back scattered electron image of NWA 11509. Olivine (light gray), pyroxene (medium gray), plagioclase-rich interstitial regions (dark gray), vesicles (black), sulfide (bright).

Samples and Analytical Procedures: Clean representative dust produced by cutting a sample on an IsoMet saw using a Cu alloy blade was used to conduct whole rock analysis (*WR-dust*). An intact interior fragment of NWA 11509 (~0.1 g) was also analyzed (*WR-chunk*). A ~2.4 g aliquot of NWA 11509 was crushed with an aluminum oxide mortar and pestle, then pyroxene grains were hand-picked under a microscope (*Px*). Both "whole rock" fractions and the pyroxene fraction were spiked for Lu-Hf and Sm-Nd analyses. All chemical separation procedures were carried out in clean laboratory facilities at the University of Houston, and all isotope analyses were carried out using the Nu Instruments *Nu Plasma II* MC-ICP-MS at UH.

Results: The Sm-Nd analyses of NWA 11509 whole rock (*WR-dust*) gave a present-day ε^{143}Nd = 6.67 and a measured ^{147}Sm/^{144}Nd = 0.2651, which place this specimen between the established fields for intermediate and enriched shergottites (Fig. 3). The hand-picked pyroxene fraction yielded a present-day ε^{143}Nd = 6.63, which is essentially the same as for WR-dust.

The Lu-Hf isotopic data are shown in Fig. 4. The Lu-Hf analyses of whole rock (*WR-dust*) gave a present-day ε^{176}Hf = 3.60 and a measured ^{176}Lu/^{177}Hf = 0.01742. The Lu-Hf analyses of the interior fragment (*WR-chunk*) gave a present-day ε^{176}Hf = 5.77 and a measured ^{176}Lu/^{177}Hf = 0.01669. Despite this discrepancy of 2.17 in epsilon Hf values, both "whole rock" results are still significantly different from values for other shergottites (see Fig. 3).

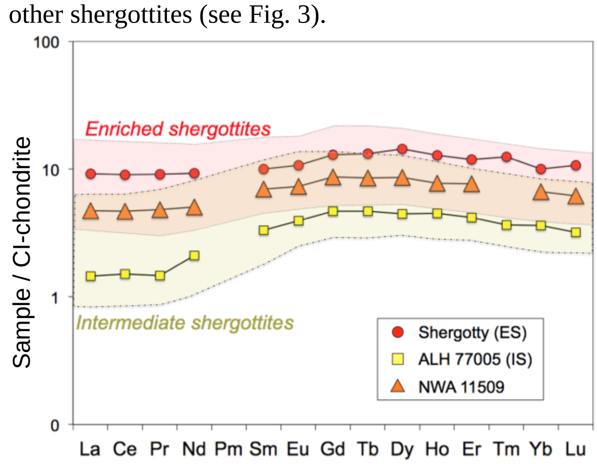

Figure 2. Chondrite-normalized REE pattern of NWA 11509 bulk rock powder (orange triangles) [1] compared to patterns for intermediate (ALH 77005) and enriched (Shergotty) shergottites, plus ranges for other intermediate and enriched shergottites (data from [3]).

The whole rock (*WR-dust*) and the pyroxene define a slope corresponding to a Lu-Hf age of 820 ± 84 Ma for $\lambda(^{176}Lu)$ = 1.865 x 10^{-11} yr^{-1} with an initial $^{176}Hf/^{177}Hf$ value of 0.283542 ± 0.000031 using the Isoplot regression program [4]. The interior fragment (*WR-chunk*) and the pyroxene define a slope corresponding to a Lu-Hf age of 518 ± 88 Ma.

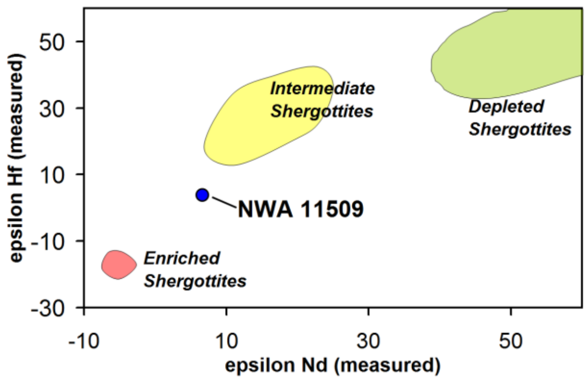

Figure 3. Radiogenic isotopic compositions of shergottites (data from [5-7] and our unpublished analyses). The Nd and Hf isotopic ratios for NWA 11509 fall between those established for enriched and intermediate shergottites.

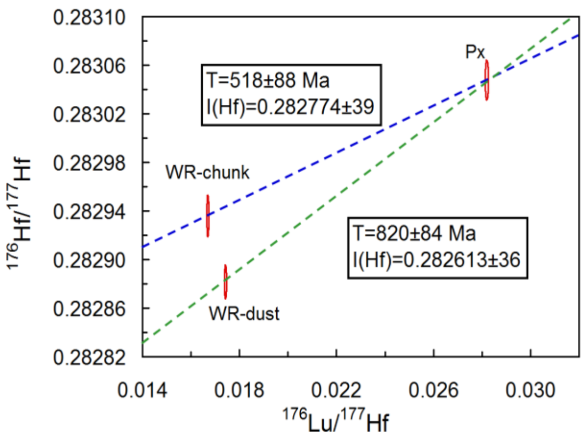

Figure 4. Lu-Hf systematics for NWA 11509. Error bars are 2σ. 'WR-chunk' = interior fragment, 'WR-dust' = IsoMet dust, and 'Px' = hand-picked pyroxene.

Discussion: The three samples from NWA 11509 analyzed so far do not permit a more precise Lu-Hf isochron crystallization age to be determined. However, the apparent age range of 518-820 Ma is significantly older than any other crystallization ages of intermediate (166-345 Ma) and enriched (150-207 Ma) shergottites [8-12]. Considering the relatively coarse grainsize as well as shock-melted phases in this specimen, the 0.1 g interior fragment (*WR-chunk*) might not be very representative of the whole rock, and furthermore might be more compromised by localized resetting during shock melting.

The modeled source $^{176}Lu/^{177}Hf$ and $^{147}Sm/^{144}Nd$ isotope ratios were calculated using a two stage model assuming a differentiation age of 4.513 Ga [13] and the CHUR parameters of [14] for both 820Ma and 518Ma. The calculated source $^{176}Lu/^{177}Hf$ and $^{147}Sm/^{144}Nd$ compositions are 0.03797 and 0.1957 for 820 Ma, and 0.03727 and 0.2008 for 518 Ma, respectively. These calculated source compositions are in good agreement despite the apparent age differences. The source compositions for NWA 11509 suggest that it is derived from source mixtures that are somewhat similar to those that produced the other known intermediate shergottites, but further extends the observed range in intermediate source compositions for both Lu/Hf and Sm/Nd isotopic systems.

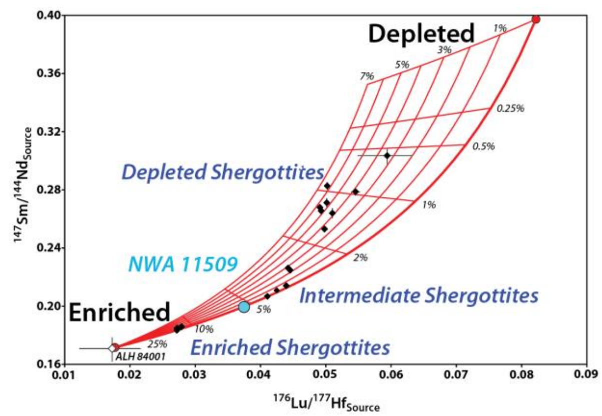

Figure 5. Source mixing array for shergottite Lu-Hf and Sm-Nd source compositions calculated using equations and mantle source compositions of [15]. Blue filled circle denotes NWA 11509; black diamonds denote other shergottites. Isotope data used for the source calculations are from [16] and references therein.

References: [1] Irving A.J. et al. (2018) *LPS* XLIX, #2279. [2] http://www.imca.cc/mars/martian-meteorites-list.htm [3] Meyer C. (2012) The Martian Meteorite Compendium. https://curator.jsc.nasa.gov/antmet/mmc/ [4] Ludwig K.R. (2003) *Berkeley Geochronology Center Spec. Pub.* 1a, 59. [5] Irving A. et al. (2015) *LPS* XLVI, #2290 [6] Irving A. et al. (2016) *LPS* XLVII, #2330. [7] Irving A. et. al. (2017) *LPS* XLVIII, #2068. [8] Borg L.E. et al. (1998) *Meteoritics & Planet. Sci., 33,* A20. [9] Borg L.E. et al. (2002) *GCA* 66, 2037−2053. [10] Nyquist L.E. et al. (2009) *GCA* 73, 4288−4309. [11] Borg L.E. et al. (2008) *LPS* XXXIX, #1851. [12] Shih C-Y. et al. (2009) *LPS* XL, #1360. [13] Borg L.E. et al. (2003) *GCA* 67, 3519−3536. [14] Bouvier A. et al. (2008) *Earth Planet. Sci. Lett.* 280, 285−295. [15] Debaille et al. (2008) *Earth Planet. Sci. Lett.* 269, 186−199. [16] Lapen T.J. et al. (2017) *Science Advances* 3, e1600922.