PETROLOGIC AND RADIOGENIC ISOTOPIC ASSESSMENT OF OLIVINE-PHYRIC, DIABASIC AND MICROGABBROIC SHERGOTTITES FROM NORTHWEST AFRICA. A. J. Irving[1], S. M. Kuehner[1], R. Andreasen[2], T. J. Lapen[2] and H. Chennaoui-Aoudjehane[3] [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irvingaj@uw.edu), [2]Dept. of Earth & Atmospheric Sciences, University of Houston, Houston, TX, [3]Dept. of Earth Sciences, Hassan II University, Casablanca, Morocco.

Introduction: The ongoing discovery of diverse Martian meteorites (now totaling about 80 unpaired specimens), predominantly (>60 %) from Morocco and elsewhere in northwestern Africa, has considerably expanded our knowledge of Martian magmatic rocks. Until (and even after) an eventual sample return mission to Mars, the rocks found as meteorites on Earth will provide invaluable insights into Martian lithologic diversity. Here we describe a large ~3.7 kg shergottite find from Jrifiya, southwestern Morocco plus others found in 2014. Nd and Hf isotopic analyses for these and Northwest Africa 6963 (from Fej Arrih, Morocco) establish key characteristics of their mantle sources.

Figure 1. *The largest (1467 g) stone from Jrifiya. The darker top surface was exposed above ground level, whereas the remainder was buried. © A. Bouragaa.*

Depleted Permafic Olivine-Phyric Shergottite from Jrifiya: Despite weathering rinds up to several millimeters thick (see Figure 1), the interiors of these stones are mostly fresh. Euhedral to subhedral olivine phenocrysts (up to 2 mm) occur in a groundmass composed predominantly of zoned, prismatically-twinned pyroxene (orthopyroxene cores $Fs_{16.5-21.7}Wo_{2.2-3.5}$; pigeonite rims $Fs_{32.2-34.1}Wo_{11.0-11.5}$; FeO/MnO = 25-36) and maskelynite ($An_{60.9-62.1}Or_{1.4-1.9}$), together with some olivine ($Fa_{47.2-48.7}$), chromite, ilmenite, Mg-bearing merrillite and pyrrhotite (see Figure 2). Olivine phenocrysts (cores $Fa_{19.1-20.4}$; rims $Fa_{36.9-39.5}$; FeO/MnO = 48-55) contain numerous tiny inclusions of chromite, as well as trapped melt inclusions (now composed of low-Ca pyroxene + silica + plagioclase + merrillite + pentlandite + glass) surrounded by radial cracks.

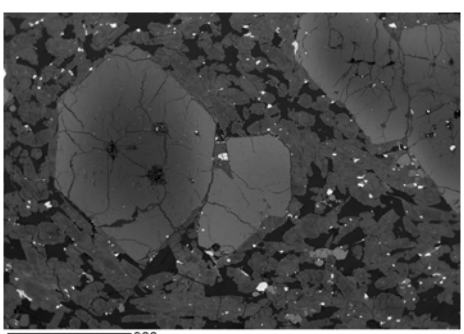


Figure 2. *BSE image of sample #14.2 showing euhedral, zoned olivine with melt inclusions.*

Enriched Mafic Diabasic Shergottite NWA 8656/8657: Multiple greenish, medium-grained, aphyric stones (total ~3.5 kg) recovered at an unknown site in early 2014 were classified under two separate names. The major constituents are complexly-zoned, prismatically-twinned clinopyroxene (pigeonite $Fs_{33.7-53.1}Wo_{11.6-15.5}$, FeO/MnO = 31-37; subcalcic augite $Fs_{20.8-26.9}Wo_{26.0-36.4}$, FeO/MnO = 28-36; ferropigeonite rims $Fs_{63.2-65.9}Wo_{14.0-17.2}$, FeO/MnO = 35-40) and maskelynite ($An_{42.3-56.6}Or_{3.0-1.5}$), along with accessory ilmenite, ulvöspinel, pyrrhotite, and merrillite, plus veinlets and pockets of vesicular shock-produced glass.

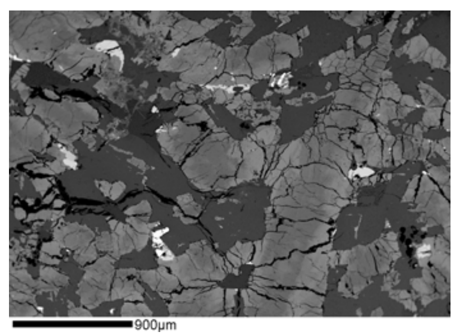
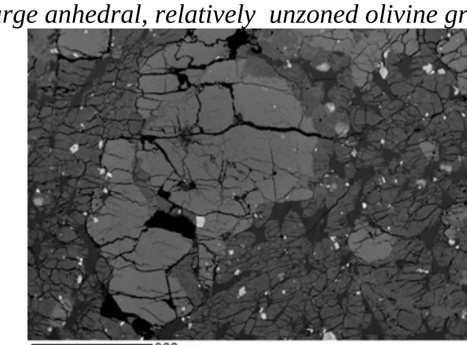


Figure 3. *BSE images of NWA 8657 **(above)** - note the zoned pyroxenes; and NWA 8705 **(below)** - note the large anhedral, relatively unzoned olivine grains.*



Intermediate Olivine-Phyric Shergottite NWA 8705: A small (6.2 grams) fresh, fusion-crusted stone purchased in Morocco by Stefan Ralew is an olivine-phyric shergottite with isotopic affinities to intermediate examples. It consists of macrocrysts (up to 1.8 mm, possibly xenocrystic) of relatively homogeneous olivine ($Fa_{30.7-34.7}$, FeO/MnO = 50-56) partially rimmed by pigeonite within a groundmass of zoned pigeonite ($Fs_{25.3-33.3}Wo_{8.1-7.4}$, FeO/MnO = 29-36) and maskelynite ($An_{59.7-62.4}Or_{1.5-1.8}$) plus minor olivine ($Fa_{38.4}$), Mg-bearing merrillite, chromite, Cr-bearing ilmenite and Ni-bearing pyrrhotite (see Figure 3b).

Intermediate Microgabbroic Shergottites from Chwichiya: A 4.2 gram stone found near Chwichiya, southern Morocco in May 2014 was classified as NWA 8637. Two larger, very similar fusion-crusted stones were later recovered nearby, and we studied a sample (#66.1). All these stones share similar microgabbroic textures and mineralogy (see Figure 4), and their mafic silicates have similar, rather homogeneous compositions (olivine $Fa_{39.9-45.2}$, FeO/MnO = 49-55; pigeonite $Fs_{26.8-31.0}Wo_{13.9-8.9}$, FeO/MnO = 29-33; augite $Fs_{17.0-18.5}Wo_{38.0-34.9}$, FeO/MnO = 24-32). However, plagioclase (*vesicle-free* maskelynite) in NWA 8637 is less calcic and more potassic ($An_{51.4-54.8}Or_{4.7-4.0}$) than in the otherwise similar Chwichiya stones ($An_{60.8-64.8}Or_{2.0-0.9}$).

The larger Chwichiya stones are similar in texture and all mineral compositions to NWA 7032/7272 [1] (found in 2011, but purportedly outside Morocco). However, NWA 7032 is isotopically *depleted*, and maskelynite in both this and the paired stone contains *vesicles* (indicative of higher shock), so pairing with the Chwichiya stones appears to be ruled out.

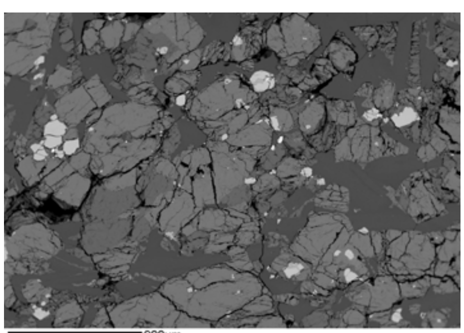


Figure 4. *BSE image of NWA 8637. Olivine (light gray), pyroxenes (medium gray), plagioclase (darker gray), Ti-chromite, ilmenite and pyrrhotite (brightest).*

Radiogenic Isotopic Compositions: Clean interior fragments (~100 mg) of three of the newly-discovered specimens plus NWA 6963 [2,3] were spiked for Lu-Hf and Sm-Nd analyses, bomb digested in $HF-HNO_3$ and measured by MC-ICP-MS. Although the analyzed material for each of these specimens may not be truly representative of their bulk compositions, the simultaneous analysis of parent-daughter elemental abundances ensures that the measured isotopic ratios mirror those of their sources. Given the small amount of available material of NWA 8705, we chose to recover and analyze clean cutting dust (dry mass 21.5 mg) produced during thick section preparation. Although the results are less precise (±1.0 ε units, compared to ±0.3 for the other samples), they clearly establish the intermediate isotopic character of this specimen.

Isotopic Ratios and Element Abundances (in ppm)

	sample #14.2	NWA 8656	NWA 8705	sample #66.1	NWA 6963	NWA 7032
εHf	+50.4	-19.1	+27	+39.3	-18.8	+46.9
Lu	0.17	0.25	0.11	0.17	0.24	
Hf	0.61	2.15	0.55	1.75	1.94	1.28
εNd	+55.1	-6.0	+8	+16.4	-6.1	
Sm	0.76	3.93	1.37	1.57	4.49	
Nd	0.64	1.53	0.52	0.73	1.73	

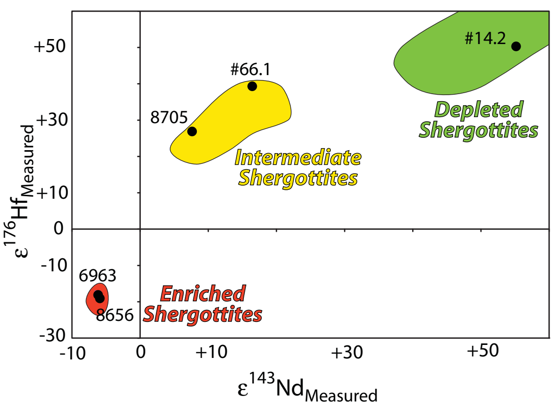


Figure 5. *Correlation of shergottite Nd and Hf isotopic compositions (fields from data compilation [4]).*

Diversity of Martian Mantle Sources for Shergottites: The new isotopic results reinforce the established pattern [5,6] of three distinct Martian source characteristics (Fig. 5), which are nevertheless heterogeneous in detail. It remains uncertain whether this represents a sporadically-populated mixing array between end-member sources, or instead evidence for at least three separate, very ancient mantle domains that did not convectively mix (and were then sampled at different times by younger plume magmatism).

References: [1] Irving A. et al. (2011) *LPS* XXXVII, #1365 [2] *Meteorit. Bull.* **101** 2012 [3] Filiberto J. et al. (2014) *Amer. Mineral.* 99, 601-606 [4] Martian Meteorite Compendium, *NASA* [5] Borg L. et al. (2003) *GCA* 67, 3519-3536 [6] Lapen T. J. et al. (2010) *Science* 328, 347-351