PETROLOGY AND COMPOSITION OF NORTHWEST AFRICA 2990: A NEW TYPE OF FINE-GRAINED, ENRICHED, OLIVINE-PHYRIC SHERGOTTITE. T. E. Bunch[1], A. J. Irving[2], J. H. Wittke[1], D. Rumble, III[3], R. L. Korotev[4], M. Gellissen[5] and H. Palme[5] [1]Dept. of Geology, Northern Arizona University, Flagstaff, AZ (tbear1@cableone.net), [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA, [3]Geophysical Laboratory, Carnegie Institution, Washington, DC, [4]Dept. of Earth & Planetary Sciences, Washington University, St. Louis, MO, [5]Institut für Geologie und Mineralogie, Universität zu Köln, Germany.

The most common group of Martian meteorites is one comprised of shergottites with relatively elevated LIL element abundances. These have been referred to as enriched shergottites, despite the fact that they do not exhibit light REE enrichment, yet they are thought be derived by partial melting of mantle source regions that are LIL-enriched *relative* to other shergottites. The first specimens to be recognized (e.g., Shergotty and Zagami) turn out to be moderately evolved igneous rocks, in comparison to more primitive olivine-bearing examples such as NWA 4468, NWA 1068 and RBT 04261/62 [1, 2, 3]. Until now, all other enriched shergottites are olivine-free, clinopyroxene-plagioclase-rich ("basaltic") rocks, ranging even to extremely evolved compositions (e.g., Los Angeles, NWA 2800).

Northwest Africa 2990 is a very fresh, partially fusion crusted, olivine-phyric shergottite (363 grams), which differs from other examples in being much more fine grained. It thus appears to be one of the most rapidly cooled enriched shergottite specimens.

Figure 1. *Top and side views of whole NWA 2990 stone (width = 7 cm). Images © A. Aaronson.*

Petrography: Small olivine phenocrysts (mean size 0.27 mm; zoned from cores of $Fa_{29.1}$ to rims of $Fa_{47.9}$; mean FeO/MnO = 53) are set in a fine-grained groundmass (<0.12 mm) of olivine ($Fa_{45.8-49.7}$), twinned tabular pigeonite (cores $Fs_{32.2}Wo_{8.6}$, rims $Fs_{41.1}Wo_{10.8}$; FeO/MnO = 33), augite ($Fs_{26}Wo_{28.8}$; FeO/MnO = 29), maskelynite ($An_{64.3-66.2}Or_{2.3-2.7}$), chromite [Cr/(Cr+Al) = 0.81-0.85], titanomagnetite, ilmenite (2.72 wt.% MgO), pyrrhotite, and merrillite.

Figure 2. *Partially cross-polarized optical thin section image (width = 5 mm).*

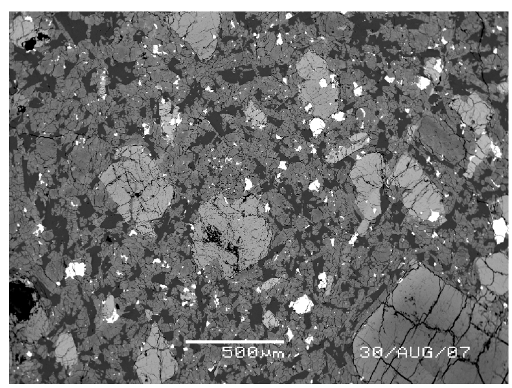

Figure 3. *BSE image showing larger zoned olivine, pigeonite (gray), maskelynite (black), oxides (white).*

Oxygen Isotopes: Analyses of acid-washed whole sample material by laser fluorination gave the following results, respectively: $\delta^{18}O$ = 4.312, 4.536; $\delta^{17}O$ = 2.500, 2.621; $\Delta^{17}O$ = 0.232, 0.236 per mil. These values fall in the lowest part of the range for laser fusion determinations on 42 Martian meteorites [see 4].

Bulk Composition: The fine grain size and homogeneity of this specimen facilitated production of a representative powder for analysis by XRF and INAA, with the following results:

	NWA 2990	***NWA 1068*** [2]	***NWA 2990***	
			V	290 ppm
SiO_2	51.08		Sc	57.4
TiO_2	0.62	0.77	Co	33.6
Cr_2O_3	0.11	0.63	Ni	100
Al_2O_3	9.24	5.75	La	1.46
FeO_T	16.42	20.48	Ce	3.4
MnO	0.44	0.46	Nd	2.1
MgO	8.06	16.5	Sm	1.05
CaO	11.67	7.91	Eu	0.48
Na_2O	1.74	1.14	Tb	0.33
K_2O	0.16	0.16	Yb	1.22
P_2O_5	0.49		Lu	0.192
SUM	100.03		Hf	1.31
			Ta	0.13
Mg/(Mg+Fe)	0.467	0.589	Th	0.27

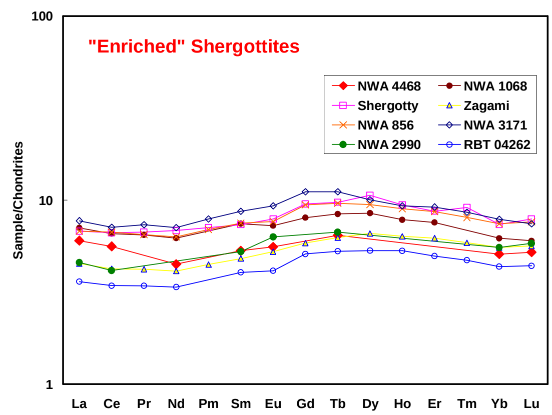

Figure 4. *Chondrite-normalized REE patterns for NWA 2990 and other enriched shergottites [1, 2, 3, 5]*

Discussion: NWA 2990 is less olivine-rich than NWA 1068/1110, and also has much lower bulk Cr and Ni abundances and higher CaO and Al_2O_3 contents. The core olivine compositions indicate equilibrium with a liquid with Mg/(Mg+Fe) of 0.440 (for an olivine/melt $K_D^{Fe/Mg} = 0.33$), which is close to the value for the bulk rock, and thus implies that NWA 2990 probably represents a magmatic liquid. In contrast, the NWA 1068 magma apparently accumulated additional (probably cognate) olivine and chromite phenocrysts, and thus is not a liquid composition. NWA 2990 is distinctly porphyritic, but all stages of grain growth apparently occurred with greater density of nucleation sites and/or more rapid cooling in comparison to other porphyritic shergottites. One possibility is that NWA 2990 is from near the wall of a subsurface magma conduit rather than a surface lava flow.

Preliminary bulk rock Hf isotopic data [6] demonstrate that NWA 2990 is an atypical enriched shergottite, since it has a very elevated positive ε_{Hf} value. This implies that its mantle source is very different from that of other enriched shergottites (all of which have negative ε_{Hf} values).

Although having similar REE abundances to those for NWA 4468 (Figure 4), NWA 2990 is the least magnesian (and most calcic) of the several known olivine-bearing, enriched shergottites. NWA 4468 appears to be the most primitive example based on its bulk Mg/(Mg+Fe) of 0.600 [7] and its very magnesian pyroxene compositions (see Figure 5). In contrast, RBT 04262 and NWA 1068 have pyroxene compositions that are generally more ferroan, despite their relatively magnesian bulk compositions, perhaps as a result of magma mixing. NWA 2990 evidently is genetically (and texturally) different from those samples.

	4468	***RBT***	***1068***	***2990***
FeO	23.0	20.6	20.48	16.42
Cr_2O_3	0.84	1.05	0.63	0.11
Ni	320	291	232	100
Sc	25.6	31.0	37	57.4
Mg/Mg+Fe)	0.600	0.651	0.589	0.467
Olivine (Fa)	***30-41***	***28-40***	***28-58***	***29-50***

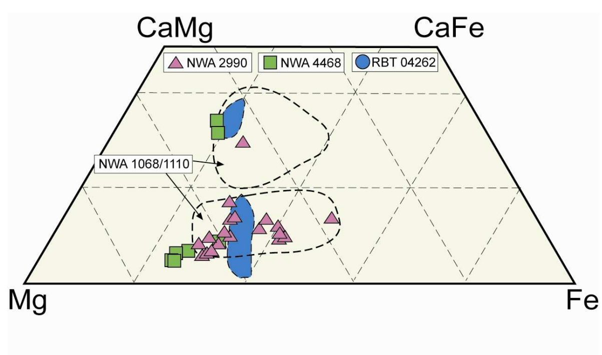

Figure 5. *Pyroxene compositions for NWA 2990 and other olivine-bearing enriched shergottites [1, 2, 3]*

References: [1] Irving A. J. et al. (2007) *Lunar Planet. Sci.* **XXXVIII**, #1526 [2] Barrat J.-A. et al. (2001) *GCA* **67**, 507-527 [3] Mittlefehldt D. W. and Herrin (2008) *72nd Meteorit. Soc. Mtg.*, #5327; Anand M. et al. (2008) *Lunar Planet. Sci.* **XXXIX**, #2173 [4] Rumble D. and Irving A. J. (2009) *Lunar Planet. Sci.* **XL**, this conference [5] Lodders K. (1998) *MAPS* **33**, A183-A190; Barrat J.-A. et al. (2001) *MAPS* **36**, 23-29; Irving A. J., Herd C. D. K. et al., unpubl. data [6] Lapen T. J. et al. (2009) *Lunar Planet. Sci.* **XL**, this conference [7] Shirai N. et al. (2009) unpubl. data.