

**NWA 2990** - 363 grams  
**NWA 5960** - 147 grams  
**NWA 6234** - 55.7 grams  
**NWA 6710** - 74.4 grams  
Enriched Olivine-phyric Shergottite



*Figure 1: Sawn surface of NWA 2990. Photo by Theodore Bunch (2009). Scale unknown, but piece weighs 21 grams.*

### **Introduction**

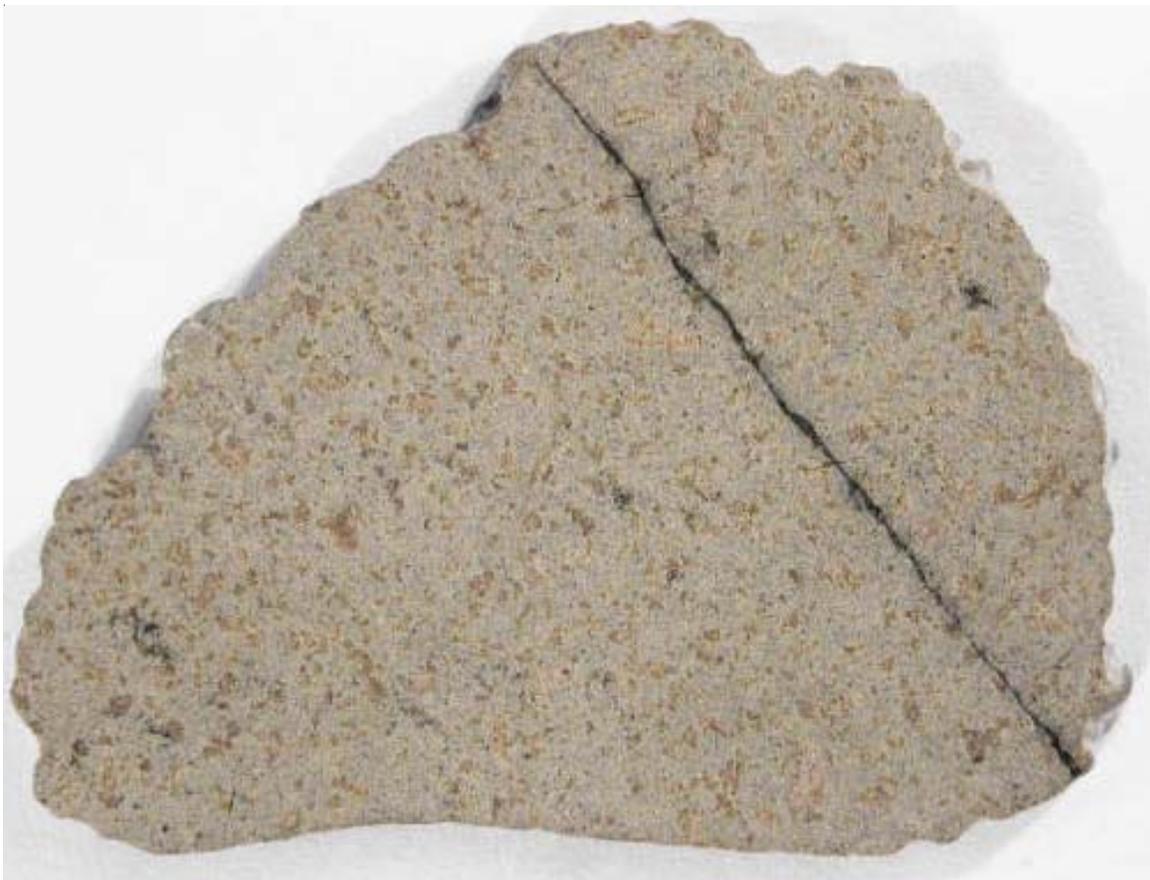
NWA 2990 is a fine-grained, olivine-rich, shergottite with a nearly complete fusion crust on two sides (Bunch *et al.* 2009). It appears to be relatively fresh (unweathered). It is apparently paired with 6710, 5960 and 6234 (Irving *et al.* 2011). They are apparently obtained from Mali (Meteoritical Bulletin).

### **Petrography**

Figures 1, 3 and 10 show that these samples have a fresh, unaltered interior. Small olivine phenocrysts (0.3 mm) are set in a fine-grained groundmass of pyroxene, maskelynite and opaque minerals (figure 1). Minor black spots of “impact melt glass” are present in NWA2990 and a very nice glass vein is seen in NWA6236.



*Figure 2: Photo of NWA2990 whole (from Bunch *et al.*; photo by A. Aaronson).*



*Figure 3: Photo of slab cut from NWA6234, showing black glass vein.*

### **Mineralogy**

**Olivine:** Olivine phenocrysts are zoned  $Fe_{71-52}$ . Olivine in the groundmass is  $Fe_{50-46}$ .

**Pyroxene:** Both pigeonite and sub-calcic augite are present (figure 2).

**Opaques:** Chromite, Ti-rich magnetite, ilmenite, pyrrhotite are reported.

### **Chemistry**

The chemical composition of NWA 2990 determined by Korotev was reported in Bunch et al. (2009). Figure 3 shows the REE pattern. Such a pattern indicates it is “enriched” in large ion lithophile elements. The bulk composition of 6234 has significantly higher FeO and MgO and significantly lower  $SiO_2$ ,  $Al_2O_3$  and CaO compared with NWA 2990 (Filiberto et al. 1012)..

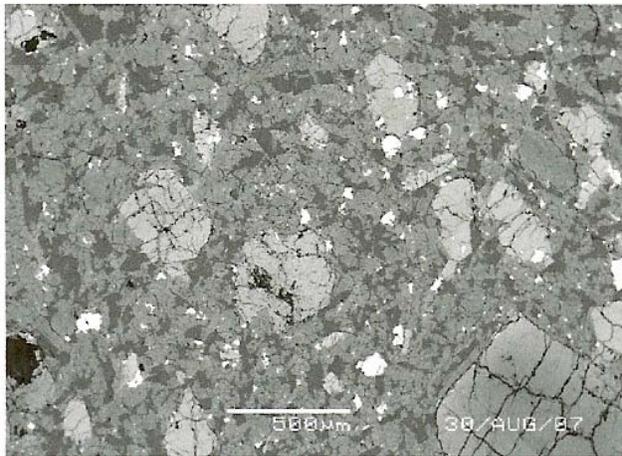
The abundance of highly-siderophile elements was reported by Brandon et al. (2012).



*Figure 4: Photo of NWA6234. Cube is 1 cm.*



*Figure 5: 2 photos of slices of 6710 from Chladni's Heirs*



**Figure 6:** Backscatter electron image of NWA 2990 showing olivine and pyroxene phenocrysts in fine-grained matrix. Scale bar is 500 microns (from Bunch et al. 2009).

### Radiogenic age dating

NWA2990 and its equivalents have not been dated. The Lu and Hf content and isotopic composition of Hf was reported by Lapan et al. (2009). The Hf isotopic composition appears to be “unusual”.

### Other Studies

Oxygen isotopes, determined by Rumble, were reported in Bunch et al. (2009).

Os isotopes were reported by Brandon et al. (2012).

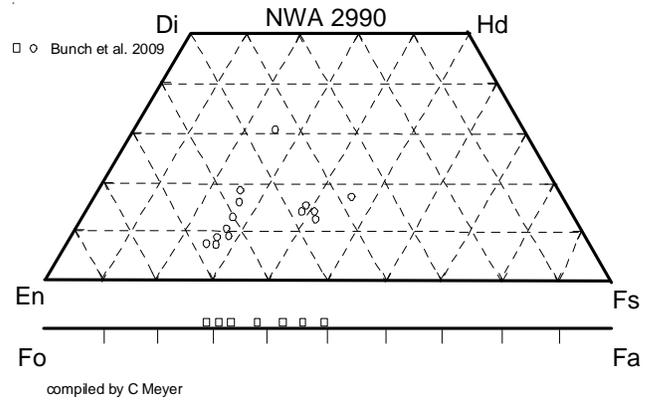
### Processing

There are numerous photos of sawn surfaces. Nothing is known about the other pieces -

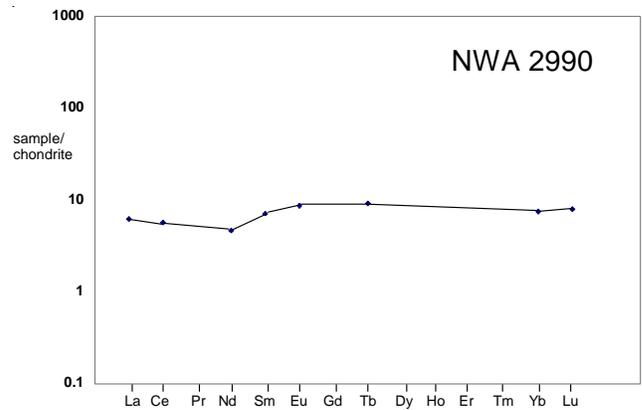
### References for NWA2990, 5960, 6234, 6710

Brandon A.D., Puchel I.S., Walker R.J., Day J.M.D., Irving A.J. and Taylor L.A. (2012) Evolution of the Martian mantle inferred from the <sup>187</sup>Re-<sup>187</sup>Os isotope and high siderophile element systematics of the Shergottite meteorites. *Geochim. Cosmochim. Acta* **76**, 206-235.

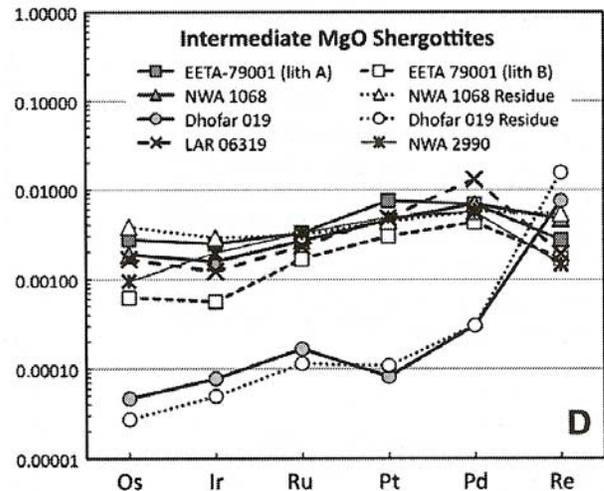
Bunch T.E., Irving A.J., Wittke J.H., Rumble D., Korotev R.L., Gellissen M. and Palme H. (2009) Petrology and composition of Northwest Africa 2990: A new type of fine-grained enriched, olivine-phyric Shergottite (abs#2274). *Lunar Planet. Sci.* **XL**, Lunar Planetary Institute, The Woodlands.



**Figure 7:** Pyroxene and olivine for NWA 2990 (from Bunch et al. 2009).



**Figure 8:** Normalized rare-earth-element pattern for NWA 2990 (data from Bunch et al. 2009).

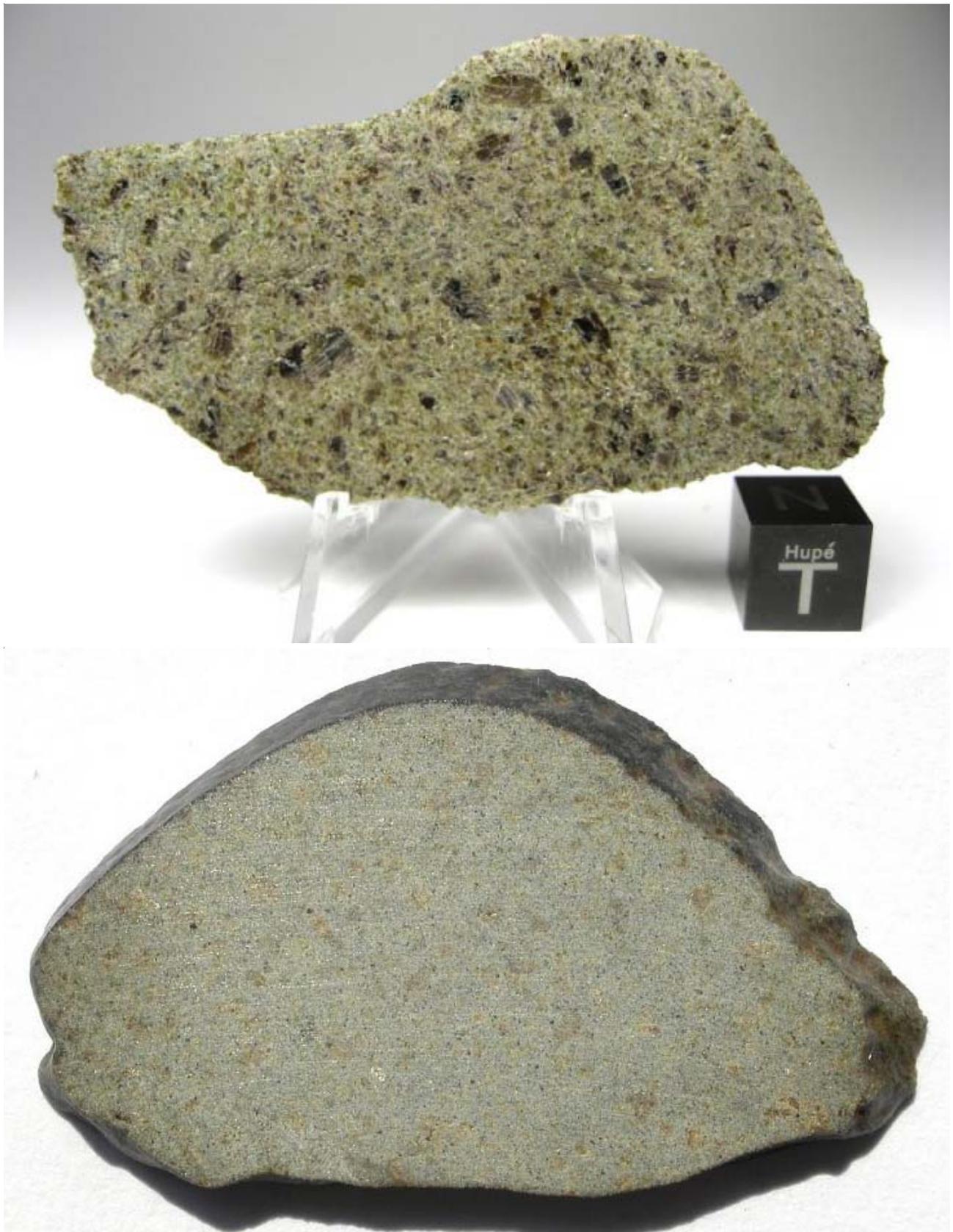


**Figure 9:** PGE and Re (from Brandon et al. 2012).

Filiberto J. and 15 authors (2011) Maximizing the science return from 3.3 g of Martian meteorite: A consortium study of olivine-phyric Shergottite Northwest Africa 6234 (abs). AGU

**Table 1. Composition of NWA2990 and NWA6234.**

	2990	6234		6234	
reference	Bunch09	Filiberto12		MB 99	Filiberto J., Chin Emily, Day J.M.D., Gross J., Musselwhite
weight				sawdust	D.S., Penniston-Dorland Sarah, Schwenzer S.P. and
SiO2 %	51.08	(a) 44.6		44.7	Treiman A.H. (2012) Geochemistry of intermediate
TiO2	0.62	(a) 0.82	0.79		olivine-phyric Shergottite Northwest Africa 6234
Al2O3	9.24	(a) 5.17			(abs#1139). <i>Lunar Planet. Sci. Conf. XLIII</i> Lunar
FeO	16.42	(a) 21.3	22.1	22.6	Planetary Institute @ The Woodlands.
MnO	0.44	(a) 0.56			
MgO	8.06	(a) 17.1		16.3	Filiberto J., Chin E., Day J.M.D., Franchi I.A., Greenwood
CaO	11.67	(a) 6.77		6.4	R.C., Gross J., Penniston-Dorland S.C., Schwenzer S.P.
Na2O	1.74	(a) 1.04			and Treiman A.H. (2012) Geochemistry of intermediate
K2O	0.16	(a) 0.08			olivine-phyric Shergottite Northwest Africa 6234, with
P2O5	0.49	(a) 0.81			similarities to basaltic Shergottite Northwest Africa 480
S %					and olivine-phyric Shergottite Northwest Africa 2990.
sum					<i>Meteorit. &amp; Planet. Sci.</i> <b>47</b> , 1256-1273.
Sc ppm	57.4	(b)			
V					
Cr	830	3935	3642		Franz H.B., Farquhar J. and Irving A.J. (2010) Acid volatile
Co	33.6	(b)			sulfur isotopic composition of seven
Ni	100	(b)		540	Shergottites from Northwest Africa (abs#2341). <i>Lunar</i>
Cu					<i>Planet. Sci.</i> <b>XLI</b> . Lunar Planetary Institute, Houston.
Zn					
Ga					
Ge ppb					
As					Gross Juliane, Filiberto J., Treiman A.H. and Herd C.D.K.
Se					(2012) Petrography, mineral chemistry and
Rb					crystallization history of olivine-phyric Shergottite
Sr					NWA6234: A new intermediate melt composition
Y					(abs#2693). <i>Lunar Planet. Sci.</i> <b>XLIII</b> , Lunar Planetary
Zr					Institute, Houston.
Nb					
Mo			<b>Brandon 2012</b>		
Ru ppb			2.11		Irving A.J., Herd C.D.K., Gellissen M., Kuehner S.M. and
Rh					Bunch T.E. (2011a) Paired fine-grained, permafic
Pd ppb			3.2		olivine-phyric Shergottites Northwest Africa 2990/5960/
Ag ppb					6234/6710: Trace element evidence for a new type of
Cd ppb					Martian mantle source or complex lithospheric
In ppb					<b>assimilation</b> process (abs#5232). <i>Meteorit. &amp; Planet.</i>
Sn ppb					<i>Sci.</i> <b>46</b> , A108.
Sb ppb					
Te ppb					
Cs ppm					
Ba					Lapen T.J., Righter M., Brandon A.D., Beard B.L., Shafer J.
La	1.46	(b)		1.3	and Irving A.J. (2009) Lu-Hf isotope systematics of
Ce	3.4	(b)		3.1	NWA4468 and NWA2990: Implications for the sources
Pr					of Shergottites (abs#2376). <i>Lunar Planet. Sci.</i> <b>XL</b> ,
Nd	2.1	(b)		2	Lunar Planetary Institute @ The Woodlands.
Sm	1.05	(b)		1.1	
Eu	0.48	(b)			
Gd					
Tb	0.33	(b)			Matzen A.K., Beckett J.R., Baker M.B. and Stopler E.M.
Dy					(2011) Fe <sup>2+</sup> -Mg partitioning between olivine and
Ho					Martian basaltic melts (abs#5528). <i>Meteorit. &amp; Planet.</i>
Er					<i>Sci.</i> <b>46</b> , A150.
Tm					
Yb	1.22	(b)		1.2	
Lu	0.192	(b)		0.17	Weisberg M.K. et al. (2009a) <i>Met. Bull.</i> #95. <i>Meteorit. &amp;</i>
Hf	1.31	(b)			<i>Planet. Sci.</i> <b>44</b> , 1-33.
Ta	0.13	(b)			
W ppb			<b>Brandon 2012</b>		Weisberg M.K. et al. (2010a) <i>Met. Bull.</i> #97. <i>Meteorit. &amp;</i>
Re ppb			0.06		<i>Planet. Sci.</i> <b>45</b> , 449-493.
Os ppb			0.44		
Ir ppb			0.87		
Pt ppb			4.24		
Au ppb					
Th ppm	0.27	(b)			
U ppm					



*Figure 10 a, b: Additional photos of sawn surfaces of NWA6710 (from internet, caution ! ).*