NWA1068 – 577 grams
NWA1110 – 118 grams
NWA1183 – 140 grams?
NWA1775 – 25 grams
NWA2373 – 18 grams
NWA2969 – 11.7 grams
Enriched Olivine-phyric Shergottite

***Figure 1**: Photograph of NWA 1068 (scale is 1 cm). Photo kindly provided by Bruno Fectay and Carine Bidaut.*

Introduction

NWA 1068 was found in the Moroccan Sahara in April 2001 by a local team called "La Mémoire de la Terre" and given the field name "Louise Michel". It has no fusion crust and is greenish-brown in color (figure 1). A main mass (522g) and 22 small fragments were recovered (Barrat *et al*. 2002b). **NWA 1110** (several fragments, 118 grams) was purchased from meteorite dealers in Morocco in September 2001 and appears to be paired with NWA 1068 (Irving and Kuehner). The exact strewn field of this meteorite is not known, but appears to be in Morocco (Barrat *et al.* 2002; Russell *et al.* 2002). **NWA1183** is a provisional number given to a whole bunch of fragments (1 – 5 grams each) that have apparently been recovered and sold in Erfoud, Morocco.

Mineralogical Mode for NWA1068 and 1110

	Barrat *et al.*	**Mikouchi (2002)**
	2002 a, b	202
Olivine	21 %	27.2 %
Pyroxene	52	51.6
Maskelynite	22	15.5
Phosphate	2	1.8
Opaques	2	2.5
Mesostasis	1	

In texture, mineralogy and bulk chemistry, NWA 1068 appears similar to other basaltic shergottites, EETA79001, Dar al Gani 476, Sayh al Uhaymir 005 and Dhofar 019, but the REE pattern of NWA 1068 is not depleted in light REE and is instead very similar to that of Shergotty.

Figure 2: *Photo of NWA1110 from internet.*

Figure 3: *Photograph of pieces of NWA 1110 (probably paired with NWA 1068). Photograph and information from JPL web site (Ron Baalke).*

The crystallization age of NWA1068 is 185 m.y., with an exposure to cosmic rays of about 2 – 3 m.y. These samples are weathered.

Petrography

NWA 1068 has a porphritic texture consisting of olivine phenocrysts (up to 2 mm) in a fine-grained groundmass (grain size ~100 microns). The olivine phenocrysts occur in clusters, contain chromite and melt inclusions and appear corroded/resorbed (Barrat *et al*. 2002). Papike et al. (2009) compared NWA1110 with the other shergottites, producing and incredible amount of mineral data.

Wadhwa and Crozaz (2002) analyzed a melt inclusion (figure 6) within an olivine, and found that it had a REE pattern parallel to that of the bulk rock, indicating that the olivine phenocrysts formed from a magma similar to that of the NWA 1068 parent melt.

NWA 1068 contains veins of terrestrial calcium carbonate, small "melt" pockets and numerous shock veins (Barrat *et al.* 2002b).

Mineral Chemistry

Olivine: The cores of the olivine megacrysts are homogeneous (Fo_{70}) with distinct outer rims up to 100 microns wide, zoned to Fo_{50-60}. There is no outer zoning where olivine grains are touching. Shearer et al. (2008) studied the trace element content of olivine in NWA1110.

Pyroxene: Both pigeonite and augite are present as subhedral to euhedral crystals in about equal proportions (figure 2). Pyroxenes are normally zoned ($En_{57}Wo_5$ to $En_{40}Wo_{13}$ and $En_{55}Wo_{21}$ to $En_{35}Wo_{28}$) (figure 5a,b).

Maskelynite: Shocked plagioclase crystals are normally zoned An_{53} toAn_{49}.

Opaque minerals: Chromite is found associated with olivine. Ilmenite and ulvöspinel are found in the mesostasis.

Phosphates: Barrat *et al.* (2002) reported analyses of both merrillite and apatite in NWA 1068.

Whole-rock Composition

NWA 1068 has a relatively flat REE pattern, unlike that of the other olivine-bearing shergottites, which have (rather extreme) light REE depletions (figure 3). Key element ratios such as Fe/Mn (=45), Al/Ti (=6.6) and Ga/Al (=4.4 10^{-4}) are typical of Martian meteorites.

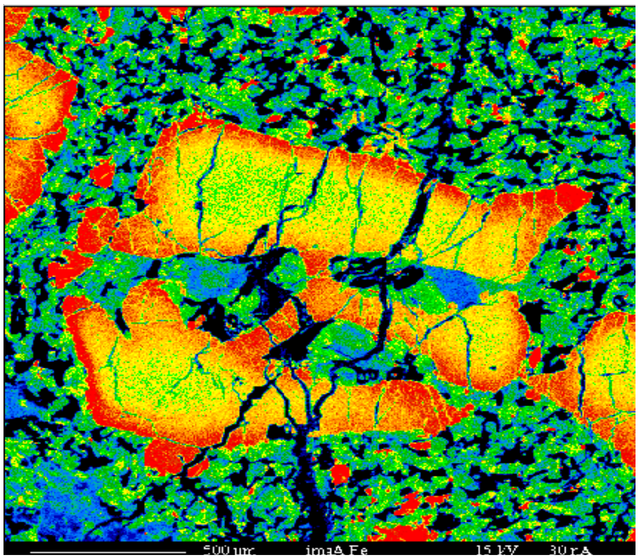

Figure 4: X-ray map (Fe) of olivine megacrysts in matrix of NWA 1068 showing homogeneous cores zoning to Fe-rich rims (credit Jean-Alix Barrat and Marcel Bohn). Field of view about 2 mm.

Sr, Ba and Pb are relatively high compared with unweathered shergottites (figure 4), but Th/U is normal and NWA 1068 does not have a Ce anomaly, so it has been concluded that this “hot desert” find is not badly weathered (Barrart *et al.* 2002b).

The abundance of highly-siderophile elements was reported by Walker et al. (2009) and Brandon et al. (2012) (figure 11).

Radiogenic Isotopes

Shih et al. (2003) have dated NWA 1068 by Rb-Sr and Sm-Nd (figure 9 and 10). The apparent crystallization age (185 Ma) is typical of basaltic shergottites.

Cosmogenic Isotopes

The exposure age of NWA1068 was reported as 2.2 – 3 m.y. based on ^{10}Be concentration (Nishiizumi et al. 2004).

Other Isotopes

The isotopic composition of Os was reported by Brandon et al. (2012).

Shock Effects

Thin shock veins and small pockets of shock melt glass are found in the groundmass. Barrat *et al.* (2002) report analyses of this glass.

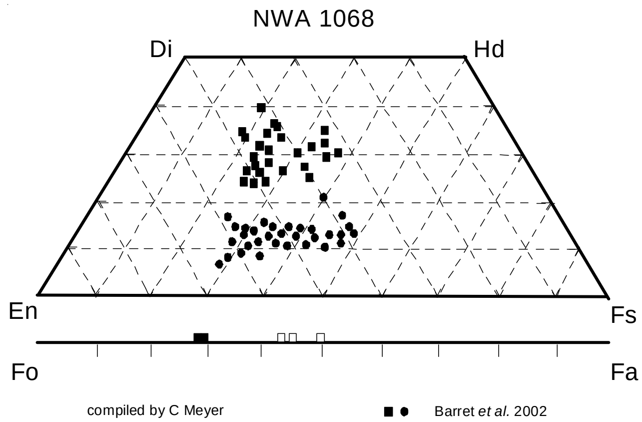

Figure 5a: Pyroxene and olivine composition diagram for NWA 1068 (data replotted from Barrat et al. 2002).

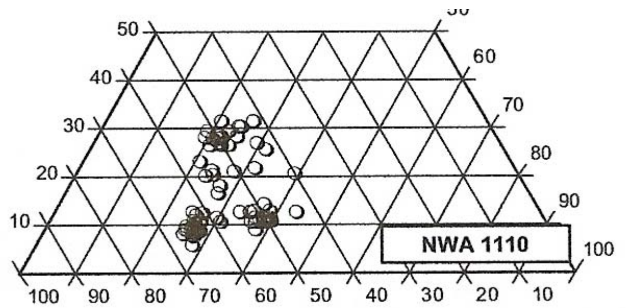

Figure 5b: Pyroxene and olivine composition diagram for NWA 1110 (data from Papike et al. 2012).

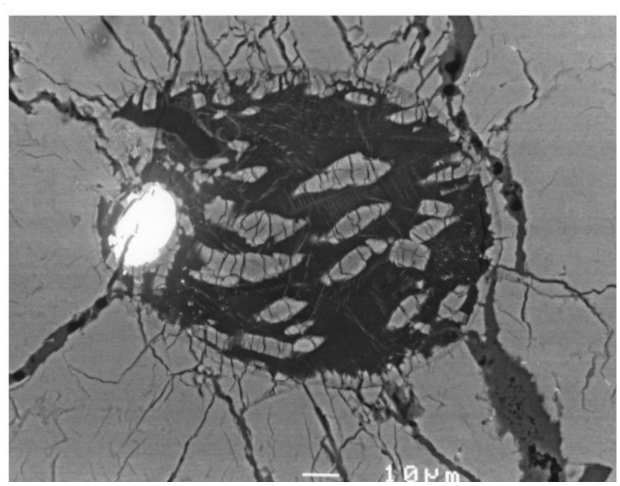

*Figure 6: BSE photo of melt inclusion in olivine in NWA1068 (credit Jean-Alix Barrat and Marcel Bohn). This is figure 8 in Barrat et al. GCA **66**, 3512.*

Terrestrial Weathering

The occurrence of veins of calcium carbonate demonstrates that NWA 1068 has been weathered after its fall. It has elevated Sr, Ba and Pb concentrations

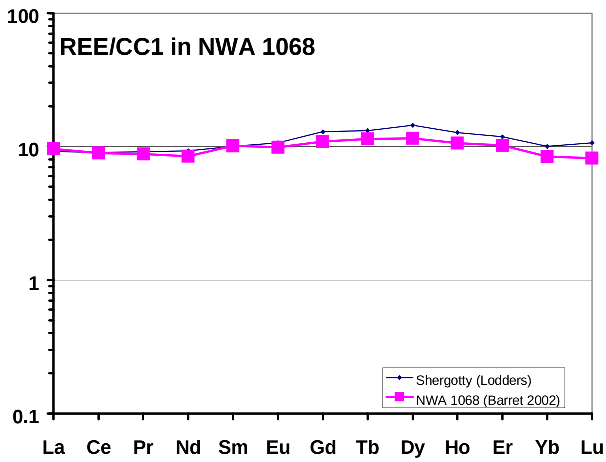

***Figure 7**: Rare earth element diagram for NWA 1068 compared with Shergotty (data from Barrat et al. 2002 and Lodders 1998).*

(Barrat *et al.* 2002). Surfaces are coated with reddish desert varnish.

<u>Processing Info</u>

The sizes of the small pieces collected along with NWA 1068 referred to above are (19.2 g, 10.4 g, 6.0 g, 3.2 g, 2.0 g, 2.4 g, 1.9 g, 1 g, 1 g, 0.9 g, 0.8 g, 0.6 g, 0.5 g, 0.4 g, 0.3 g etc). NWA 1110 was also in pieces, and there are certain to be others, still to be found !

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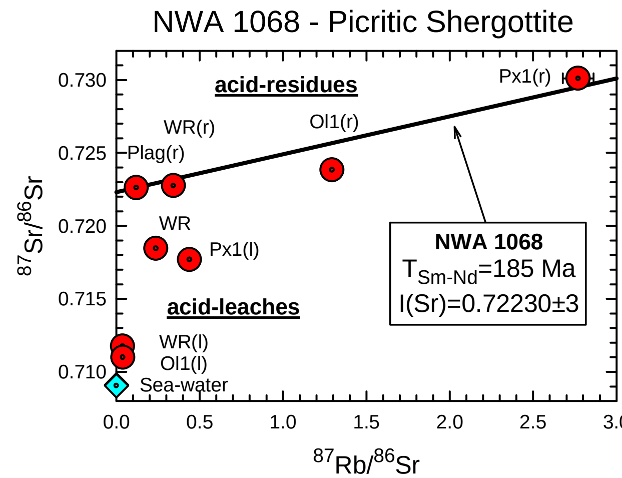

***Figure 9:** Rb-Sr isochron from Shih et al. 2003.*

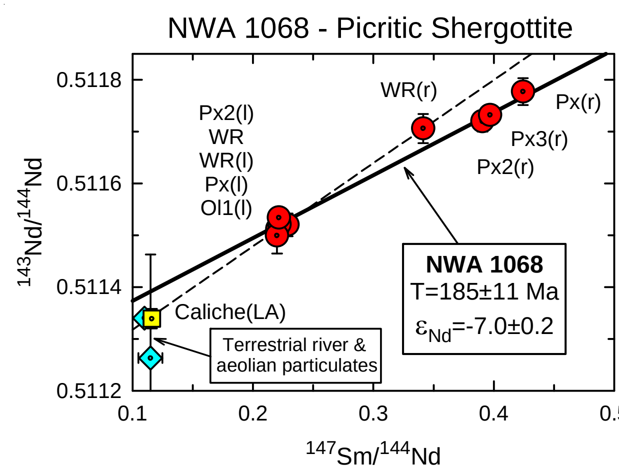

***Figure 10:** Sm-Nd isochron for NWA1068 by Shih et al. 2003.*

***Figure 11:** PGE and Re from Brandon et al. 2012.*

Table 1: Composition of NWA1068.

reference	Barrat 2002	
weight		
SiO2		
TiO2	0.77	(a)
Al2O3	5.75	(a)
FeO	20.48	(a)
MnO	0.46	(a)
CaO	7.91	(a)
MgO	16.5	(a)
Na2O	1.14	(a)
K2O	0.16	(a)
P2O5		
sum		
Li ppm	4.34	(b)
Be	0.35	(b)
Sc	37	(b)
V	280	(b)
Cr	4317	(b)
Co	56.2	(b)
Ni	232	(b)
Cu	14	(b)
Zn	49	(b)
Ga	13.4	(b)
Ge		
Rb	5.75	(b)
Sr	67	(b)
Y	17.19	(b)
Zr	62.14	(b)
Nb	4.37	(b)
Mo		
Cs ppm	0.45	(b)
Ba	*127*	(b)
La	2.25	(b)
Ce	5.38	(b)
Pr	0.783	(b)
Nd	3.82	(b)
Sm	1.49	(b)
Eu	0.552	(b)
Gd	2.14	(b)
Tb	0.414	(b)
Dy	2.8	(b)
Ho	0.59	(b)
Er	1.63	(b)
Tm		
Yb	1.37	(b)
Lu	0.198	(b)
Hf	1.58	(b)
Ta	0.2	(b)
W ppb	520	(b)
Th ppm	0.409	(b)
U ppm	0.1	(b)

technique: (a) ICP/AES, b) ICP-MS

Table 2: PGE and Re (Brandon et al. 2012).

	NWA1068
Os ppb	0.86
Ir ppb	0.7
Ru ppb	1.72
Pt ppb	3.94
Pd ppb	3.94
Re ppb	0.186

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