

**NWA 480** - 28 grams  
**NWA1460** - 70 grams  
**NWA5029** - 17.7 grams  
Intermediate Basaltic Shergottite



*Figure 1: Photograph of NWA 480 kindly provided by Bruno Fectay and Carine Bidaut.*

### **Introduction**

**NWA 480** was found in November 2000 in Morocco (Barrat *et al.* 2001, 2002; Grossman and Zipfel 2001). It was almost completely covered with fusion crust (figure 1) and appeared to be rather fresh with only a few spots of weathering products on the surface. Apparently, NWA 480, was sold to the National Centre for Space Studies (CNES), where it is “*being put to use to prepare for analysis of samples returned by planned missions to Mars*” (according to Philippe Gillet) and is being studied by *Consortium Théodore Monod*.

In December 2001, **NWA 1460** (70.2 grams) was acquired in Agadir, Morocco (Irving and Kuehner 2003). This sample is also covered with a complete fusion crust and appears to be paired with NWA 480 (*preliminary assessment based on comparison of figure 1 with figure 3*).

An additional stone (**NWA5029**) was purchased in 2003 in M’hamid, Morocco by Fectay and Bidaut (Meteoritical Bulletin). It also has a similar texture, but it is not quite the same (see below).

The age of NWA1460 has been determined to be 346 m.y. with exposure to cosmic rays for 2.6 m.y.

### **Petrography**

NWA480 has a coarse-grained basaltic texture consisting predominately of subhedral to euhedral pyroxene (up to 5 mm) and interstitial, lath-shaped maskelynite (Grossman and Zipfel 2001). NWA1460 is illustrated in figures 2 and 3 and NWA5029 in figure 5. These samples have predominate zoned pyroxene surrounded by lath-shaped plagioclase (now maskelynite)(figure 4). Zoning continues to extreme iron enrichment and fine-grained fayalite-hedenbergite-silica intergrowths at the outer rim of the pyroxene. Accessory phases include merrillite, apatite,



**Figure 2:** Copyrighted photograph of NWA 1460 taken by Nelson Oakes showing nearly complete fusion crust.

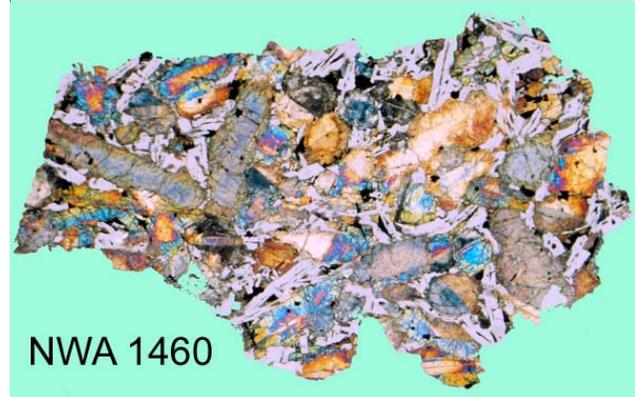
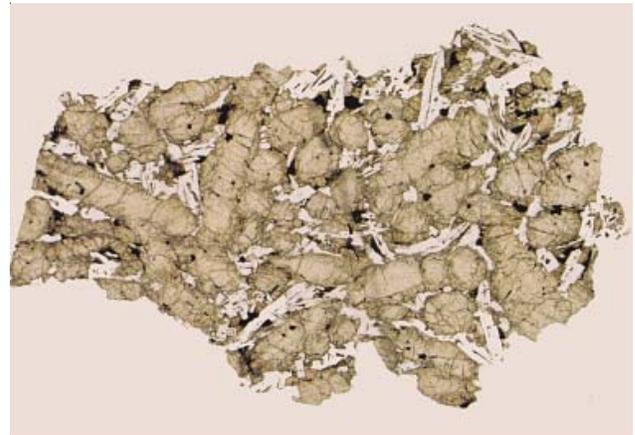


**Figure 3:** Photograph of sawn surface of NWA 1460 showing basaltic texture similar to that of NWA 480. Photo by Nelson Oakes.

titanomagnetite, ilmenite, chromite, pyrrhotite, silica, baddeleyite and K-rich glass (Irving and Kuehner 2003).

Beck et al. (2004) have performed a detailed study of Li concentration and isotopic composition in minerals from NWA480.

NWA480 contains “melt pockets”, as well as maskelynite and stishovite (Barrat *et al.* 2002; Beck et al. 2006), indicating that it has been shock-melted. Chennaoui Aoudjehane (2006) has examined the cathodoluminescence spectra.



**Figure 4:** Thin section photo of NWA1640 (from Ted Bunch).

### Mineralogical Mode

	Barrat <i>et al.</i> (2002)
Pyroxene	72 vol. %
Plagioclase	25
Phosphate	1
Opaques	1

### Mineral Chemistry

**Pyroxenes:** Pyroxenes in NWA 480 (figure 6) are complexly zoned with Mg-rich cores ( $\text{En}_{77}\text{Fs}_{20}\text{Wo}_3$ - $\text{En}_{65}\text{Fs}_{29}\text{Wo}_6$ ), surrounded by Mg-rich augite ( $\text{En}_{41}\text{Fs}_{29}\text{Wo}_{30}$ ) and finally zoned to Fe-rich pigeonite ( $\text{En}_5\text{Fs}_{84}\text{Wo}_{11}$ ). The zoning in NWA1460 is exactly the same (Irving and Kuehner 2003). There is no exsolution in the pyroxene except for the most Fe-rich rim.

**Maskelynite:** All of the plagioclase has been shocked to form maskelynite ( $\text{An}_{46-50}\text{Ab}_{52-48}\text{Or}_2$ ).

**Phosphates:** Both merrillite and chlor-apatite are present in NWA 480. Fayalite-silica symplectite intergrowth is illustrated surrounding merrillite in figure 7 of Barret *et al.* (2002).



**Figure 5:** Photo of 2.7 gram slab of NWA5029 (photo by Fectay and Bidaut).

**Oxides:** Analyses of ilmenite and chromite are given in Barrat *et al.* (2002).

**Sulfide:** Lorand *et al.* (2006) determined that the sulfide in NWA480 was pyrrhotite and give an analysis.

**Silica:** Silica grains found included in maskelynite have been found to be a mixture of high-pressure silica glass and stishovite by Raman spectroscopy and cathodoluminescence (Barrat *et al.* 2002, Chennaoui Aoudjehane *et al.* 2005).

*Note: Crozaz et al. (2001) have determined the REE pattern of pyroxenes, apatite and merrillite in NWA 480. The low-Ca pyroxenes are found to have 'elevated La' – presumably due to terrestrial contamination, despite the fresh appearance of this meteorite.*

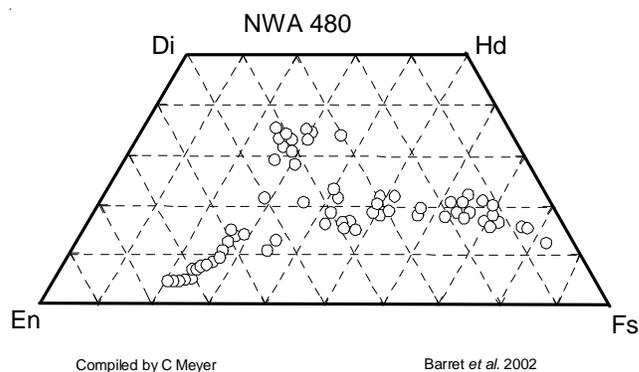
### **Whole-rock Composition**

The chemical composition of NWA 480 is reported by Barrat *et al.* (2001, 2002) (Table 1). The REE pattern (figure 7) was found to be “similar” to ALH77005.

NWA 480 has normal Th/U, Ba/La and Sr/Nd ratios similar to Antarctic Martian meteorites, indicating that it is a fresh meteorite, free of the effects of terrestrial weathering (Barrat *et al.* 2002).

### **Radiogenic Isotopes**

Nyquist *et al.* (2006, 2009) have dated NWA1460 by Rb-Sr and Sm-Nd ( $336 \pm 15$  b.y. and  $350 \pm 16$  b.y.) (figures 7 and 8). The  $^{40}\text{Ar}$  plateau diagram is in agreement (figure 9).



Compiled by C Meyer

Barrat *et al.* 2002

**Figure 6:** Pyroxene quadrilateral for NWA 480 (data replotted from Barrat *et al.* 2002).

### **Cosmogenic Isotopes and Exposure Ages**

Marty *et al.* (2001) and Mathew *et al.* (2003) report an “average exposure age” of  $2.4 \pm 0.2$  m.y. Nishiizumi *et al.* (2004) reported a  $^{10}\text{Be}$  exposure age of 2.2 - 3 m.y. for pieces of NWA1460.

### **Other Isotopes**

Barrat *et al.* (2001, 2002) determined the isotopic composition of oxygen as  $\delta^{17}\text{O} = 2.91\%$ ,  $\delta^{18}\text{O} = 4.78\%$ , with  $\Delta^{17}\text{O} = +0.42\%$ .

Nishiizumi *et al.* (2004) determined  $^{10}\text{Be}$  and  $^{41}\text{Ca}$  on NWA1460.

Hoffmann *et al.* (2011) has compared the magnetic properties of these three samples.

### **Processing**

Photos of NWA480 and NWA1460 show that they were both first sliced by a saw cut across one end (figure 1 and 3). NWA1460 was processed at JSC. Figure 10 compares two of these rocks.

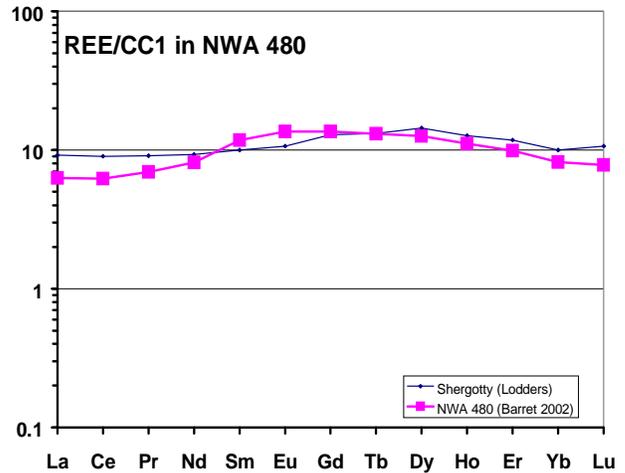
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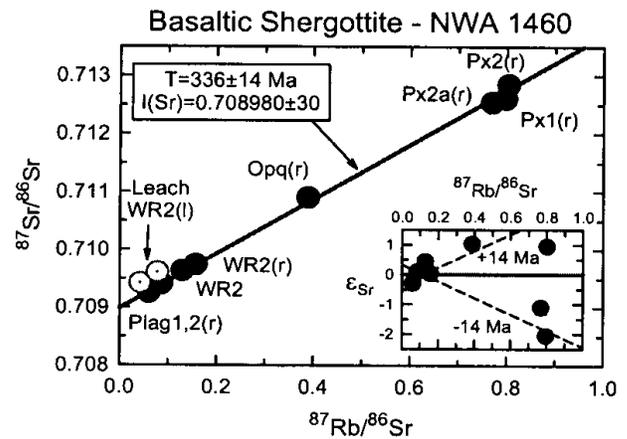
**Table 1: Composition of NWA 480 and 1460.**

reference weight	1460	
	Barret 02	Nyquist 09
SiO <sub>2</sub> %		
TiO <sub>2</sub>	1.16 (a)	
Al <sub>2</sub> O <sub>3</sub>	6.46 (a)	
FeO	19.44 (a)	
MnO	0.51 (a)	
CaO	9.32 (a)	
MgO	10.06 (a)	
Na <sub>2</sub> O	1.26 (a)	
K <sub>2</sub> O	0.1 (a)	
P <sub>2</sub> O <sub>5</sub>		
sum		
Li ppm	2.93 (b)	
Be	0.21 (b)	
S		
Cl		
Sc	28 (b)	
V	202 (b)	
Cr	2121 (a)	
Co	37.6 (b)	
Ni	63 (b)	
Cu	17.6 (b)	
Zn	64 (b)	
Ga	16.27 (b)	
Ge		
As		
Se		
Br		
Rb	2.67 (b)	2.36 (c)
Sr	49.3 (b)	52.1 (c)
Y	16.46 (b)	
Zr	58.74 (b)	
Nb	1.99 (b)	
Mo		
Pd ppb		
Ag ppb		
Cd ppb		
I ppm		
Cs ppm	0.19 (b)	
Ba	28.4 (b)	
La	1.48 (b)	
Ce	3.77 (b)	
Pr	0.619 (b)	
Nd	3.7 (b)	2.8 (c)
Sm	1.73 (b)	1.36 (c)
Eu	0.76 (b)	
Gd	2.67 (b)	
Tb	0.477 (b)	
Dy	3.05 (b)	
Ho	0.62 (b)	
Er	1.57 (b)	
Tm		
Yb	1.33 (b)	
Lu	0.19 (b)	
Hf	1.64 (b)	
Ta	0.1 (b)	
W ppb	340 (b)	
Re ppb		
Os ppb		
Ir ppb		
Au ppb		
Tl ppb		
Bi ppb		
Th ppm	0.22 (b)	
U ppm	0.064 (b)	

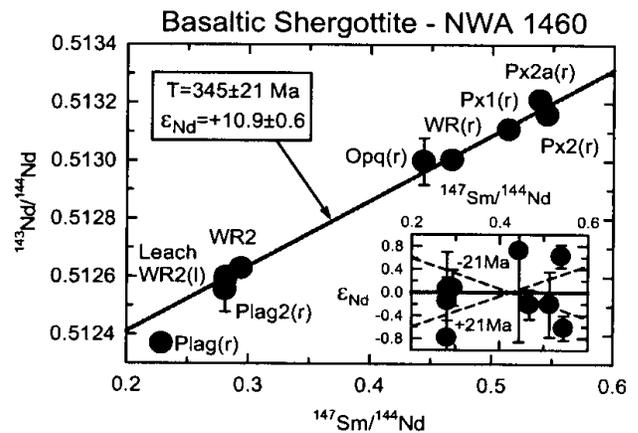
technique (a) ICP-AES, (b) ICP-MS, (c) TIMS



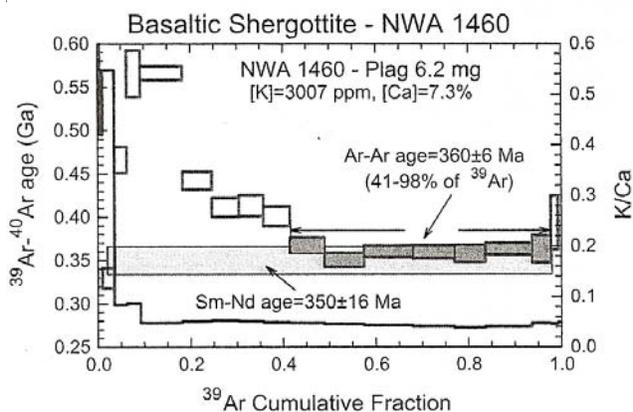
**Figure 6:** Normalized rare earth element diagram for NWA 480 and Shergotty (data from Barrat et al. 2002 and Lodders 1998).



**Figure 7:** Rb-Sr isochron for NWA 1460 (Nyquist et al. 2006).



**Figure 8:** Sm-Nd isochron for NWA 1460 (Nyquist et al. 2006).



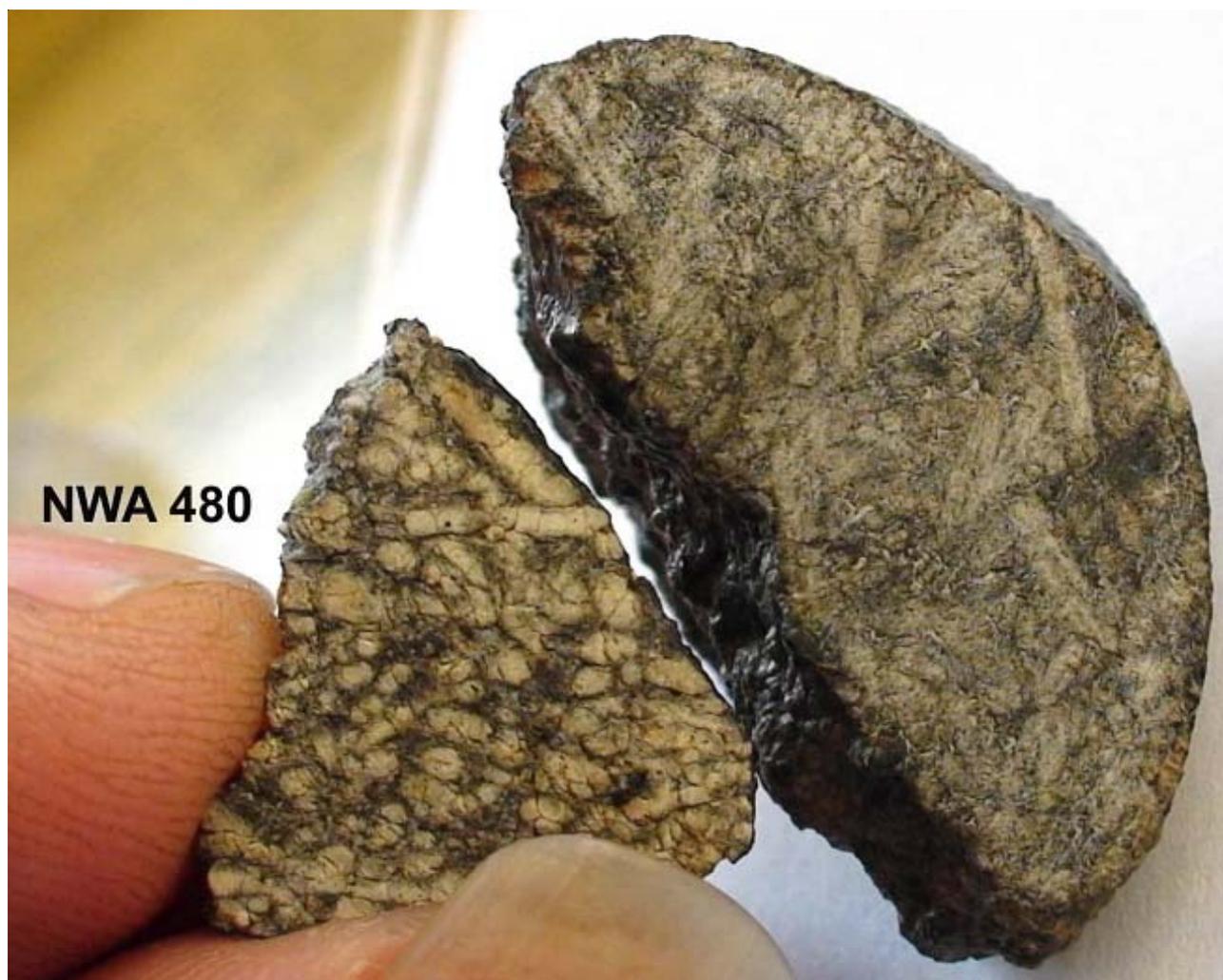
**Figure 9:**  $^{40}\text{Ar}$  plateau age for NWA1460 (from Nyquist et al. 2006).

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**Figure 10:** Comparison of NWA5029 with NWA480 (when looked at this way, not the same).

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