

**NWA 817** – 104 grams  
Nakhlite



*Figure 1: Photograph of NWA 817 kindly provided by Bruno Fectay and Carine Bidaut.*

**Introduction**

NWA817 was found in Morocco in November 2000 (Sautter *et al.* 2000; Grossman and Zipfel 2001) by Bruno Fectay and Carine Bidaut. NWA817 is similar to, but different from, the other nakhlites (Mikouchi and Miyamoto 2001). It has a very fresh fusion crust (figure 1). It is 1.35 b.y old with an exposure to cosmic rays for about 11 m.y.

**Petrography**

NWA817 is an olivine-bearing clinopyroxenite with a cumulate texture (Sautter *et al.* 2002). The intercumulus mesostasis is made of feldspars including trace amounts of sulfide droplets, Ti-magnetite and acicular pyroxene. NWA817 has a higher percentage of mesostasis than the other nakhlites. Pervasive alteration produced reddish clay minerals, including a

hydrous ferrous silicate ~ = “smectite”. However, terrestrial weathering is thought to be minor as indicated by the absence of weathering of the sulfides (Gillet *et al.* 2001, 2002).

The pyroxenes and olivines in NWA817 zone to become more iron rich than in the other nakhlites (Sautter *et al.* 2002).

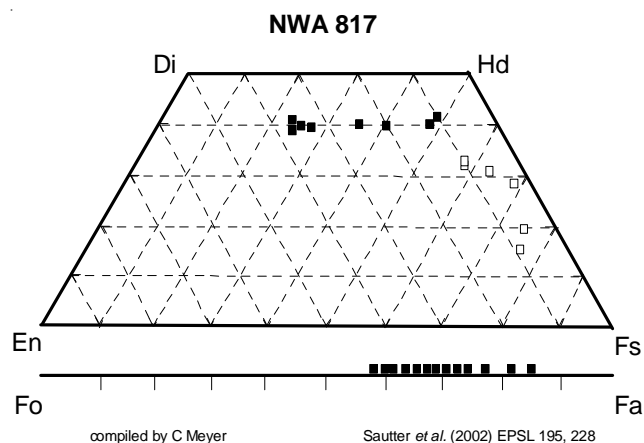
A photomicrograph of a thin section of NWA817 is to be found in Sautter *et al.* Photos of this meteorite can also be seen at <http://www.jpl.nasa.gov/snc/nwa817.html>

**Mineral Chemistry**

***Olivine:*** Olivine is Fo<sub>44</sub> in the core zoned to Fo<sub>14</sub> in the rim. It contains magmatic inclusions. There is a trace

**Mineralogical Mode**

	<b>Sautter <i>et al.</i> (2002)</b>	<b>Gillet <i>et al.</i> (2002)</b>
Pyroxene	69 vol. %	69
Olivine	10	15
Mesostasis	20	15
Oxides	1	1
<i>Hydrous phase</i>		trace



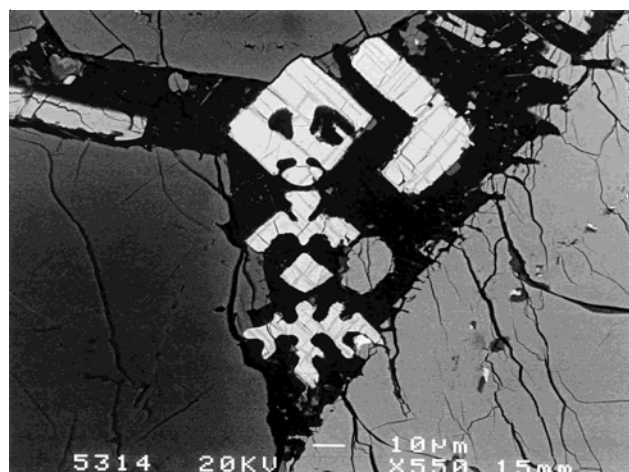
**Figure 2:** Composition diagram for pyroxene and olivine in NWA 817 (data replotted from Sautter *et al.* 2002).

fayalite in the mesostasis. According to Sautter *et al.* (2002), olivine has relatively high Ca content (Ca = 0.6%) consistent with crystallization at low pressure from a basaltic melt.

**Pyroxene:** Sub-calcic augite is rather homogeneous  $En_{38-27}Fs_{24-34}Wo_{38-40}$ , but zones to become hedenbergite (figure 2). Wadhwa *et al.* (2001) find that the REE contents of augite are higher than for other nakhlites, but have generally the same pattern. Treiman *et al.* (2006) found a lack of consistent zoning of Li, Be or B in pyroxenes from NWA817.

**Opaque Oxides:** Dramatic, skeletal, Ti-magnetite crystals are a unique feature of mesostasis of this nakhlite (figure 3). The Ti-magnetite contains minute ilmenite lamellae. Unlike Nakhla, NWA817 does not contain discrete ilmenite grains.

**“Smectite”:** Gillet *et al.* (2001, 2002) have found that the composition of reddish alteration phase is different from that of the other nakhlites. SEM, TEM, optical observations, Raman and x-ray spectra suggest that this alteration phase is made up of well-crystallized material and is not a mixture of various crystalline and/or amorphous phases. Analysis of this phase shows it is very Fe-rich, Al-poor (table 2). Raman and x-ray spectra indicate that it is a smectite-related mineral. Sautter *et al.* (2002) also report several analyses of “alteration phases” in NWA817.



**Figure 3.** Fantastic Ti-magnetite crystals in NWA 817 (credit Jean-Alix Barrat). Previously published as figure 2d in Sautter *et al.*

**Sulfides:** Sulfides in NWA817 were compared with sulfides in other nakhlites by Chevier *et al.* (2011). Trace pyrrhotite is only partly oxidized (Gillet *et al.* 2002).

**Feldspar:** The feldspar in NWA817 is  $Ab_{74}An_{13}Or_{14}$  to  $Ab_{69}An_{17}Or_{15}$ , with significant iron content ( $Fe_2O_3$  up to 10%).

**Cristobalite:** Sautter *et al.* (2002) report trace cristobalite in the mesostasis of NWA 817.

### Whole-rock Composition

The chemical composition (figure 4) is similar to that of the other nakhlites (FeO = 19.84%). The ratios  $FeO/MnO = 37$  and  $Ga/Al = 3.9 \times 10^{-4}$  are evidence of Martian origin (Sautter *et al.* 2000, 2002).

### Radiogenic Isotopes

Marty *et al.* (2001) compute a K-Ar age of ~ 1.35 b.y. for NWA817.

### Cosmogenic Isotopes and Exposure Ages

Marty *et al.* (2001) report an average exposure age of  $9.7 \pm 1.1$  m.y. for NWA817 – also similar to that of the other nakhlites.

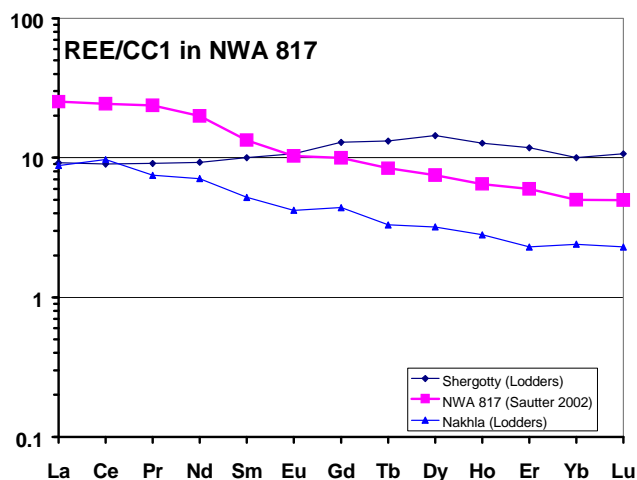
### Other Isotopes

Oxygen isotopes with  $\Delta^{17}O = +0.39$  prove the Martian origin (Sautter *et al.* 2002) of this meteorite. Rumble and Irving (2009) reported  $\Delta^{17}O = +0.257$ .

**Table 1: Composition of NWA 817.**

reference weight	Sautter 2002	
SiO <sub>2</sub>		
TiO <sub>2</sub>	0.61	(a)
Al <sub>2</sub> O <sub>3</sub>	3.23	(a)
FeO	19.84	(a)
MnO	0.53	(a)
CaO	13.07	(a)
MgO	10.31	(a)
Na <sub>2</sub> O	0.94	(a)
K <sub>2</sub> O	0.32	(a)
P <sub>2</sub> O <sub>5</sub>		
sum		
Li ppm	7.43	(a)
Be	0.44	(a)
Sc	47	(a)
V	181	(a)
Cr	1519	(a)
Co	49	(a)
Ni	71	(a)
Cu	12.7	(a)
Zn	71.5	(a)
Ga	6.77	(a)
Ge		
As	0.67	(b)
Se		
Br	0.97	(b)
Rb	6.06	(a)
Sr	145	(a)
Y	9.86	(a)
Zr	29.72	(a)
Nb	4.6	(a)
Mo	0.17	(b)
Pd ppb		
Ag ppb	<0.05	(b)
Sb ppb	0.025	(b)
Cs ppm	0.25	(a)
Ba	167	(a)
La	5.92	(a)
Ce	14.7	(a)
Pr	2.11	(a)
Nd	9.02	(a)
Sm	1.97	(a)
Eu	0.576	(a)
Gd	1.96	(a)
Tb	0.305	(a)
Dy	1.81	(a)
Ho	0.36	(a)
Er	0.953	(a)
Tm		
Yb	0.817	(a)
Lu	0.121	(a)
Hf	0.78	(a)
Ta	0.245	(a)
W ppb	450	(a)
Re ppb		
Os ppb		
Ir ppb		
Au ppb	0.001	(b)
Th ppm	0.6	(a)
U ppm	0.136	(a)

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



**Figure 4:** Normalized rare earth element diagram for NWA 817 (compared with Nakhla and Shergotty). Data from Sautter *et al.* (2002).

Xenon isotopes in NWA817 are reported and discussed by Marty *et al.* (2001) and Marty and Marti K. (2002). Early magmatic differentiation of Mars (<35 Ma) is required to account for the extensive fractionation of <sup>129</sup>I from <sup>244</sup>Pu.

Hydrogen isotopes of the alteration phase,  $\delta D = -170 \pm 14 \text{ ‰}$ , as determined by ion microprobe (Gillet *et al.* 2002), are lighter than for other Martian meteorites.

### Extra-terrestrial Weathering

Reddish alteration, similar in appearance to that in the other nakhlites, is found cross-cutting olivines, pyroxenes and mesostasis. However, pre-terrestrial carbonates and other evaporitic minerals have not been identified so far (Gillet *et al.* 2001, 2002). Terrestrial weathering does not appear to be as severe as for other meteorites from the Sahara desert.

### **References for NWA817**

**Table 2: Iddingsite composition.**

<i>reference</i>	Gillet 2002	
SiO <sub>2</sub>	46.51	(a) 42.82
TiO <sub>2</sub>	0.03	(a) 0.06
Al <sub>2</sub> O <sub>3</sub>	2.26	(a) 0.21
FeO	28.42	(a) 36.45
MnO	0.28	(a) 0.55
CaO	0.14	(a) 0.25
MgO	7.56	(a) 5.69
Na <sub>2</sub> O	0.06	(a) 0.18
K <sub>2</sub> O	0.42	(a) 0.41
P <sub>2</sub> O <sub>5</sub>		
<i>sum</i>	85.68	86.65
Y ppm	1.81	(b)
La	1.46	(b)
Ce	2.6	(b)
Pr	0.32	(b)
Nd	0.95	(b)
Sm	0.15	(b)
Eu	0.2	(b)
Gd	0.08	(b)
Tb	0.019	(b)
Dy	0.17	(b)
Ho	0.051	(b)
Er	0.21	(b)
Tm	0.036	(b)
Yb	0.32	(b)
Lu	0.067	(b)

*technique: (a) electron probe, (b) ion probe*