XIX. NWA 817

Clinopyroxenite
104 grams

***Figure XIX-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 XIX-1).

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).

Mineralogical Mode

	Sautter *et al.* (2002)	**Gillet *et al.* (2002)**
Pyroxene	69 vol. %	69
Olivine	10	15
Mesostasis	20	15
Oxides	1	1
Hydrous phase		trace

Photos of this meteorite can also be seen at http://www.jpl.nasa.gov/snc/nwa817.html

Mineral Chemistry

Olivine: Olivine is Fo_{44} in the core zoned to Fo_{14} in the rim. It contains magmatic inclusions. There is a trace 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.

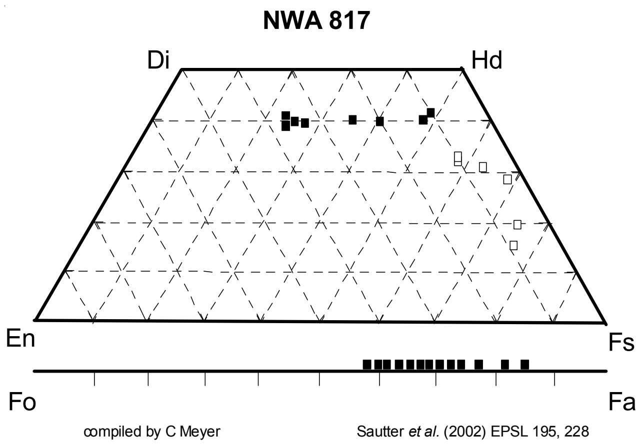

Figure XIX-2: *Composition diagram for pyroxene and olivine in NWA 817 (data replotted from Sautter et al. 2002).*

Pyroxene: Sub-calcic augite is rather homogeneous $En_{38-27}Fs_{24-34}Wo_{38-40}$, but zones to become hedenbergite (figure XIX-2). Wadhwa *et al.* (2001) find that the REE contents of augite are higher than for other nakhlites, but have generally the same pattern.

Opaque Oxides: Dramatic, skeletall, Ti-magnetite crystals are a unique feature of mesostasis of this nakhlite (figure XIX-3). The Ti-magnetite contains minute ilmenite lamalae. 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 (*see table III-2*). 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 XIX-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.

Sulfides: 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.

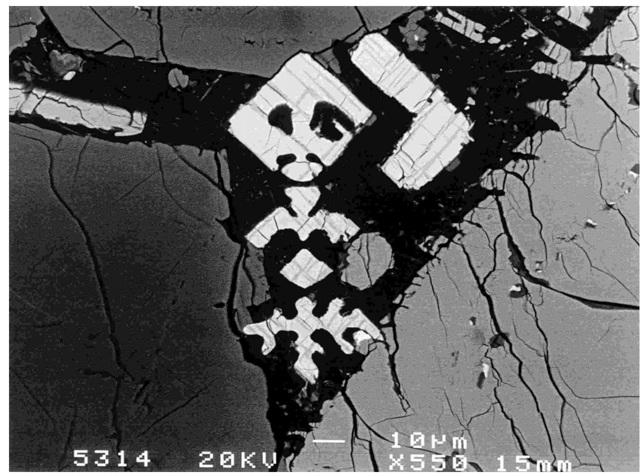

Figure XIX-3. *Fantastic Ti-magnetite crystals in NWA 817 (credit Jean-Alix Barrat). Previously published as figure 2d in Sautter et al. 2002, EPSL **195**, 225.*

Whole-rock Composition

The chemical composition (table XIX-1) is similar to that of the other nakhlites (FeO = 19.84%). The ratios FeO/MnO = 37 and Ga/Al = 3.9 x 10^{-4} are evidence of Martian origin (Sautter *et al*. 2000, 2002). Note that the REE content is higher in NWA817 than for Nakhla, although generally similar (figure XIX-4).

Radiogenic Isotopes

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

Cosmogenic Isotopes and Exposure Ages

Marty *et al.* (2001) report an average exposure age of 9.7 ± 1.1 Ma for NWA817 – also similar to that of the other nakhlites.

Other Isotopes

Oxygen isotope ratios with $\delta^{18}O$=5.44; $\delta^{17}O$=3.2; and $\Delta^{17}O$ = + 0.37 prove the Martian origin of this meteorite (Sautter *et al.* 2002).

Table XIX-1: Composition of NWA 817.

reference	Sautter 2002	
weight	107 mg	
SiO2		
TiO2	0.61	(a)
Al2O3	3.23	(a)
FeO	19.84	(a)
MnO	0.53	(a)
CaO	13.07	(a)
MgO	10.31	(a)
Na2O	0.94	(a)
K2O	0.32	(a)
P2O5		
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

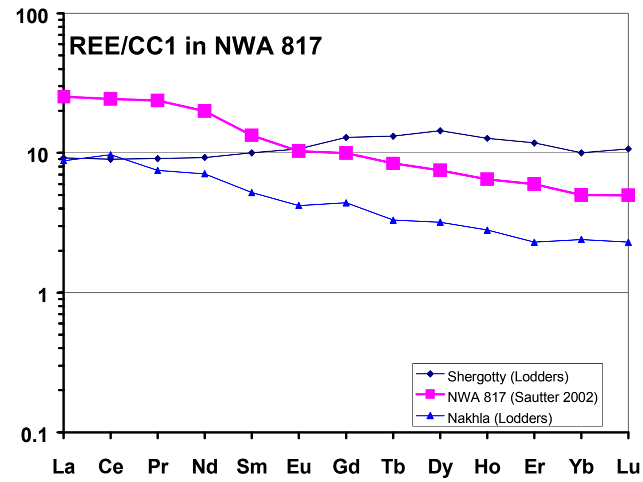

***Figure XIX-4**: Normalized rare earth element diagram for NWA 817 (compared with Nakhla and Shergotty). Data from Sautter et al. (2002), EPSL **195**, 233.*

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

Hydrogen isotopes of the alteration phase, $\delta D = -170 \pm 14$ ‰, as determined by ion micropobe (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 of NWA 817 does not appear to be as severe as for other meteorites from the Sahara desert.

Table XIX-2: Iddingsite composition.

reference	Gillet 2002		
SiO2	46.51	(a)	42.82
TiO2	0.03	(a)	0.06
Al2O3	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
Na2O	0.06	(a)	0.18
K2O	0.42	(a)	0.41
P2O5			
sum	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