Northwest Africa 032, 479

Unbrecciated basalt
~300, 156 g

Figure 1: Cut face of a piece of NWA032.

Introduction

Northwest Africa (NWA) 032 was found in the Saharan desert in October 1999, and weighs approximately 300 g (Fig. 1). The stone is covered with fusion crust, but the exterior also has patches of white calcite and also red to orange ferric oxide or oxyhydroxide (Fagan et al., 2002; Korotev et al., 2001). The interior is an unaltered unbrecciated crystalline basalt with phenocrysts of olivine, pyroxene and chromite (Figs 2 and 3). A paired stone, NWA 479, weighs 156 g (Barrat et al., 2001, 2005).

Figure 2: close up of cut slab of NWA 032 illustrating the olivine phenocrysts in a dark grey groundmass.

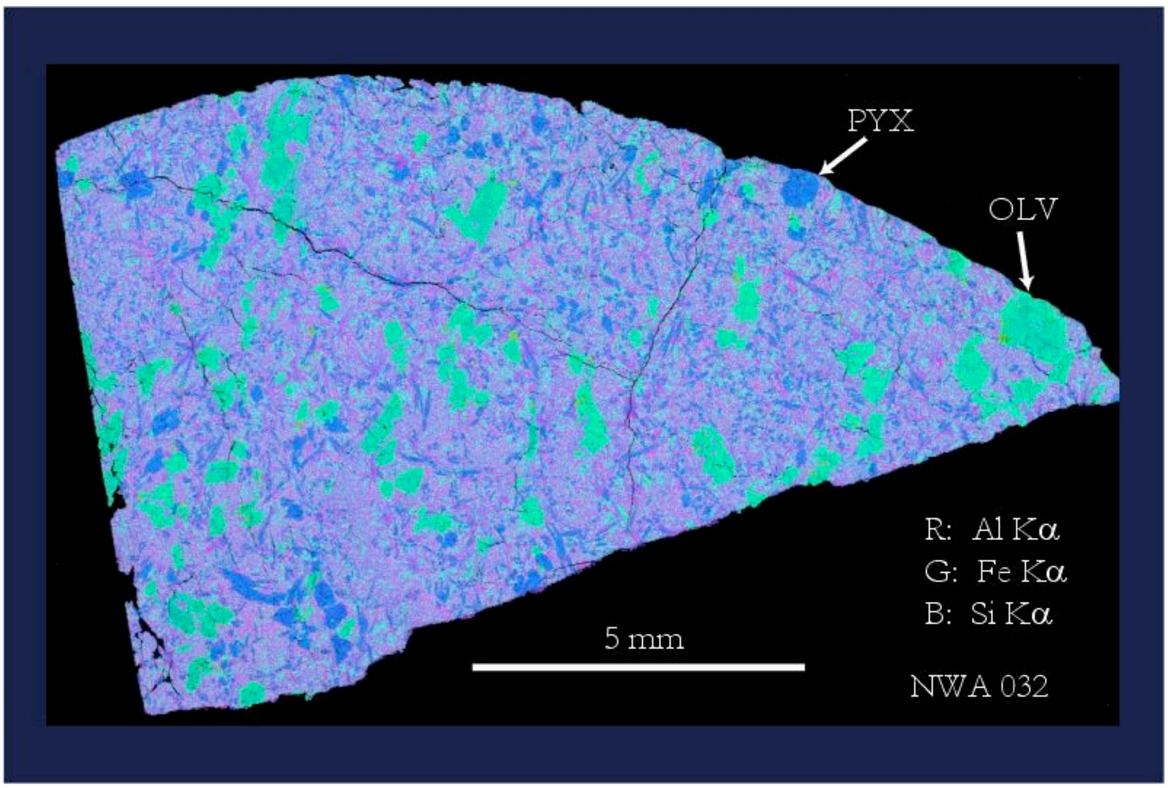


Figure 3: X-ray map of a thin section of NWA 032 showing green olivine phenocrysts, blue pyroxenes, and a purplish groundmass (from Fagan et al., 2003).

Petrography and Mineralogy

Olivine (11.3%), Pyroxene (4.8%), and chromite (0.3%) phenocrysts are in a groundmass (80.4%) of feldspar, pyroxene, ilmenite, troilite and metal. There are ubiquitous shock melt veins (3.2%). Olivine phenocrysts are zoned from Fo_{66} cores to Fo_{50} rims. Pyroxenes exhibit a large compositional range from low Ca bronzites to close to pyroxferrite at the FeO-rich end (Fig. 4). Pyroxenes from NWA 479 completely overlap those found in NWA 032 (Fig. 5). Chromites are zoned from Cr-rich cores to ulvospinel rims (Fig. 6). Undulatory/mosaic extinction in the olivine and pyroxene, along with the presence of ringwoodite and wadsleyite in shock melt veins from NWA 479, attest to the high shock state of these meteorites.

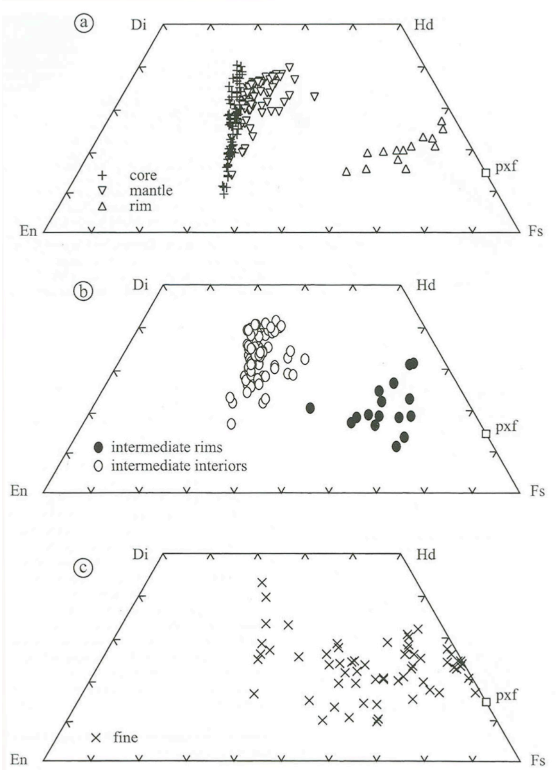
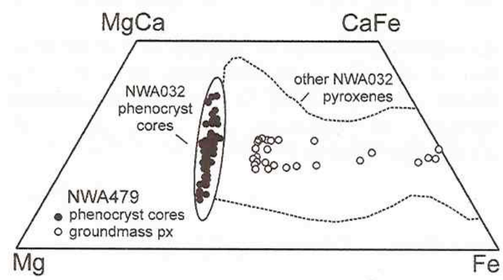


Figure 4: Pyroxene compositions from NWA 032 including phenocrysts (top), intermediate (middle) and fine grained (bottom) (from Fagan et al., 2002).

Figure 5: compositions from NWA 479 showing overlap with NWA 032 pyroxenes (from Barrat et al., 2005).



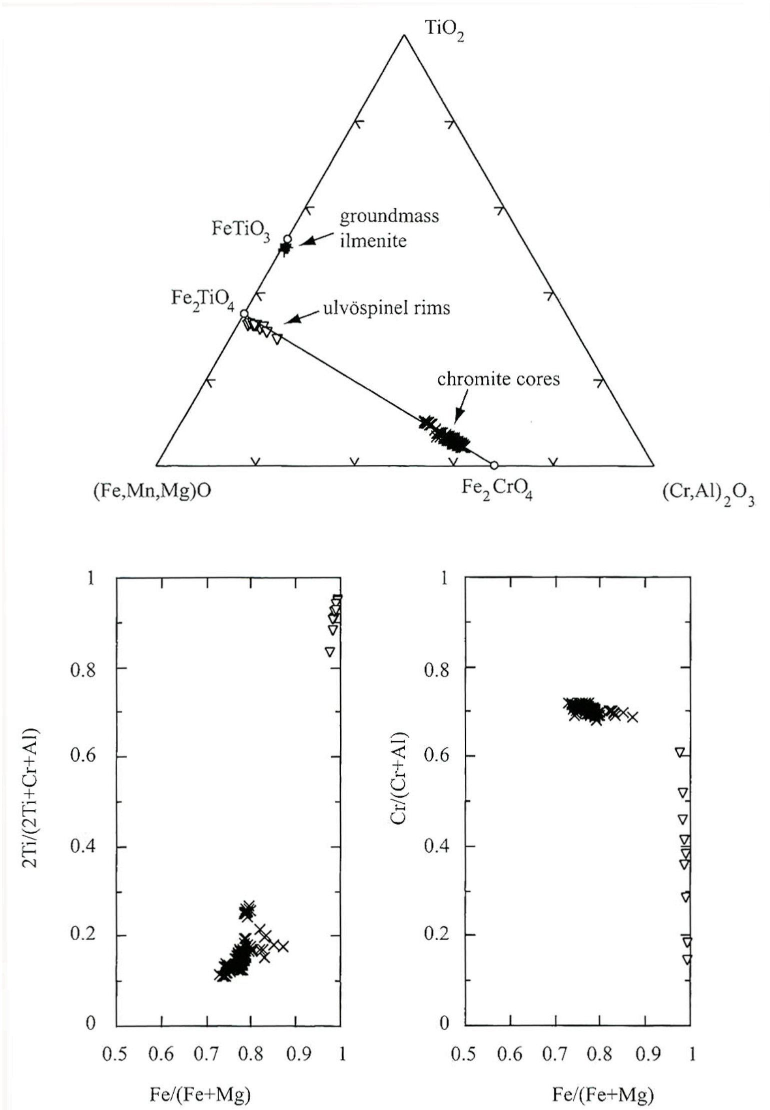


Figure 6: Spinel cores and rims from NWA 032 (Fagan et al., 2002).

Chemistry

NWA 032 has a composition very similar to low Ti basalt such as those found in the Apollo 12 and 15 collection (Fig. 7 and 8; Table 1). It represents a liquid composition because the olivine phenocryst cores are identical in composition to those expected from the bulk composition and Mg-Fe Kd (Fagan et al., 2002). Both NWA 032 and NWA 479 exhibit LREE enrichment (Fig. 9), and also have high Th/Sm. The latter cannot be due to magmatic fractionation from a more familiar parental liquid, since there is no known major phase that will fractionate these two elements. Instead it may be from a region of the Moon unsampled by Apollo or Luna collections. Additionally, olivine phenocrysts record variable and heavy Li isotopic composition, having δ^7Li as high as +15, compared to much lower (0 to +4) for terrestrial mantle (Barrat et al., 2005). The variation has been ascribed to diffusivity control, but the heavy character of the values has been attributed to the giant impact that formed the Moon.

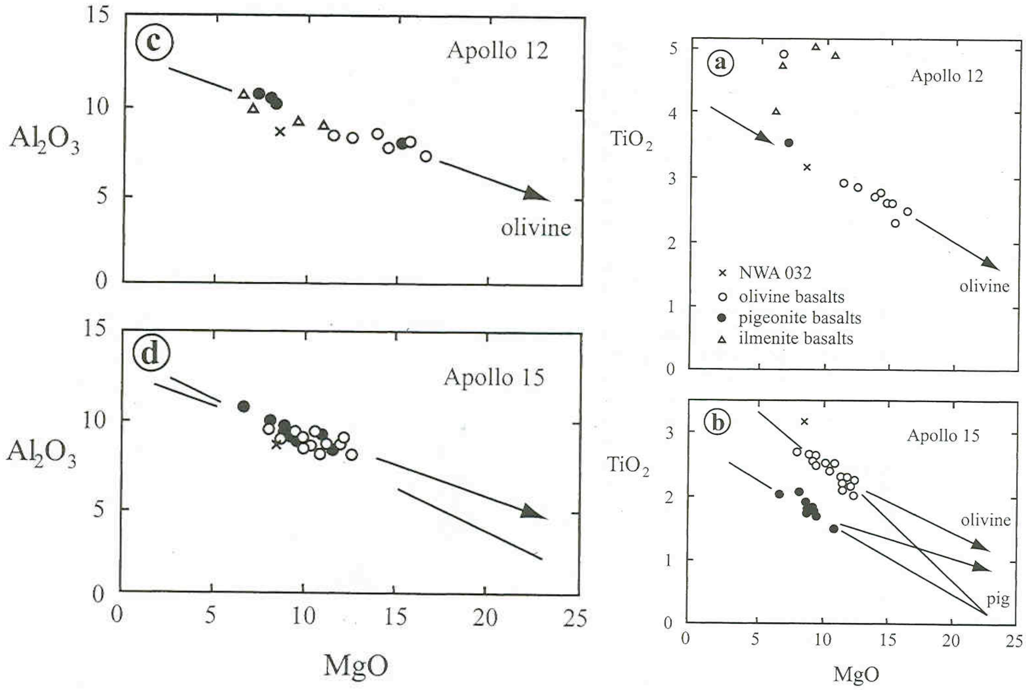


Figure 7: Al_2O_3 vs. MgO for NWA 032 (x) compared to Apollo 12 and 15 basalts.
Figure 8: TiO_2 vs. MgO for NWA 032 (x) compared to Apollo 12 and 15 basalts, showing fractionation vector for olivine and pigeonite (from Fagan et al., 2002).

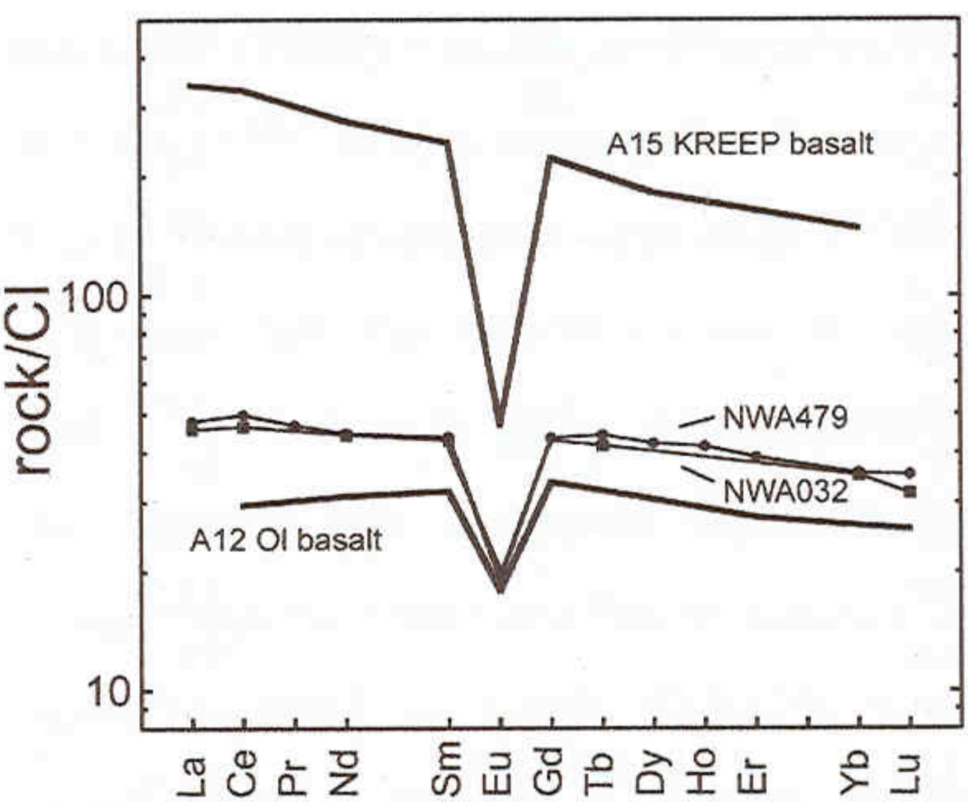


Figure 9: Rare earth element patterns for NWA 032 and 479, compared to Apollo 12 olivine basalt and KREEP illustrating their LREE nature (from Barrat et al., 2005)

Radiogenic age dating

^{39}Ar-^{40}Ar plateau ages for two fragments from NWA 032 yield ages of ~ 2.8 Ga (Fig. 10; Fagan et al., 2002; Fernandes et al., 2003).

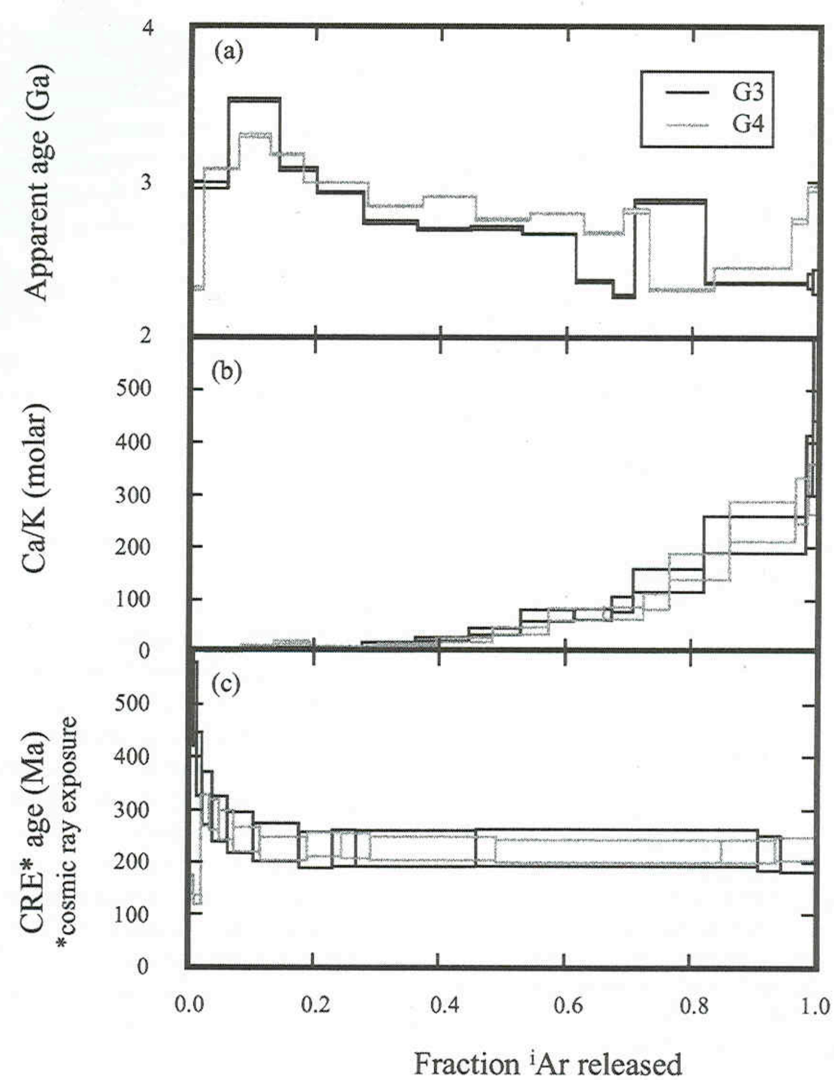


Figure 10: Apparent age, Ca/K, and CRE age for two fragments of NWA 032 (from Fernandes et al., 2003; Fagan et al., 2002).

Cosmogenic isotopes and exposure ages

Residence time in the lunar regolith has been measured by Fernandes et al. (2003) and Lorenzetti et al. (2005) at 212 Ma and 207 Ma, respectively. However, Lorenzetti et al. (2005) argue that NWA 032 experienced a multi-stage exposure at different shielding depths. The transit time from Moon to Earth was 0.042 Ma, terrestrial residence time < 0.01 Ma, and a therefore a time of ejection of 0.05 Ma (Lorenzetti et al., 2005).

Table 1a. Chemical composition of NWA 032/479

reference	1	2	3
Weight (mg)	550	184	132
method	g	e	a,b
SiO_2 %	44.7		
TiO_2	3.08		3.15
Al_2O_3	8.74		9.48
FeO	23	22.1	20.94
MnO	0.33		0.29
MgO	8.45		7.21
CaO	10.9		10.99
Na_2O	0.37	0.347	0.34
K_2O	0.11		<0.1
P_2O_5			
S %			
sum			
Sc ppm		56	61
V			132
Cr		2744	2614
Co		42	40.6
Ni		50	49.2
Cu			34.2
Zn			30.5
Ga			4.31
Ge			
As			
Se			
Rb			1.78
Sr		142	132
Y			65.71
Zr		175	206
Nb			15.26
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			
Sb ppb			
Te ppb			
Cs ppm			0.051
Ba		242	371
La		11.2	11.75
Ce		29.7	31.77
Pr			4.52
Nd		21	21.21

Sm	6.61	6.73
Eu	1.1	1.13
Gd		8.9
Tb	1.56	1.66
Dy		10.73
Ho		2.35
Er		6.46
Tm		
Yb	5.79	5.86
Lu	0.802	0.893
Hf	5	5.05
Ta	0.62	0.8
W ppb		310
Re ppb		
Os ppb		
Ir ppb		
Pt ppb		
Au ppb	4	
Th ppm	1.9	2.01
U ppm	0.45	0.46
Li ppm		12.69
Be		1.22
C		
S		
F ppm		
Cl		
Br		
I		
Pb ppm		1.02
Hg ppb		
Tl		
Bi		

technique (a) ICP-AES, (b) ICP-MS, (c) IDMS, (d) EMPA, (e) INAA, (f) XRF, (g) wet chemistry

References: 1) Fagan et al. (2002); 2) Korotev et al. (2001); 3) Barrat et al. (2004)