Northwest Africa 482

Anorthositic impact melt breccia
1015 g

Figure 1: NWA 482 showing brown crust that is both terrestrial weathering (varnish) and fusion crust. Sample is approximately 10 cm in width.

Introduction

Northwest Africa (NWA) 482 was found in the Sahara desert, and purchased by M. Farmer in January 2001 in Morocco. It has a smooth dark fusion crust together with a dark brown layer of crust that could be desert varnish or from terrestrial weathering (Fig. 1). In hand sample, it is clearly a breccia with a fine grained light grey matrix and brighter light grey to white clasts. Cataclastic regions and impact melt veins also criss-cross the sample (Fig. 2).

Figure 2: Slab of NWA 482 illustrating its feldspathic mineralogy and also the cataclastic and impact melt vein textures. Scale cube has 1 cm edges.

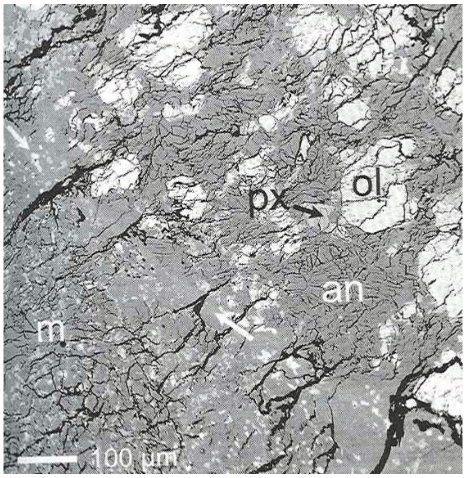


Figure 3: BSE image of a portion of NWA 482 showing a spinel troctolite clast (upper right), glassy matrix (lower left) and a thin impact melt vein at the boundary (arrow) (from Dauber et al., 2002).

Petrography and Mineralogy

There are three kinds of materials present in NWA 482 – matrix (67%), clasts (22%) and glass (11%), according to the section studied by Dauber et al. (2002). The matrix is feldspathic and is estimated to be comprised of 85% plagioclase, 5% olivine, 10% pyroxene, and minor metal and ilmenite. Clasts are ~27% mineral and ~ 63% lithic, that latter of which are comprised of anorthosite (some FAN-like), spinel troctolite (Fig. 3), cataclastites, with a marked absence of Mg-suite lithologies (Dauber et al., 2002; Warren et al., 2005; Korotev et al., 2003). Olivines in the mineral and lithic clasts range from Fo_{65-77} (Fig. 4 and 5). Plagioclase is anorthite-rich, and the pyroxenes have Mg# consistent with highlands lithologies (Fig. 5 and 6). The spinels are aluminous – similar to other highlands troctolities, but much less Cr than mare basalts (Fig. 7). The glass compositions are variable, but overall anorthositic with an average FeO content of 2.82 wt% (Dauber et al., 2002). Shock levels in the meteorite are variable, but range between 30 and 75 GPa (Dauber et al., 2002).

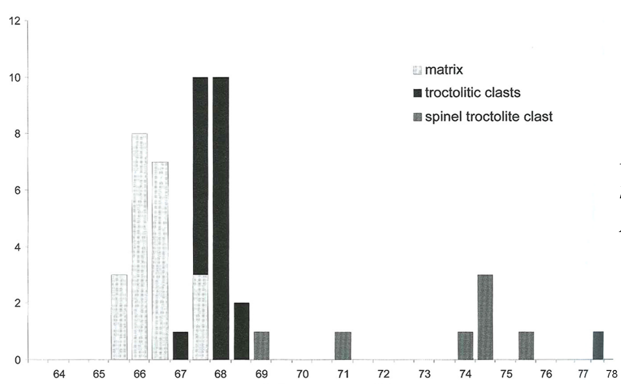


Figure 4: Histogram of olivine compositions measured in mineral and lithic clasts from NWA 482 (from Dauber et al., 2002).

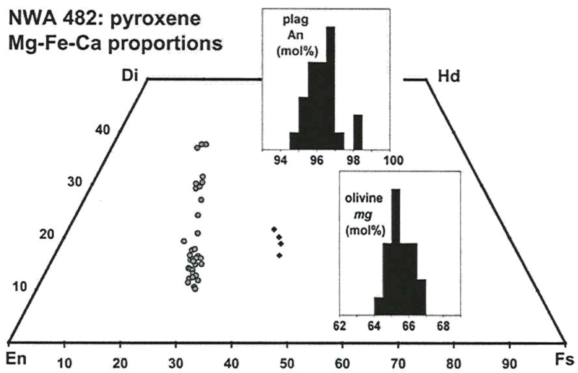


Figure 5: Pyroxene, olivine, and plagioclase compositions measured in NWA 482, showing the high Mg# of pyroxenes, the narrow compositional range of the olivine and anorthitic plagioclase (from Warren et al., 2005).

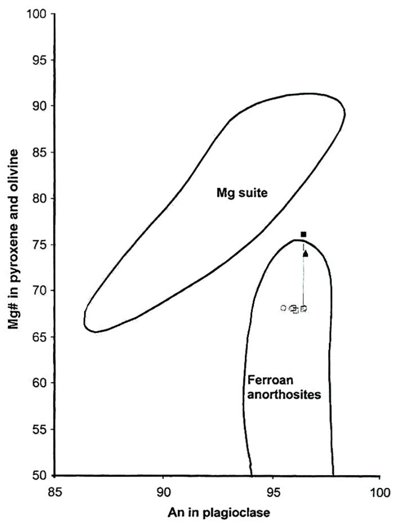


Figure 6: Compositions of coexisting pyroxenes and plagioclase in NWA 482 clasts demonstrating the absence of Apollo-like Mg-suite compositions (from Dauber et al., 2002).

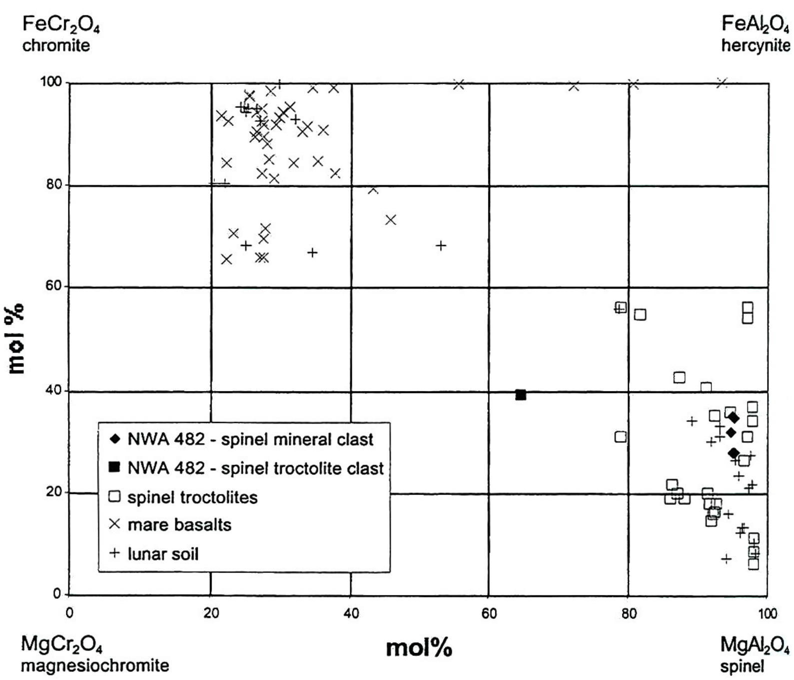
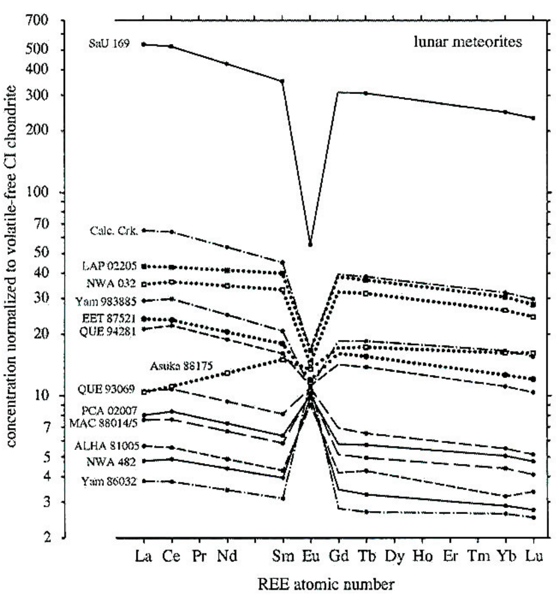


Figure 7: Spinel compositions measured in NWA 482 clasts illustrating the Al-rich nature compared to more Cr-rich spinels in mare basalts (from Dauber et al., 2002).

Chemistry

The composition of NWA 482 is among the most feldspathic of the lunar meteorites (Table 1). Its low FeO and high Al_2O_3 nearly define the end of the range (Korotev et al., 2003; Korotev, 2005). Compositionally it is very similar to the MAC 88104 and 88105 lunar feldspathic meteorites, but it has a distinctly different exposure age which precludes a launch pairing. Any KREEP component is low, given the very low REE contents of the sample (Fig. 8; Dauber et al., 2002; Warren et al., 2005; Korotev et al., 2003). Additionally, the high shock levels of NWA 482 have apparently not caused re-equilibration of movement of REE in the various clasts (Fig. 9; Consolmagno et al., 2005).

Studies of highly siderophile elements and Os isotopes have been undertaken to identify the impactor rock type that produced the impact melts. Based on both Os isotopic measurements and bulk HSE contents and ratios, the impactor component in NWA 482 was most similar to enstatite chondrites (EH; Fig. 10; Puchtel et al., 2008). This is in contrast to Apollo 17 impact melt rocks that overlap with other chondritic fields (ordinary and carbonaceous) as well as in fields that are not represented by known chondritic materials (Puchtel et al., 2008).



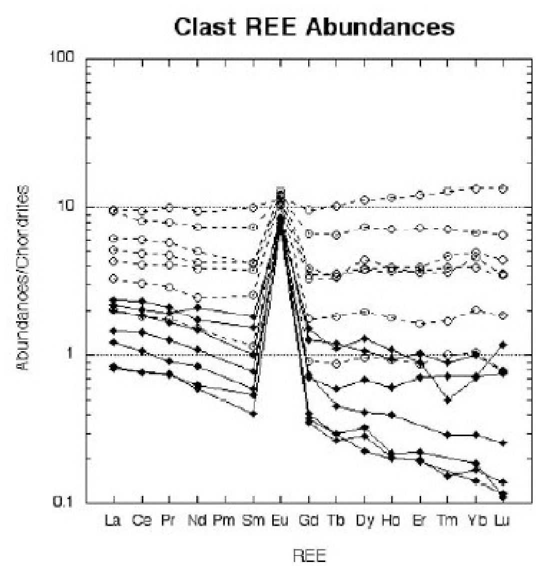


Figure 8: Rare earth element (REE) diagram for many lunar meteorites showing the REE-poor NWA 482 compared to many other feldspathic lunar meteorites (from Korotev, 2005).

Figure 9: Rare earth element (REE) diagram for several clasts from NWA 482 (dashed and open symbols; from Consolmagno et al., 2005) showing a range of contents that were apparently not affected by high shock levels.

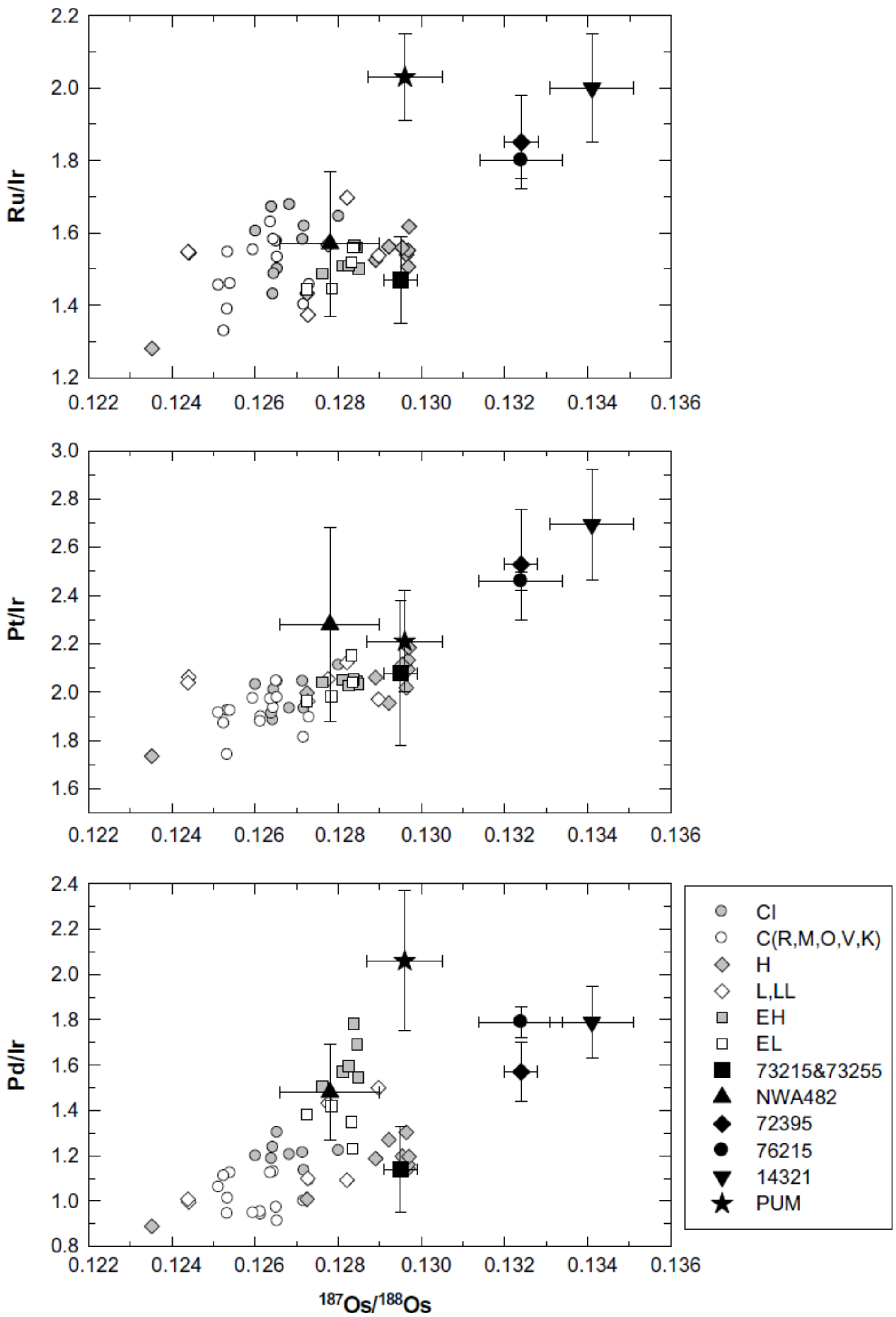


Figure 10: Os isotopic and Ru/Ir, Pt/Ir, and Pd/Ir ratios for chondritic groups as compared to the impactor component in NWA 482 and some Apollo impact melt breccias (from Puchtel et al., 2008). Note the similarity between NWA 482 and EH or EL chondrites for a number of different ratios.

Radiometric ages

^{39}Ar-^{40}Ar measurements of bulk and glass from NWA 482 (from Dauber et al., 2002), yield a diverse spectrum of ages, but the high temperature steps (1300 to 1450 °C) produce ages that have an average of 3740 to 3750 Ma (Fig. 11; bulk and glass). Lower temperature steps yielded younger ages that are high K/Ca material that could be terrestrial contamination. The 3750 Ma ages represent most likely lithification or shock ages rather than crystallization age, and is similar to the range documented for the Orientale basin. There is also evidence for a younger event at ~ 2400 Ma (Dauber et al., 2002). The combination of KREEP-poor and young ages suggests a far side origin for NWA 482 (Dauber et al., 2002).

Cosmogenic exposure ages

NWA 482 has the oldest measured lunar regolith ages for a lunar meteorite at 2070 Ma (Lorenzetti et al., 2005). A transit age has been measured by ^{10}Be at 0.9 Ma (Nishiizumi et al., 2001). A ^{36}Cl terrestrial age of 0.06 to 0.12 Ma (Nishiizumi et al., 2001) has been revised downwards to 0.015 Ma (Dauber et al., 2002). And finally, an ejection age of 0.28 Ma was proposed by Nishiizumi et al. (2001).

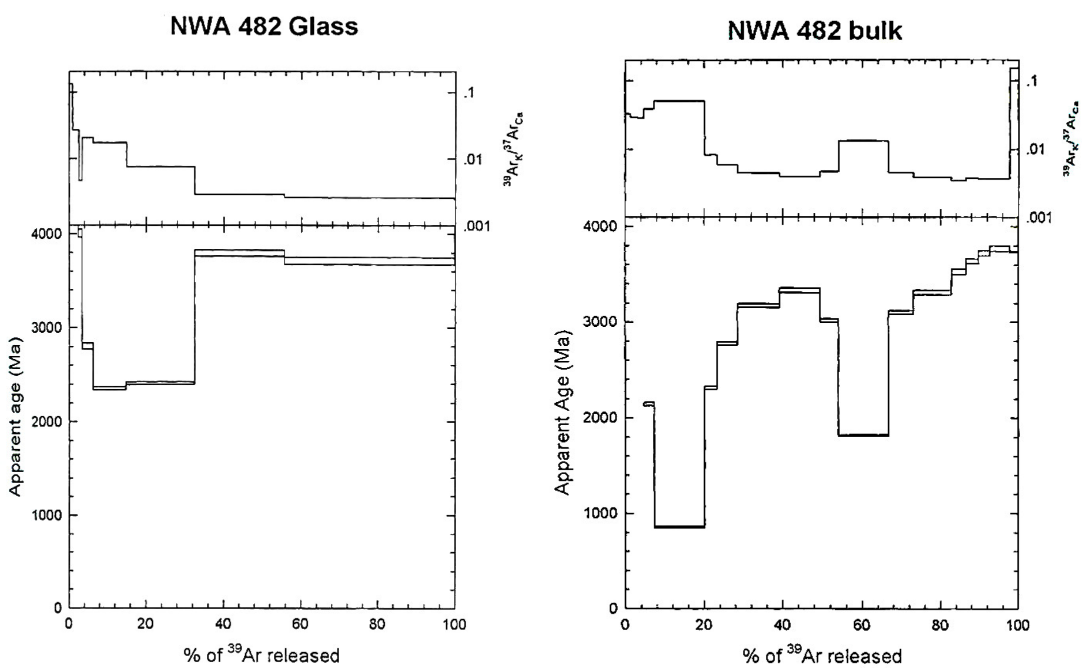


Figure 11: ^{39}Ar-^{40}Ar measurements of bulk and glass from NWA 482 (from Dauber et al., 2002).

Table 1: Chemical composition of NWA 482

reference	1	2	2	3	4
weight	186	334.5			650
method	e	e	d	c	b

SiO_2 %	44.92		43.90	43.7	
TiO_2	0.183		0.160	0.13	
Al_2O_3	28.050		29.400	31.4	
FeO	3.898	3.760	3.800	2.82	
MnO	0.051		0.050	0.04	
MgO	4.130		4.280	3.15	
CaO	16.650	17.100	18.470	17.6	
Na_2O	0.380	0.377	0.260	0.41	
K_2O	0.036	0.040	0.035	0.02	
P_2O_5			0.040	0.04	
S %					
sum	98.3016		100.395	99.31	
Sc ppm	7.1	6.93			
V	16				
Cr	5100	519		411	
Co	14.5	13.21			
Ni	170	144		383	
Cu					
Zn					
Ga	3.3				
Ge					
As	<0.12	0.12			
Se					
Rb		<4			
Sr	127	171			
Y					
Zr	<29	21			
Nb					
Mo					
Ru					9.14
Rh					
Pd ppb					8.02
Ag ppb					
Cd ppb					
In ppb					
Sn ppb					
Sb ppb	<6	9			
Te ppb					
Cs ppm	<0.052	<0.08			
Ba	30	30			
La	1.55	1.523			
Ce	3.5	3.99			
Pr					
Nd	2.45	2.5			
Sm	0.77	0.788			
Eu	0.79	0.75			
Gd					

Tb	0.172	0.161		
Dy	1.3			
Ho	0.21			
Er				
Tm				
Yb	0.67	0.634		
Lu	0.097	0.0904		
Hf	0.6	0.582		
Ta	0.092	0.066		
W ppb		<600		
Re ppb				0.539
Os ppb				6.176
Ir ppb	5.9	5.3		5.7
Pt ppb				11.6
Au ppb	2.8	3.4		
Th ppm	0.23	0.24		
U ppm	0.052	0.08		

technique (a) ICP-AES, (b) ICP-MS, (c) EMPA, (d) FB-EMPA, (e) INAA, (f) RNAA, (g) XRF

Table 1b. Light and/or volatile elements for NWA482

Li ppm	
Be	
C	
S	
F ppm	
Cl	
Br	2.1
I	
Pb ppm	
Hg ppb	
Tl	
Bi	

1) Warren et al.(2005); 2) Korotev et al. (2003); 3) Dauber et al. (2002) shock melt glass; 4) Puchtel et al. (2008)