THE L3-6 REGOLITH BRECCIA NORTHWEST AFRICA 869: PETROLOGY, NOBLE GASES, AND COSMOGENIC RADIONUCLIDES.

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Introduction: NWA 869 represents one of the largest meteorite finds from Northwest Africa. It consists of thousands of fusion-crusted individuals from less than a gram up to more than 20 kg. The total mass of recovered material is on the order of 7 metric tons [1]. NWA 869 has been classified as an L4-6 fragmental breccia [2]. Unfortunately, the strewnfield is undocumented and huge amounts of material have been distributed worldwide as unclassified meteorites. The Nomenclature Committee of the Meteoritical Society declares: "Scientists are advised to confirm the classification of any specimen they obtain before publishing results under this name" [2].

Fig. 1: Typical brecciation texture of NWA 869. Scale cube is 1 cm.

Aims of this study: 1) We define petrographic criteria for an unambiguous identification of NWA 869 samples. This should help to clarify pairings with other NWA chondrites and to properly choose material for future research on this meteorite. 2) Noble gases and radionuclides on bulk samples and separated lithologies were measured to obtain information on the irradiation history of the meteoroid during transit and its breccia components on the parent asteroid prior to lithification. These data are also used to estimate transit time and meteoroid size.

Samples and analytical techniques: Fifteen lithological units were separated from six different individuals, characterized by optical and scanning electron microscopy and measured for noble gases and radionuclides (Tab. 1). Modal composition was measured by point-counting on cut surfaces with a total area of 591 cm^2, using 5 additional individuals (Tab. 2).

Macroscopic description: Many individuals of NWA 869 are characterized by a leather-like fusion crust, chipped off in places by ground collision. The hereby exposed surfaces show a typical greenish grey color, sometimes visible brecciations (light and/or dark clasts) and very characteristic wind ablation features.

Petrology: NWA 869 is a coarse-grained breccia with fragment sizes up to 5.5 cm in the investigated samples (Fig. 1, Tab. 2). It displays a light and dark structure consisting of unequilibrated and equilibrated chondrite clasts, some of which are shock-darkened, impact melt rocks and exotic clasts, embedded into greyish matrix material (Fig. 1). NWA 869 is of shock level S3 [2] and seems to be relatively stable against weathering (W1) due to shock compaction.

Bulk texture. The overall texture of NWA 869 gives the impression that angular clasts (shocked and/or metamorphosed), originating from coherent bedrock, are embedded into a formerly loose assortment of intact chondrules and chondrule and lithic debris, lithified by shock compaction.

Modal composition. NWA 869 is dominated by matrix material (74 vol%), followed by light-colored equilibrated (type 5/6) clasts (20 vol%) and shock-darkened clasts (4 vol%). Impact melt rocks and clasts of petrologic type 3 typically make up about 1 vol% each (Tab. 2).

Matrix. The matrix appears to represent a distinct lithology by itself, showing a typical greyish color. Although partly clastic, large volumes are characterized by a homogeneous texture made up of intact chondrules.

Type 3 clasts. These clasts are characterized by the presence of chondrule glass and large variations in olivine composition. Their existence proves that NWA 869 has never been strongly heated as an entity.

Type 5/6 clasts. These clasts are typically light colored with oxide staining (Fig. 1, upper right).

Shock-darkened clasts. These black clasts are of various petrologic type with silicates that have been "shock-impregnated" by sulfide and metal.

Impact melt rocks. A variety of light-colored, mostly clast-poor impact melt rocks has been found, either as angular fragments or as subrounded entities. They show strong depletions of metal and sulfide, i.e. gravitational separation of silicate melt and metal-sulfide melt must have occured on the parent asteroid.

Exotic clasts. Several clasts with achondritic texture have been found, which are currently under study.

Tab. 1: List of investigated NWA 869 separates

lithology	sample	analyses	
		noble gases	radio nuclides
bulk	MB-13 SM-03-1 M-05-38-1 M-05-38-2 MS-04-1 #D		X X X X X X
matrix	MB-13-d M-05-38-2-e #D-a	X X X	
type 5/6 clasts	MB-13-c M-05-38-2-b M-05-38-2-d	X X X	
shock-darkened clasts	MB-13-a M-05-38-2-c	X X	
impact melt rocks	SM-03-1-1-a	X	

Tab. 2: Modal composition of NWA 869
(point counting method; 1140 points, 591 cm^2)

lithology	vol %	max. clast size [mm]
matrix	73.6	
type 5/6 clasts	20.3	55
shock-darkened clasts	3.9	33
impact melt rocks	0.9	45
type 3 clasts	0.8	15
metal > 2 mm	0.3	6
sulfide > 2 mm	0.2	5

Noble gases: Nine separates (Tab. 1) were measured for He, Ne and Ar isotopes. Solar wind implanted gases were found in 5 samples, confirming that NWA 869 is a regolith breccia [3]. All three matrix samples, one shock-darkened clast and the measured impact melt rock contain significant amounts of solar wind implanted ^{20}Ne (Fig. 2) and ^{36}Ar. Solar He and radiogenic ^{4}He have been effectively lost, probably due to shock effects. Concentrations of $^{21}Ne_{cos}$ show significant variations between samples (Fig. 2), reflecting the effects of both large meteoroid size and pre-irradiation (see below).

Cosmogenic Radionuclides: ^{10}Be and ^{26}Al have been measured in the silicate fraction of 6 samples (Tab. 1). The concentrations vary by a factor of 8 to 10, indicating irradiation in an object with a radius on the order of 2 m. Both isotopes are well correlated (Fig. 3), with an average ^{26}Al/^{10}Be ratio of 3.4 ± 0.4, which is typical for large objects. The ratio of about 3.8 in the two most shielded samples could indicate that ^{10}Be is not quite saturated, indicating a CRE age of about 5 Ma. All samples contain significant amounts of neutron-capture produced ^{36}Cl (up to ~15 dpm/kg). Measurements of cosmogenic radionuclides in the metal phase are in progress.

^{21}Ne is not linearly correlated with either ^{10}Be or ^{26}Al, suggesting that some of it was produced during exposure in the parent body regolith. Calculating CRE ages using ^{21}Ne/^{26}Al ratios [4] we find values of 4-20 Ma. Assuming that 4 Ma is the time of transit irradiation, several lithologies have been preirradiated up to 16 Ma in the parent body regolith.

Summary: NWA 869 represents an L chondritic regolith breccia containing preirradiated components. The meteoroid had an initial radius of about 2 m with a mass of about 110 metric tons. The transit time to Earth was about 4-5 Ma. Large variations of shielding depths between samples indicate that break-up of the meteoroid must have occured high in atmosphere. This would also explain the large inferred ablation loss, which is typical for large chondrite showers.

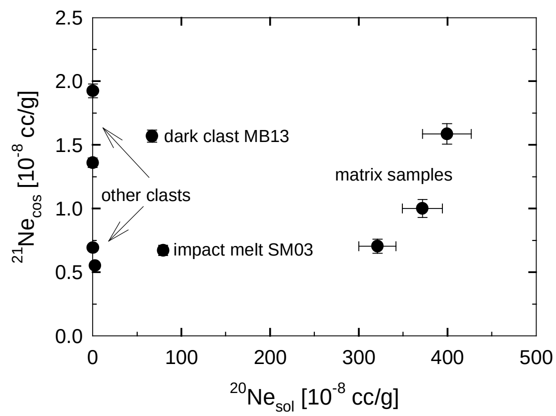

Fig. 2: Relationship of cosmogenic ^{21}Ne concentrations vs. solar ^{20}Ne concentrations in NWA 869 separates

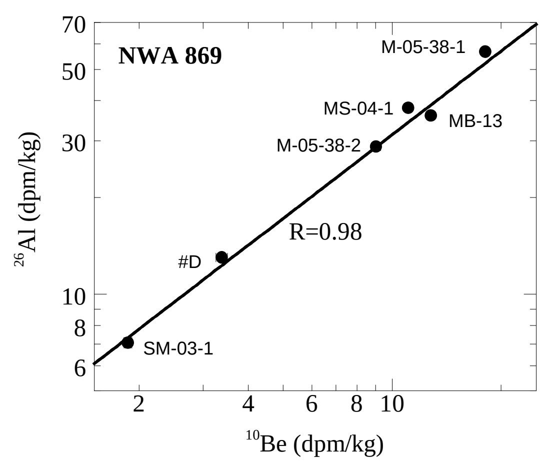

Fig. 3: Relationship of ^{26}Al concentrations vs. ^{10}Be concentrations in NWA 869 separates

References: [1] Bessey D. (2007) *pers. comm.*. [2] Connolly H.C. et al. (2006) The Met. Bull., No. 90, *Meteoritics & Planet. Sci. 41*, 1383-1418. [3] Osawa T. and Nagao K. (2006) *Antarct. Meteorite Res. 19*, 58-78. [4] Graf et al. (1990) *Geochim. Cosmochim. Acta, 54*, 2521-2534.