EVIDENCE FOR RECENT NEAR-CATASTROPHIC COLLISION ON LARGE CHONDRITIC METEOROID, NORTHWEST AFRICA 869. K. C. Welten[1], M. W. Caffee[3], M. D. Leclerc[3], A. J. T. Jull[3], K. Metzler[4], L. Franke[5], U. Ott[5], [1]Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA (E-mail: kcwelten@berkeley.edu); [2]Department of Physics, Purdue University, West Lafayette, IN 47907, USA; [3]NSF Arizona AMS facility, University of Arizona, Tucson, AZ 85721, USA; [4]Westfälische Wilhelms-Universität, Institut für Planetologie, 48149 Münster, Germany; [5]Max Planck Institute, für Chemie, 55128 Mainz, Germany.

Introduction: Northwest Africa (NWA) 869 represents one of the largest meteorite finds from the Saharan desert. It consists of thousands of fusion-crusted individuals from less than one gram up to more than 20 kilograms with an estimated total weight on the order of 7 metric tons. This meteorite was initially classified as an L4-6 fragmental breccia, but was recently reclassified as an L3-6 chondrite breccia [1]. Noble gas measurements revealed that NWA 869 contains solar gases [2] and hence is a regolith breccia. Since the abundance of regolith breccias among L-chondrites is only ~3% [3], NWA 869 represent a rather unique and large sample of the lithified regolith of the L-chondrite parent body.

In this paper, we present concentrations of noble gases and cosmogenic radionuclides on bulk samples and separated lithologies. With this information we determine the irradiation history (transit time, shielding depths) of the meteoroid during transit from parent body to Earth and the irradiation history of its breccia components on the parent asteroid prior to lithification. In addition, we used ^{14}C and ^{10}Be measurements to determine the terrestrial age of this meteorite.

Experimental Methods: We selected six fragments of the NWA 869 shower, including MB-13, M-05-38-1, M-05-38-2, SM-03-1, MS-04-1 and #D, which are described in more detail in [1]. We dissolved 40-80 mg of purified metal, along with a carrier solution containing Be, Al, Cl and Ca, in 1.5 N HNO_3. After dissolution, we took a small aliquot of the dissolved sample for chemical analysis by atomic absorption spectrometry. For radionuclide analysis in the stone fraction, we dissolved 120-140 mg along with Be and Cl carrier in a mixture of HF/HNO_3. Be, Al and Cl were chemically separated and purified for analysis by accelerator mass spectrometry (AMS). The AMS measurements of ^{10}Be, ^{26}Al and ^{36}Cl were carried out at PRIME Laboratory, Purdue University [4]. Results are shown in Table 1.

Bulk samples were crushed and treated with 100% phosphoric acid to remove terrestrial carbonates. Aliquots ranging in size from 45–100 mg were mixed with ~5 g of iron chips in an alumina crucible and placed in an oven at 500 °C to remove low-temperature terrestrial contaminants. The sample was heated in a RF induction furnace to 1400 °C in a flow of oxygen and all carbonaceous gases were converted to CO_2. The CO_2 was converted to graphite and the $^{14}C/^{12}C$ ratio was measured at the Arizona AMS facility [5]. The total amount of ^{14}C atoms was corrected for an average extraction background of $(5.7 \pm 3.4) \times 10^5$ atoms ^{14}C, following the procedure of [5]. Results are shown in Table 1.

Noble gases were measured in ten samples, using procedures similar to those described in [6]. Concentrations of trapped ^{20}Ne and cosmogenic ^{21}Ne are given in Table 1.

Results. Concentrations of cosmogenic ^{10}Be, ^{26}Al and ^{36}Cl in the metal and stone fraction of NWA 869 specimens show large variations, up to a factor of ~18. These large variations are consistent with irradiation in a large object with a pre-atmospheric radius of 2.0-2.5 m and a mass of 120-230 metric tons. Interestingly, the two most shielded samples show elevated $^{26}Al/^{10}Be$ ratios of ~3.8 in the stone fraction and elevated $^{36}Cl/^{10}Be$ ratios of 6.5-9.2 in the metal fraction. These elevated ratios are best explained by a recent impact on the NWA meteoroid, that excavated enough material to bring the two most shielded samples, #D and SM-03-1, close enough to the surface to be exposed to a much higher cosmic-ray flux, without affecting the production rates of the other four samples, which must have originated from the other side of the meteoroid.

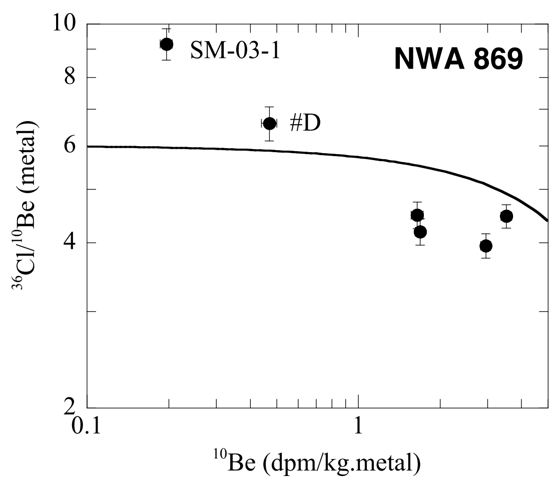

Figure 1. Relationship between $^{36}Cl/^{10}Be$ ratio and ^{10}Be concentration in metal phase of NWA 869 meteorites. The solid curve represents the relationship for chondrite falls.

Measured ^{14}C concentrations in five NWA 869 fragments range from 8.5 to 27 dpm/kg, relative to an average saturation value for L-chondrites of 51 ± 7 dpm/kg [5]. The ^{14}C content of 27 dpm/kg in the least shielded sample (M05-38-1) constrains the terrestrial age of NWA 869 to <5.2 kyr. We determined a more precise terrestrial age based on the $^{14}C/^{10}Be$ ratio, which is relatively constant at ~2.5 [7]. Three of five NWA samples show a constant $^{14}C/^{10}Be$ ratio of 1.5 ± 0.1 (Fig. 2), corresponding to a terrestrial age of 4.4 ± 0.7 kyr. The two most shielded samples (based on ^{10}Be) show elevated $^{14}C/^{10}Be$ ratios of 4.5-6.5 in bulk samples, consistent with our scenario of a recent impact event on the NWA 869 meteoroid, which exposed these samples to a higher cosmic-ray flux. Based on the combined radionuclide data, we estimate that this impact occurred 50-100 kyr ago.

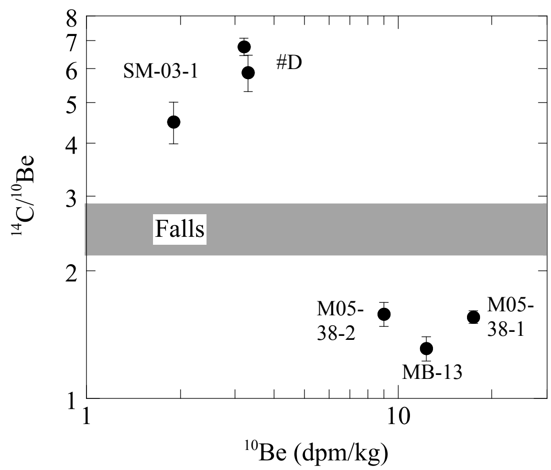

Figure 2. Relationship between $^{14}C/^{10}Be$ ratio and ^{10}Be concentration in bulk samples of NWA 869 meteorites. The grey bar represents the average saturation ratio of ~2.5 for chondrite falls [7].

Noble gas results. Matrix and bulk samples of NWA 869 contain significant amounts of solar neon and argon, but are virtually free of solar He ($^{4}He/^{20}Ne_{sol}$ ~7), which may have been lost – along with radiogenic ^{4}He – during one or more impact events ~3 Gyr ago. Cosmogenic ^{21}Ne concentrations range from 0.55 to 1.92 x 10^{-8} cm^3 STP/g and show poor correlation with cosmogenic ^{10}Be and ^{26}Al. The combined ^{21}Ne and ^{26}Al concentrations indicate a 4π exposure age of ~5 Myr, consistent with the saturated ^{10}Be and ^{26}Al concentrations. Excesses of ^{21}Ne in some matrix and clast samples indicate minimum regolith exposure ages up to ~6 Myr, assuming exposure at a depth of ~50 g/cm^2 on the L-chondrite parent body.

In a plot of $(^{3}He/^{21}Ne)_c$ vs. $(^{22}Ne/^{21}Ne)_c$ half of the samples are consistent with the Bern line, while two samples, SM-03-1 and #D, show evidence of ^{3}He loss. The loss of ^{3}He supports our scenario in which these two samples were affected by a recent impact on the NWA 869 meteoroid 50-100 kyr ago.

Conclusions. Based on concentrations of ^{10}Be, ^{26}Al and ^{36}Cl, we conclude that the NWA 869 samples were irradiated at depths of <10 cm to ~140 cm in an object with a pre-atmospheric radius of 225 ± 25 cm. This size corresponds to a mass of 120-230 metric tons. The recovered mass of >7 metric tons, suggests that 90-95% of the mass was lost by ablation during atmospheric passage. The $^{14}C/^{10}Be$ ratio in three NWA 869 samples yields a terrestrial age of 4.4±0.7 kyr, which is consistent with the relatively low degree of weathering (W1). Elevated $^{36}Cl/^{10}Be$ and $^{14}C/^{10}Be$ ratios can best be explained by a scenario in which a recent near-catastrophic impact event on the NWA meteoroid 50-100 kyr ago excavated a crater of ~80 cm deep, exposing previously buried samples to a much higher cosmic-ray flux during the remainder of its exposure history. This scenario is supported by the very low cosmogenic $^{3}He/^{21}Ne$ ratios in these two samples, indicating recent loss of cosmogenic ^{3}He.

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References: [1] Metzler K. et al. (2008) *LPSC 39,* #1120. [2] Osawa T. and Nagao K. (2006) *Antarctic Meteorite Research,* 19, 58. [3] Bischoff A. et al. (2006). "*MESS II*", pp. 679. [4] Sharma P. et al. (2000). *NIM* B172, 112. [5] Jull A. J. T., et al. (1993) *Meteoritics*, 28, 188. [6] Scherer et al. (1998) *MAPS* 33, 259. [7] Kring D. et al. (2001) *MAPS* 36, 1057.

Table 1. Concentrations of trapped ^{20}Ne and cosmogenic ^{21}Ne (in 10^{-8} cm^3 STP/g), as well as cosmogenic radionuclides ^{14}C in bulk, and ^{10}Be, ^{26}Al and ^{36}Cl (in dpm/kg) in stone (s) and metal (m) fraction of NWA 869.

Sample	$^{21}Ne_{tr}$	$^{21}Ne_c$	^{14}C(b)	^{10}Be(s)	^{26}Al(s)	^{36}Cl(s)	^{10}Be(m)*	^{26}Al(m)*	^{36}Cl(m)*
M-05-38-1	241	1.51	27.1±0.4	18.1±0.4	56.8±1.0	11.8±0.3	3.54±0.16	2.32±0.18	15.7±0.3
MB-13	0.2-399	1.58-1.92	16.1±1.0	12.8±0.3	35.9±0.8	9.5±0.2	2.96±0.13	1.94±0.11	11.7±0.3
MS-04-1	–	–	–	11.1±0.3	38.0±0.8	21.7±0.6	1.67±0.08	1.08±0.20	7.4±0.2
M-05-38-2	0-372	0.55-1.36	14.2±0.9	9.0±0.3	28.8±0.7	11.7±0.3	1.70±0.08	1.16±0.10	7.1±0.1
#D	321	0.76	21.0±1.0	3.4±0.1	13.0±0.3	12.5±0.6	0.47±0.03	–	3.1±0.1
SM-03-1	80	0.69	8.5±0.9	1.9±0.1	7.1±0.3	5.0±0.1	0.20±0.01	–	1.8±0.1

*^{10}Be and ^{26}Al were corrected for contributions from silicates; ^{36}Cl was normalized to Ni content of 9 wt%.