**U-Pb AND Ar-Ar CHRONOLOGY OF LUNAR METEORITE NORTHWEST AFRICA 4472.** K. H. Joy[1,2,3], R. Burgess[4], R. Hinton[5], V. A. Fernandes[4,6,7], I. A. Crawford[1], A. T. Kearsley[2], A. J. Irving[8] and EIMF[5]. [1]The Joint UCL / Birkbeck Dept. of Earth Sciences, London, WC1E 6BT, UK. [2]IARC, Dept. of Mineralogy, The Natural History Museum London, UK [3]STFC, The Rutherford Appleton Laboratory, UK. [4]University of Manchester, UK. [5]Edinburgh Ion Microprobe Facility, University of Edinburgh, UK. [6]Berkeley Geochronology Center, USA. [7] Dept. of E&P Sci., University of California, Berkeley,USA. [8]University of Washington, Seattle, USA. (K.Joy@ucl.ac.uk).

**Introduction:** North West Africa (NWA 4472) is a KREEPy lunar meteorite regolith breccia [1-5]. It comprises a diverse lithic clast component (<5 mm) consolidated in a fragmented clast supported matrix. Lithic fragments are compositionally affiliated with lunar High Mg-Suite (HMS), High Alkali Suite (HAS), mare basalt and impact melt lithologies [5]. NWA 4472's bulk composition [reported by 2, 3] is rich in incompatible trace elements, consistent with being derived from a regolith within the nearside lunar Procellarum KREEP Terrane [6]. Here we report preliminary radiometric age dating studies of sub-splits of NWA 4472.

**Methodology:** Bulk sample $^{40}$Ar-$^{39}$Ar resistance furnace step heating was conducted on an irradiated sub-split (mass of 0.0222 g) at the University of Manchester. Ar was released between 400–1600°C in steps of 30 mins. duration following the technique of [7].

*In situ* U-Pb and Pb-Pb dating of phosphates was conducted at the University of Edinburgh using a Cameca ims-1270 ion probe with a 4 nAmp beam current and a 20 × 15 µm spot size. Samples were polished and gold coated. Apatites were calibrated against a Grenville Province apatite (Dover Mine). No merrillite standard was available for this study, therefore only $^{207}$Pb/$^{206}$Pb ages will be discussed for this phase.

**$^{40}$Ar-$^{39}$Ar Results:** The Ar-Ar age spectrum for NWA 4472 is shown in Fig. 1. Ca/K ratios increase progressively with temperature steps from about 15 to a maximum of 100 (Fig. 1a). These element ratios are consistent with microprobe measurements of clast bulk compositions [5], and suggests that HAS clasts (Ca/K ratios ~0-15) released gas at lower (<950°C) temperature steps, compared with KREEPy impact melt clasts (Ca/K ratios ~20-40) and finally mare basalt and HMS material (Ca/K ratios generally >40).

Ar release data forms a reasonable correlation on a plot of $^{36}$Ar/$^{40}$Ar vs. $^{39}$Ar/$^{40}$Ar (Fig. 1c) indicating that Ar is essentially a mixture of trapped and radiogenic Ar components. The trapped composition, given by the intercept on the y-axis of $^{36}$Ar/$^{40}$Ar = 0.44 ($^{40}$Ar/$^{36}$Ar = 2.27), suggests the presence of surface-irradiated clasts / mineral fragments (i.e. a soil exposed to the solar wind). The correlation is not an isochron as such, but it is consistent with apparent ages between 2.85-3.2 Ga as indicated by the trapped Ar corrected age spectrum in Fig. 1b (85% of the data fall between these limits).

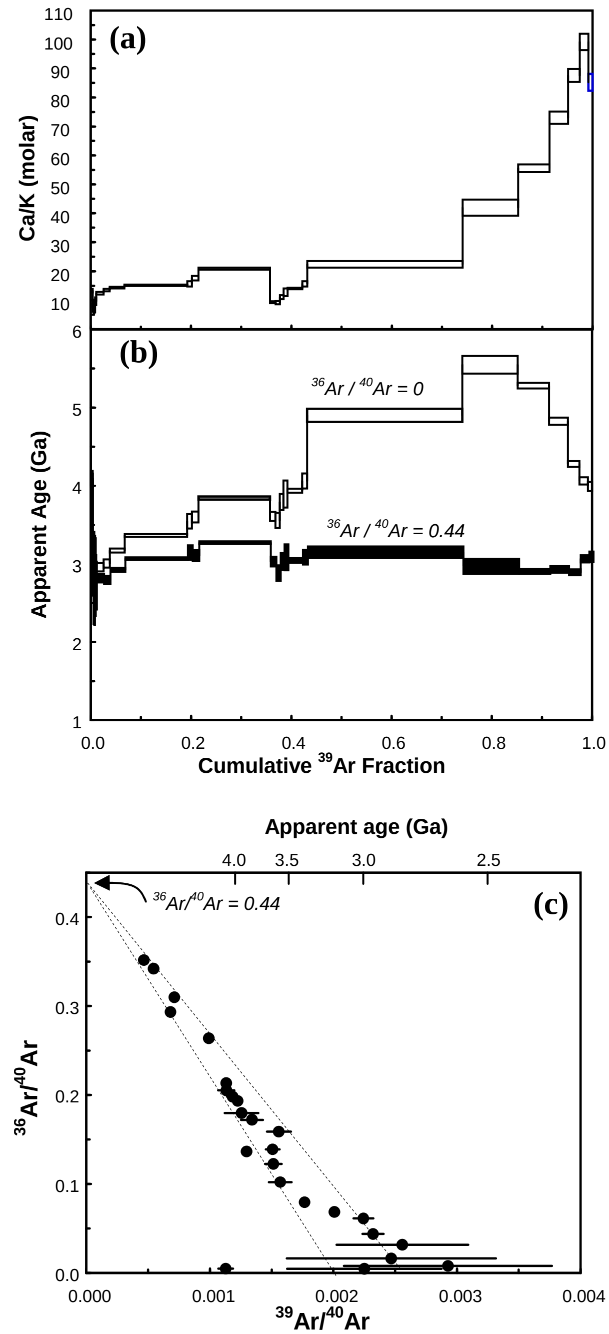


**Figure 1**. (a) Ca/K release with cumulative $^{39}$Ar release fraction. (b) Uncorrected age spectrum (unfilled boxes) and corrected age spectrum (filled boxes) for trapped Ar where $^{36}$Ar/$^{40}$Ar = 0.44. (c) $^{36}$Ar/$^{40}$Ar versus $^{39}$Ar/$^{40}$Ar correlation showing regression trend to y-axis intercept at $^{36}$Ar/$^{40}$Ar = 0.44. Box heights and error bars are 2σ.

Cosmogenic exposure irradiation (calculated from the $^{38}Ar/^{36}Ar$ ratio of the high temperature release steps) suggest a near surface regolith residence time of ~300 Ma. This, and the presence of trapped solar wind Ar, is consistent with the findings of [5] that NWA 4472 is a regolith breccia sample.

**U-Pb and Pb-Pb Phosphate Results:** Apatite and merrillite (dehydrated whitlockite [8]) U-Pb isotope data was obtained in three sections of NWA 4472. Apatites were analyzed in both discrete mineral grains within the NWA 4472 matrix, and in polymict mare basalt clasts such as the clast shown in Fig. 2. Results are summarized in Fig. 3 and below:

- Five points analyzed in zoned fluorapatite grains within the basalt clast shown in Fig. 2 yielded an average $^{207}Pb/^{206}Pb$ age of 3931 ± 18 Ma (2σ) and have a U-Pb concordia age (Fig. 3: red ellipses) of 3937 ± 18 Ma (2σ).
- Two analyses within a discrete matrix fluorapatite grain gave an average $^{207}Pb/^{206}Pb$ age of 4345 ± 24 Ma (2σ) and have a U-Pb concordia age (Fig. 3: green ellipses) of 4344 ± 14 Ma (2σ).
- An analysis of a second matrix apatite grain gave a $^{207}Pb/^{206}Pb$ age of 4070 ± 18 Ma (2σ) and has a U-Pb concordia age (Fig. 3: yellow ellipse) of 4070 ± 27 Ma (2σ).
- An analysis within a third matrix fluorapatite grain gave a $^{207}Pb/^{206}Pb$ age of 3966 ± 12 Ma (2σ) and has a U-Pb concordia age (Fig. 3: blue ellipse) of 3968 ± 20 Ma (2σ).

The majority of the merrillite grains analyzed in this study were isolated fragments within the NWA 4472 matrix (i.e. they were not associated with any other mineral phase). Two merrillite grains yielded $^{207}Pb/^{206}Pb$ ages of 3936 ± 22 Ma (2σ) and 3936 ± 18 Ma (2σ), which is consistent with the dates (3.93-3.94 Ga) of apatites within the basalt clast shown in Fig. 2. Two other merrillite grains gave similar slightly older $^{207}Pb/^{206}Pb$ ages of 3951 ± 16 Ma (2σ) and 3956 ± 18 Ma (2σ) that cannot be specifically correlated with any of the apatite age dates shown in Fig. 3.

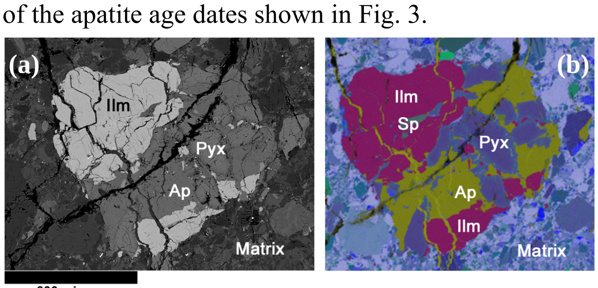


**Figure 2.** (a) Back scatter electron image of evolved basalt clast with large apatite phases and zoned clinopyroxenes. (b) X-ray element map of same clast colored so that Si = blue, Al = white, Mg = green, Fe = red, Ca = yellow (apatites and terrestrial contamination in fractures) and Ti = pink (ilmenite). Scale bar = 300 µm.

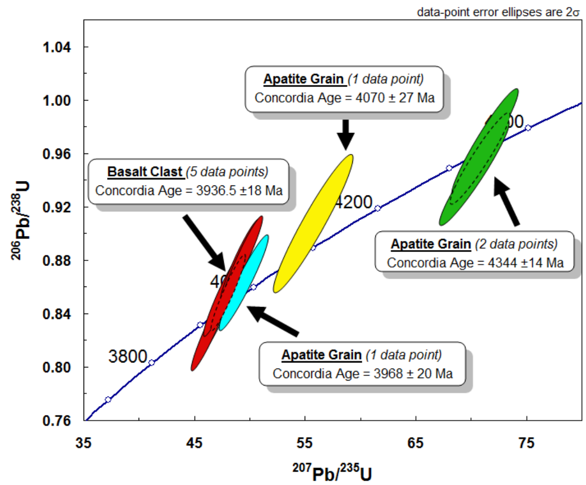


**Figure 3.** U-Pb concordia plot constructed using Isoplot [9]. Apatite data is shown for a mare basalt clast (red coloration) and three isolated matrix apatite fragments. Solid ellipses represent analyzed data and dashed ellipses are Isoplot [9] concordia ages. Decay constant errors are included in the error calculation.

**Discussion:** The NWA 4472 regolith breccia meteorite has sampled a range of Pre-Nectarian (>3.92 Ga) lunar volcanic and plutonic lithologies.

We interpret the U-Pb and Pb-Pb ages as representing the crystallization ages of various lithic components within the NWA 4472 regolith. The evolved mare basalt fragment (Fig. 2) dated to be 3.93-3.94 Ga, and the matrix apatite and merrillite grains (3.94-4.07 Ga) are consistent with the ages of Apollo 15, 16 and 17 KREEPy mare basalts [10]. We suggest that the older apatite grain dated to be ~4.34 Ga might represent the crystallization date of the granitic (HAS) clast component.

We interpret that the apparent younger 2.85-3.2 Ga bulk sample Ar-Ar age to represent a partial resetting of the Ar-Ar system by a more recent impact event. It is possible that this is the age of the impact that assembled NWA 4472 in its present form. However, this resetting event cannot have resulted in complete loss of pre-existing Ar as the sample still retains a trapped solar wind component (Fig. 1). Our forthcoming *in-situ* UV laser Ar-Ar studies will hopefully shed new light on this interpretation.

**References:** [1] Connolly et al. (2007). Met. Bull. No. 91, *MAPS* 42, A413-A466. [2] Kuehner et al. (2007). 38th LPSC, abst. no. 1516. [3] Korotev and Zeigler (2007). 38th LPSC, abst. no. 1340. [4] Joy et al. (2007). *MAPS* Vol. 42 No. 8 abst. no. 5223. [5] Joy et al. (2008). *39th LPSC*. abst. no. 1132. [6] Jolliff et al. (2000). *JGR*. Vol. 105 pp. 4197-4216. [7] Burgess and Turner (1998). *MAPS*. Vol. 33. pp.105-116. [8] Jolliff et al. (2006). *Am. Min.*. Vol. 91. pp. 1583–1595. [9] Ludwig (2008). *Berkeley Geochronology Center, Special Publication No. 4*. [10] Nyquist and Shih (1992). *GCA*. Vol. 56. pp. 2213-2234.

**Acknowledgements:** We thank NERC, STFC and the Leverhulme Trust for funding.