PETROLOGY, BULK COMPOSITION, AR-AR AGE AND IR EMISSION SPECTRUM OF LUNAR GRANULITE NORTHWEST AFRICA 4881. V. A. Fernandes[1,2], A. J. Irving[3], S. M. Kuehner[3], M. Gellissen[4], R. L. Korotev[5] and J. L. Bandfield[2] [1]Berkeley Geochronology Center, Berkeley, CA, [2] Dept. Earth & Planetary Science, Univ. California, Berkeley, CA, USA; [3]Earth & Space Sciences, University of Washington, Seattle, WA, [4]Inst. für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Germany, [5]Earth & Planet. Sciences, Washington University, St. Louis, MO (veraafernandes@yahoo.com).

The find site for the lunar granulitic breccia Northwest Africa 3163 yielded further material, which has been classified as Northwest Africa 4483 and Northwest Africa 4881. Together these pieces constitute a single meteorite weighing at least 2448 grams, which evidently broke apart upon landing (or subsequently), and which has lain in the Saharan desert for 12,000 years (A. J. T. Jull, unpubl. data). Like Northwest Africa 3163 [1], the 606 gram Northwest Africa 4881 stone is partly coated by a pale, translucent fusion crust revealing the fine grained fragmental interior (Figure 1). We report here on preliminary ^{40}Ar-^{39}Ar age data for this rock, bulk major and trace element abundances, and a thermal infrared emission spectrum obtained in support of future orbital remote sensing of the Moon.

Figure 1: *Whole NWA 4881 stone (image © S. Ralew and M. Altmann)*

Petrology: NWA 4881 is a fine grained recrystallized breccia composed of larger plagioclase grains ($An_{96.1-98}Or_{<0.1}$; converted extensively to maskelynite) poikilitically enclosing very small grains (mostly 30-80 microns) of low-Ca pyroxenes ($Fs_{32.0-64.5}Wo_{9.5-13.1}$, FeO/MnO = 51.1-62), olivine ($Fa_{40.4-58.8}$, FeO/MnO = 91-100), Ti-chromite, ilmenite, troilite and metal. As was concluded for NWA 3163 [1], NWA 4881 evidently was a fragmental breccia which was buried fairly deep in the lunar crust and recrystallized to form the present granulitic texture. Such lithologies are otherwise known from only a few small clasts in Apollo breccias [2].

Bulk Composition: Major element analyses by XRF were conducted at the University of Cologne on clean cutting fines collected during slicing of the type specimen to produce material for both ^{40}Ar-^{39}Ar dating at the Berkeley Geochronology Center and emission spectra at Arizona State University. Trace element analyses by INAA were conducted on multiple small fragments of a separate small slice, and major elements were determined by electron microprobe (EMP) analysis on post-irradiation fused beads. Based on INAA data for subsamples, NWA 4881 is a little more mafic than NWA 3163, but otherwise has the same distinctive very low abundances of incompatible elements [3].

	EMP	***XRF***	***INAA***	
SiO_2 (wt%)	45.5	44.2	Sc (ppm)	14.6
TiO_2	0.21	0.21	Co	14.5
Cr_2O_3	0.19	0.13	Ni	60 ± 20
Al_2O_3	25.8	26.2	Ba	86
FeO_T	6.00	5.67	La	0.91
MnO	0.10	0.08	Ce	2.5
MgO	5.86	4.43	Sm	0.53
CaO	15.9	15.3	Eu	0.64
Na_2O	0.28	-	Tb	0.13
K_2O	0.03	-	Yb	0.59
P_2O_5	0.05	0.03	Lu	0.086
SUM	100.0		Hf	0.33
			Th	0.11
			V	27(XRF)
Mg/(Mg+Fe)	0.635	0.582	Ir (ppb)	2.3 ± 0.9

^{40}Ar-^{39}Ar Age Dating: Preliminary results for bulk sample ^{40}Ar-^{39}Ar laser step heating show that the Ar-release of NWA 4881 is complex, and suggests different effects likely due to its long history of impacts and resetting by burial metamorphism. The initial ~17% of gas release is dominated by implanted ^{40}Ar released by different domains and evidenced by the rapid increase and decrease in apparent ages. However, there is an overall decline in apparent ages to a minimum of 1.953±0.026 Ga (2σ). After this step, there is a gradual increase in apparent ages, and between 40 and 98% of total ^{39}Ar release there is a poorly defined plateau. This region shows a constant Ca/K ~1000 suggesting a predominance of pyroxene releasing the Ar. From a ^{40}Ar/^{39}Ar versus ^{36}Ar/^{39}Ar plot (Figure 2), it is evident that the data set can be divided into two groups: low-temperature steps dominated by a combination of trapped-excess-implated ^{40}Ar with an initial ^{40}Ar/^{36}Ar of ~300, a ^{38}Ar/^{36}Ar of ~0.1869, and a y-intercept of a non-definable age; and high-temperature release which shows an initial ^{40}Ar/^{36}Ar of ~100, a ^{38}Ar/^{36}Ar 1.2-1.5 suggesting a predominance in cosmogenic Ar, and a y-intercept corresponding to an age of 1.173±0.184 Ga. Correcting the high-temperature steps for their initial trapped component of ~100, a calculated age of 1.335±0.032 Ga is obtained over ~80% ^{39}Ar release.

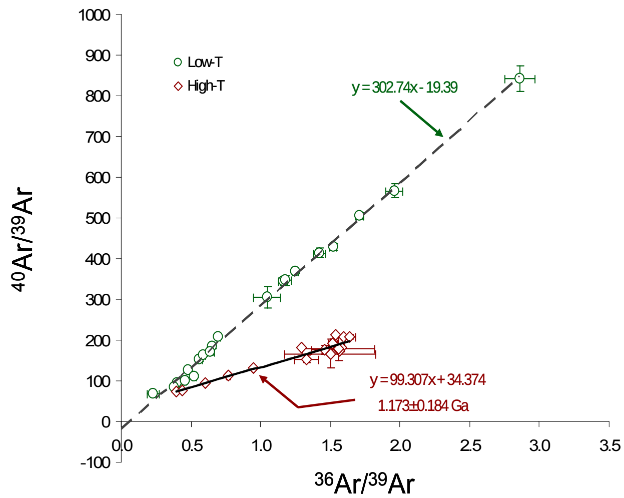

Figure 2. *^{40}Ar/^{39}Ar versus ^{36}Ar/^{39}Ar for NWA 4881. The y-intercept corresponds to the age of the data array and the slope of the line to the value of the trapped ^{40}Ar/^{36}Ar.*

Currently, a second aliquot of NWA 4881 is being analyzed for ^{40}Ar-^{39}Ar in an attempt to further evaluate the complexity in the Ar release reported here.

IR Emission Spectrum: Thermal infrared emission spectra were collected at Arizona State University on a ~12 gram slice of NWA 4881 (and similarly on a slice of lunar mare basalt NWA 3160). The emissivity spectra are sensitive to the bulk mineralogy of the sample and the presence of strong absorption features near 500, 900, and 1050 cm^{-1} indicate the dominance of Fe-rich olivine and Ca-rich plagioclase in the sample. There are several clear differences with the spectrum of NWA 3160, which has much more muted features consistent with the very fine grained, glassy nature of the groundmass of this sample.

Although the lunar environment has complicating effects for thermal infrared spectroscopy, there is a clear potential for distinguishing the bulk composition of lunar terrains using remote sensing data. Laboratory and remotely sensed spectral data may be used to link the surface outrops to meteorite compositions in a manner similar to that accomplished with Martian spacecraft datasets and meteorites [e.g., 4]. The multispectral data to be returned from the Diviner radiometer on the Lunar Reconnaissance Orbiter [5] will provide the initial test for this concept.

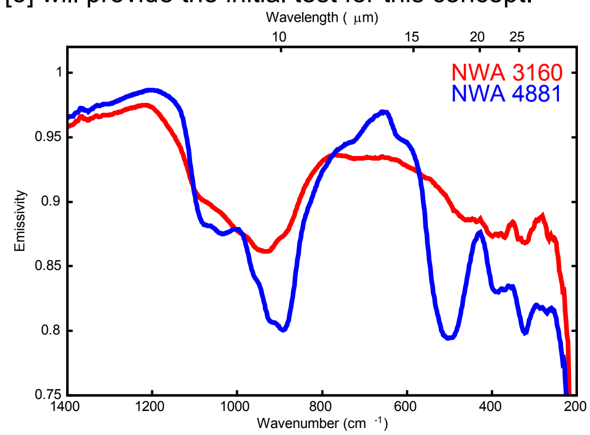

Figure 3. *Laboratory thermal emission spectra of lunar mare basalt NWA 3160 and lunar granulite NWA 4881.*

Discussion: Lunar meteorite NWA 4881 is a representative of the complex and powerful effects of impact bombardment over the lunar surface that conferred its granulitic texture: burial and deep" subsolidus metamorphism. Bulk chemical composition suggests low content in incompatible elements suggesting its provenance from an area different from Procellarum KREEP Terrain. Preliminary ^{40}Ar-^{39}Ar data suggests that the last cooling event, likely due to an impact, occurred at ~1.34 Ga. An increase in impact ages at about this time was also reported by [6] for Apollo 12 impact spherules. IR emission spectral data of NWA 4881 show clear differences with paired metoerite NWA 3160 due to the difference in grain size. The combination of laboratory with remotely sensed data is optimal to find surface outcrops similar to meteorite compositions.

References: [1] Irving A. J. et al. (2006) Lunar Planet. Sci. XXXVII, #1365 [2] Cushing J. A. et al. (1999) MAPS 34, 185-195 [3] Korotev R. L. et al. (2009) Lunar Planet. Sci. XL (this conference) [4] Hamilton V. E. et al. (2003) Meteorit. Planet. Sci. 38, 871-885 [5] Chin G. et al. (2007) Space Sci. Rev. 129, 391-419. [6] Levine et al. (2005) Geophys. Res. Lett. 32, L15201, doi:10.1029/2005GL022874.