^{40}AR-^{39}AR AGES AND CHEMICAL COMPOSITION FOR LUNAR MARE BASALTS: NWA 4734 AND NWA 4898.

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Introduction: For the past decade the number and types of lunar rocks recognized as such has increased, allowing an augmentation in the number of ages determined for rocks from the Moon, namely those of lunar basalts. Considering that most lunar basaltic meteorites are younger than the Apollo and Luna samples, we continue our pursuit in finding young basalts (3.2 -1.2 Ma) comparable to those suggested by [1,2]. It is likely that many of the more recent impacts affected only basaltic flows that are on the top of the lunar surface, and thus target those that were erupted more recently. Therefore, it is important to determine the age of these samples to acquire a better understanding of the evolution and composition of the basalt sources within the lunar mantle that erupted in more recent times. These young ages are not necessarily related to shock events as is sometimes supposed, i.e. that major impacts reset Ar-Ar ages (e.g. Ar-Ar age of 2.779± 0.056 Ga for NWA 032 [3] was confirmed by Rb-Sr- 2.852 ± 0.065 Ga [4]). Here we present ^{40}Ar-^{39}Ar radioisotopic data for new lunar mare basalts, NWA 4734 and NWA 4898.

Samples and method: The ^{40}Ar-^{39}Ar laser stepped-heating technique has been applied to two unbrecciated lunar basalts in an attempt to determine the crystallisation and impact ages experienced by the meteorites NWA 4898 and NWA 4734. Inspection of the two basalts by SEM/EMPA was conducted on fragments adjacent to those used for ^{40}Ar-^{39}Ar age determination.

Northwest Africa 4898, an almost completely fusion-crusted 137 g stone [5], is an intergranular fine-grained basalt [6] similar to Dhofar 287 having a mineralogical assemblage (Fig.1) mostly composed of plagioclase (An_{91}) and zoned pyroxene laths ($En_{1-45}Fs_{28-76}Wo_{17-28}$). Olivine is also present as megacrysts [6]. Minor phases include needle shaped ilmenite, euhedral chromite and rare troilite and Fe-Ni metal [6]. As for impact shock features, plagioclase is totally converted to maskelynite [6], and olivine and pyroxenes show irregular fractures, with olivine also displaying strong mosaicism [6]. Based on the shock features, NWA 4898 is in the 2b stage and experienced a shock pressure of ~28-34 GPa [7]. With 2.3% TiO_2, 12% Al_2O_3, 17% FeO and 8% MgO, NWA 4898 is the first feldspathic basalt among the lunar meteorites. The major-element composition is similar to sample 12038 of Apollo 12, but REE concentrations are lower and the light REE are depleted. Preliminary Rb-Sr whole rock analyses [8] have suggested an age of 3.600±0.059 Ga. Northwest Africa 4734 has a coarse-grained texture resembling that observed in several shergottites [5]. The major phases in basalt NWA 4734 (Fig.2) are plagioclase (An_{88-92}; partly converted to maskelynite [5]), zoned pyroxene ($En_{1-52}Fs_{27-76}Wo_{9-30}$), olivine with a Mg# 45, and ulvöspinel. As noted by [9], NWA 4734 is compositionally and texturally indistinguishable from the LaPaz Icefield basalts of Antarctica and is a potential launch pair.

^{40}Ar-^{39}Ar ages: Prior to irradiation, 1-3 bulk fragments from NWA 4898 and NWA 4734, and in the case of NWA 4734 (in the case of NWA 4734 also plagioclase and pyroxene mineral separates) were obtained so that duplicated analyses could be conducted. A ~100 hour irradiation was required to acquire the necessary neutron fluence. The preliminary results were obtained 9 months after irradiation (Fig.2), thus much ^{37}Ar decayed prior to analyses.

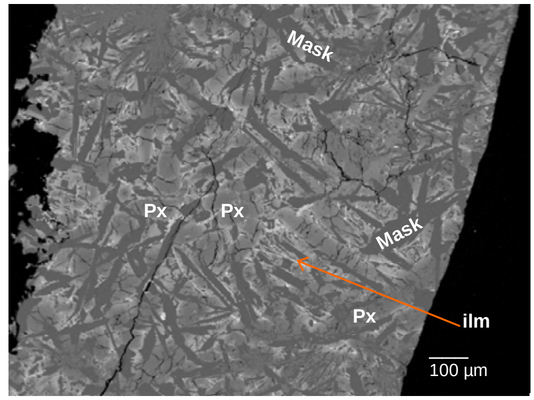

Figure 1. *BSE composite of NWA 4898.*

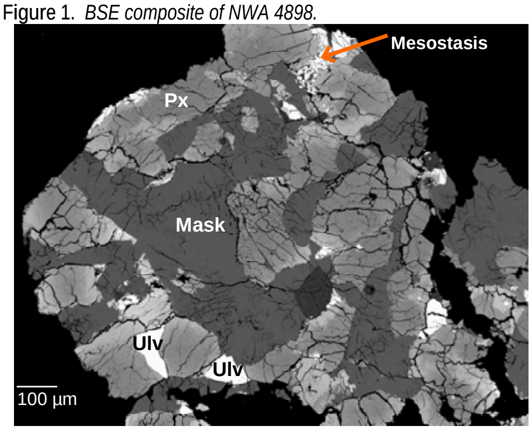

Figure 2. *BSE composite of NWA 4734.*

Four aliquots of NWA 4898 (1.61 - 2.80 mg) were used for ^{40}Ar-^{39}Ar step heating to replicate results. Ages are based on (SJ77 and specify standard- Hb3gr- [10]). All age errors reported are at 2σ and exclude contributions from the age of the standard and the ^{40}K decay constants. The Ar releases for the four aliquots show little to negligible trapped ^{40}Ar, and thus no correction was applied. The initial ~2% of Ar release show likely terrestrial contamination and these steps are not accounted for when calculating an age (Fig. 3). All steps considered show $^{38}Ar/^{36}Ar$ values close to the cosmogenic value of 1.54, and thus further suggesting the non-existence of trapped Ar in this basalt. The following step shows a maximum apparent age at about 3.735 Ga, which is followed by systematically decreasing ages likely resulting from ^{39}Ar recoil from a phase relatively richer in K (i.e. plagioclase) to a phase relatively K-poor (i.e. pyroxene), and commonly seen in samples showing a fine-grained texture such as is the case of basalt NWA 4898. As shown in the Ca/K release spectrum, there is a progressive increase from the low

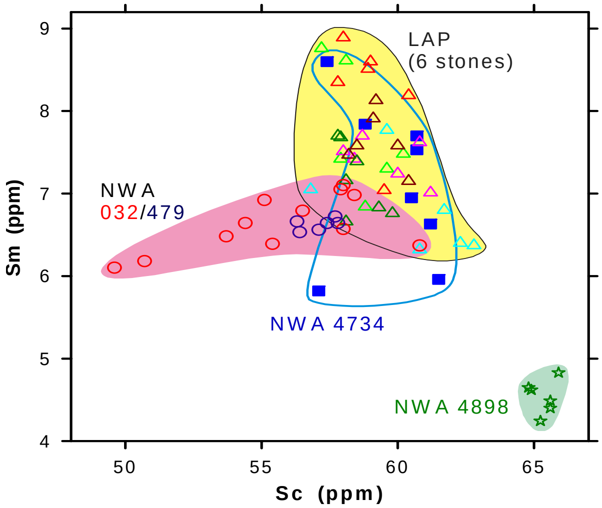

Figure 3. *Subsamples of NWA 4734 overlap in composition with those of the LAP stones for all elements measured. All other basaltic lunar meteorite lie off the scale of the plot.*

to the high temperature steps which is suggestive of a gradual predominance in the release from a phase with relatively lower Ca/K to one with relatively higher Ca/K. Thus, an integrated age is calculated based on the Ar released over the steps affected by this effect: 3.520±0.060 Ga (aliquot-1), 3.467±0.060 Ga (aliquot-2), 3.520±0.080 Ga (aliquot-3) and 3.480±0.080 Ga (aliquot-4). All aliquots form a well defined isochron on a $^{40}Ar/^{36}Ar$ vs. $^{39}Ar/^{36}Ar$ with an age of 3.536±0.020 Ga. These results are identical to previous ones determined by Rb/Sr [8].

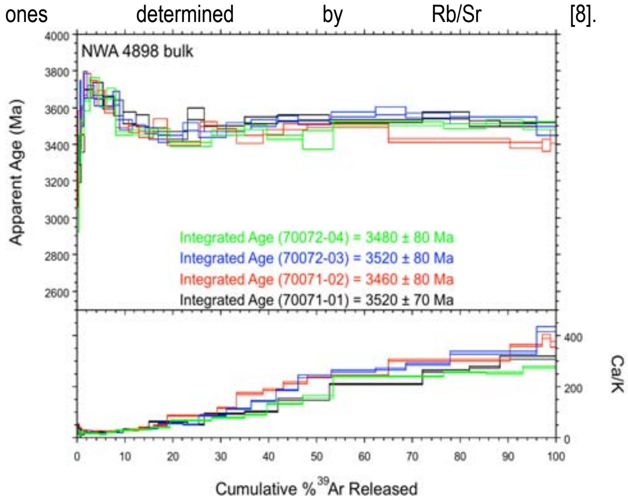

Figure 3. *Apparent age vs. %* ^{39}*Ar-release for four aliquots from lunar basalt NWA 4898.*

Two aliquots of NWA 4734 (3.42 and 4.18 mg) were also analysed by ^{40}Ar-^{39}Ar. The Ar release (red line in Fig.4) shows also the effect due to ^{39}Ar-recoil observed for NWA 4898, and there is a corresponding increase in Ca/K from low to high temperature steps suggesting the predominance of release from plagioclase to pyroxene. Similarly, integrated ages are: 2.720±0.020 Ga (aliquot -1) and 2.766±0.022 Ga (aliquot-2). These ^{40}Ar-^{39}Ar ages are indistinguishable from those obtained for NWA032/479 [3] and just lightly younger than the Ar age obtained or basalt LAP 02205 [11].

Cosmic-Ray Exposure (CRE) ages: $^{38}Ar/^{36}Ar$ values for the intermediate and high temperature steps are indistinguishable of the cosmogenic value of 1.54. Accordingly, no correction for solar wind

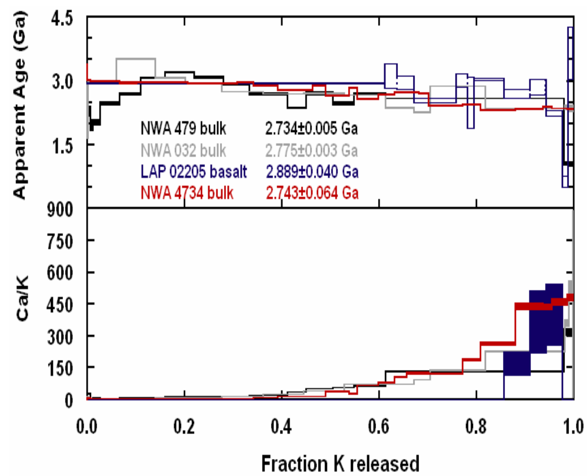

Figure 4. *Apparent age vs. %* ^{39}*Ar-release for two aliquots from lunar basalt NWA 4734.*

was made and ^{38}Ar cosmic-ray production rates of 1.031x10^{-8} cc/g/Ma and 1.082x10^{-8} cc/g/Ma for NWA 4898 and NWA 4734 respectively were calculated based on the method of [12], which takes into account the contribution from Ca, Fe, Ti, Cr, Mn, K, and Ni. For these calculations, bulk chemical composition of NWA 4898 reported in [6] and for NWA 4734 obtained by [9] were used. The calculated CRE-age for NWA 4898 aliquots is ~31 Ma, and for NWA 4734 aliquots is ~570 Ma.

Summary: Based on the chemical composition, petrological characteristics [13-16] and crystallisation ages [3, 10, 17-19], previous studies have suggested the lauch pairing and possible source pairing of samples NWA 032/479 and LAP-family. The new basaltic meteorite NWA 4734 is compositionally and texturally similar to these meteorites, and its ^{40}Ar-^{39}Ar age is also indistinguishable (Fig.4). ^{40}Ar-^{39}Ar ages obtained for NWA 4898 is the same as ^{87}Rb-^{87}Sr reported by [8]. As previously suggested by [8] NWA 4898 mantle source is the most depleted in $^{147}Sm/^{144}Nd$ and only moderately depleted in terms of $^{87}Rb/^{86}Sr$ indicating a previously unrecognized degree of compositional heterogeneity in incompatible element-depleted lunar mantle sources.

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Refs.: [1]Hiesinger et al. (2000) JGR 105, 29,239-29,275. [2] Hiesinger et al. (2003) JGR 108: 5065, doi:10.1029/2002JE001985. [3]Fernandes et al. (2003) *MaPS, 58,* 555-564. [4]Borg et al. (2007) 70th Annual Meeting of the MetSoc., abst.#5232. [5]Connolly et al. (2007)Meteori. Bull, 93, 571-632 (2008). [6]Greshake et al (2008) 39th LSPC, abst.#1631. [7]Stöffler & Grieve (2007) Impactites. Ed. by Fettes and Demonds, 82-91. [8]Gaffney et al. (2008) 1st NLSI LSC, abst.# 2064. [9]Korotev et al. (this conference). [10] Jourdan and Renne (2007) GCA 71, 387-402. [11]Fernandes et al. (in press). [12]Eugster and Michel (1995) *GCA* 59,177–199. [13] Righter et al. (2005) MaPS 40, 1703-1722; [14]Zeigler et al. (2005) MaPS 40, 1073-1101; [15]Joy et al.(2006) 41, 1003–1025; [16] Day and Taylor (2007) MaPS 42: 3-17; [17]Nyquist et al. (2005) 36th LPSC abst.#1374); [18]Anand et al. (2006) GCA 70, 246-264; [19]Rankenburg et al. (2007) GCA71, 2120–2135.