$^{39}Ar/^{40}Ar$ AGES OF SINGLE GRAINS FROM SHERGOTTITE NWA 2626: PUSHING THE LIMITS OF LASER STEP-HEATING.

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Introduction: We report $^{39}Ar/^{40}Ar$ ages for single grains separated from the martian meteorite NWA 2626. The shergottite NWA 2626 consists mainly of olivine and low-Ca pyroxene in a groundmass containing pigeonite, maskelynite, merrillite, and other minor phases [1]. Irving [2] classifies this meteorite as a *permafic* (current boundaries 0.5 ≤ Mg/[Mg+Fe]≤ 0.7 and 3.6 ≤CaO ≤9), *depleted* (La/La(CI)<1 and Lu/Lu(CI)~6) olivine phyric shergottite.

Table 1.

Meteorite	Sm/Nd	$^{39}Ar/^{40}Ar$
Dar al Gani 476	474±11 [3]	1000 [4]
Dhofar 019	575±7 [3]	707±16 [4]
		672±72 [5]
NWA 1195	347±13 [6]	
NWA 1460	350±16 [7]	360±6 [7]
QUE 94201	327±10 [3]	700±100 [8]
SaU 005/94	445±18 [9]	2000 [4]
		800±100 [5]
Yamato 980459	472±27 [9]	1000 [4]

Relative to the enriched group of phyric shergottites, the depleted subgroup tends to have older Sm/Nd crystallization ages (200-600 Ma) (Table 1) *vs*. <200 Ma. The determination of $^{39}Ar/^{40}Ar$ ages has proved troublesome for some shergottites. Release patterns may be disturbed, possibly as a result of weathering or terrestrial contamination (e.g., [9]) and the apparent ages may exceed the Sm/Nd ages by a factor of two or more (Table 1).

Recoil and diffusion, among other factors, can affect Ar release patterns. Mineral separations, especially of K-rich phases, can help although milligram-size separates may contain appreciable concentrations of impurities. To minimize these effects, and to exploit the improved sensitivity of modern laser-based systems and ion counters for analyzing noble gases, we have been studying individual grains separated from meteorites [10]. Here we apply the method to NWA 2626.

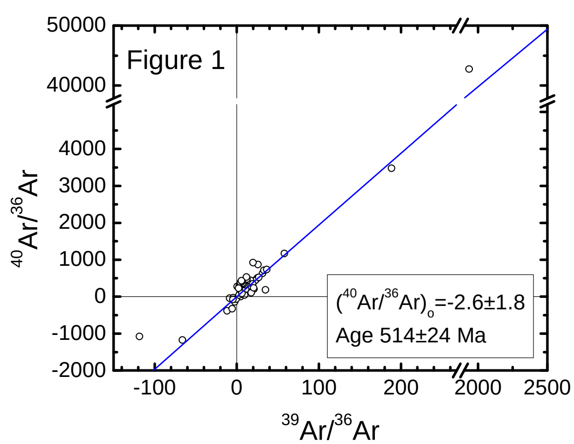
Experimental methods: By handpicking, we separated 13 grains from a gently crushed portion of NWA2626. Prior to irradiation, the grains were mounted on a C round without polishing and examined with EDS in an electron microprobe. The grains were irradiated (with Cd shielding) for 80 h at the USGS Triga reactor along with reference minerals FC-2 sanidine (28.02 Ma) and Hb3Gr amphibole (1073.6 Ma). Eleven single grains were heated in 3-11 steps with a CO_2 laser; two grains had only enough gas for one total fusion step. The Ar isotopes were analyzed using a MAP 215-50 spectrometer operated in pulse-counting mode.

Results: *EDS and XRD* - Three grains are maskelynite, qualitatively andesine to labradorite in composition. The rest are non-stoichiometric (NS). Their overall composition is pyroxenic, but with variable oxide abundances (wt%): Si (≤63), Al (≤28), Fe (≤8), Mg (≤21), Ca (≤12), Na (≤5) and P (≤ 2). XRD spectra are consistent with highly substituted pyroxene containing a glass component.

Blanks – A typical system blank for one step comprised (10^{-18} mol $^{36-40}Ar$): 2±1, 27±3, 0.5±0.2, 2±1, and 600±25. For comparison, the geometric means for the typical sample step before blank corrections were: 2.7±0.3, 32±2, 0.9±0.4, 12±1, and 880±30. Counting rates were sufficiently high and stable to allow reproducible measurements of ^{40}Ar (±15%) and ^{39}Ar (±13%), but not of $^{36,37,38}Ar$. In most cases, however, blank-corrected ^{36}Ar signals were greater than zero.

Isochron Ages – An isochron plot for all grains except 48 (possibly terrestrial) and 51 and yields an age of 514 ± 24 Ma (Figure 1) and an intercept $^{40}Ar/^{36}Ar$ = 0 within the uncertainties. The fit parameters may be misleading as most of the data plot in a region close to the origin. Examination of the isochrons for maskelynites 45 and 46 suggests the presence of non-radiogenic ^{40}Ar. Within the rather large uncertainties, the $^{40}Ar/^{36}Ar$ intercepts are consistent with terrestrial Ar or perhaps Ar from the martian mantle.

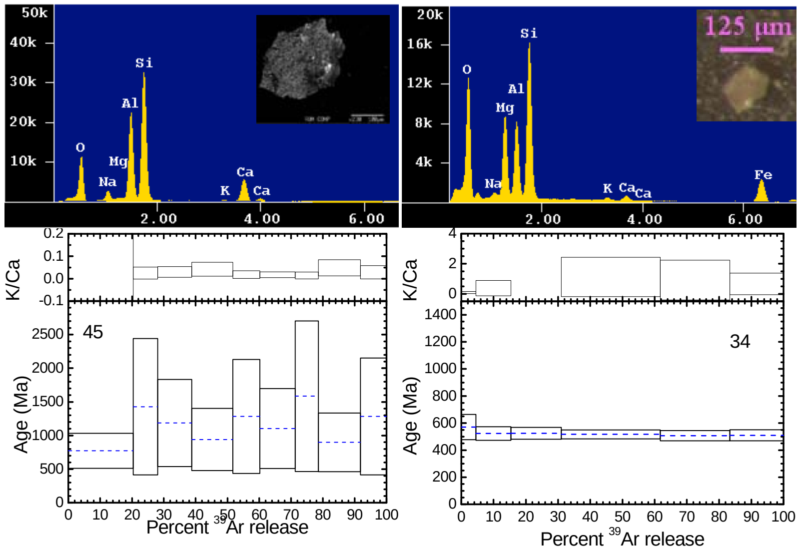
Plateau Ages – Grains 33-36 have undisturbed



plateaus with an average, weighted age of 500±14 Ma; the plateau for 34 is best (Figure 2).

K concentrations – K concentrations are generally unremarkable except in grains 34 and 48, where

Figure 2. BSE image of 45, reflected light image of 34, EDS spectra and Ar release diagrams for maskelynite 45 and multi-phase grain 34.



they are large. At this time, we are unsure how to interpret these results.

Discussion: *Trapped or unsupported* ^{40}*Ar*(≡^{40}*Ar*^{x}) - Judging from isochron plot intercepts, most of the NS pyroxenes contain no ^{40}Ar^{x}, despite the suggestion of glass components in the XRD data. Nonetheless, ^{40}Ar^{x} may be present. If so release must occur in a more-or-less fixed ratio to ^{39}Ar, so as not to disturb the plateaus. This hypothesis draws some strength from the plateau plots for the maskelynites 45 (Figure 2) and 46, which give larger ages and are more or less flat, although with large uncertainties are large. If the samples contain ^{40}Ar^{x}, then our calculated ages are too old. Bogard et al. [4] have argued that the presence of ^{40}Ar inherited from the parental magma(s) compromise(s) many, though not necessarily all of the ^{39}Ar/^{40}Ar ages, as stressed by [5].

Conclusions: Despite having pushed the sensitivity and blank limits of our mass spectrometer, we have obtained what appear to be credible ages for 4 of 13 grains from NWA 2626. Our best estimates of the ^{39}Ar/^{40}Ar age are from the isochron for all samples, 514±24 Ma, and the weighted average for non-stoichiometric pyroxenes 33-36, 500±14 Ma. These ages are consistent with Sm/Nd ages for three other depleted, permafic shergottites, DaG 476, Dho 019, and SaU 005.

We see no evidence for the pervasive presence of a martian argon component with a ^{40}Ar/^{36}Ar ratio larger than 298.6 the terrestrial value, although such argon could be below our detection limit. Two maskelynites give older apparent plateau ages, probably because they contain some trapped argon.

References: **[1]** Irving A.J., Bunch T.E., Wittke H., and Kuehner S.M. (2005) *LPSC.* **36**, 1229. **[2]** Irving A.J. (2011) Martian Meteorites. http://www.imca.cc/mars/ martian-meteorites.htm. **[3]** Borg L. and Drake M.J. (2005) *J. Geophys. Res.* 110, doi:10.1029/2005JE002402. **[4]** Bogard D., Park J., and Garrison D. (2009) *MAPS.* **44**, 905-923. **[5]** Korochantseva E.V., Trieloff M., Buikin A.I., Hopp J. (2009) *MAPS.* **44**, 293-321. **[6]** Symes S.J.K., Borg L.E., Shearer C.K., and Irving A.J. (2008) *GCA* **72**, 1696-1710. **[7]** Nyquist L.E., Bogard D.D., Shih C.-Y., Park J., Reese Y.D., Irving A.J. (2009) *GCA* **73**, 4288-4309. **[8]** Bogard D.D. and Garrison D.H. (1999) *MAPS.* **34**, 451-473.**[9]** Shih Y., Nyquist L. E., and Reese Y. (2007) *LPSC* **38**, 1745.**[10]** Lindsay F.N., Haavisto T., Turrin B., Herzog G.F., and Swisher III C.C. (2010) *MAPS* **45**, A120.

Table 2. Ar ages and K concentrations of NWA 2626.

ID[a]	Mass µg	Isochron age Ma	(^{40}Ar/^{39}Ar)$_o$	Plateau age Ma	Steps	Fusion age Ma	K ppm	Comments
32[b]	29	900±400	0±300	290±40	5 of 6	370±40	300	Disturbed plateau
33[b]	13	480±110	60±60	410±50	7 of 7	460±90	400	
34[b]	13	560±100	0±200	517±18	6 of 6	518±18	4600	High K
35[c]	24	230±170	50±130	520±30	10 of 11	520±40	700	
36[c]	17	1000±1100	0±600	310±70	3 of 3	320±80	200	
37[b]	32		50±50	240±40	4 of 9	740±50	400	Disturbed plateau
38[b]	20	540±100	0±50	--		400±40	500	Disturbed plateau
45[d]	16	0±800	360±190	930±170	9 of 9	1100±200	900	Trapped ^{40}Ar?
46[d]	4.5	800±800	200±400	1100±400	3 of 3	1100±400	900	Trapped ^{40}Ar?
48[d]	9.5	157±31	252±20	306±16	4 of 5	477±15	8400	Terrestrial?
49[b]	8.5	--		--		580±140	300	Low gas yield
50[b]	15	--		--		321±38	200	Low gas yield
51[b]	20	--		--		190±40	100	Low gas yield

a) Run 213xx-01. **b)** Non-stoichiometric pyroxene. **c)** NS Pyroxene, P-bearing. **d)** Maskelynite.