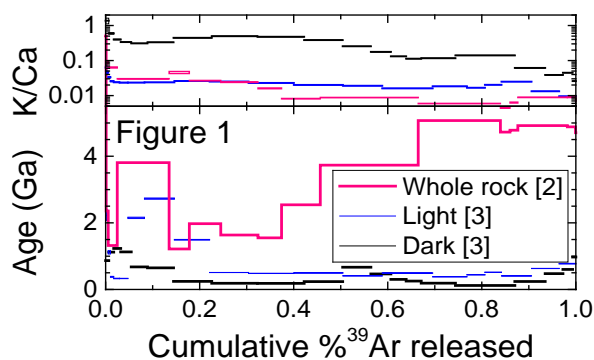


$^{40}\text{Ar}/^{39}\text{Ar}$ AGES OF MASKELYNITE GRAINS FROM ALHA 77005. B. Turrin^{1,3}, J. Park^{4,2,3}, G.F. Herzog^{2,3}, F.N. Lindsay^{2,3}, J.S. Delaney^{2,3}, L.E. Nyquist⁵, and C. Swisher III^{1,3}. ¹Dept. Earth Planet. Sci., ²Dept. Chem. & Chem. Biol., ³Rutgers Univ., Piscataway, NJ 08854, ⁴Lunar & Planetary Institute, Houston, Texas 77058, ⁵KR/NASA Johnson Space Center, Houston, TX 77058.

Introduction: We present $^{40}\text{Ar}/^{39}\text{Ar}$ measurements for twelve small (20-60 μg) maskelynite samples from the heavily shocked martian meteorite ALHA 77005. The reported modal composition for ALHA 77005 is 50-60% olivine (Fa_{28}), 30-40% pyroxene ($\text{Wo}_5\text{Fs}_{23}\text{En}_{72}$), ~8% maskelynite (An_{53}), and ~2% opaques by volume [1]. The meteorite is usually classified as a lherzolite.

Previous Studies - $^{40}\text{Ar}/^{39}\text{Ar}$ results from previous work display disturbed release spectra [2,3]. In study [2], $^{40}\text{Ar}/^{39}\text{Ar}$ measurements on a 52-mg whole-rock sample produced an extremely disturbed release spectrum, with all calculated apparent ages > 1 Ga, (Fig. 1).

In a subsequent study [3], a light and a dark phase were analyzed. A 2.3-mg sample of the light, relatively low-K phase produced a disturbed release spectrum. For the first 20% of the $^{39}\text{Ar}_K$, most of the apparent ages exceeded >1 Ga; the remaining 80% yielded ages between 0.3-0.5 Ga. The integrated age for this phase is 0.9 Ga.



The dark, relatively high-K phase also yielded a disturbed spectrum with two dips, the first at ~1 Ga for 15% of the $^{39}\text{Ar}_K$ release and the second at ~0.12 Ga. The integrated age for this phase is 0.38 Ga. These data are best fit by a standard isochron with an intercept (trapped $^{40}\text{Ar}/^{36}\text{Ar}$ ratio) of 290 ± 13 and an age of ~0.1 Ga, less than the reported Rb-Sr and Sm-Nd ages of 0.18 Ga [4].

The results from [2,3] indicate that Ar/Ar systematics are heterogeneous to a scale of ~1 mg or less. However, the less disturbed spectra of the low mass samples of [3] suggested that a further reduction in sample size might produce less complicated release spectra and hence more readily interpretable ages.

Experimental Methods: *Sample preparation.* The sample was crushed using an agate mortar and pestle.

Under a binocular microscope twelve grains were identified as maskelynite and selected for further study. Elemental compositions of the hand-picked material were determined by either EDX or x-ray fluorescence. The material was also examined by Raman spectroscopy.

Irradiation - The grains were weighed and loaded into an Al-disk along with the reference Fish Canyon sanidine (FC-2; 28.2 Ma) for neutron irradiation at the USGS TRIGA reactor. At the reactor facility, the samples were wrapped in Cd foil and irradiated with fast neutrons for 80 h.

Sample Extraction and Mass Spectrometry- Irradiated samples were transferred into a stainless steel sample disk and loaded into the extraction system for analyses. Samples were step-heated using a 40-watt CO_2 laser focused through a 6-mm integrator lens for power levels up to ~1 watt/ mm^2 . For power levels >1 watt/ mm^2 , a 2-mm integrator lens was substituted for the 6-mm lens. Prior to admission to the mass spectrometer, the extracted gases were exposed to a SAES GP-50 getter to remove the reactive gases ([5]).

Isotopic measurements were made on a MAP 215-50 mass spectrometer. Spectrometer mass fractionation was monitored by analyzing replicate air aliquots interspersed among sample unknowns following [6]. For this series of measurements, typical system blanks are as follows (10^{-17} mol): (^{40}Ar = 7.25; ^{39}Ar = 0.17; ^{38}Ar = 0.01; ^{37}Ar = 1.22; ^{36}Ar = 0.09).

Results and Discussion: Without corrections for

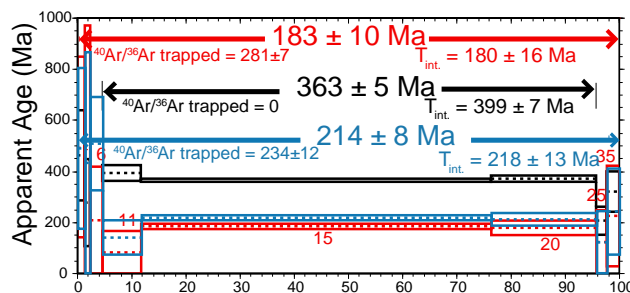
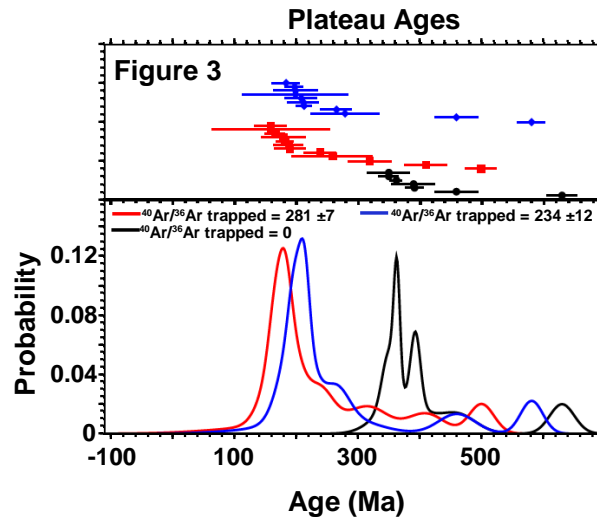


Figure 2.

trapped ^{40}Ar , seven of the twelve samples produce plateaus similar to the ones shown in Figure 2. Five of the seven plateau ages cluster between 300 and 400 Ma, forming a prominent node at 360 Ma in the combined age distribution (Fig. 3).



Ages Corrected for Trapped ^{40}Ar without Adjustment for Cosmogenic ^{36}Ar - When the isotopic data from the twelve samples are plotted individually on $^{40}\text{Ar}/^{36}\text{Ar}$ by $^{39}\text{Ar}/^{36}\text{Ar}$ isotope correlation diagrams, the data define isochrons and indicate an average trapped $^{40}\text{Ar}/^{36}\text{Ar}$ ratio of 281 ± 7 ($n=12$). With the use of this value to correct for trapped ^{40}Ar , all twelve of the plagioclase samples produce plateaus, seven of them with ages between 150 and 200 and peaking at 177 ± 6 Ma (Fig. 3). Five of the plagioclase grains with higher apparent ages may have higher trapped $^{40}\text{Ar}/^{36}\text{Ar}$ ratios or may have inherited purely radiogenic ^{40}Ar .

Ages Corrected for Trapped ^{40}Ar with Adjustment for Cosmogenic ^{36}Ar - The isotopic data were cast on a $^{38}\text{Ar}/^{36}\text{Ar}$ vs. $^{37}\text{Ar}/^{36}\text{Ar}$ isotope correlation diagram to determine the trapped $^{38}\text{Ar}/^{36}\text{Ar}$ ratio (intercept); the average was 0.27 ± 0.03 , consistent with the value of [7,8] for the martian atmosphere. With the additional relation $^{36}\text{Ar}_c = 0.65 \times ^{38}\text{Ar}_c$, we applied the lever rule to the measured $^{38}\text{Ar}/^{36}\text{Ar}$ ratio to calculate the concentration of trapped ^{36}Ar in each release step.

The twelve samples were then replotted on $^{40}\text{Ar}/^{36}\text{Ar}$ by $^{39}\text{Ar}/^{36}\text{Ar}$ isotope correlation diagram and fit with a straight line. The new intercept was 234 ± 12 . In effect, the cosmogenic corrections shift the plateau age distributions to slightly older values. Eleven of the twelve samples produce plateaus ages Fig (3). Of the eleven plateau ages, seven lie between 180 and 215 Ma of which four are in the 180-to-200 Ma range; four other plagioclase grains give anomalously old ages. The variance-weighted average of the lower-age cluster, 205 ± 10 Ma, is our preferred value for the Ar/Ar age of ALHA 77005 maskelynite.

Conclusions: At the 50- μg scale, we obtain $^{40}\text{Ar}/^{39}\text{Ar}$ plateau ages for ALHA 77005 that approach concordance but are $\sim 15\%$ older than ages clocked by

other geochronometers. Eleven of twelve ALHA 77005 plagioclase samples produce plateau ages. Seven of the grains show a tight distribution about an age of 205 ± 10 Ma, similar to but about 15% larger than the reported Rb-Sr and Sm-Nd ages of 180 Ma [4].

The intercept of the 'cosmogenic-corrected' isochron, $^{40}\text{Ar}/^{36}\text{Ar} = 234 \pm 12$, differs from best estimates of ratio of 1800 for the martian atmosphere [9]. The value we obtain is close to but also different from that of the terrestrial atmosphere, 298 [10]. As we omitted the low-temperature releases from the isochron fits, it seems unlikely that the trapped component is terrestrial and more likely that extra ^{40}Ar was inherited from the parent magma.

Four samples have apparent ages appreciably older than 200 Ma. These results show that not all maskelynite grains in ALHA 77005 are alike with respect to K-Ar systematics. While the analysis of milligrams of plagioclase/maskelynite from shergottites usually results in flatter plateau diagrams, it may disguise grain-to-grain variability. In any case, the distribution of ages that we observe suggests that ALHA 77005 had a complicated thermal history.

References:

- [1] Meyer C. (2012) The Martian Meteorite Compendium. <http://curator.jsc.nasa.gov/antmet/mmc/>
- [2] Bogard D.D. and Garrison D.H. (1999) *MAPS*, 34, 451-473.
- [3] Shankar N. et al (2008) *LPS* 39, Abstract #1924.
- [4] Nyquist L.E. et al (2001) *Space Sci. Rev.*, 96, 105-164.
- [5] Carr M.J. et al (2007) *Geochem. Geophys. Geosys.*, 8, doi:10.1029/2006GC001396.
- [6] Turrin B.D. et al (2010) *Geochem. Geophys. Geosys.*, 11, doi:10.1029/2009GC003013.
- [7] Pepin R.O. (1991) *Icarus*, 92, 2-79.
- [8] Bogard D.D. (1997) *JGR*, 102, E1, 1653-1661.
- [9] Garrison D.H. and Bogard D.D. (1998) *MAPS*, 33, 721-736.
- [10] Lee J.-Y. et al (2006) *GCA*, 70, 4507-4512.