Excess ^{40}Ar in Martian Shergottites, K-^{40}Ar Ages of Nakhlites, and Implications for *In Situ* K-Ar Dating of Mars' Surface Rocks. **Donald D. Bogard and Jisun Park[1],** ARES, code KR, NASA, Johnson Space Center, Houston, TX 77058 ([1]NASA Postdoctoral Program fellow)

Overview. To define martian history, we require ages of geological processes and surface features. Estimated ages from surface crater densities have limitations, and the ages measured for martian meteorites cannot be associated with specific martian locales. Some have suggested sending a robotic spacecraft to Mars to measure rock ages using the classical K-^{40}Ar technique, considered the easiest to implement. At JSC we have determined ^{39}Ar-^{40}Ar ages of many martian meteorites. Essentially all of the shergottites, but not the nakhlites, contain excess ^{40}Ar that renders their K-Ar formation ages difficult to determine. Here we address these two issues. What is the origin of this excess ^{40}Ar in shergottites, and what insights do these Ar-Ar data give for potentially measuring K-Ar ages on the martian surface?

Background. There are different possible explanations for Ar-Ar "ages" of shergottites appearing older than their generally accepted formation ages determined from other radiometric systems (1,2). Some shergottites contain veins and pockets of impact-produced melt that incorporated the martian atmosphere (1,3). However, some shergottite samples contain excess $^{40}Ar_{xs}$ (relative to the formation age) that is neither incorporated martian atmosphere nor undegassed ^{40}Ar formed by radioactive decay within the sample. From Ar-Ar analyses of feldspathic and pyroxene mineral separates of both coarse- and fine-grained phases of the Zagami shergottite (4), we concluded that the $^{40}Ar_{xs}$ was originally contained in the basaltic magma and was incorporated into Zagami during crystallization. The relatively low shock-heating temperature determined for Zagami (5) would not permit this $^{40}Ar_{xs}$ to be residual from a much older age. Arguments against $^{40}Ar_{xs}$ in Zagami having been implanted from the martian atmosphere are: 1) similar $^{40}Ar_{xs}$ concentrations exist in plag. & pyx. minerals and in CG and FG phases; 2) $^{40}Ar_{xs}$ is distributed through the mineral lattice, rather than being located in specific melt phases; and 3) excess Ar does not typically show the martian atmospheric ratio.

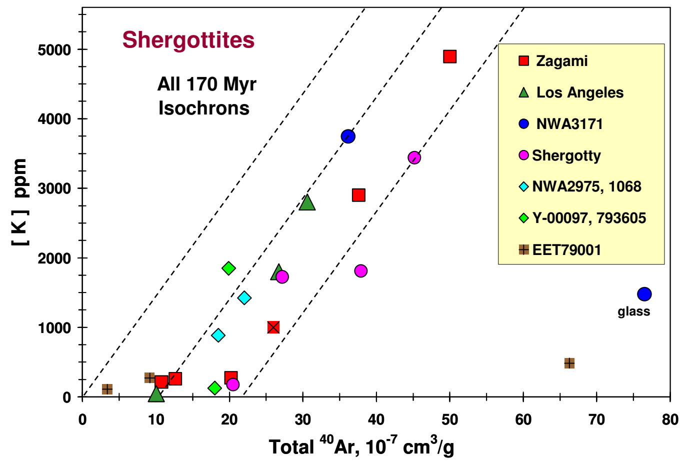
Here we present data on $^{40}Ar_{xs}$ concentrations in several additional basaltic shergottites, which show similar formation ages to Zagami and which likely derived from the same martian source region. The nature and distribution of $^{40}Ar_{xs}$ in these samples is better examined in a common isochron plot of total K versus total ^{40}Ar, rather than in standard Ar-Ar age spectra. Further, this way of presenting the data illuminates issues associated with robotic K-Ar dating such samples on Mars.

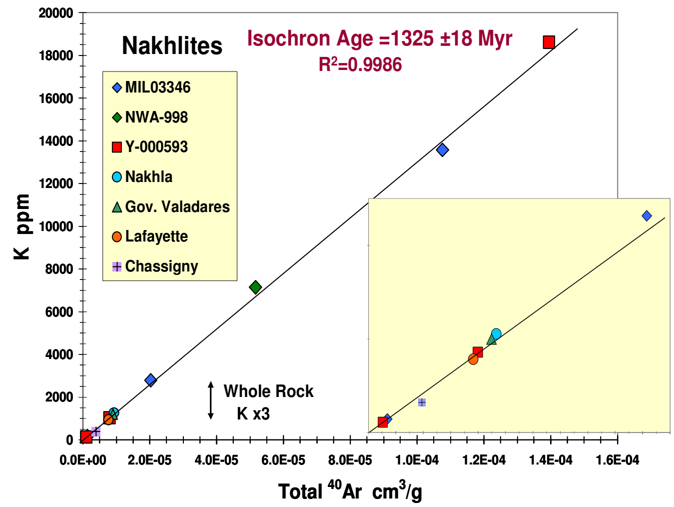
Shergottites. Figure 1 shows a K vs. ^{40}Ar isochron plot for nine shergottites, which other radiometric dating techniques indicate have a similar (possibly same) formation age of ~170 Myr (2,6,7,8). Most data are Ar-Ar analyses acquired at JSC, and inter-laboratory bias in measuring K and ^{40}Ar concentrations are not a factor. Three Shergotty data are from (9) and one Zagami datum is from (10). Samples showing larger [K] are feldspathic separates; samples with very low [K] are pyroxene separates; and samples with intermediate [K] are whole rock. The dashed lines all have the same slope and represent an isochron age of 170 Myr. It is obvious that none of the data are consistent with a K-Ar age as young as 170 Myr <u>unless</u> excess ^{40}Ar is present in all samples. Almost all of the data (including Zagami) are consistent with an ~170 Myr age and 1-2.5 $x10^{-6}$ cm^3STP/g of an excess ^{40}Ar component. Like Zagami samples, most of these additional shergottites display no evidence for the presence of martian atmospheric Ar. However, the sample of NWA-3171 impact glass does indicate the presence of martian atmosphere Ar. This datum plots far to the right, as does that for a melt sample of EET79001 (1). ***These additional meteorite data confirm the conclusion presented by (4) that $^{40}Ar_{xs}$ in Zagami was incorporated from the magma during crystallization and indicate that similar $^{40}Ar_{xs}$ concentrations were acquired by all of these related shergottites***.

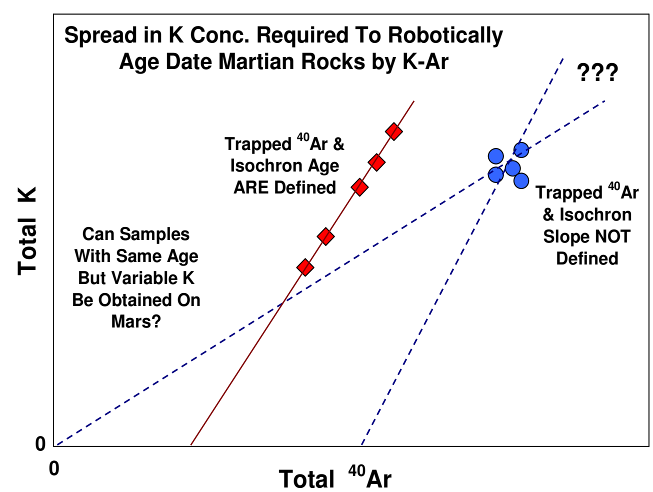
An analogous isochron plot (not shown) was made using JSC data for samples of three depleted shergottties (Dag-476, SaU-005, and Y-980459). These data are consistent with isochrons having a slope of ~470 Myr, the approximate formation age for these meteorites (11,12), and $^{40}Ar_{xs}$ contents of 5-20 $x10^{-7}$ cm^3/g. Thus, all of these analyzed shergottites appear to contain similar amounts of an excess ^{40}Ar component likely inherited from the parent magmas.

Nakhlites. An analogous K versus ^{40}Ar isochron plot for martian nakhlites presents a different situation compared to shergottites. Figure 2 shows Ar-Ar data for six nakhlites plus the Chassigny dunite. (The colored plot to the right magnifies the plot up to [K]=3,000 ppm.) Again, samples showing larger [K] are feldspathic separates, samples with very low [K] are pyroxene separates, and samples with intermediate [K] are whole rock. All data are from JSC, except that a whole rock analysis of Lafayette is from (13). Collectively, these nakhlite data define a precise (R^2=0.9986) isochron age of 1325 ±18 Myr, in excellent agreement with, but more precisely defined than the range in ages obtained on individual nakhlites by other chronometers (2,12,14,15,16). Further, because the isochron intercepts the origin ([K]= 23±103), these nakhlite samples contain essentially no $^{40}Ar_{xs}$. ***This isochron presents strong evidence that these nakhlites formed within a narrow time interval.***

Robotic K-Ar Dating. The dilemma that would be faced in dating these meteorite samples *in situ* with a robot on the martian surface is in knowing whether they did or did not contain $^{40}Ar_{xs}$. To answer this question clearly would require that a K-^{40}Ar isochron be produced from samples possessing sufficiently different [K] so as to define the isochron slope. This point is illustrated in Fig. 3. ***If the isochron slope is not defined, the presence or absence of*** $^{40}Ar_{xs}$ ***and thus the K-Ar age cannot be determined***.







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