$^{40}AR/^{39}AR$ DATA FROM THE RICHARDSON MINING DISTRICT, BIG DELTA QUADRANGLE, ALASKA

Evan Twelker, Jeffery A. Benowitz, and Travis J. Naibert

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INTRODUCTION

During the 2017 and 2018 field seasons, geologists from the Alaska Division of Geological & Geophysical Surveys (DGGS) conducted geologic mapping and sampling in the Richardson mining district southeast of Fairbanks, including parts of the Big Delta B-4, B-5, B-6, and C-6 quadrangles (fig. 1). The project area has produced approximately 122,000 ounces of gold (Singh and others, 2017), mostly from placer mines, and it includes the Uncle Sam, Montecristo, Richardson, Tower, and Hilltop lode gold exploration properties. The goal of DGGS's work in this area is to conduct a mineral-resource assessment and to build an improved understanding of the area's geology and controls on gold mineralization to facilitate industry exploration targeting.

The four $^{40}Ar/^{39}Ar$ ages reported here are all from samples at or near mid-Cretaceous intrusion-related gold prospects. Skarn hornblende from the Banner Creek area (18RN069) yielded an age of 104.0 ± 1.6 Ma, which places its formation relatively early in the magmatic history of the district. Fine-grained, holocrystalline granodiorite in the immediate vicinity of the Democrat prospect yielded a biotite cooling age of 96.9 ± 2.0 Ma (18RN568), slightly older than the white mica age reported for the nearby mineralized rhyolite dike (89.4 ± 0.7 M; McCoy and others, 1997). White mica from a sericite-pyrite altered, quartz-feldspar porphyry dike in the Rosa Pass area yielded an age of 87.0 ± 1.5 Ma (17MBW526), similar to that found by McCoy and others (1997) at Democrat. Sericite-altered intrusive rock from drill core at the Lone Tree prospect yielded an age of 93.2 ± 1.2 Ma (18ET057), somewhat younger than the $^{40}Ar/^{39}Ar$ age determined for presumably magmatic white mica from a dike at the nearby Naosi prospect on the Montecristo property (100.0 ± 0.7 Ma; Naibert and others, 2018).

The analytical data tables associated with this report are available in digital format as comma-separated value (CSV) files. Additional details about the organization of information are noted in the accompanying metadata file. All files can be downloaded from the DGGS website (http://doi.org/10.14509/30530).

Samples collected during this project will be stored at DGGS for the duration of the project and will be available for public viewing upon request. Once the project concludes, the samples and pulps will be stored at the Alaska Geologic Materials Center in Anchorage.

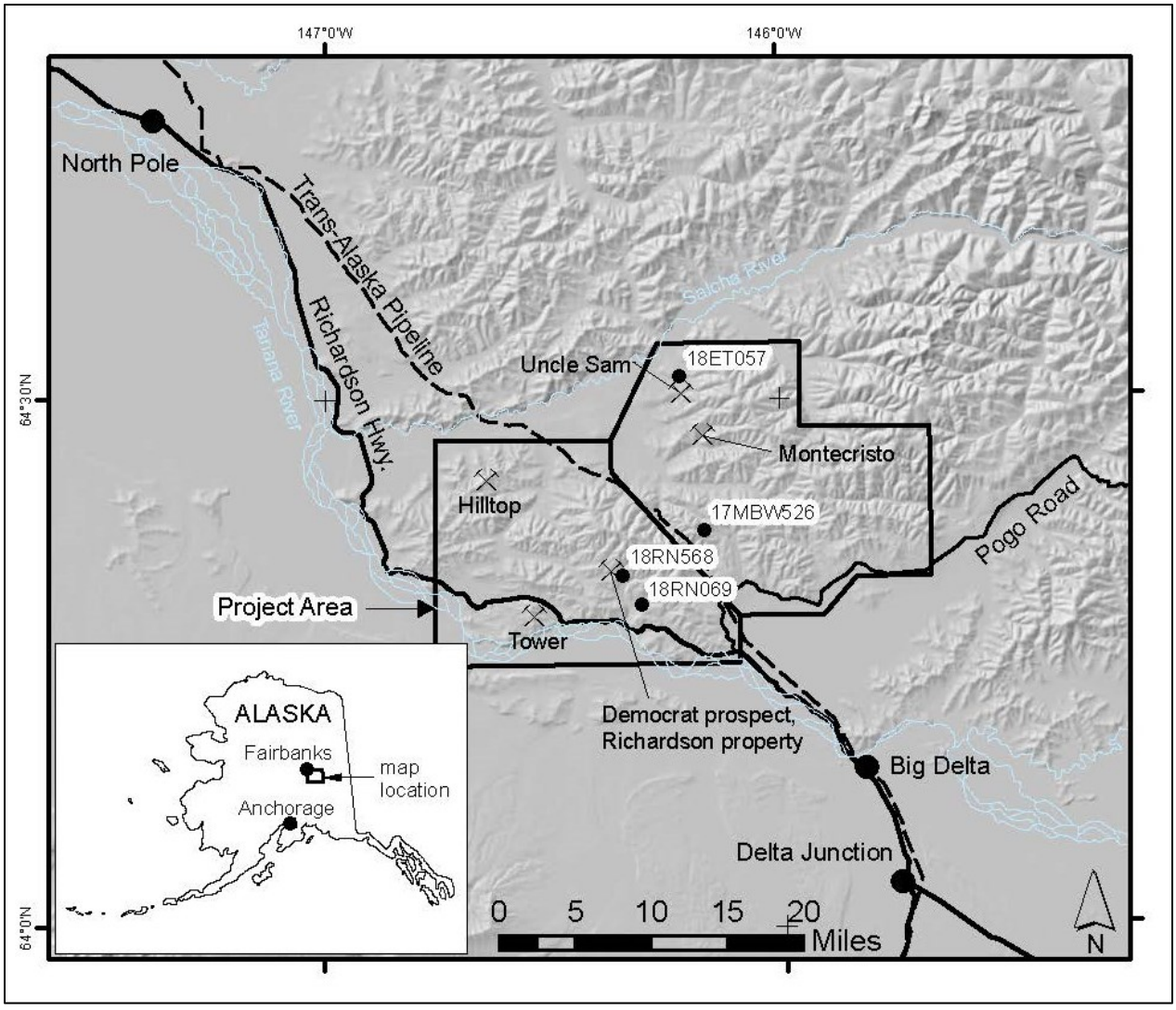

Figure 1. Map showing the location of samples in this report, the DGGS Richardson Project area, and selected gold exploration properties.

DOCUMENTATION OF METHODS

Sample Collection

Fresh, unweathered samples from surface outcrops or drill core were collected by DGGS field geologists and were selected for dating based on the presence of sufficiently large crystals appropriate for dating. Except where noted, sample location coordinates (in WGS84 datum) were obtained using GPS-enabled field tablets, with a typical reported accuracy of +/- 10 meters. Samples were examined under a binocular microscope and in thin section to select unaltered mineral phases before sample preparation.

Sample Preparation

Four rock samples were submitted to the Geochronology Laboratory at the University of Alaska Fairbanks (UAF) for $^{40}Ar/^{39}Ar$ analysis. The samples were crushed, sieved, washed, and hand-picked for muscovite, sericite, biotite, and hornblende mineral phases. The monitor mineral MMhb-1 (Samson and Alexander, 1987) with an age of 523.5 Ma (Renne and others, 1994) was used to monitor neutron flux (and calculate the irradiation parameter, J). The samples and standards were wrapped in aluminum foil, loaded into aluminum cans of 2.5-cm diameter and 6-cm height. The samples were irradiated in position 5c of the uranium-enriched research reactor at McMaster University in Hamilton, Ontario, Canada for 20 megawatt-hours.

Analytical Methods

Upon their return from the reactor, the samples and monitors were loaded into 2-mm-diameter holes in a copper tray, which was then loaded in an ultra-high-vacuum extraction line. The monitors were fused, and samples heated, using a 6-watt argon-ion laser following the technique described in York and others (1981), Layer and others (1987), and Benowitz and others (2014). Argon purification was achieved using a liquid nitrogen cold trap and a SAES Zr-Al getter at 400°C. The samples were analyzed in a VG-3600 mass spectrometer at the Geophysical Institute, University of Alaska Fairbanks. The argon isotopes measured were corrected for system blank and mass discrimination, as well as calcium, potassium, and chlorine interference reactions following procedures outlined in McDougall and Harrison (1999). Typical full-system 8-minute laser blank values (in moles) were generally 2×10^{-16} mol ^{40}Ar, 3×10^{-18} mol ^{39}Ar, 9×10^{-18} mol ^{38}Ar, and 2×10^{-18} mol ^{36}Ar, which are 10–50 times smaller than the sample/standard volume fractions. Correction factors for nucleogenic interferences during irradiation were determined from irradiated CaF_2 and K_2SO_4 as follows: $(^{39}Ar/^{37}Ar)Ca = 7.06 \times 10^{-4}$, $(^{36}Ar/^{37}Ar)Ca = 2.79 \times 10^{-4}$ and $(^{40}Ar/^{39}Ar)K = 0.0297$. Mass discrimination was monitored by running calibrated air shots. The mass discrimination during these experiments was 1.3 percent per mass unit. During sample analysis, calibration measurements were made on a weekly to monthly basis to check for changes in mass discrimination with no significant variation observed during these intervals.

RESULTS AND SAMPLE DESCRIPTIONS

A summary of the $^{40}Ar/^{39}Ar$ results is provided in table 1 and in the accompanying digital data tables, with ages quoted to the ± 1-sigma level and calculated using the constants of Renne and others (2010). The integrated age is the age given by the total gas measured and is equivalent to a potassium-argon (K-Ar) age. Age spectra, Ca/K, and Cl/K plots are included in the appendix. The spectrum provides a plateau age if three or more consecutive gas fractions represent at least 50 percent of the total gas release and are within two standard deviations of each other (Mean Square Weighted Deviation [MSWD] less than 2.5). When a spectrum did not provide a plateau age under the above definition, a weighted-average age was calculated. Below we provide sample descriptions and additional discussion of the results of each age analysis, noting our preferred age determination.

18RN069 – Hornblende skarn, Banner Creek area

Sample description (from field notes, thin section petrography): Hornblende-bearing skarn; green-black, massive, recrystallized; grain size: 1.0 to 40.0 mm; Mineralogy: 80 percent hornblende, 0.5 mm (euhedral) to 40 mm (oikocrysts), fresh and unchloritized; 14 percent epidote, anhedral, 0.2 to 1 mm, intergrown with hornblende; plagioclase (1 percent, interstitial); trace fluorite; 5 percent limonite after unknown mineral. Weathering: pervasive; sample from outcrop.

A homogeneous hornblende separate from sample 18RN069 was analyzed. The analysis did not allow for the calculation of a plateau age determination because all the criteria for a plateau age were not met (≥ 3 consecutive steps), hence a weighted-average age is presented. The integrated age (103.0 ± 1.6 Ma) and the weighted average age (104.0 ± 1.6 Ma) are within uncertainty. We prefer the weighted average age of **104.0 ± 1.6 Ma** for sample 18RN069 because of the higher atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the documented loss.

18RN568 – Equigranular granodiorite dike near the Democrat prospect

Sample description (from field notes and thin section petrography): Granodiorite dike; white and black, equigranular, with less than 1 percent potassium feldspar phenocrysts to up to 4 mm; groundmass grain size: 0.5 to 2.0 mm; Mineralogy: 15 percent biotite (subhedral, less than 5 percent to chlorite), 25 percent quartz (anhedral; undulose extinction), 40 percent plagioclase (zoned; less than 10 percent to sericite), 15 percent potassium feldspar. Very fresh, minimal weathering or alteration; sampled from outcrop.

A homogeneous biotite separate from sample 18RN568 was analyzed. The integrated age (95.9 ± 1.4 Ma) and the plateau age (96.9 ± 2.0 Ma) are within uncertainty. We prefer the plateau age of **96.9 ± 2.0 Ma** for sample 18RN568 because of the higher atmospheric content of the lower and higher temperature-step heat release. No isochron age determination was possible because of the homogenous radiogenic content of the release.

17MBW526 – Quartz-felspar porphyry dike, altered to sericite-pyrite assemblage

Sample description (from field notes): Porphyry; white to tan, porphyritic, grain size: 0.1 to 3 mm; mineralogy: phenocryst quartz 2 percent, subhedral feldspar 1 percent, euhedral pyrite 1 percent. Quartz and altered feldspar phenocrysts in fine-grained feldspathic groundmass. Clots of white mica may be after biotite or plagioclase. Cubic pyrite to 7 mm. Quartz-sericite-pyrite alteration. Location not recorded in field; estimated to within 50 m. Sampled from float.

A homogeneous sericite separate from sample 17MBW526 was analyzed. The analysis did not allow for the calculation of a plateau age determination because all the criteria for a plateau age were not met (≥ 3 consecutive steps), hence a weighted-average age is presented. The integrated age (88.0 ± 1.1 Ma) and the weighted average age (87.0 ± 1.5 Ma) are within uncertainty. We prefer the weighted average age of **87.0 ± 1.5 Ma** for sample 17MBW526 because of the higher atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the documented loss.

18ET057- Sericite-altered intrusive rock with minor sulfide, Lone Tree prospect

Sample description (from field notes and thin section petrography): Intensely sericitized, fine-grained granite. Equigranular, with average grain size about 1 mm. Most feldspar is pervasively replaced by very fine-grained (50 micron) sericite, though some orthoclase remains unsericitized. Subhedral white mica (1 percent; 0.2-1 mm) is locally intergrown with opaque minerals and may have originated as biotite, while other white mica could have a magmatic origin. Contains minor disseminated sulfide. It was collected from drill core (hole LT-002) at the Lone Tree prospect, at a depth of 971 ft (296 m).

A homogeneous muscovite separate from sample 18ET057 was analyzed. The integrated age (93.4 ± 1.1 Ma) and the plateau age (93.2 ± 1.2 Ma) are within uncertainty. We prefer the plateau age of **93.2 ± 1.2 Ma** for sample 18ET057 because of the higher atmospheric content of the lower and higher temperature-step heat release. No isochron age determination was possible because of the homogenous radiogenic content of the release.

Table 1. Age results, including integrated age, plateau or weighted-average age, and interpretive details.

Sample	Min.	Integrated Age (Ma)	Plateau or Weighted Average Age (Ma)	Plateau Information
18RN069	HO	103.0 ± 1.6	**104.0 ± 1.6***	2 out of 9 fractions 96.1% ^{39}Ar release MSWD = 0.04
18RN568	BI	95.9 ± 1.4	**96.9 ± 2.0**	6 out of 8 fractions 91.3% ^{39}Ar release MSWD = 2.25
17MBW526	SER	88.0 ± 1.1	**87.0 ± 1.5***	2 out of 8 fractions 63.6% ^{39}Ar release MSWD = 1.97
18ET057	MU	93.4 ± 1.1	**93.2 ± 1.2**	5 out of 8 fractions 75.2% ^{39}Ar release MSWD = 1.08

Samples analyzed with standard MMhb-1 with an age of 523.5 Ma.
*Did not meet all the criteria for a plateau age, hence a weighted-average age determination is presented.
Most robust age determination in **bold**.

ACKNOWLEDGMENTS

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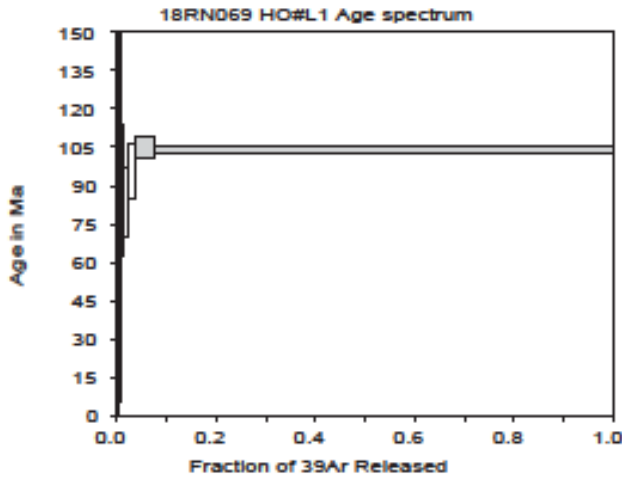
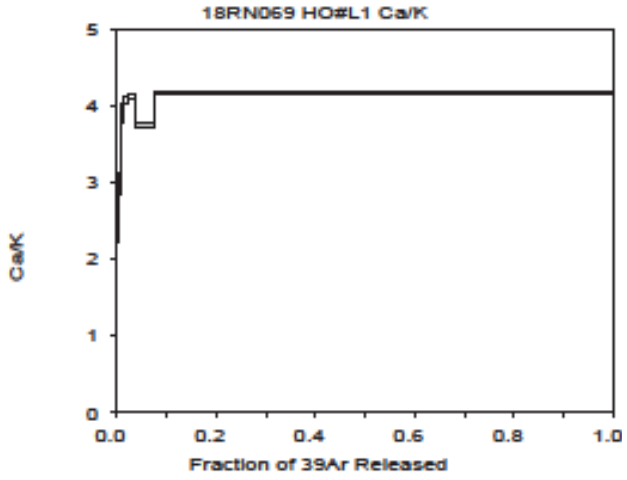
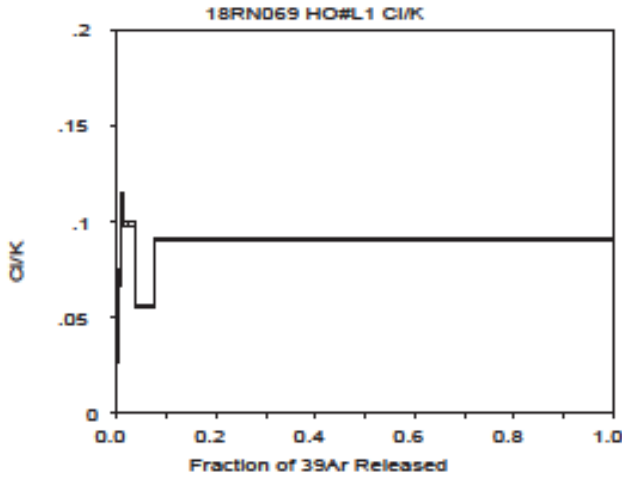
APPENDIX: PLOTS OF $^{40}AR/^{39}AR$ AGE SPECTRA AND CA/K AND CL/K RATIOS

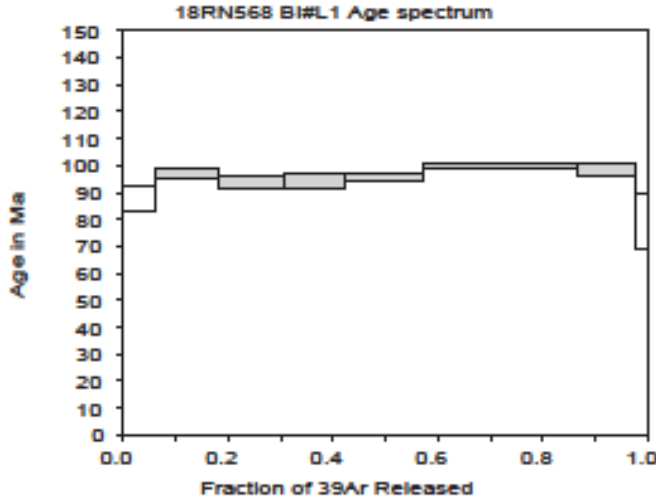
18RN069

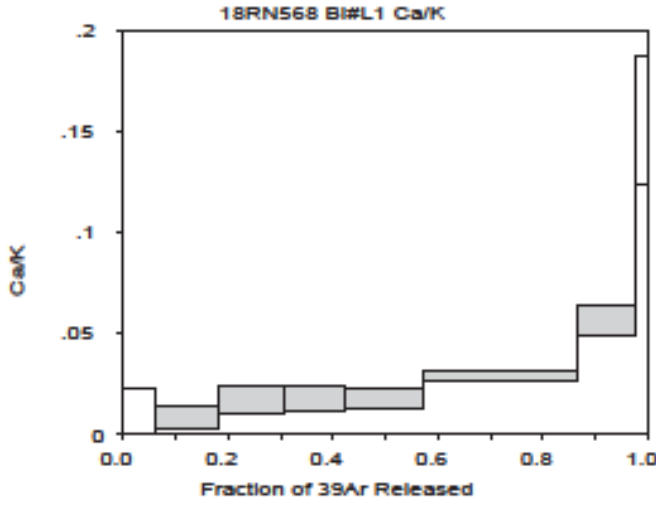


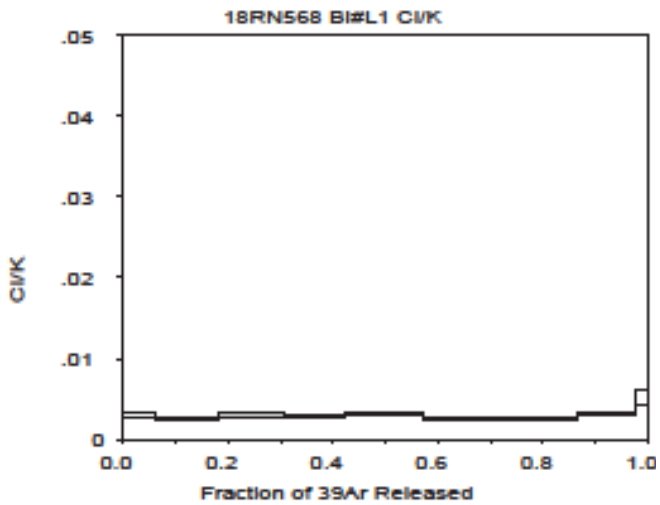




18RN568


18RN568 BI#L1 Age spectrum
Age in Ma
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


18RN568 BI#L1 Ca/K
Ca/K
.2
.15
.1
.05
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


18RN568 BI#L1 Cl/K
Cl/K
.05
.04
.03
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.01
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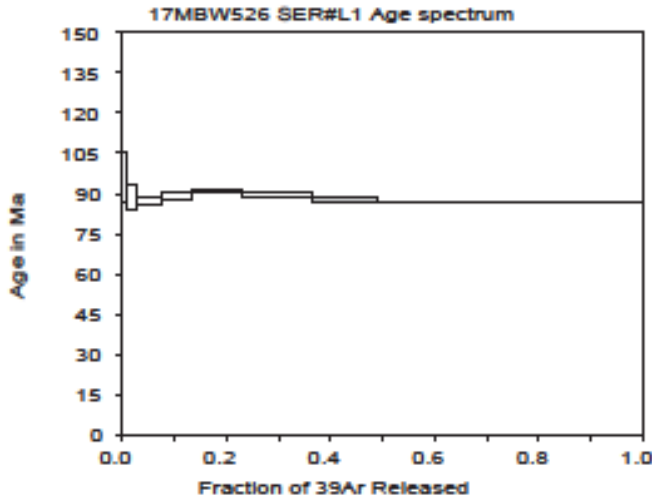
Fraction of 39Ar Released

17MBW526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Age in Ma
150
135
120
105
90
75
60
45
30
15
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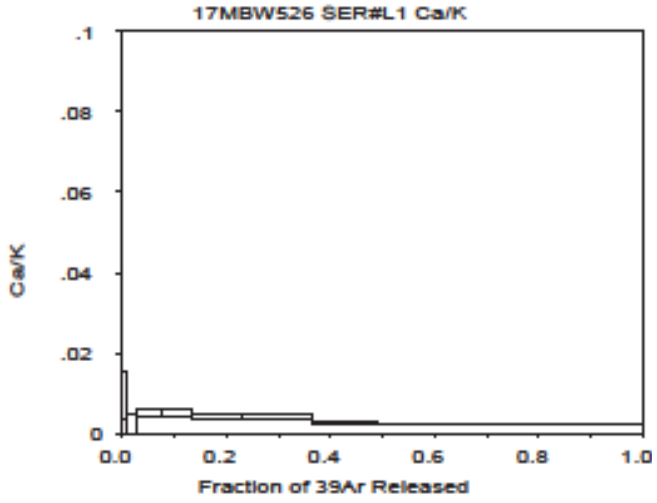
0.4
0.6
0.8
1.0
Fraction of 39Ar Released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Ca/K
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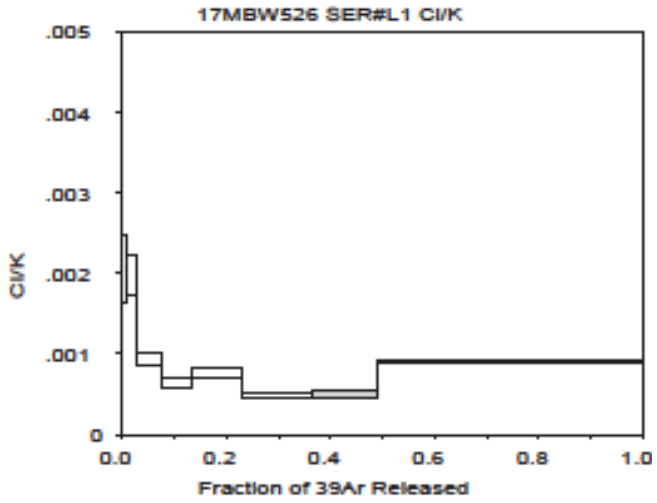
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Cl/K
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.003
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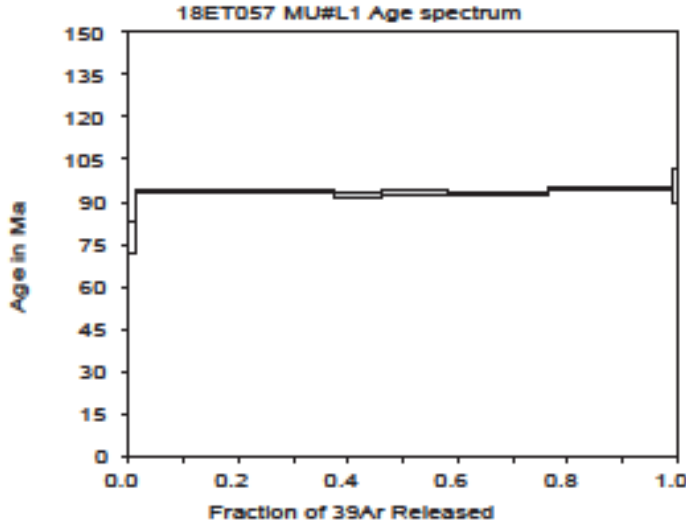
Fraction of 39Ar Released

18ET057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Age in Ma
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120
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30
15
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0.6
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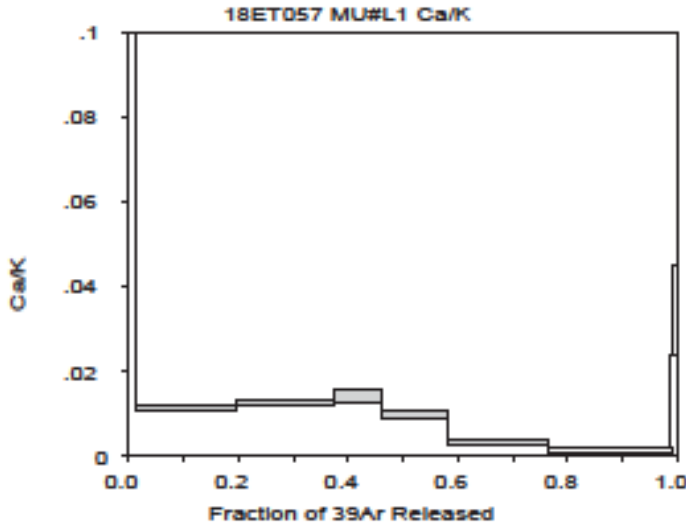
Fraction of 39Ar Released


18ET057 MU#L1 Ca/K
Ca/K
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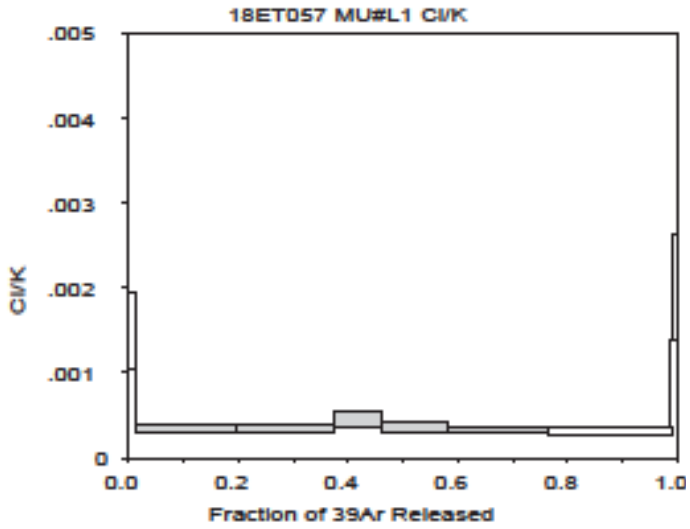
.08
.06
.04
.02
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


18ET057 MU#L1 Cl/K
Cl/K
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.003
.002
.001
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released