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Jeff A. Benowitz[1], Paul W. Layer[1], Alicja Wypych[2], and Evan Twelker[2]

INTRODUCTION

This report presents $^{40}Ar/^{39}Ar$ step-heating geochronology results for igneous and metamorphic rocks from the Alaska Division of Geological & Geophysical Surveys' (DGGS) Wrangellia Mineral Assessment project, part of a multi-year effort focusing on improving the publicly available geoscientific information for the western Wrangellia terrane. The DGGS Mineral Resources section carried out geologic mapping and sampling in the eastern Denali Highway region between Watana Creek and Paxson from July 29 through August 7, 2015. The project focused on characterization of a broad section of Wrangellia stratigraphy, including Late Triassic rocks of the Ni–Cu–Co–PGE- and Cu–Ag-mineralized Wrangellia large igneous province, as well as modern geochemical characterizations of skarn-, vein-, and basalt-hosted Cu mineralization. Published DGGS data related to this project include geophysical surveys, a geologic map, and several geochemical and geochronologic datasets (Burns and others, 2014; Twelker and others, 2015; Wypych and others, 2015; Benowitz and others, 2015). The Wrangellia Mineral Assessment project was conducted as part of the State of Alaska's *Strategic and Critical Minerals Assessment* project, an initiative designed to evaluate Alaska's potential for rare-earth elements, platinum-group elements, and other similarly supply-challenged resources in the United States.

The samples described in this report were selected and analyzed to improve our understanding of the geology and structural history of the Wrangellia Mineral Assessment project area. A metagabbro rock sample returned a Late Triassic crystallization age consistent with regional ages for Nikolai Greenstone-related magmatism; however, the two amphibole separates ages do not overlap, and have larger errors than expected due to alteration. An Early Cretaceous age obtained on a syenogranite pluton could correspond to similar ages of an Early Cretaceous porphyry event within the Grubstake Cu–Au porphyry system, Slana Region (Meyers and others, 2015). Finally, we obtained Oligocene ages for a dacitic dike and a schist; the schist age constrains the timing of displacement on a thrust fault in the area.

Analyses were performed by the University of Alaska Fairbanks (UAF) Geochronology Laboratory, and results were reported by Jeff Benowitz and Paul Layer. Products included in this data release are a summary of sample collection methods, the laboratory report, analytical data tables and associated metadata, and plots of the $^{40}Ar/^{39}Ar$ age spectra and Ca/K and Cl/K ratios. All components of this data release are available on the DGGS website, http://doi.org/10.14509/29699.

METHODOLOGY

Sample Collection Techniques

Field geologists collected fresh, unweathered samples from surface outcrops; samples were selected based on the presence of sufficiently large crystals to enable mineral separations. Samples were collected with location coordinates (WGS84 datum) determined using handheld GPS units (Trimble Juno T5), with a reported accuracy

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of about 10 m. Before processing, the samples were examined under a binocular microscope, or thin sections were prepared and scrutinized, to avoid analyzing altered mineral phases.

Analytical Methods

Four samples were submitted to the Geochronology Laboratory at UAF for $^{40}Ar/^{39}Ar$ analysis. Laboratory staff crushed, sieved, washed, and hand-picked pure mineral phase separates of datable minerals (biotite, muscovite, or hornblende). 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 and 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 of McMaster University in Hamilton, Ontario, Canada for 20 megawatt-hours.

Upon their return from the reactor, the samples and neutron-flux monitors were loaded into 2-mm-diameter holes in a copper tray that was then loaded into 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 an 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. While doing our experiments, calibration measurements were made on a weekly to monthly basis to check for changes in mass discrimination, with no significant variation seen during these intervals.

DISCUSSION

A summary of all the $^{40}Ar/^{39}Ar$ results is provided in table 1, with all 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. Each spectrum yields 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). Below we provide additional discussion of the results of each age analysis, noting our preferred age determination.

15ET134

Metagabbro; dark green, altered, massive, and porphyritic; grain size 1–4 mm; mineralogy – anhedral plagioclase 40%, amphibole 60%. Anhedral relicts of feldspar(?) phenocrysts in a fine-grained, often chloritized amphibole groundmass. The feldspar relicts are replaced by a mixture of chlorite and sericite; amphibole is anhedral, with hornblende cores overgrown on the edges by actinolite(?). Unidentified skeletal opaque mineral (3 mm) disseminated throughout the sample. Mapped as Kqd-p (pyroxene–hornblende diorite, porphyry phase) by Kline and others (1990).

Hornblende (HO)
(Run #1)

An amphibole separate from sample 15ET134 was analyzed. The integrated age (271.4 ± 6.4 Ma) and the plateau age (219.1 ± 7.4 Ma) are not within error. No isochron age determination was possible because of the homogenous radiogenic content of the release.

Hornblende (HO)

(Run #2)

An amphibole separate from sample 15ET134 was analyzed. The integrated age (262.7 ± 3.7 Ma) and the plateau age (201.2 ± 4.6 Ma) are not within error. No isochron age determination was possible because of the homogenous radiogenic content of the release.

Overall

The mineral separate from this sample is likely actinolite, based on both runs having Ca/K ratios >50. Both runs produced Triassic Period age determinations, but the plateau ages from both runs are not within error. We prefer a Triassic age interpretation for this sample.

15DR140

Syenogranite; white to light pink on weathered surface and white on fresh surface. Holocrystalline, hypidiomorphic, grain size 1–7 mm; mineralogy – potassium feldspar 40%, plagioclase 25%, interstitial quartz 25%, elongate hornblende 8%, and biotite flakes 2%. Both the biotite and hornblende are black and look relatively unweathered. Large, subhedral to euhedral, up to 7-mm-long potassium feldspars and 5-mm-long plagioclase (slightly sericitized) form the majority of the rock. 3-mm-long hornblende crystals are subhedral to euhedral and, like biotite, often slightly chloritized. Biotite forms books that are medium grained. Mapped as Unit **grs1** (post-accretionary granitic unit 1) of Nokleberg and others (2015).

Hornblende (HO)

A homogeneous hornblende separate from sample 15DR140 was analyzed. The integrated age (354.3 ± 122.0 Ma) and the plateau age (138.4 ± 0.8 Ma) are not within error. We prefer the plateau age of **138.4 ± 0.8 Ma** for sample15DR140 because of the anomalously old age of the lower temperature step-heat release. No isochron age determination was possible because of the homogeneous radiogenic content of the release.

15LL175

Porphyry dike; light gray, unweathered, porphyritic; grain size 0.1–7 mm; mineralogy – subhedral feldspar 20%, euhedral hornblende 10%, anhedral quartz 2%, subhedral biotite 2%, opaque 1%, and groundmass 65%. Some feldspar clusters represent lithic fragments (about 2% of the rock); the phenocrysts (up to 7 mm in diameter) are often rounded on the edges and have undulatory extinction. Rare quartz (5 mm in diameter) is resorbed on the edges, whereas hornblende and rare biotite crystals are subhedral to euhedral and significantly smaller. The groundmass looks recrystallized, and is a very-fine-grained mixture of quartz, feldspar, and amphibole ± sericite. The rock appears to be intrusive due to its relationship with surrounding serpentinite. This age is in agreement with multiple K-Ar ages obtained on Susitna Batholith and unnamed rhyodacite tuff of Nokleberg and others (1992).

Biotite (BI)

A homogeneous biotite separate from sample 15LL175 was analyzed. The integrated age (29.1 ± 0.2 Ma) and the plateau age (29.3 ± 0.2 Ma) are within error. We prefer the plateau age of **29.3 ± 0.2 Ma** for sample 15LL175 because of the high atmospheric content of the lower temperature step-heat release. No isochron age determination was possible because of the homogenous radiogenic content of the release.

15LL170

Schist; foliated; mineralogy – quartz 49%, biotite 20%, feldspar 15%, white mica 15%, graphite 1%, cordierite 0.1%. Mica, interfoliated with quartz ± feldspar layers, defines foliation. Large porphyroblasts of feldspar (up to 5 mm in diameter) are recrystallized, with resorbed quartz zones and aluminum silicates(?), are rotated, and have quartz shadows forming S-C fabric. About 15-m long and 1-m wide zone found within a dunite body. Bears a strong resemblance to Maclaren schist of Nokleberg and others (2015).

Biotite (BI)

A homogeneous biotite separate from sample 15LL170 was analyzed. The integrated age (33.1 ± 0.2 Ma) and the plateau age (33.2 ± 0.2 Ma) are within error. We prefer the plateau age of **33.2 ± 0.2 Ma** for sample 15LL170 because of the high atmospheric content of the lower temperature step-heat release. No isochron age determination was possible because of the homogeneous radiogenic content of the release.

White Mica (MU)

A homogeneous white mica separate from sample 15LL170 was analyzed. The integrated age (40.5 ± 0.4 Ma) and the plateau age (35.0 ± 10.8 Ma) are within error. We prefer the plateau age of **35.0 ± 10.8 Ma** for sample 15LL170 because of the high atmospheric content of the lower and higher temperature step-heat releases. No isochron age determination was possible because of the homogeneous radiogenic content of the release. Based on the overall high atmospheric content (>85%) and low gas release, this mineral separate is likely not muscovite.

ACKNOWLEDGMENTS

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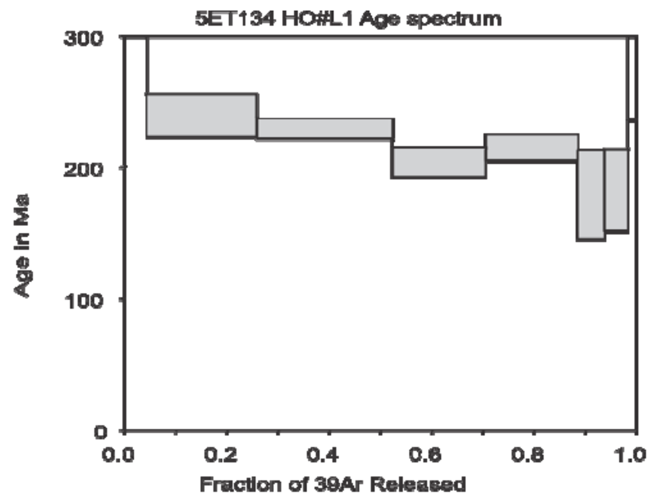
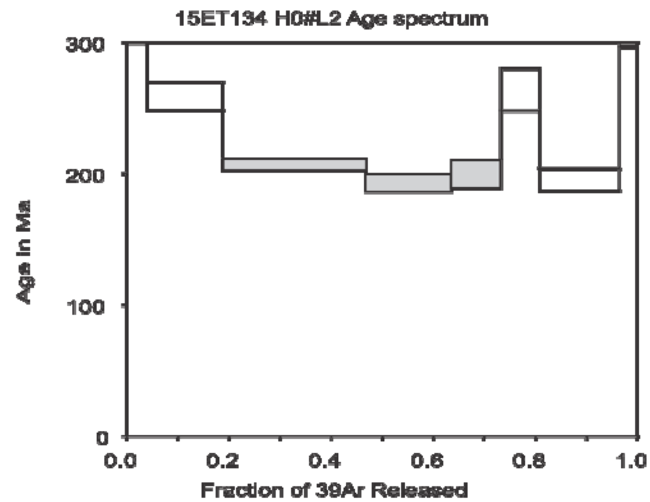
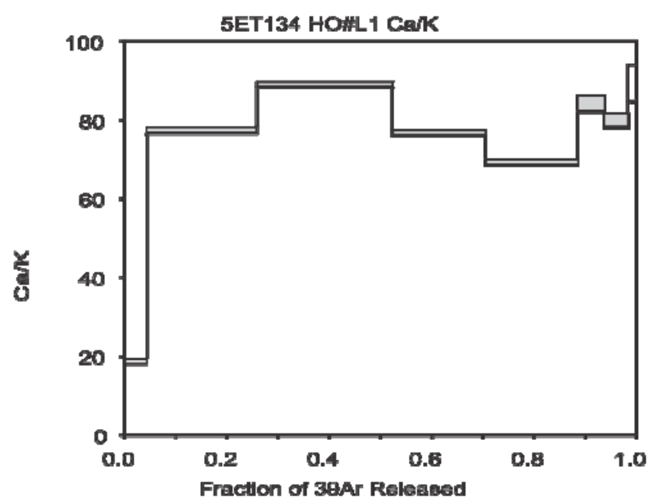
APPENDIX: Plots of $^{40}Ar/^{39}Ar$ age spectra and Ca/K and Cl/K ratios

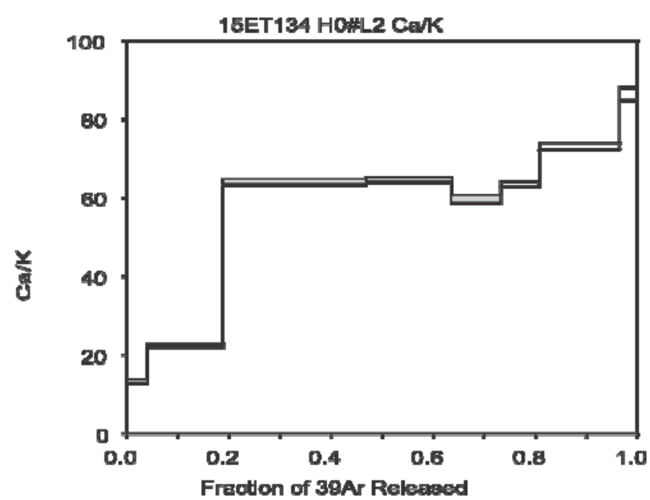
Gray-shaded steps were used for plateau age determinations.

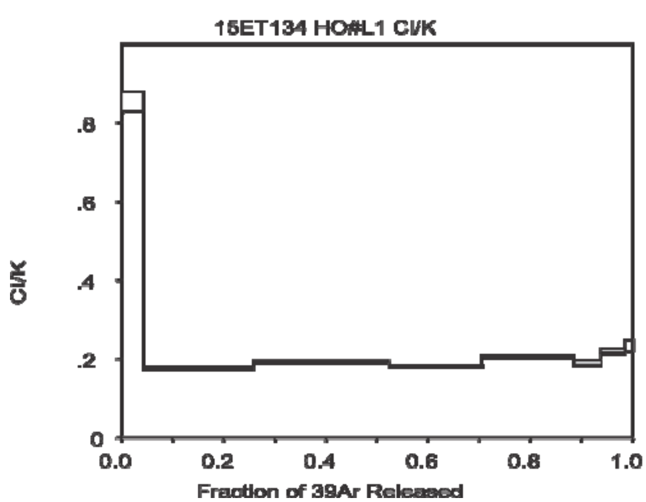
Sample 15ET134

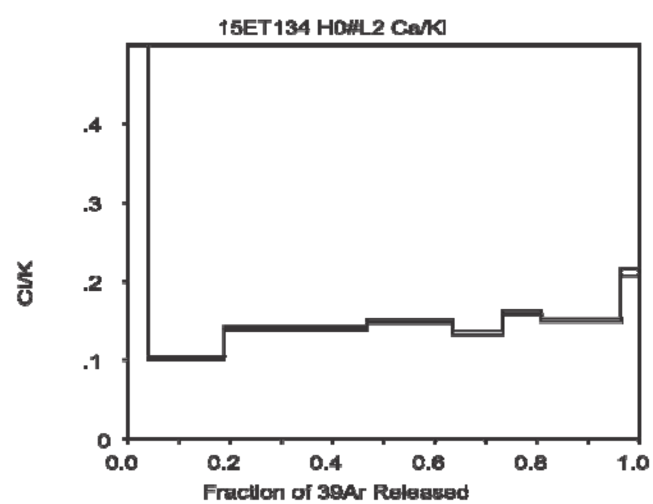












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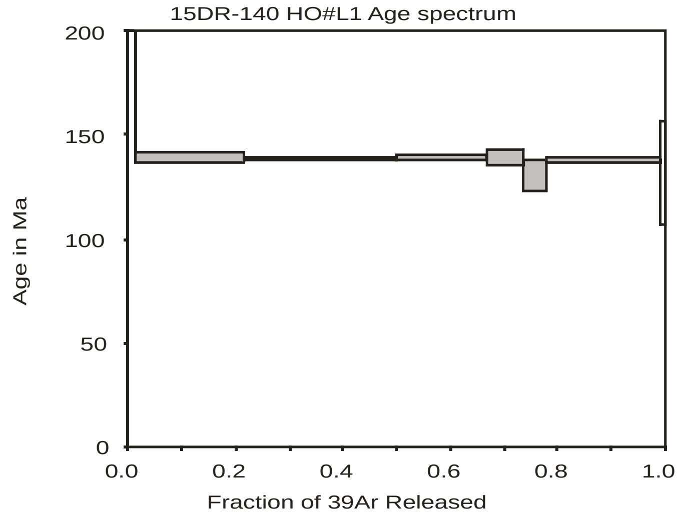

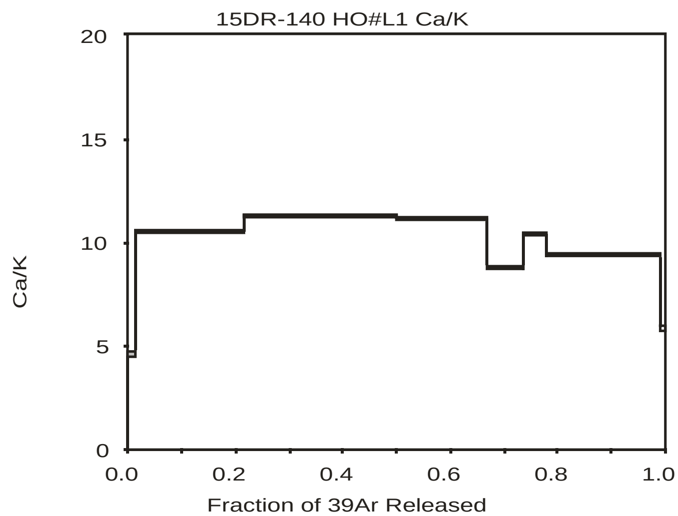

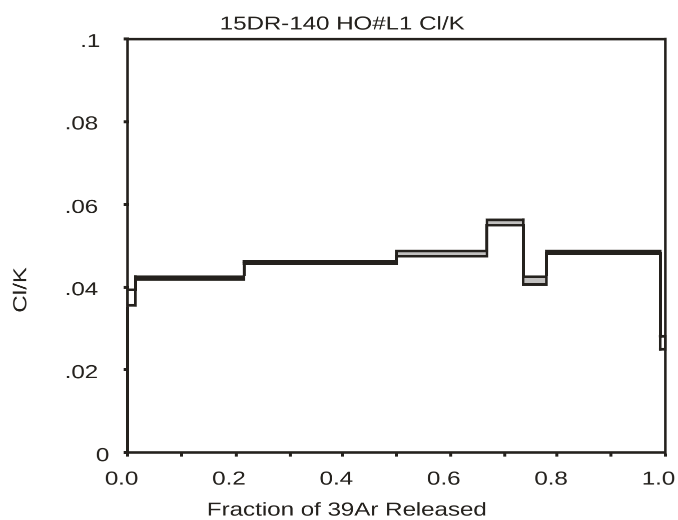

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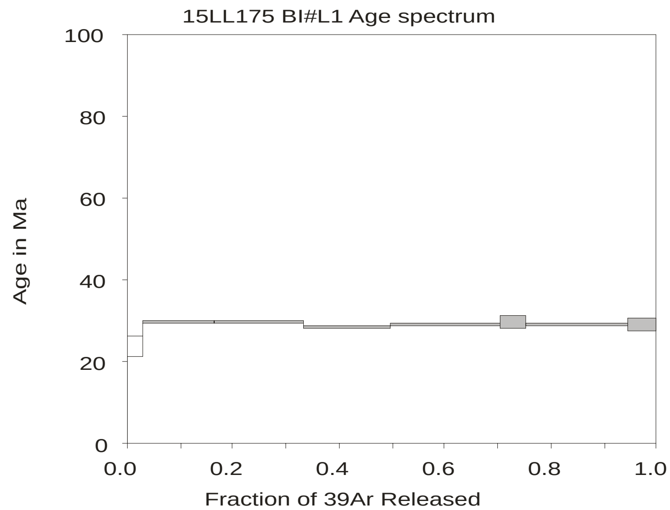

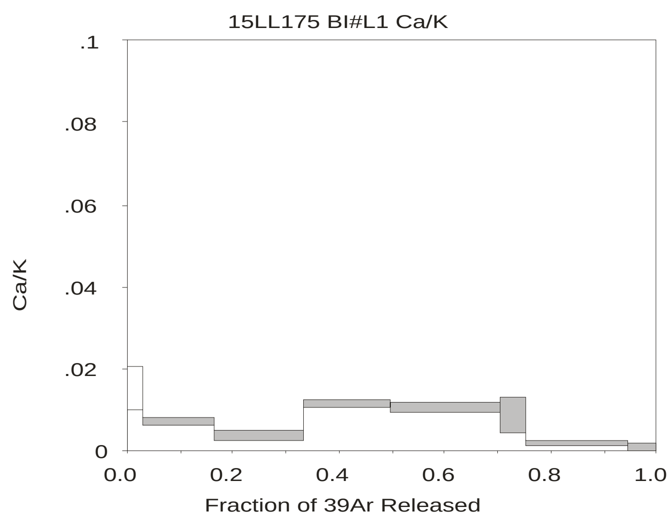

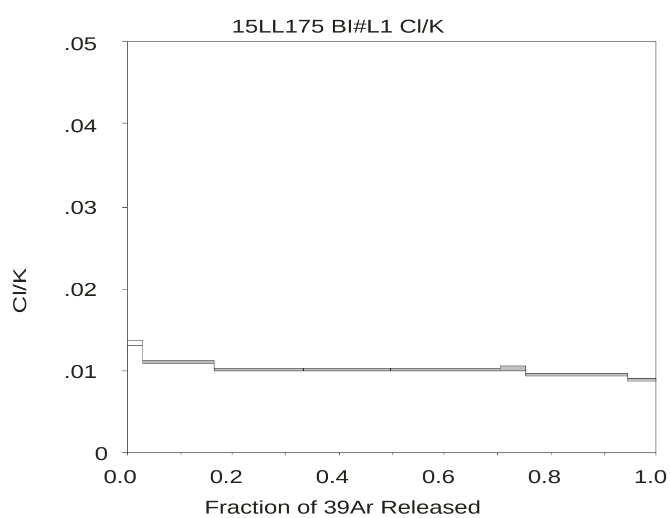

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