Alaska Division of Geological & Geophysical Surveys

Raw Data File 2014-21
Version 1.0.1

^{40}AR/^{39}AR DATA, STYX RIVER MAP AREA, LIME HILLS C-1 QUADRANGLE, ALASKA

by

Jeff A. Benowitz, Paul W. Layer, and Karri R. Sicard

$2.00

December 2014

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STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
Division of Geological & Geophysical Surveys
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Fairbanks, Alaska 99709-3707

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^{40}AR/^{39}AR DATA, STYX RIVER MAP AREA, LIME HILLS C-1 QUADRANGLE, ALASKA

by

Jeff A. Benowitz[1], Paul W. Layer[1], and Karri R. Sicard[2]

ABSTRACT

This DGGS Raw Data File presents ^{40}Ar/^{39}Ar age dating results for selected igneous rocks encountered in the Styx River area of the western Alaska Range. Crystallization ages on biotite and hornblende from plutonic rocks range from about ~60 to ~63 Ma, while a sericite alteration age in plutonic rocks altered by a dike swarm also is around ~63 Ma. Sericite alteration associated with a copper–molybdenum porphyry ranges from ~10 to ~11 Ma. Analyses were performed by the University of Alaska Fairbanks Geochronology Laboratory, and results were reported by Paul Layer and Jeff Benowitz. This data release includes the following products: 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, Ca/K, and Cl/K ratios. All components of this data release are downloadable from the DGGS website, doi:10.14509/29134, at no charge.

INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) Mineral Resources Section conducted four weeks of fieldwork on the Styx River Project in the Lime Hills C-1 Quadrangle during summer 2013 as part of the state-funded Airborne Geophysical/Geological Mineral Inventory (AGGMI) Program. This work included refining contacts, subdividing major map units, and identifying new dikes and faults. The resulting 1:63,360-scale geologic map and supporting geochemical (Sicard and others, 2014), petrologic, and geochronologic data will foster a better understanding of the geology and mineral potential of the area.

The study area lies in the Styx River and Farewell geophysical survey tracts, located about 100 miles northwest of Anchorage in the Lime Hills, Tyonek, Talkeetna Mountains, and McGrath quadrangles. Mineral exploration within the geophysical survey area is active and ongoing for deposit types including porphyry copper ± molybdenum ± gold, reduced intrusion-related gold, and polymetallic veins in the geophysical survey tracts is active and ongoing. Lead–zinc skarns, molybdenum-bearing quartz veins, sediment-hosted base-metal, platinum-group-element, and rare-earth-element deposit types are also present. The majority of these mineral occurrences are related to numerous Cretaceous- and Tertiary-age plutonic complexes, dike swarms, and

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volcanic fields. Tertiary plutons in the mapping area with similarities to the copper–gold-bearing Tertiary Mount Estelle diorite highlight new areas of potential Cu–Au–Mo mineralization.

We selected samples for $^{40}Ar/^{39}Ar$ analysis to characterize and distinguish plutonic complexes and mineralization events, and to unravel the magmatic, structural, and metallogenic evolution of the area. The study area was selected primarily because it was located in the survey tracts with the largest number of plutons and volcanic rocks according to previous regional geologic mapping.

SAMPLE COLLECTION TECHNIQUES

Field geologists collected rock samples from surface outcrops. Care was taken to collect fresh, unweathered samples displaying sufficiently large grains for the mineral separate samples, when possible. Location coordinates (WGS84 datum) were collected using handheld GPS units, with a typical reported accuracy of about 10 m or less. Prior to processing, thin sections of the samples were petrographically inspected to ensure that mineral specimens selected for magmatic crystallization dating were free of alteration, and that samples with sericite alteration had coarse enough sericite present for mineral separation.

ANALYTICAL METHODS

For $^{40}Ar/^{39}Ar$ analysis, rock samples were submitted to the Geochronology Laboratory at the University of Alaska Fairbanks (UAF) where they were crushed, sieved, washed, and hand-picked for hornblende, biotite, and/or sericite 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 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 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 (2013). 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 UAF Geophysical Institute. 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 min 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.

Mass discrimination was monitored by running calibrated air shots. The mass discrimination during these experiments was 1.3 percent per mass unit. Throughout the data collection process, weekly to monthly calibration measurements were made to check for changes in mass discrimination, with no significant variation seen during these intervals. 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 $(^{40}Ar/^{39}Ar)K = 0.0297$. The Ca/K ratio is determined from ^{37}Ar produced from ^{40}Ca and ^{39}Ar produced from ^{39}K, and the Cl/K ratio as determined from ^{38}Ar produced from ^{37}Cl and ^{39}Ar produced from ^{39}K.

DISCUSSION

A summary of all the $^{40}Ar/^{39}Ar$ analyses is included the accompanying data distribution file set, 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. 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] <2.5). All samples show well-defined plateaus. Weighted averages of the plateaus are reported. Below, we provide additional discussion of the results of each age analysis and note our preferred age determination.

13DR035A: Sericite (SER) from an altered mafic dike in the Tertiary Mount Estelle pluton

A sericite separate from sample **13DR035A** was analyzed. The integrated age (63.7 ± 0.5 Ma) is within error of both the plateau age (63.8 ± 0.4 Ma) and the isochron age (63.9 ± 0.4 Ma). We prefer the isochron age of **63.9 ± 0.4 Ma** because of similar precision to the plateau age and because the isochron age determination takes into account the initial ^{40}Ar component.

This represents an alteration age because we dated interstitial sericite in altered Mount Estelle plutonic rock. The sample came from an area on strike with a dike swarm that introduced new dike material to the north, but this age is more consistent with hydrothermal alteration of the original Mount Estelle Pluton during circulation of late stage magmatic fluids.

13RN204A: Sericite (SER) within felsite overprinted by a quartz-sericite-pyrite alteration zone in the Merrill Pass pluton that was altered in porphyry-style mineralization as in the Copper Joe prospect area

A sericite separate from sample **13RN204A** was analyzed. The integrated age (12.7 ± 0.2 Ma) is not within error of either the plateau age (11.5 ± 0.1 Ma) or the isochron age (11.3 ± 0.2 Ma). We prefer the plateau age of **11.5 ± 0.1 Ma** because of the slightly higher precision over the isochron age determination.

This result represents an alteration age of the host rock in a pervasive quartz–sericite–pyrite overprint zone with stockwork quartz–molybdenite veinlets.

13LF205A: Sericite (SER) from a selvedge of a chalcopyrite-bearing quartz vein cutting through an altered porphyry-style mineralization zone in the Merrill Pass pluton

A sericite separate from sample **13LF205A** was analyzed. The integrated age (11.7 ± 0.1 Ma) is not within error of either the weighted average age (MSWD >2.5; 10.7 ± 0.1 Ma). No isochron age determination was possible because of the homogenous radiogenic content of the step releases used for the weighted average age determination. We prefer the weighted average age of **10.7 ± 0.1 Ma** because the first few heating steps showed anomalous older ages and high atmospheric content, which are both associated with alteration.

This result represents an alteration age because sericite was dated and the pyrite–chalcopyrite–molybdenite-bearing quartz vein was introduced to the host rock subsequent to original crystallization of the pluton.

13RN312A: Biotite (BI) from the Mount Estelle pluton

A biotite separate from sample **13RN312A** was analyzed. The integrated age (61.9 ± 0.2 Ma) is within error of both the plateau age (62.0 ± 0.3 Ma) and the isochron age (62.0 ± 0.2 Ma). We prefer the isochron age of **62.0 ± 0.2 Ma** because of the slightly higher precision of the plateau age and because the isochron age determination takes into account the initial ^{40}Ar component.

We interpret this age as the magmatic crystallization of this part of the copper–gold-bearing Mount Estelle biotite hornblende granodiorite, which has multiple phases of intrusion. This age differs from previously published ~70.1 to ~66.7 Ma ages to the northeast, extending the timespan of plutonism in this large complex. This date correlates well with the hornblende date from the same rock (below).

13RN312A: Hornblende (HO) from the Mount Estelle pluton

A hornblende separate from sample **13RN312A** was analyzed. The integrated age (62.4 ± 0.6 Ma) is within error of both the plateau age (62.0 ± 0.5 Ma) and the isochron age (61.8 ± 0.5 Ma). We prefer the isochron age of **61.8 ± 0.5 Ma** because of the similar precision to the plateau age and because the isochron age determination takes into account the initial ^{40}Ar component.

We interpret this age as the magmatic crystallization of the copper–gold-bearing Mount Estelle biotite hornblende granodiorite, which has multiple phases of intrusion. This age differs from previously published ~70.1 to ~66.7 Ma ages to the northeast, extending the timespan of plutonism in this large complex. This date correlates well with the biotite date from the same rock.

13LF168A: Biotite (BI) from a diorite in the South Fork pluton

A biotite separate from sample **13LF168A** was analyzed. The sample produced a stair-stepping upward age spectrum associated with loss/alteration. The integrated age (62.8 ± 0.2 Ma) is within broad error of the weighted average age (MSWD >2.5; 63.5 ± 0.4 Ma). No isochron age determination was possible because of the documented loss. We prefer the weighted average age of **63.5 ± 0.4 Ma** because it takes into account the documented loss (~2%).

This age represents a magmatic crystallization age for this dioritic phase of the pluton, and correlates well with the hornblende from the same sample (below).

13LF168A: Hornblende (HO) from a diorite in the South Fork pluton

A hornblende separate from sample **13LF168A** was analyzed. During sample preparation the altered state of the mineral phases was noted. The sample produced an irregular, hump-shaped age spectrum that is often associated with hornblende alteration. The integrated age (65.3 ± 0.4 Ma) is within broad error of both the weighted average age (non-consecutive steps; 65.1 ± 0.5 Ma) and the isochron age (63.8 ± 0.4 Ma). We prefer the isochron age of **63.8 ± 0.4 Ma** as an approximation of the geologic age of this mineral phase because of the slightly higher precision of the weighted average age and because the isochron age determination takes into account the initial ^{40}Ar component.

This age represents a magmatic crystallization age for this dioritic phase of the pluton, and correlates well with the biotite from the same sample.

ACKNOWLEDGMENTS

This project is funded through the Governor's Strategic and Critical Minerals Assessment Capital Improvement Project, a component of the ongoing Alaska Airborne Geophysical/Geological Mineral Inventory Program funded by the Alaska State Legislature and managed by the State of Alaska, Department of Natural Resources, Division of Geological & Geophysical Surveys. Samples in this report were collected, described, logged, and prepared in part by Larry Freeman, David Reioux, Karri Sicard, Evan Twelker, Erik Bachmann, Amy Tuzzolino, and Alicja Wypych of DGGS and by Rainer Newberry of the University of Alaska Fairbanks Department of Geology & Geophysics.

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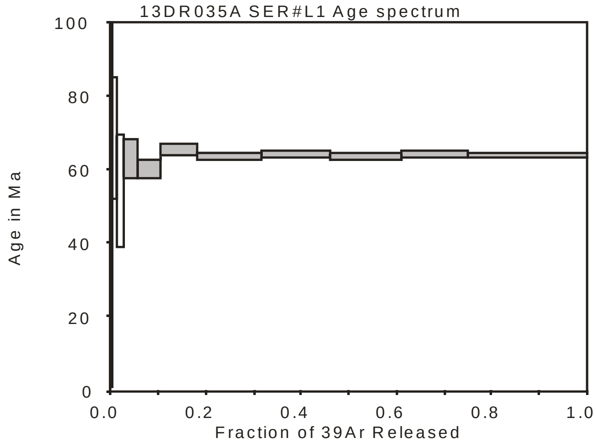
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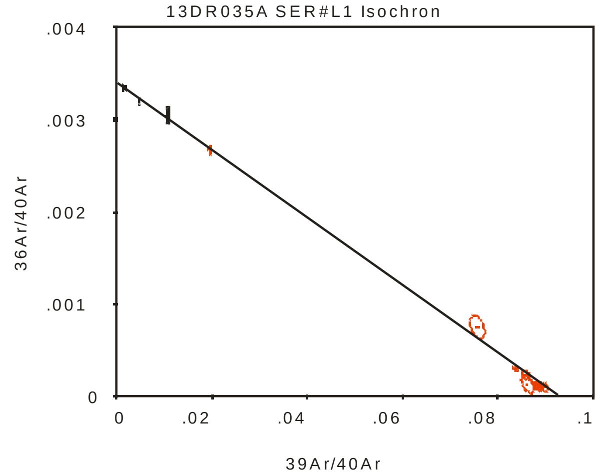
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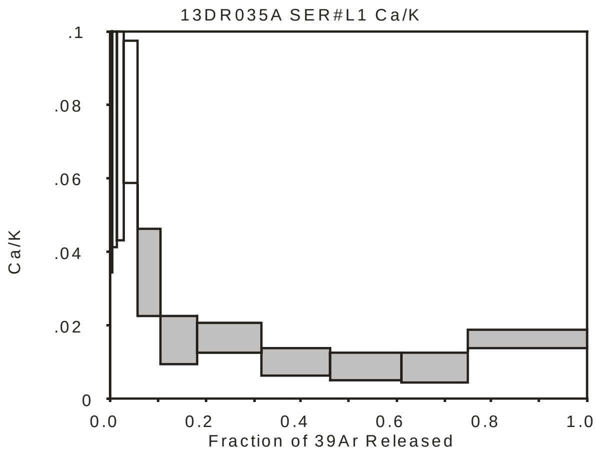
39Ar/40Ar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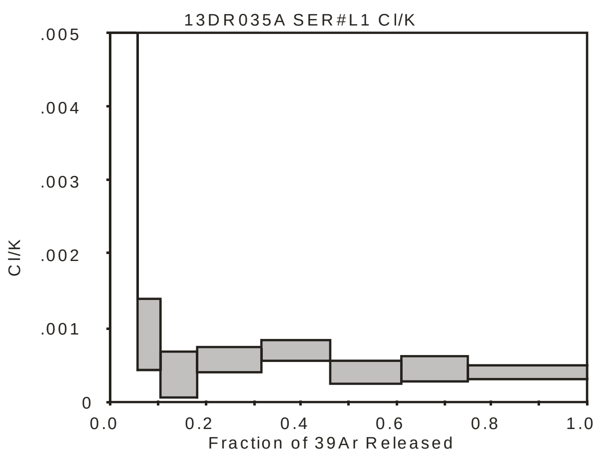
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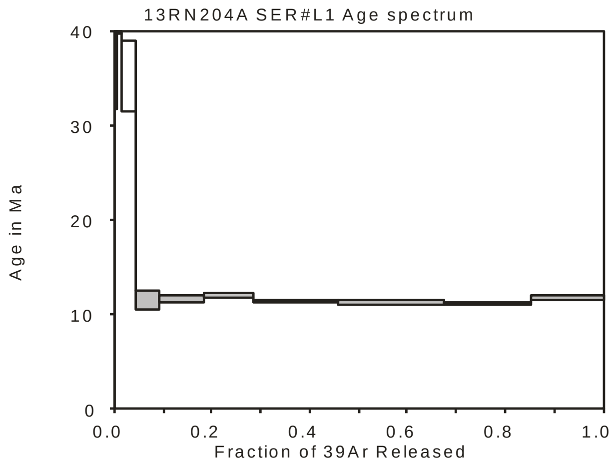
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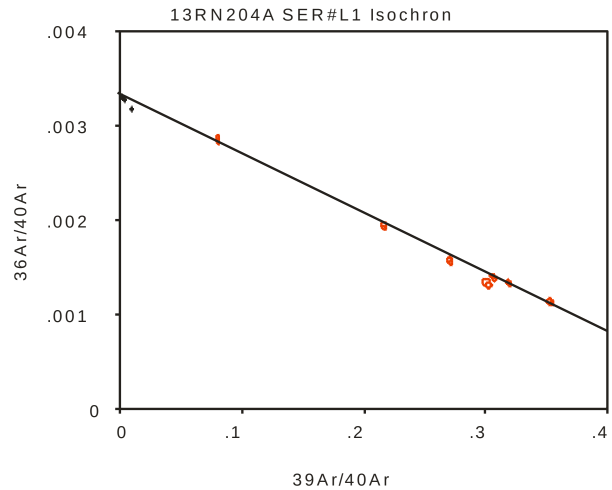
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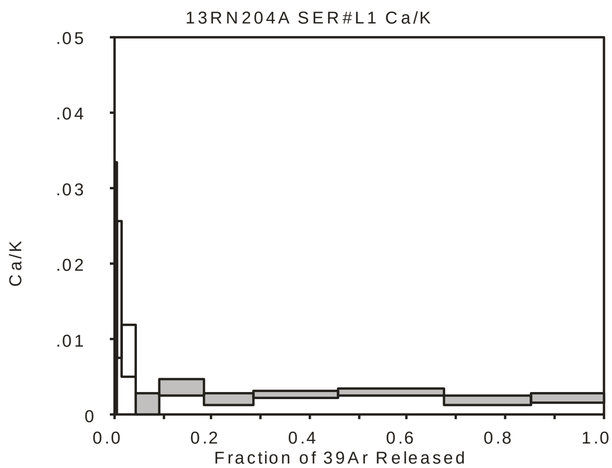
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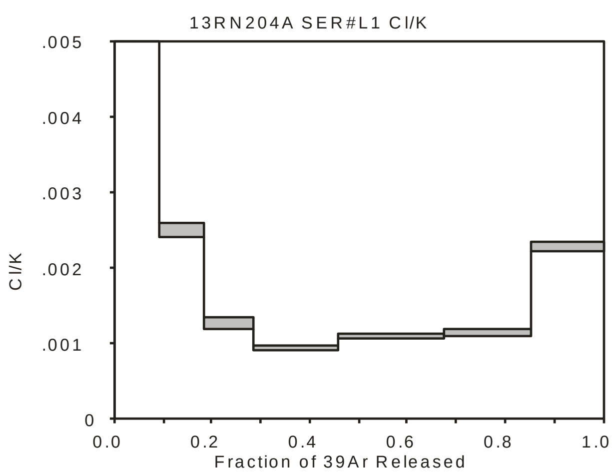
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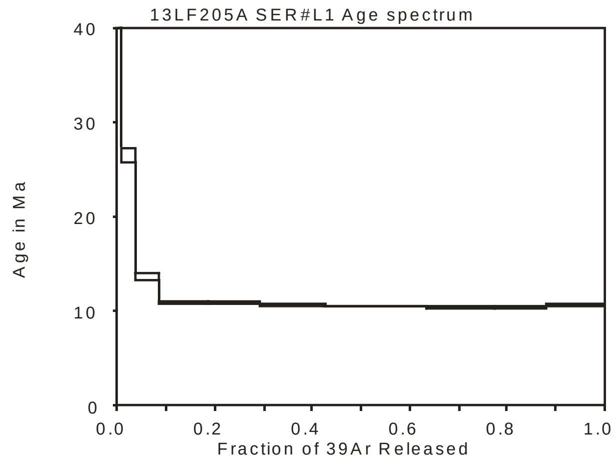
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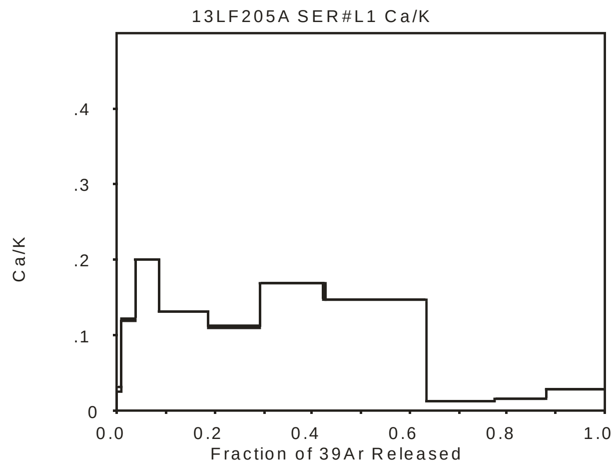
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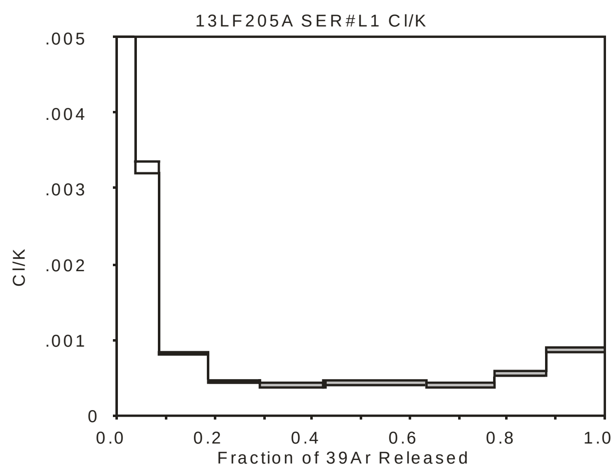
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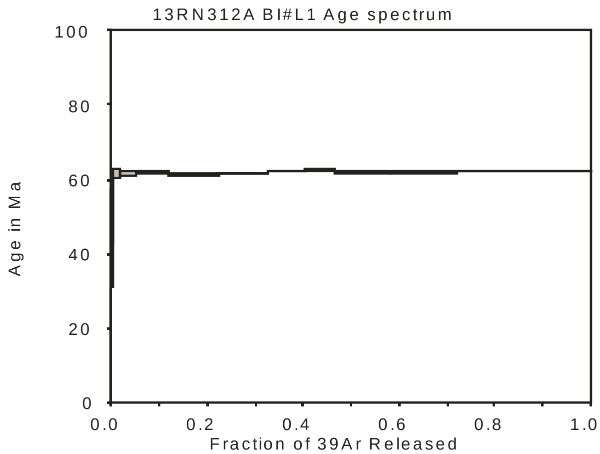
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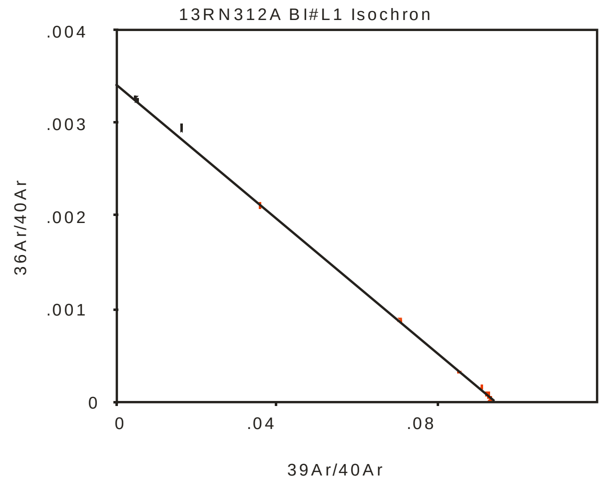
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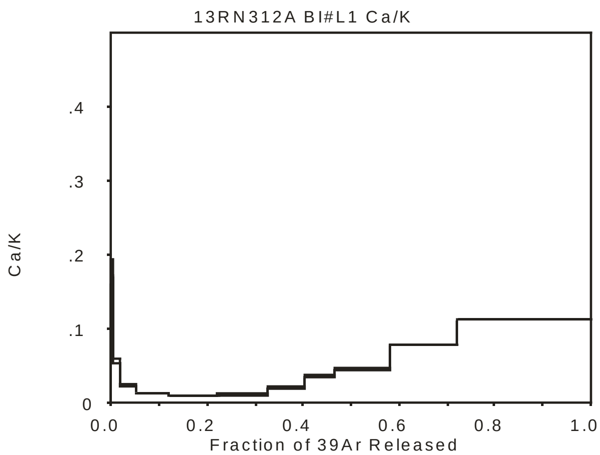
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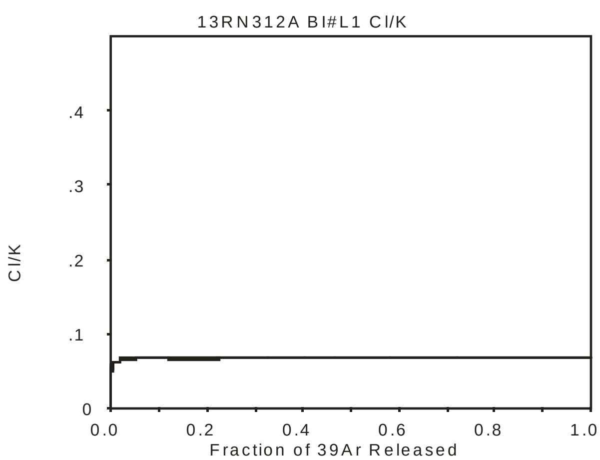
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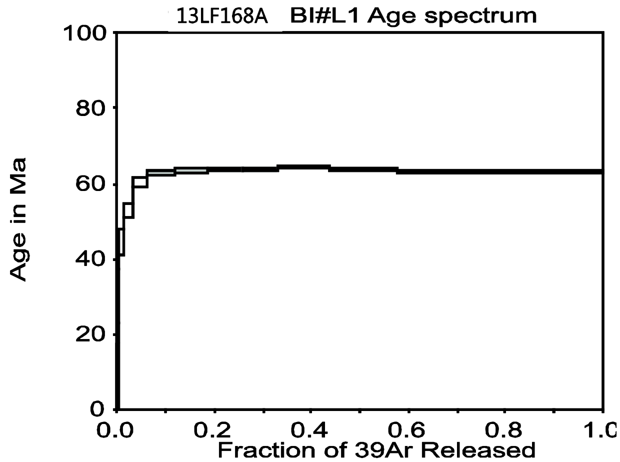
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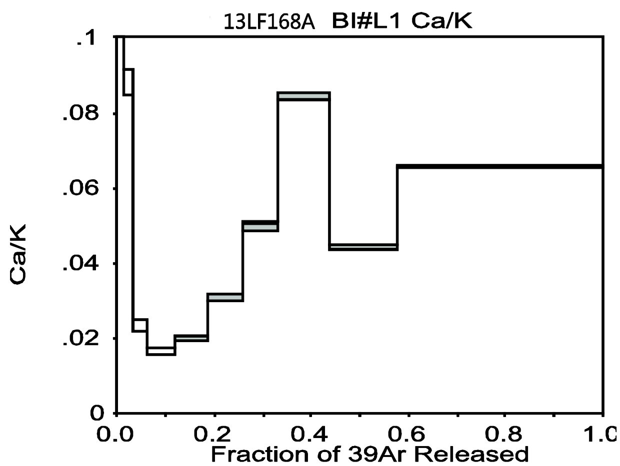
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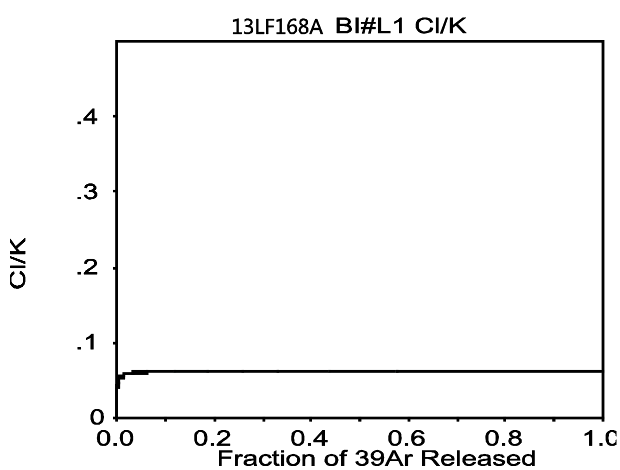
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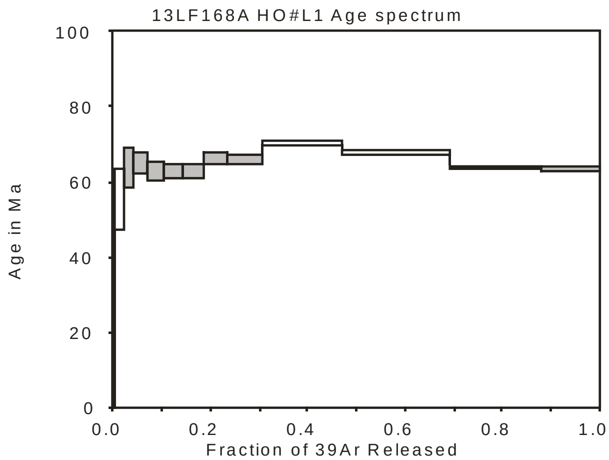
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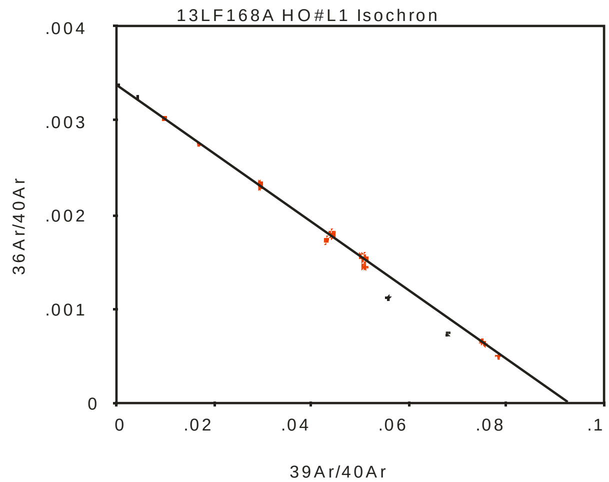
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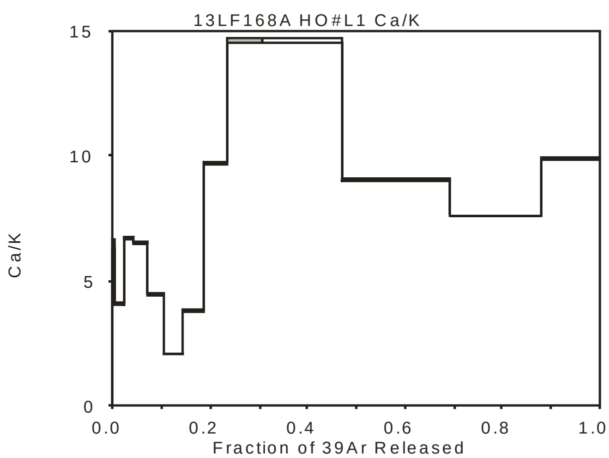
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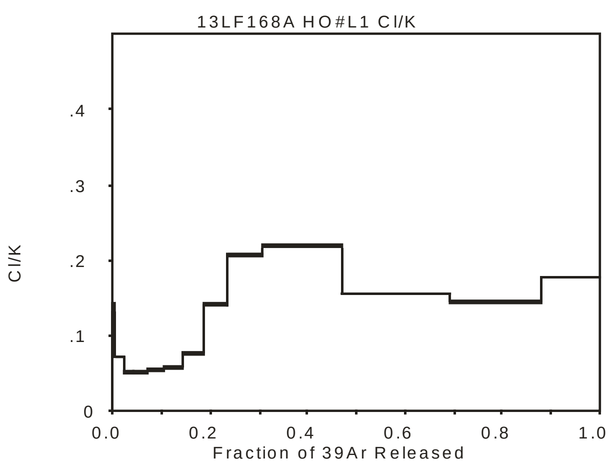
1.0
Fraction of 39Ar Released


13LF168A HO#L1 Cl/K
Cl/K
.4
.3
.2
.1
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released