Division of Geological & Geophysical Surveys

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by

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View to east of granodiorite (15KS073) overlooking Mentasta road and Tok Cutoff. Photograph by K.R. Sicard.

$2.00

JUNE 2017

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Released by

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
Division of Geological & Geophysical Surveys
3354 College Road
Fairbanks, Alaska 99709-3707

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

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) geologic mapping project in the Tanacross A-5 and A-6 quadrangles and adjoining areas. This project is part of a multi-year effort focusing on improving the publicly-available geological and geochemical data and assessing the mineral potential of the Tanacross quadrangle. The project focused on detailed mapping, identification, sampling and characterization of Devonian-Mississippian metamorphic rocks, Triassic and Cretaceous intrusions, and surficial geology, as well as modern geochemical characterizations of skarn, vein, and volcanogenic massive sulfide (VMS) hosted mineralization.

The DGGS Mineral Resources section spent 321 person-days in the field in 2015 and 2016 to conduct approximately 540 square miles of 1:63,360-scale geologic mapping and sampling in the Tok River area, of central Alaska. The new geologic map will greatly improve the understanding of the geology, structural history, and mineral potential of the area (Sicard and others, *in press)*. This area includes exposures of Devonian-Mississippian metamorphic rocks, metamorphosed Triassic gabbroic intrusions, and Cretaceous granodiorite intrusions and basaltic andesite lava flows. The area lies between the Delta mineral belt to the west, which has been the focus of exploration into VMS, and skarn deposits of the Tetlin project to the east. The area also contains numerous inactive and possibly active faults and multiple stages of deformation and magmatism, which are critical for understanding the geologic history of the eastern Alaska Range. Reconnaissance scale geologic mapping of the Tanacross quadrangle was completed by Foster (1970) at a scale of 1:250,000.

Our results indicate the Hona granodiorite pluton intruded the area in the Late Cretaceous between 76 and 71 Ma. We determined Cretaceous metamorphic ages from 126 to 121 Ma for hornblende, biotite, sericite and muscovite from multiple samples of upper greenschist to amphibolite grade rocks. This is consistent with regional argon results that imply this area is in the upper plate of the Yukon Tanana Terrane (Hansen and Dusel-Bacon, 1998). Basaltic andesite dikes returned Late Cretaceous (99.0 ± 0.5 Ma) and Tertiary (58.4 ± 0.3 Ma) ages from biotite; these constrain late brittle faulting in the area. Finally, we obtained a Late Cretaceous age (71.5 ± 0.5) for a basaltic andesite flow; these ages constrain the timing of displacement on some of the faults in the map area. Sample 15ET005 represents a failed attempt to date a hydrothermal vein.

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/10.14509/29727.

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 leftover mineral separates will be stored at the Alaska Geological Materials Center in Anchorage.

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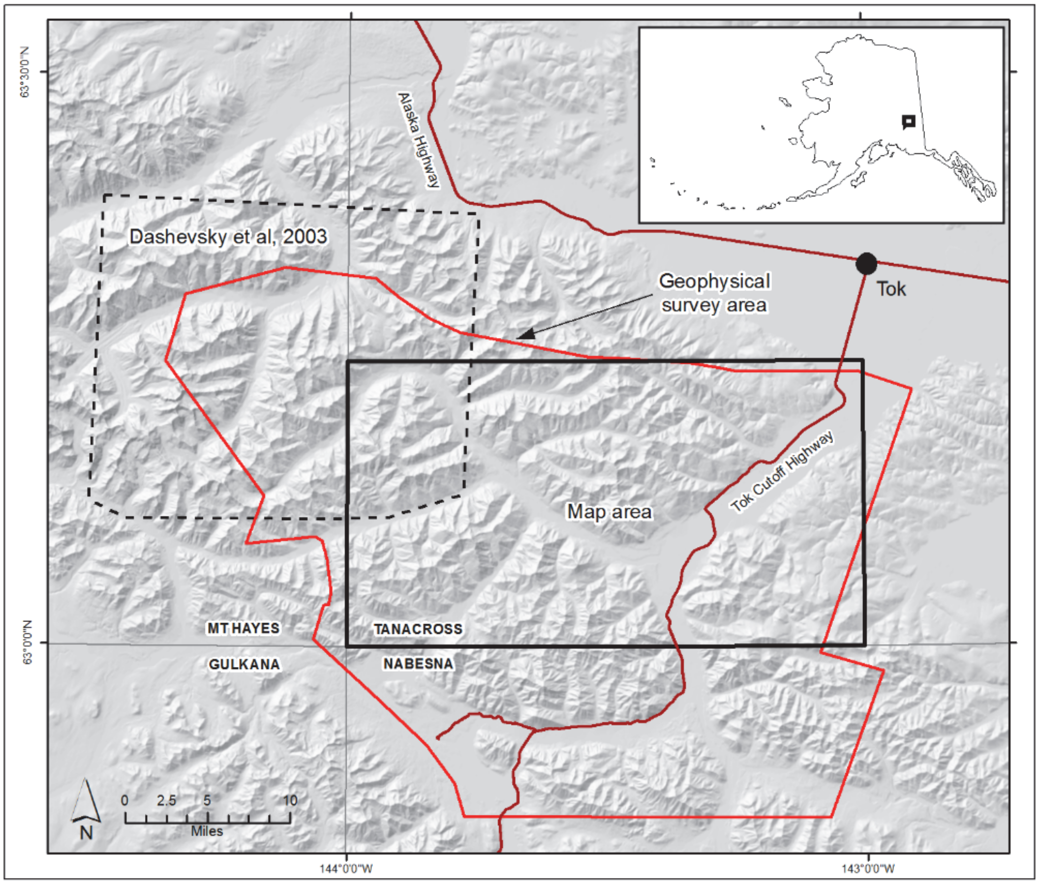

Figure 1. Location of the map area (black), the Tok geophysical survey (red; Emond and others, 2015), and the previously published Delta District geologic map (dashed; Dashevsky and others, 2003).

METHODOLOGY

Sample Collection Techniques

Fresh, unweathered samples from surface outcrops were collected by DGGS field geologists; samples were selected based on the presence of sufficiently large crystals and/or fresh glassy matrix. Sample-location coordinates (in WGS84 datum) were collected using handheld Trimble Juno T5 GPS units, with typical reported accuracy of about 10 meters. Before processing, samples were examined under a binocular microscope, and in some cases, thin sections were prepared and scrutinized, to avoid analyzing altered mineral phases. Major-oxide and trace-element geochemical data are published and available on the DGGS website for most of the samples based on the year the rocks were collected and analyzed (Wypych and others, 2015; Wypych and others, 2016).

Analytical Methods

For $^{40}Ar/^{39}Ar$ analysis, fourteen rock samples (one rock had both biotite and hornblende crystals analyzed) were submitted to the Geochronology Laboratory at UAF. The samples were crushed, sieved, washed, and hand-picked for either phenocryst-free rock chips (1,000-500 micron size fraction), or hornblende, biotite, or sericite (1,000-150 micron size fraction) 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.

Upon return from the reactor, the samples and monitor minerals were loaded into 2-mm-diameter holes in a copper tray, which 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 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 the timeframe of sample analysis, 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.

RESULTS AND DISCUSSION

A summary of all $^{40}Ar/^{39}Ar$ results is provided in the accompanying spreadsheets, 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] 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 additional discussion of the results of each age analysis, noting our preferred age determination, or a lack thereof.

MAFIC IGNEOUS AND VOLCANIC ROCKS

15AW066 – Gabbro

Rock description: Gabbro; pluton; greenish, weathering to a rusty brown. Equigranular; grain size: 5 to 7 mm; mineralogy: subhedral feldspar 69%, subhedral hornblende 30%, pyrite 1%. Fresh looking rock with large clots of either pyrite or chalcopyrite. Trace weathering.

Thin section notes: Very weathered; sericite overgrowths of plagioclase, vermicular intergrowth of chlorite into irregular, concave surfaces of opaques (pyrite or chalcopyrite), and resorbed hornblende crystals.

Hornblende (HO)

A homogeneous hornblende separate from sample **15AW066** was analyzed. The analysis produced an integrated age (4293.9 ± 8.6 Ma) that is anomalously old compared to regional and global ages. The percent atmospherically derived ^{40}Ar for a sample of this age is also anomalously high (12 percent). The isochron age (2180.0 ± 144.1 Ma) and the isochron regression to $^{40}Ar/^{36}Ar_i$ (577.2 ± 94.4) indicates the presence of extreme excess ^{40}Ar. No plateau age was calculated due to the documented presence of excess ^{40}Ar, and we cannot determine the age of this hornblende.

The presence of excess ^{40}Ar may be related to fluid flow. Pyrite and chalcopyrite with vermicular intergrowth of chlorite, and resorbed hornblende crystals in thin section suggest fluid flow may have altered the hornblende.

16BG105 – Gabbro dike

Rock description: Gabbro dike; dark greenish gray; grain size: 0.5 to 2 mm; mineralogy: orthopyroxene 25%, clinopyroxene 10%, feldspar 30%, euhedral biotite 35%. Secondary chlorite and calcite, unfoliated.

Thin section notes: Large crystals of feldspar, interlocked between pyroxene and biotite crystals, are slightly sericitized. Biotite is slightly replaced by chlorite. Parts of the rock are chloritized and sericitized, but most of the crystals look fresh.

Biotite (BI)

A homogeneous biotite separate from sample **16BG105** was analyzed. The integrated age (99.3 ± 0.4 Ma) and the plateau age (99.0 ± 0.5 Ma) are within error. We prefer the plateau age of **99.0 ± 0.5 Ma** for sample 16BG105 because of the high atmospheric content of the initial heating steps. No isochron age determination was possible because of the documented loss.

The plateau age of the biotite is interpreted as a magmatic crystallization age for the gabbro dike, which may be correlative to compositionally similar basalt to basaltic andesite dikes elsewhere in the project area. The dike is offset by a northeast-trending high-angle, brittle fault, which constrains the timing of the fault to younger than 99 Ma and suggests an upper age limit on similar faulting in the area.

16KS215 – Gabbro dike

Rock description: Gabbro dike; dark brown, weathering orange, porphyritic, grain size: 0.05 to 3 mm; mineralogy: tabular feldspar 5%, flakes biotite 10%, groundmass 80%. At least 2-m-thick, either a sill or a planar crosscutting dike. Pervasive weathering.

Biotite (BI)

A homogeneous biotite separate from sample **16KS215** was analyzed. The integrated age (58.7 ± 0.3 Ma) and the plateau age (58.4 ± 0.3 Ma) are within error. We prefer the plateau age of **58.4 ± 0.3 Ma** for sample 16KS215 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.

The plateau age of the biotite is interpreted as a magmatic crystallization age for the gabbro dike. The dike is offset by a northeast-trending high-angle, brittle fault, which constrains the timing of the fault to younger than 58 Ma and suggests an upper age limit on similar faulting in the area.

15LF064 – Basalt

Rock description: Basalt; flow; weathering brown; aphanitic and porphyritic; grain size: 0.03 to 2 mm; mineralogy: plagioclase phenocrysts 15%, pyroxene phenocrysts 5%, olivine 1%. Possibly vesicular/amygdaloidal, round pits on weathered surface. Blocky to lath-shaped plagioclase, altered brown pyroxene. Partial weathering.

Thin section notes: Fresh looking rock with nice euhedral plagioclase laths containing Carlsbad and albite twinning, some inclusions, and minor deformation twins. Aphanitic background primarily composed of plagioclase. Contains trace olivine crystals.

Whole rock (WR)

A homogeneous whole rock separate from sample **15LF064** was analyzed. The integrated age (72.2 ± 0.2 Ma) and the weighted average age (71.7 ± 0.5 Ma) are within error. We prefer the weighted average age of **71.7 ± 0.5 Ma** for sample 15LF064 because of the high atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the homogenous radiogenic content of the release.

The weighted-average age is interpreted as the crystallization age of the lava flow, which was previously inferred to be a Tertiary flow (Foster, 1970).

FELSIC INTRUSIVE ROCKS

15DR001 – Granite

Rock description: Granite; white with black spots, grain size: 1 to 5 mm; mineralogy: quartz 45%, feldspar 30%, hexagonal biotite 20%, elongate hornblende 5%. Good unweathered books of biotite and laths of hornblende. Hornblende are smaller than the biotite. Outcrop has at least 2 phases. A mafic phase and a less mafic phase. Mafic phase has 50% or more mafic minerals.

Thin section notes: Twinned plagioclase (1-5 mm), also containing deformation twins. Fresh and large (1-4 mm) biotite crystals. Hornblende crystals (.2-2 mm) are overgrown by plagioclase and biotite and cores contain very fine-grained opaques and biotite. No metamorphic fabric.

Rumble Creek Pluton looking south from sample collection site for 15DR001 on Rumble glacier. Photograph by David Reioux.

Hornblende (HO)

A homogeneous hornblende separate from sample **15DR001** was analyzed. The integrated age (101.9 ± 0.5 Ma) and the plateau age (99.3 ± 0.6 Ma) are within error. We prefer the plateau age of **99.3 ± 0.6 Ma** for hornblende from sample 15DR001 because of the high atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the homogenous radiogenic content of the release.

The plateau age is interpreted as the magmatic crystallization age of the Rumble Creek granitic pluton. The hornblende age from this sample is older than the biotite age, reflecting the slightly higher closure temperature of hornblende relative to biotite.

Biotite (BI)

A homogeneous biotite separate from sample **15DR001** was analyzed. The integrated age (94.9 ± 0.4 Ma) and the plateau age (95.6 ± 0.4 Ma) are within error. We prefer the plateau age of **95.6 ± 0.4 Ma** for biotite from sample 15DR001 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.

The plateau age for this sample likely reflects post-emplacement cooling of the Rumble Creek granitic pluton through biotite closure. The biotite age from this sample is younger than the hornblende age due to the slightly lower closure temperature of biotite relative to hornblende.

15KS073 – Granodiorite

Rock description: Granodiorite; pluton with xenoliths; black and white when fresh, red and brown weathering on fracture surfaces; massive, hypidiomorphic, granular; grain size: 0.1 to 0.5 mm; mineralogy: tabular potassium feldspar 30 %, interstitial quartz 25%, hornblende laths 25%, interstitial plagioclase 15%, biotite 5%. Fresh rock. Weak fabric seen in tabular feldspars. Quartz-feldspar veins, and slip surfaces with chlorite, calcite, and iron oxide. Xenoliths have a sugary mafic background, with tabular feldspar phenocrysts. Note: xenoliths were excluded from the submitted sample. See photo of rock and sample location on cover page.

Thin section notes: Reasonably fresh sample with some chlorite alteration and sericite overgrowths on feldspar. Quartz crystals have evidence for grain boundary migration and contain subgrains.

Hornblende (HO)

A homogeneous hornblende separate from sample **15KS073** was analyzed. The integrated age (109.1 ± 0.7 Ma) and the plateau age (100.7 ± 0.8 Ma) are not within error. We prefer the plateau age of **100.7 ± 0.8 Ma** for sample 15KS073 because of the high atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the homogenous radiogenic content of the release.

The plateau age is interpreted as a magmatic crystallization age of this granodiorite pluton due to fresh hornblende and primary igneous textures.

HONA PLUTON

15AW021 – Granodiorite

Rock description: Granodiorite; hypabyssal pluton; light gray, massive, porphyritic; grain size: 2 to 5 mm; mineralogy: plagioclase 40%, potassium feldspar 30%, quartz 20%, biotite 5%. Rock looks fresh, no visible sulfides. Fracture-controlled weathering.

Thin section notes: Phenocrysts are composed of biotite, feldspar and quartz crystals. Biotite crystals are fresh except for ragged edges, and about half have deformation twins. Feldspar crystals have zoning, sericite overgrowths, myrmekite, and deformation twins. Undulatory extinction of quartz crystals. Groundmass is primarily composed of very small interlocking feldspar crystals.

Biotite (BI)

A homogeneous biotite separate from sample **15AW021** was analyzed. The integrated age (72.8 ± 0.9 Ma) and the plateau age (73.1 ± 0.9 Ma) are within error. We prefer the plateau age of **73.1 ± 0.9 Ma** for sample 15AW021 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.

The plateau age from this Hona granodiorite pluton sample is interpreted as a magmatic crystallization age. It is from the same shallow pluton system as samples 15KS026 and 15ET031 (an apophysis), which have the same mineralogy and porphyritic textures. The biotite age of this sample is slightly younger than the hornblende age of 15KS026 due to the lower closure temperature of biotite versus hornblende.

15ET031 – Porphyry dike

Rock description: Porphyry; dike; white and black; grain size: 0.1 to 5 mm; mineralogy: phenocrysts of hornblende 10%, feldspar (plagioclase?) phenocrysts 20%, quartz phenocrysts 3%, biotite phenocrysts 1%. Phenocrysts are in an aphanitic light gray groundmass.

Thin section notes: Twinned plagioclase (1-5 mm), also containing deformation twins. Fresh and large (1- to 4-mm-diameter) biotite crystals. Hornblende crystals (0.2- to 2-mm-long) are overgrown by plagioclase and biotite and cores contain very fine-grained opaques and biotite. No metamorphic fabric.

Hornblende (HO)

A homogeneous hornblende separate from sample **15ET031** was analyzed. The integrated age (71.8 ± 0.3 Ma) and the weighted average age (71.1 ± 0.5 Ma) are within error. We prefer the weighted-average age of **71.1 ± 0.5 Ma** for sample 15ET031 because of the high atmospheric content of the lower temperature-step heat releases. No isochron age determination was possible because of the homogenous radiogenic content of the release.

This sample is from an apophysis of the Hona granodiorite porphyry, and the weighted-average is interpreted as a magmatic crystallization age. It has the same mineralogy and textures as the shallow pluton porphyry system of samples 15AW021 and 15KS026. This hornblende weighted-average age is slightly younger than ages derived from samples 15AW021 (biotite) and 15KS026 (hornblende), suggesting it is a slightly later phase of the same plutonic system; it intruded slightly to the east of the main Hona pluton.

15KS026 – Quartz Monzonite

Rock description: Quartz Monzonite; hypabyssal pluton; light gray, weathering pink; jointed, porphyritic; grain size: 0.3 to 4 mm; mineralogy: anhedral quartz 10%, tabular potassium feldspar 40%, euhedral plagioclase 30%, hornblende laths 4%. Fresh euhedral books of biotite 4%, lacks sulfides. Fresh, with trace weathering.

Thin section notes: Phenocrysts are composed of biotite, feldspar and quartz crystals. Biotite crystals are fresh except for ragged edges, and about half have deformation twins. Feldspar crystals have zoning, sericite overgrowths, myrmekite, and deformation twins. Undulatory extinction of quartz crystals. Groundmass is primarily composed of very small interlocking feldspar crystals.

Hornblende (HO)

A homogeneous hornblende separate from sample **15KS026** was analyzed. The integrated age (74.9 ± 0.6 Ma) is within error of the plateau age (75.8 ± 0.6Ma) and the isochron age (76.2 ± 0.6 Ma). We prefer the plateau age of **75.8 ± 0.6 Ma** for sample 15KS026 because of the large error on the isochron regression to $^{40}Ar/^{36}Ar$.

This sample is from the Hona granodiorite porphyry and the plateau age is interpreted as a magmatic crystallization age. It is from the same shallow pluton system as samples 15AW021 and 15ET031 (an apophysis), with the same mineralogy and porphyritic texture. The hornblende age of this sample is slightly older than the biotite age determined for sample 15AW021; this result is consistent with the higher closure temperature of hornblende versus that of biotite.

METAMORPHIC ROCKS

15ET033 - Granitic augen orthogneiss

Rock description: Granitic augen orthogneiss; tan, seriate; grain size: 1 to 50 mm; very large potassium feldspar. Mineralogy: quartz 40%, euhedral potassium feldspar 30%, plagioclase 20%, biotite 10%. Clear metamorphic fabric, particularly along the edges of the intrusion (see photos below).

Left: Potassium feldspar augen orthogneiss with weak metamorphic fabric. Right: fine-grained orthogneiss near southern contact. Photos by Evan Twelker.

Thin section notes: Phenocrysts are composed of biotite crystals, which are fresh except for ragged edges, and about half have deformation twins. Feldspar crystals have zoning, sericite overgrowths, myrmekite, and deformation twins. Undulatory extinction of quartz crystals. Groundmass is primarily composed of very small interlocking feldspar crystals.

Biotite (BI)

A homogeneous biotite separate from sample **15ET033** was analyzed. Argon loss or alteration is indicated by the young age of the first heating step. The integrated age (124.8 ± 0.4 Ma) and the plateau age (126.2 ± 0.5 Ma) are not within error. We prefer the plateau age of **126.2 ± 0.5 Ma** for sample 15ET033. No isochron age determination was possible because of the documented loss.

The plateau age likely represents a reset of the biotite from a regional metamorphic cooling event on this presumed Mississippian (?) granitic augen orthogneiss. Fresh biotite crystals and metamorphic fabric in the thin section support metamorphic biotite overgrowth.

Originally mapped as a “megacrystic granite” at the far north edge of the map area (labeled as Mzg of Foster, 1970). The textures suggest that it is affiliated with the Devonian-Mississippian augen orthogneiss seen elsewhere in the Tanacross quadrangle. Sample 09MBW243A, described as a ‘granitic orthogneiss’ was collected about 20 miles east of Tok along the Alaska Highway and yielded a weighted-mean age of 354.6 ±

9.3 Ma based on 45 zircon measurements using laser ablation–inductively coupled plasma–mass spectrometry (Solie and others, 2014).

16ET484 – Granitic gneiss

Rock description: Granitic gneiss; brownish gray; grain size: 0.5 to 1 mm; mineralogy: quartz 45%, feldspar 40%, muscovite 8%, biotite 7%; 1-mm-scale foliation defined by micas.

Thin section notes: Rock has a well-defined SC fabric, and 0.5 to 1 mm crystals. Feldspar (10%) and quartz are recrystallized, forming porphyroclasts and aggregates. Biotite (15%) defines the foliation, is metamorphic, and contains some inclusions. White mica (10%) is slightly pleochroic, contains some inclusions, defines the foliation, and is intergrown with the biotite. Rare euhedral to subhedral garnet, no larger than 1 mm in diameter, possible kyanite present. Chloritoid and epidote present, accessory zircon present in quartz.

Muscovite (MU)

A homogeneous muscovite separate from sample **16ET484** was analyzed. The analysis produced a complex age spectrum with a central peak. The analysis did not allow for the calculation of a plateau age because the criteria for a plateau age were not met ($\geq$ 50 percent of ^{39}Ar released), hence a weighted-average age is presented. The integrated age (127.5 ± 0.5 Ma) and the weighted average age (124.7 ± 0.8 Ma) are not within error. We prefer the weighted-average age of **124.7 ± 0.8 Ma** for 16ET484 because muscovite generation during metamorphism can be prolonged and/or episodic leading to complex age spectrum, but often with a main period of muscovite formation-recrystallization. No isochron age determination was possible because of the documented loss. The complicated age may be related to the thin section observation that muscovite is intergrown with biotite. Therefore there is a possibility that this separate may have been heterogeneous.

The weighted-average age of muscovite in this granitic orthogneiss is interpreted as the age of metamorphic cooling through the muscovite argon closure temperature.

16KS042 – Quartzite

Rock description: Quartzite; tan to light purple, weathering orange; foliated, recrystallized, jointed; grain size: 0.1 to 3 mm; mineralogy: elongate quartz 87%, muscovite 12%. Distinctive coarse-grained unit with a strong foliation; 4- to 6-mm-thick quartz layers between muscovite foliation planes; less than 3% ankerite or calcite. Some folding and warping of layers with a strong lineation. Quartz veins are parallel to foliation and tension gashes crosscut the foliation. Trace weathering.

Thin section notes: Very elongate white mica defining foliation along with 2% graphite. Calcite fills secondary gaps and is rare (1%). Less than 1% pyrite cubes. Accessory euhedral zircon.

Muscovite (MU)

A homogeneous muscovite separate from sample **16KS042** was analyzed. The analysis produced a complex bimodal age spectrum indicative of possible argon loss or a prolonged period of muscovite generation or recrystallization. The integrated age (122.2 ± 0.4 Ma) and the plateau age (121.6 ± 0.5 Ma) are within error. We prefer the plateau age of **121.6 ± 0.5 Ma** for sample 16KS042 because the main phase of muscovite formation/recrystallization often occurs as a prolonged period during metamorphism. The high-temperature release of the analysis produced an age (124.3 ± 0.4 Ma; 3 out of 8 steps, MSWD= 1.34; 58.2% ^{39}Ar) that is similar to samples 16ET484 and 16MBW209, implying the muscovite from this sample records regional metamorphic cooling. No isochron age determination was possible because of the homogenous radiogenic content of the release.

The plateau age and high-temperature release age are both interpreted to estimate the metamorphic cooling age of the quartzite.

16MBW209 – Felsic metavolcanic rock

Rock description: Felsic metavolcanic rock; pale green; foliated, porphyritic, grain size: 0.0001 to 3 mm; mineralogy: chlorite 20%, white mica 10%, quartz 70%.

Muscovite (MU)

A homogeneous muscovite separate from sample **16MBW209** was analyzed. The analysis produced a complex age spectrum with a central saddle. The analysis did not allow for the calculation of a plateau age because all the criteria for a plateau age were not met ($\geq$ 3 consecutive steps), hence a weighted average age is presented. The integrated age (128.4 ± 0.4 Ma) and the weighted average age (125.2 ± 0.5 Ma) are not within error. We prefer the weighted-average age of **125.2± 0.5 Ma** for sample 16MBW209 because muscovite generation during metamorphism can be prolonged and/or episodic leading to complex age spectrum, but often with a main period of muscovite formation-recrystallization. No isochron age determination was possible because of the documented loss. This weighted-average age overlaps with the metamorphic cooling age determined for sample 16ET484.

The weighted-average age of this felsic metavolcanic rock within a greenschist facies unit is interpreted as recording regional metamorphic cooling through the muscovite argon-closure temperature.

MINERALIZED ROCK

15ET005 – Quartz vein

This sample is from the main gold-bearing quartz vein at the Shalosky prospect (Wypych and others, 2015).

Rock description: Quartz vein; light gray, massive; thin, greenish-gray blades of mica. Greenish scorodite 1%, cream-colored carbonate on fractures. Less than 1% sulfides: very fine-grained pyrite(?), and gray sulfides. Sericitic alteration, bleaching, and vein mineralization.

Thin section notes: Two populations of quartz and mica crystals; very fine-grained foliated and folded quartzite inclusions within coarser-grained vein quartz. Quartzite inclusions contain fine-grained undulatory quartz crystals, very fine-grained micas, and sericite and chlorite(?) alteration. Vein quartz has polygonal crystals, cross-cuts the quartzite, and also contains hydrothermal sericite crystals.

Sericite (SER) and White Mica

A sericite separate from sample **15ET005** was analyzed. The analysis produced an upward stair-stepping age spectrum indicative of argon loss or alteration; the lowest-power step yielded an age of 83.0 ± 0.7 Ma, and the highest-power step has an age of 114.3 ± 0.6 Ma. The integrated age is 105.6 ± 0.4 Ma. A four-step weighted-average age of 109.3 ± 0.7 Ma accounts for 39.4 percent of the ^{39}Ar release. No isochron age determination is possible because of the documented loss. This is a complex sample for which no preferred age can be confidently determined. The separate might have been mixed rather than homogeneous; including newly crystallized hydrothermal vein sericite, and hydrothermally altered metamorphic white mica from quartzite.

This sample is from within the main gold-bearing quartz vein at the Shalosky prospect. Petrography indicates part of this sample contains an inclusion of bleached micaceous quartzite wall rock within the vein. The quartzite preserves a regional metamorphic fabric of granoblastic quartz and aligned white mica that is partially altered to sericite and chlorite(?). We interpret the age results to indicate partial alteration of metamorphic white mica by hydrothermal fluids during the Late Cretaceous or early Tertiary.

ACKNOWLEDGMENTS

This project was jointly funded by the State of Alaska’s Strategic and Critical Minerals Assessment project (part of DGGS’s Airborne Geophysical/Geological Mineral Inventory program [AGGMI]), a USGS Mineral Resources Assessment Grant G16AS00003, and the USGS National Cooperative Geologic Mapping Program, STATEMAP component, under 2016 award number G16AC00182. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

We acknowledge Heidi Lingenfelter and Joe Bovee representing Ahtna, Inc., James Mery of Doyon Limited, and Mentasta Village, for providing access to private lands in the map area. U.S. Bureau of Land Management (BLM) Glennallen Field Office and of (BLM) Eastern Field Office (Fairbanks) assisted us with permitting on BLM-managed lands.

Field mapping and sample collection were conducted by Lawrence Freeman, Robert Gillis, Lauren Lande, Travis Naibert, Rainer Newberry, David Reioux, Karri Sicard, Evan Twelker, Melanie Werdon, Amanda Willingham, and

Alicja Wypych. Much appreciated field mapping, regional geologic context, and sample collection assistance came from Jeffrey Benowitz, Samuel Dashevsky, and Peter Illig.

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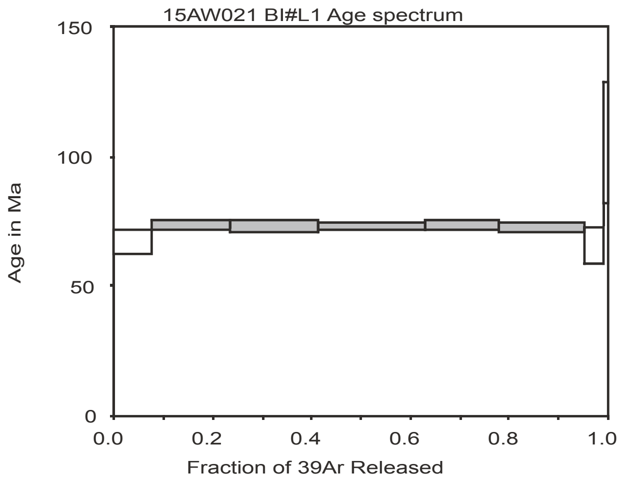
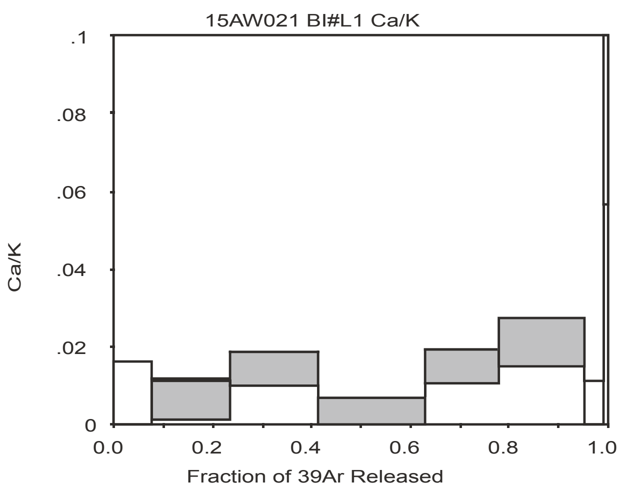
APPENDIX: PLOTS OF 40Ar/39Ar AGE SPECTRA AND Ca/K AND Cl/K RATIOS

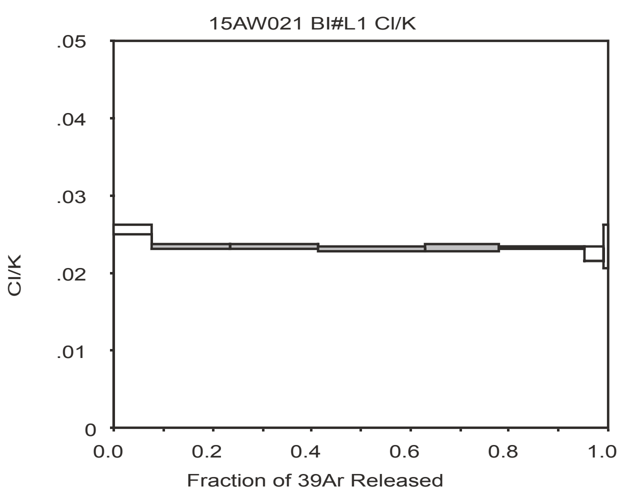
Gray-shaded steps were used for plateau age determinations.

15AW021

Biotite (BI)







15AW066

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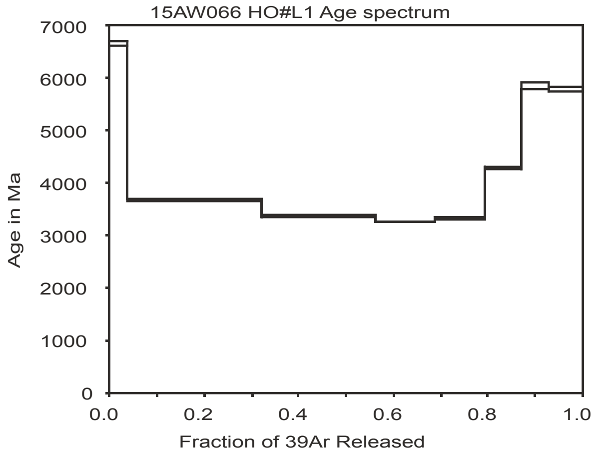

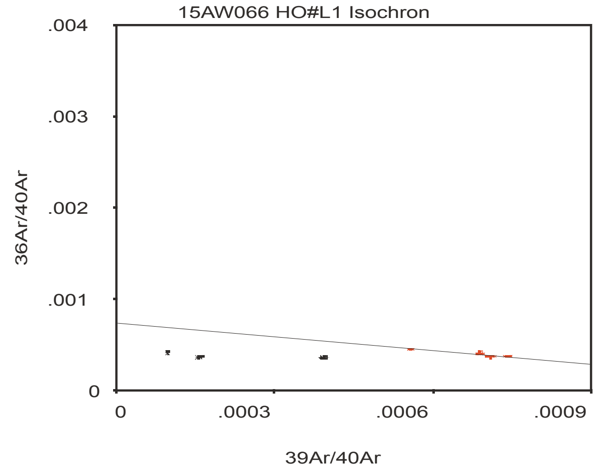

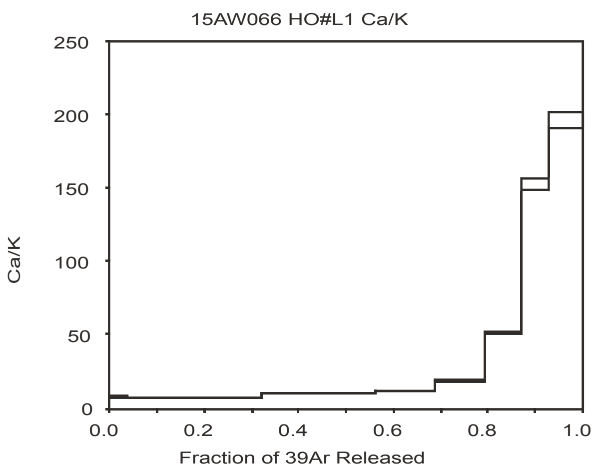

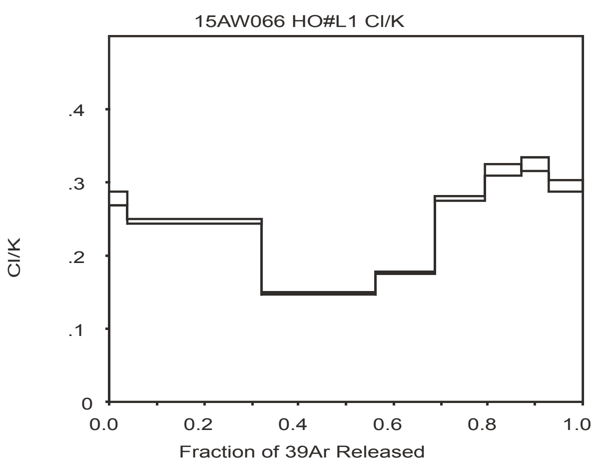

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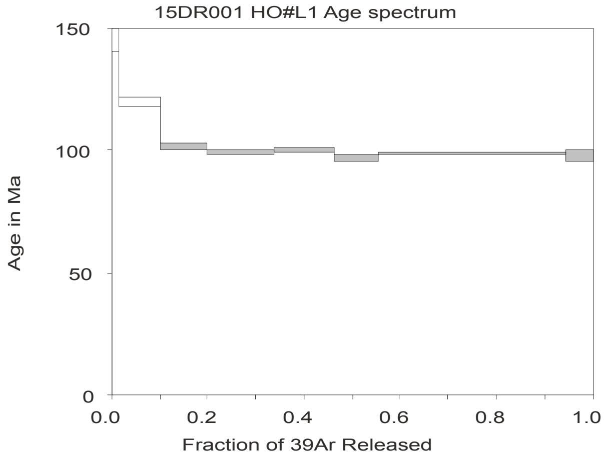

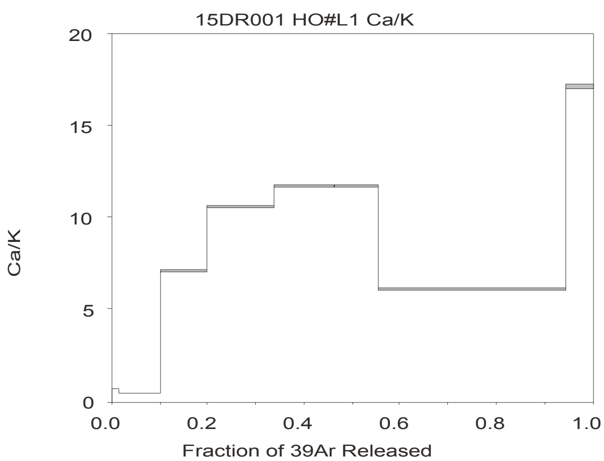

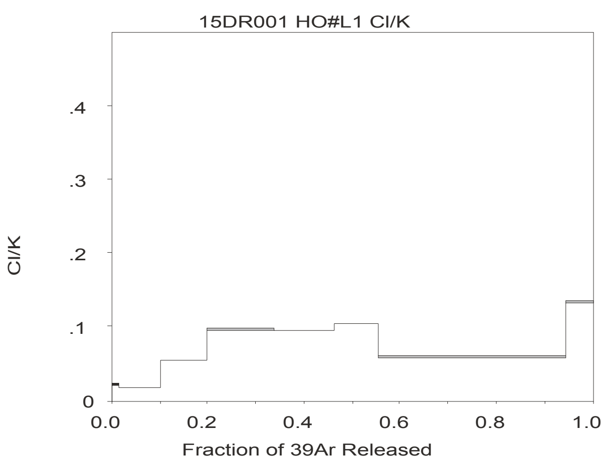

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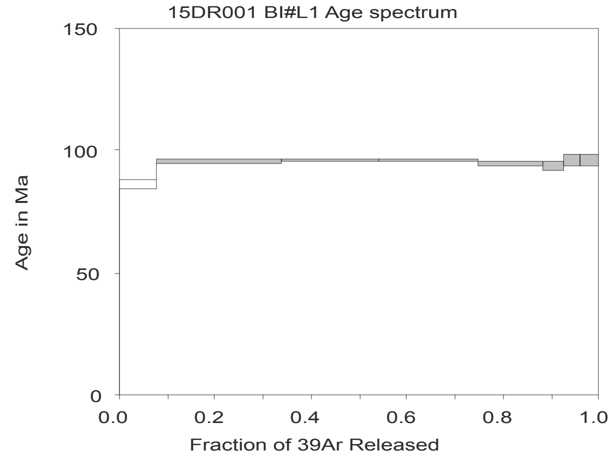

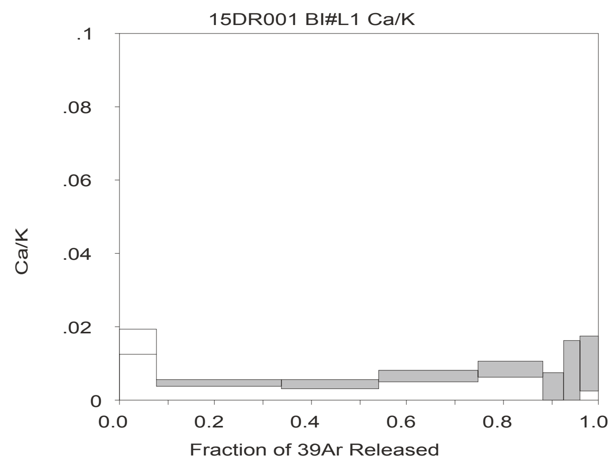

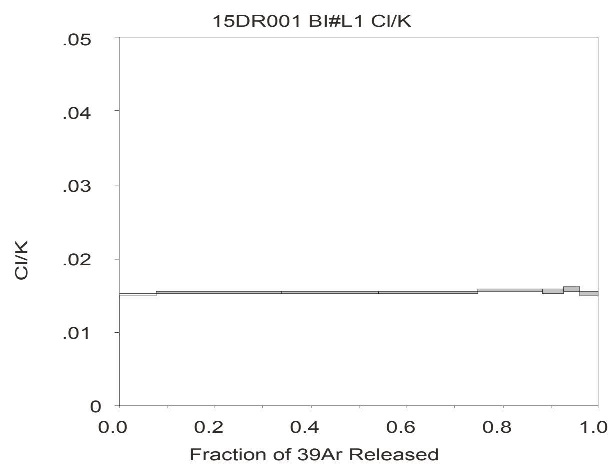

15ET005

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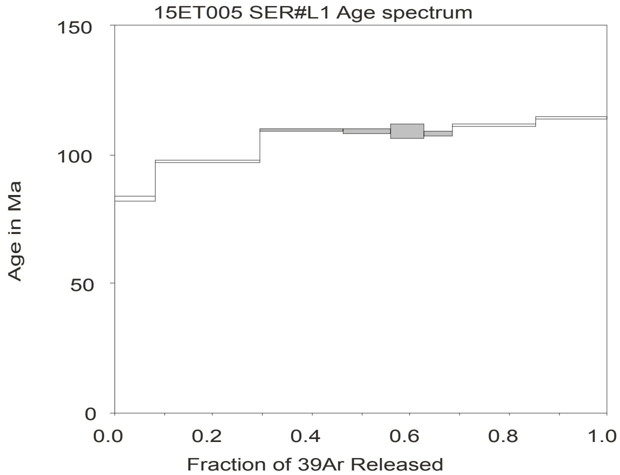

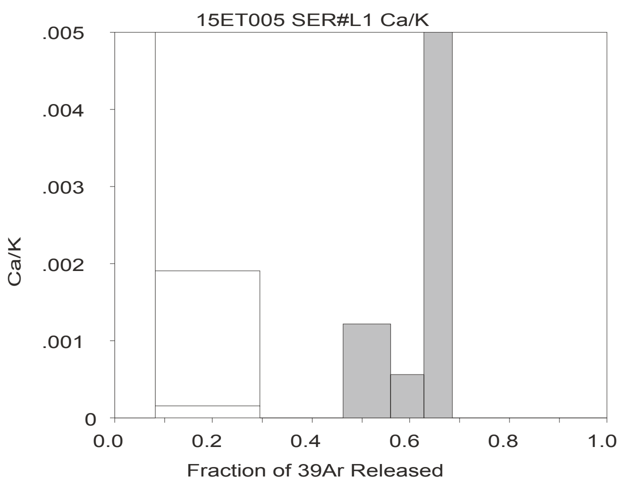

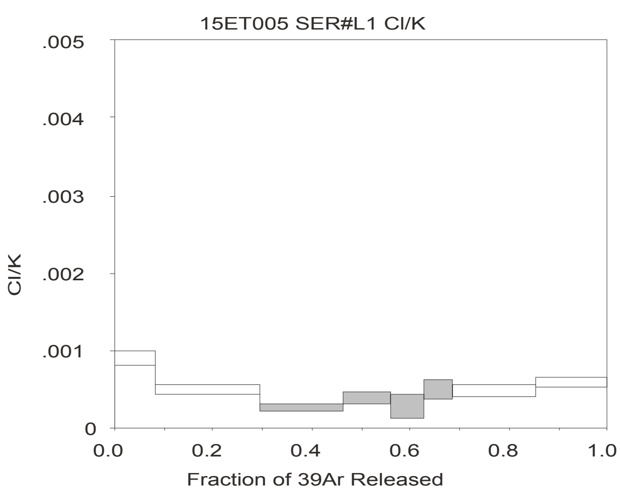

15ET031

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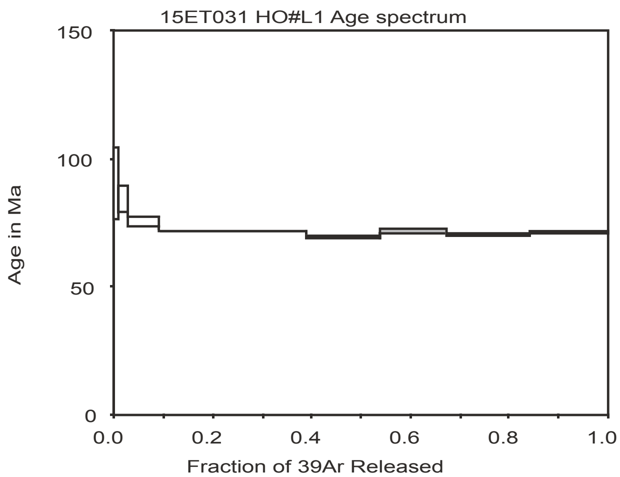

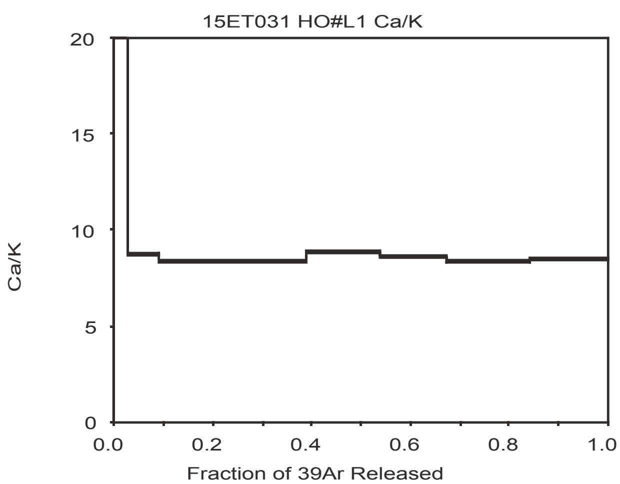

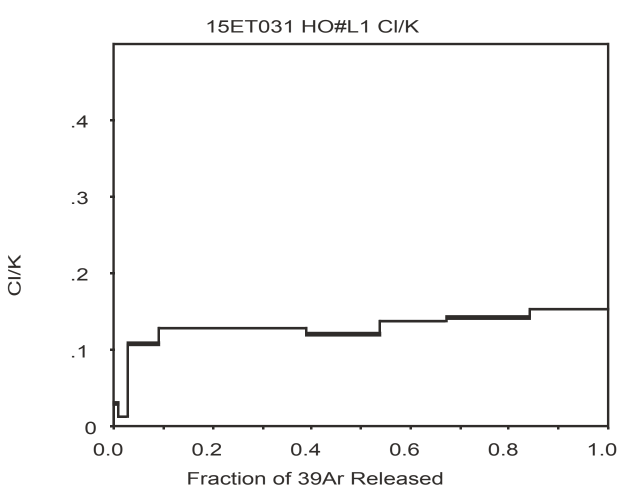

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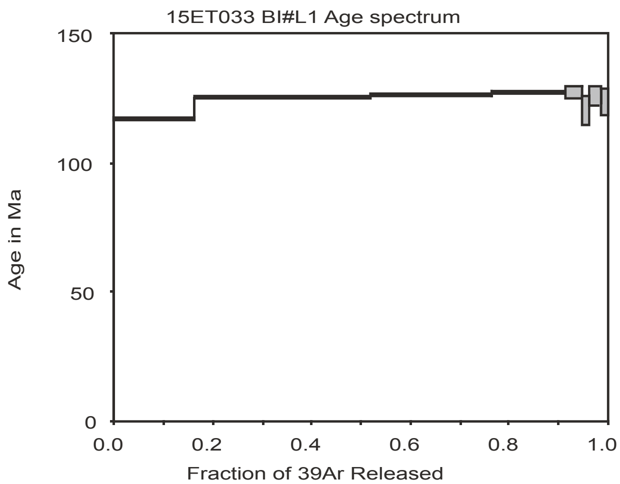

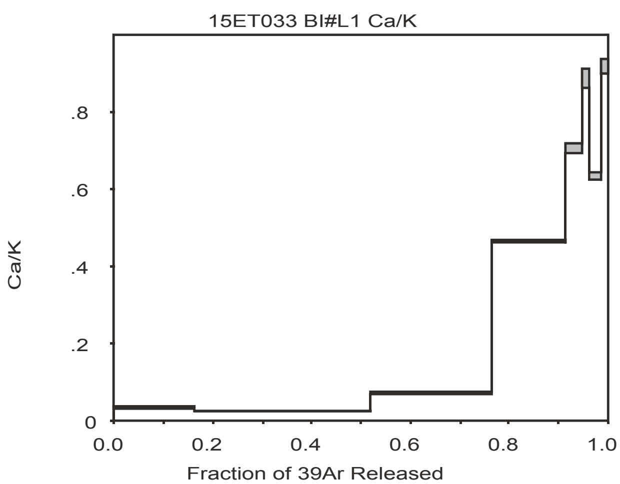

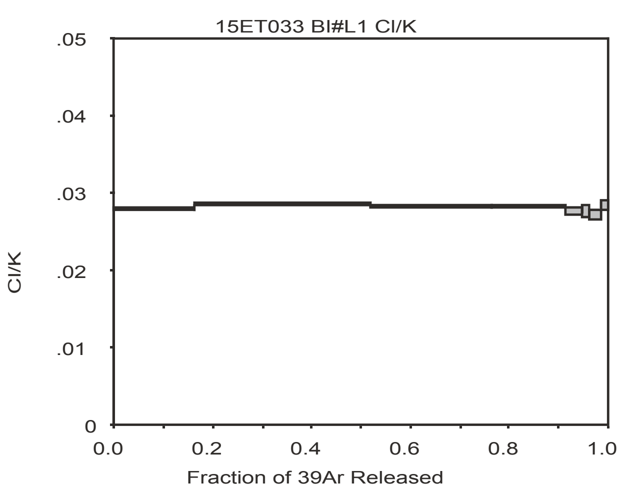

15KS026

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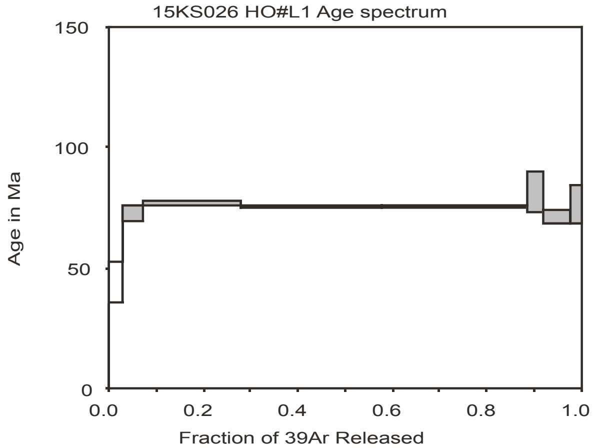

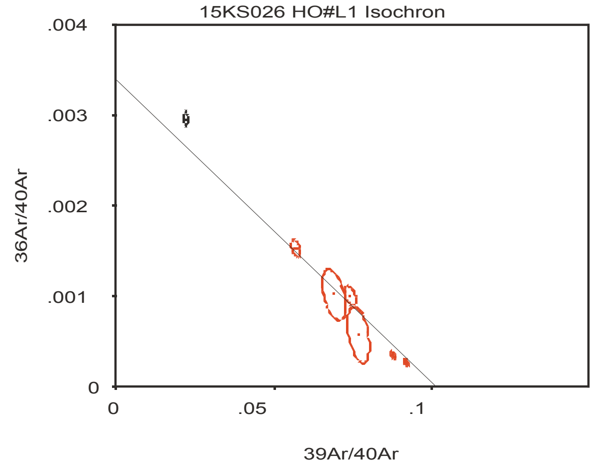

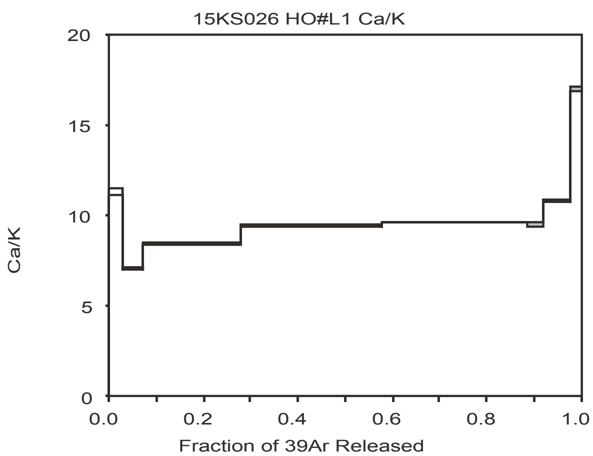

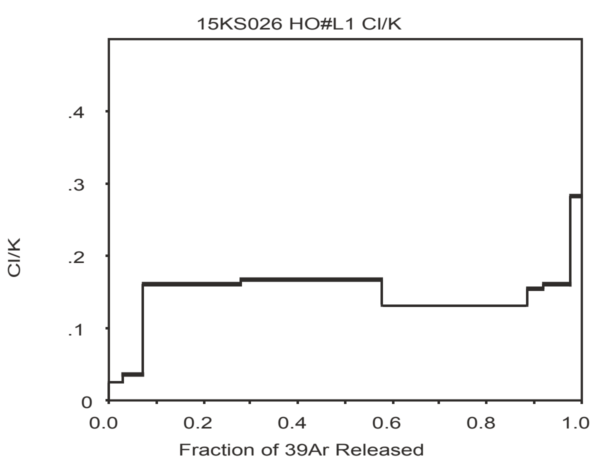

15KS073

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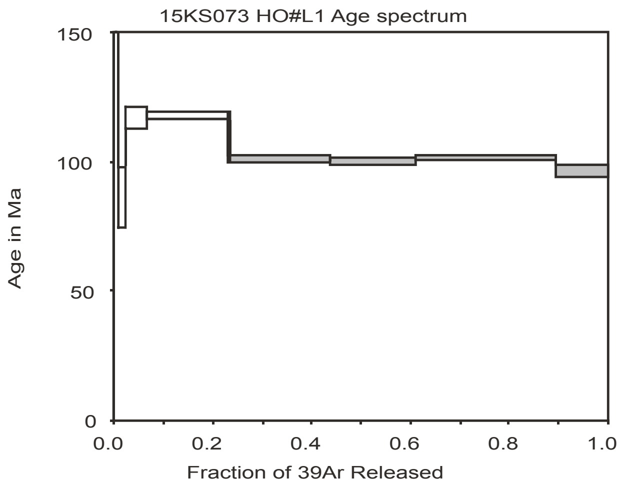
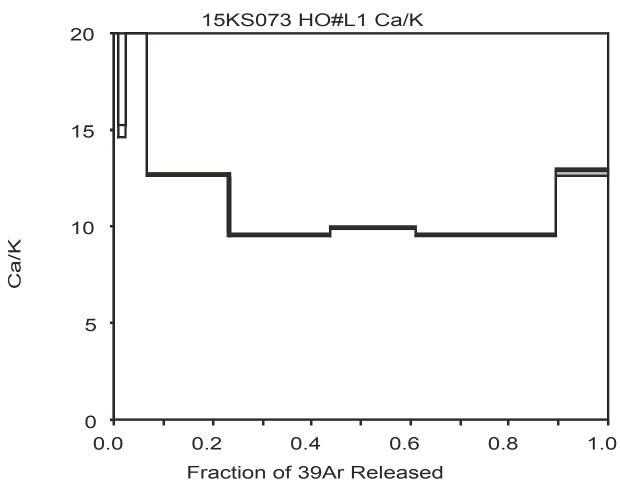
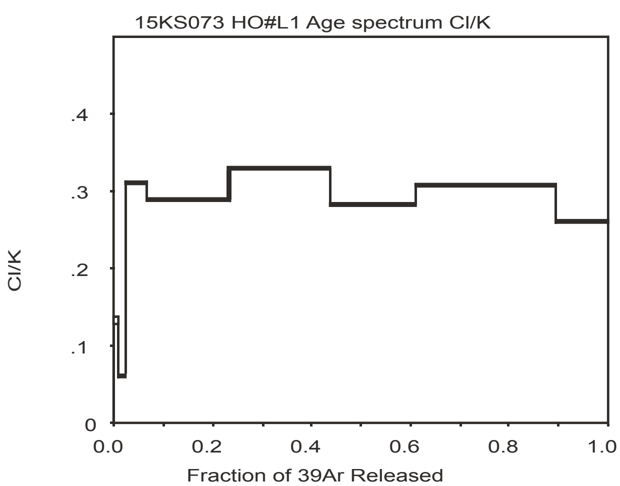
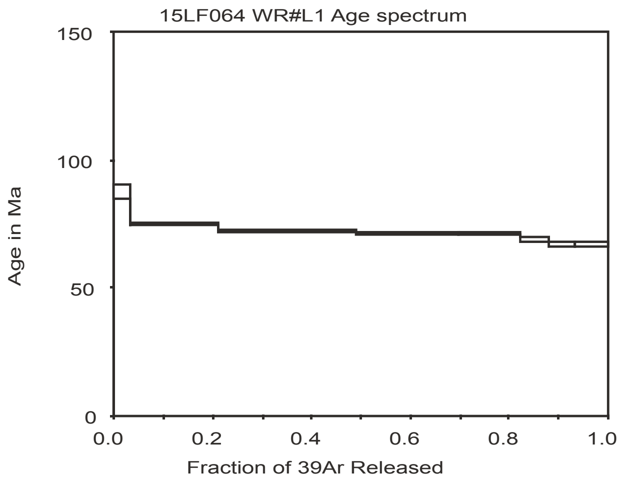


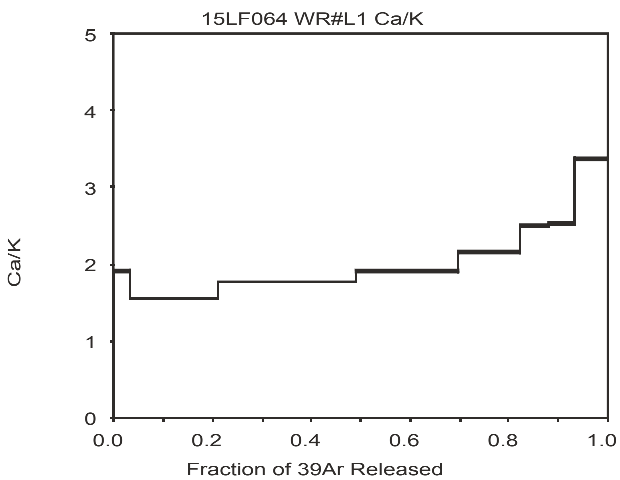


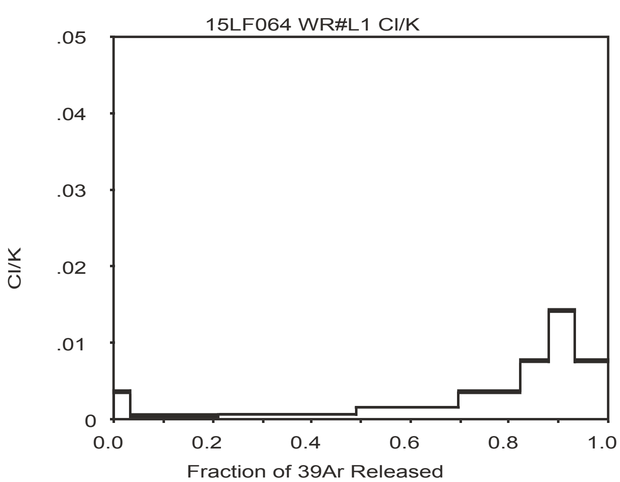


15LF064

Whole rock (WR)







16BG105

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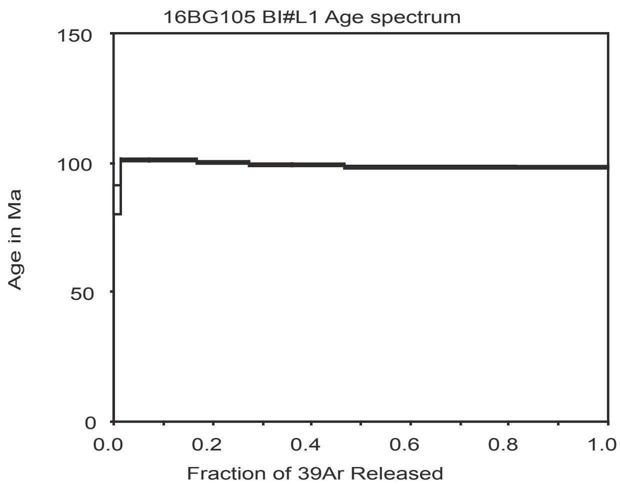

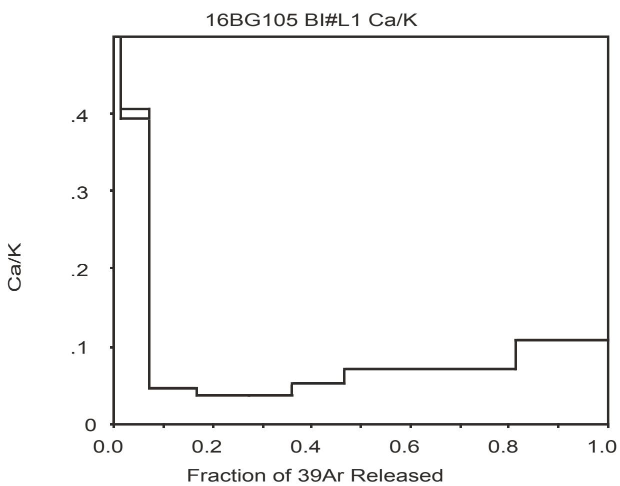

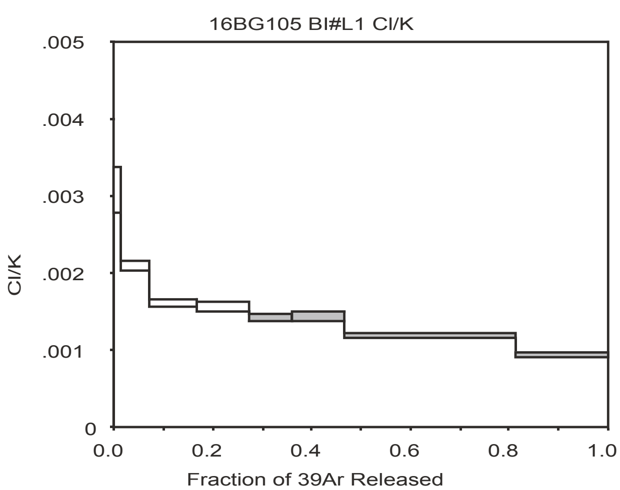

16ET484

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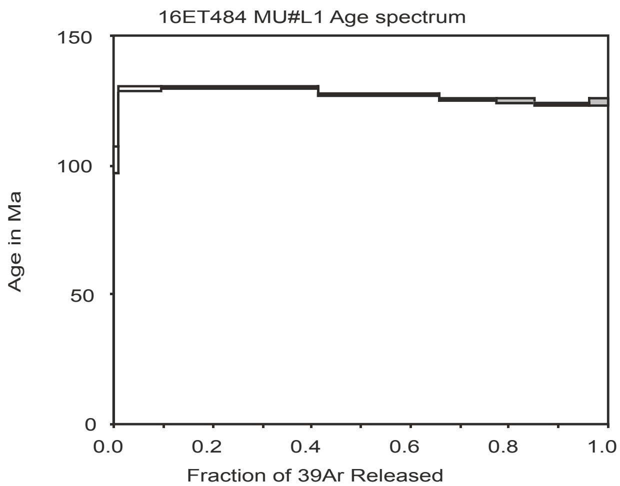

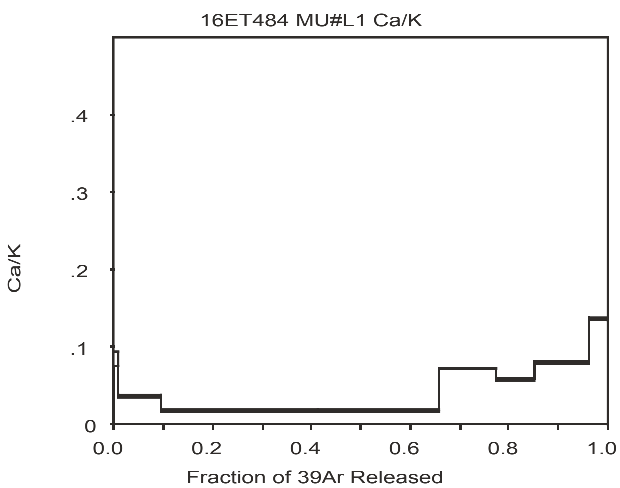

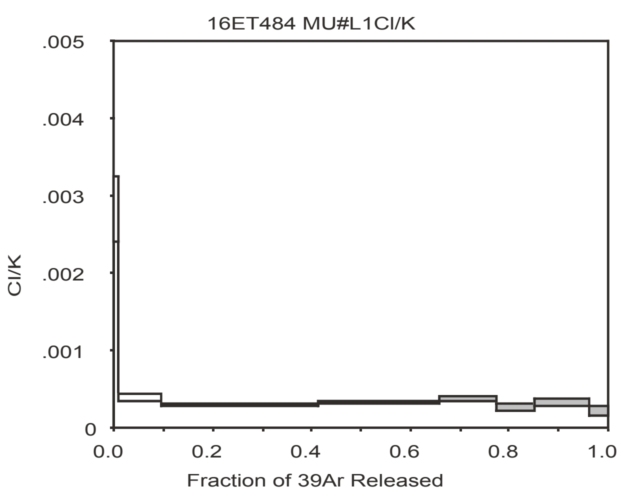

16KS042

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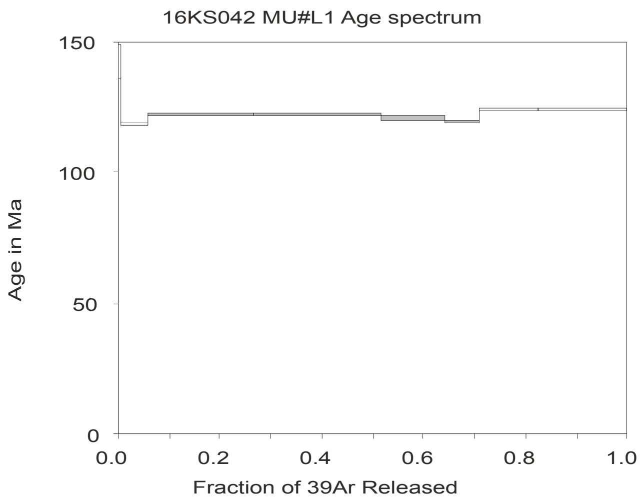

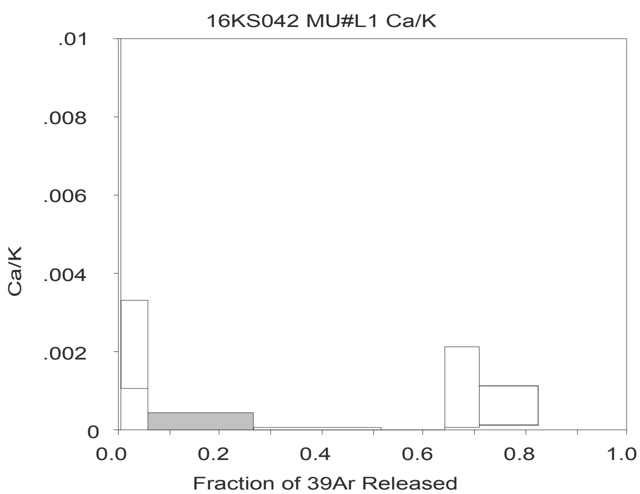

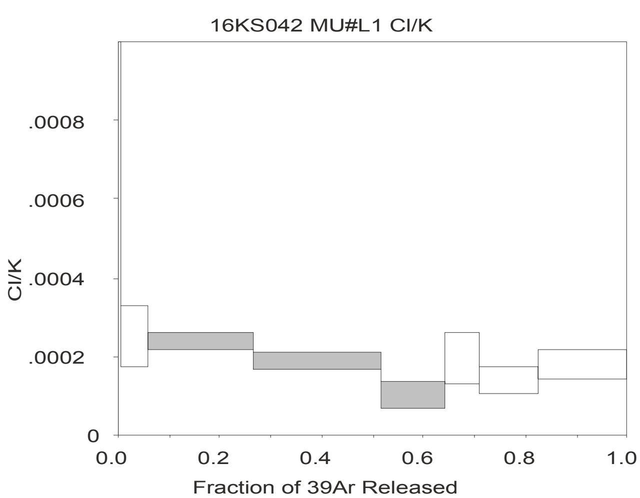

16KS215

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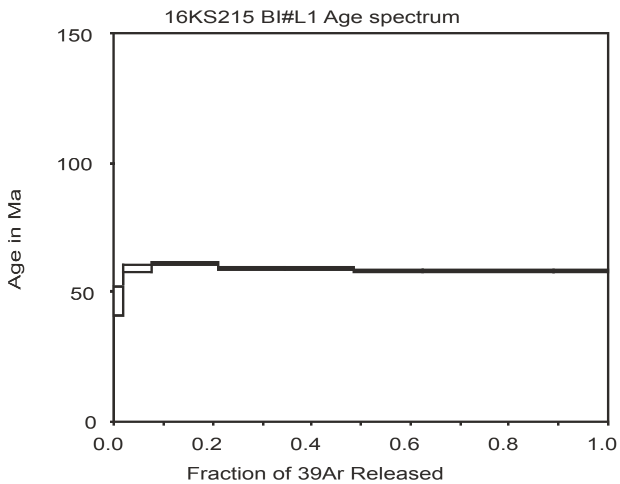

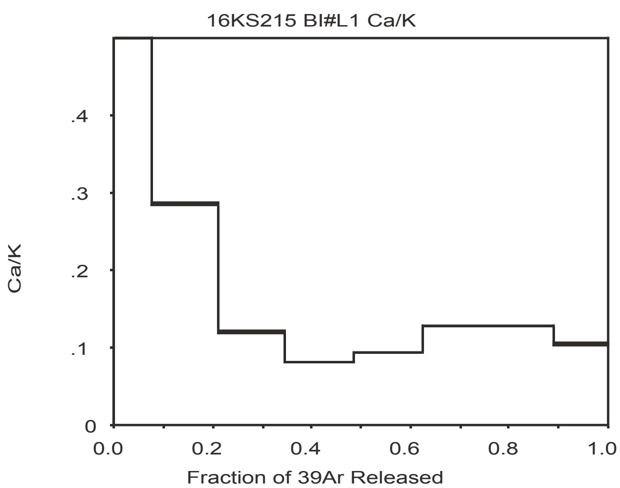

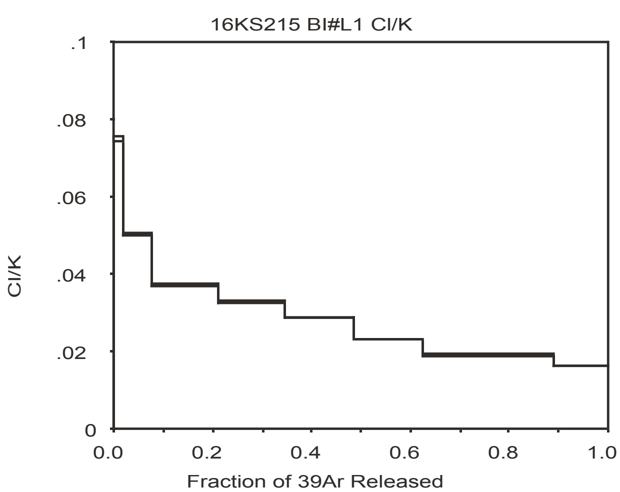

16MBW209

Muscovite (MU)