Alaska Division of Geological & Geophysical Surveys

Raw Data File 2015-3

$^{40}Ar/^{39}Ar$ DATA, SEWARD PENINSULA, ALASKA

by

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$6.00

June 2015

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

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by

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ABSTRACT

This Alaska Division of Geological & Geophysical Surveys (DGGS) Raw Data File presents $^{40}Ar/^{39}Ar$ age dating results for a volcanic whole-rock sample, selected minerals from various metamorphic rocks and igneous dikes, and white mica from both metamorphic- and hydrothermal-mineralization-related veins encountered on the southern Seward Peninsula, as well as select minerals from one plutonic rock from Cape Denbeigh, eastern Norton Sound, Alaska.

Cooling ages on glaucophane, barroisite, amphibole, paragonite, and biotite from metamorphic rocks range from 84 Ma to 209 Ma. The cooling age of white mica in a possible fault zone is 144 Ma. Cooling ages on late-stage metamorphic minerals (winchite and white mica) from veins cutting foliation in metamorphic rocks range from 117 Ma to 139 Ma. Cooling ages on white mica and adularia from hydrothermal mineralization-related veins range from 105 to 131 Ma. The cooling age for one highly alkalic dike is 107 Ma. Cooling ages for younger mafic dikes range from 80 Ma to 84 Ma. The preferred age on a whole-rock sample of basalt is 0.780 ± 0.011 Ma. Closure and cooling ages on the Cape Denbeigh granite (hornblende, K-feldspar) are 119 Ma and 113 Ma, respectively.

INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) Mineral Resources Section conducted geologic mapping and a mineral-resource evaluation on the southern Seward Peninsula, Alaska, during the summers of 2003, 2004, and 2006 as part of the state-funded Airborne Geophysical/Geological Mineral Inventory (AGGMI) Program. The DGGS airborne geophysical surveys (Burns and others, 2003, 2005), 1:50,000-scale surficial (Stevens, 2005a,b) and bedrock geologic maps (Werdon and others, in press; Werdon and others, 2005a,b,c; Newberry and others, 2005a,b), and supporting geochemical (Werdon and others, 2005d, 2007) and geochronologic data (this study; Layer and Newberry, 2004) will foster a better understanding of the geology and mineral potential of the southern Seward Peninsula, Alaska. Additionally, as part of the Coastal Hazards program, the DGGS Engineering Geology Section collected a plutonic sample from Cape Denbeigh in eastern Norton Sound, Alaska.

The study areas are in the Bendeleben, Nome, Norton Bay, and Solomon quadrangles; the nearest town is Nome. Mineral exploration on the Seward Peninsula is active and ongoing for many deposit types, which include onshore and off-shore placer gold, graphite, metamorphic/orogenic gold vein, epithermal gold vein, plutonic-related gold, skarn, metasediment-hosted base-metal sulfides, and plutonic-related tin+tantalum+fluorine±rare-earth-elements. For this study, samples were selected for $^{40}Ar/^{39}Ar$ analysis to determine metamorphic cooling ages, metamorphic-related vein ages, plutonic and volcanic rock ages, and vein ages related to hydrothermal mineral deposits and occurrences. The purpose of this study is to help unravel the metamorphic, magmatic, and metallogenic evolution of the southern Seward Peninsula.

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This data release includes the following products: a summary of sample collection and analytical 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:10.14509/29413.

SAMPLE COLLECTION TECHNIQUES

Field geologists collected rock samples from surface outcrops throughout the southern Seward Peninsula, as well as from drill core from the Rock Creek and Big Hurrah mines and Bluff prospect. Care was taken to collect fresh, unweathered samples displaying sufficiently large grains for the mineral-separate samples. Location coordinates (in NAD83 for the Cape Denbeigh sample, and NAD27 datum for all other samples) were collected using handheld GPS units, with a typical reported accuracy of about 10 m or less. All location coordinates were converted to latitude and longitude (NAD1983) coordinates using ArcGIS v. 10.2.2. Prior to submission to the laboratory for $^{40}Ar/^{39}Ar$ analysis, thin-sections of all samples (except for the Cape Denbeigh sample) were petrographically inspected to ensure that minerals selected for dating of magmatic crystallization were free of alteration, and that samples with white mica in veins had coarse enough white mica present for mineral separation.

ANALYTICAL METHODS

DGGS submitted rock samples for $^{40}Ar/^{39}Ar$ analysis to the Geochronology Laboratory at the University of Alaska Fairbanks (UAF), where they were crushed, sieved to either 100–250- or 250–500-micron size fractions, washed, and hand-picked for glaucophane, barroisite, winchite, paragonite, compositionally undetermined white mica and amphiboles, adularia, K-feldspar, and biotite. One whole rock sample of basalt was crushed, sieved, and washed. The monitor mineral MMhb-1 (Samson and Alexander, 1987) with an age of 513.9 Ma (Lanphere and Dalrymple, 2000) was used to monitor neutron flux (and calculate the irradiation parameter, J) for all but one sample. For sample 04MBW254A, a Quaternary basalt, the monitor mineral TCR-2 with an age of 27.87 Ma (Lanphere and Dalrymple, 2000) was used. 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 various positions in the uranium-enriched research reactor of McMaster University in Hamilton, Ontario, Canada, for 20 megawatt-hours (positions for each sample are documented in the accompanying data distribution file set).

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 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.

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: $(^{39}Ar/^{37}Ar)Ca = 7.06 \times 10^{-4}$, $(^{36}Ar/^{37}Ar)Ca =$

2.79×10^{-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 of the $^{40}Ar/^{39}Ar$ analyses is included in the accompanying data distribution file set, with all ages quoted to the ±1-sigma level and calculated using the constants of Lanphere and Dalrymple, 2000). 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). Weighted averages of the plateau ages are reported for selected multi-run samples. The spectrum provides a weighted-mean-average age if three or more consecutive gas fractions represent at least 33 percent of the total gas release and they are not within two standard deviations of each other (Mean Square Weighted Deviation [MSWD] greater than or equal to 2.5).

Below, samples are grouped by type (a basalt whole rock, dikes, white mica and adularia in hydrothermal veins, a plutonic rock, metamorphic vein minerals, metamorphic minerals in a possible fault zone, and metamorphic minerals). Each sample is described individually, select ages and errors are listed, including the preferred age determination for each mineral phase or whole rock sample, and finally an interpretation of what the preferred age represents.

BASALT WHOLE ROCK

04MBW254A (whole rock)

Basalt: black, vesicular, olivine-bearing lava flow

Three whole-rock separates were step heated. The three spectra yielded plateau ages of 0.802 ± 0.014 Ma, 0.774 ± 0.016 Ma, and 0.767 ± 0.012 Ma, and a 3-run-average plateau age of 0.780 ± 0.011 Ma. An isochron age of 0.778 ± 0.013 Ma, with an initial $^{40}Ar/^{36}Ar_i$ ratio of 296 ± 4, was calculated from all but three of the individual steps from the three runs. The isochron and 3-run-average plateau age are identical within error, and based on the lower error, we chose the 3-run-average plateau age (0.780 ± 0.011 Ma) as the preferred age.

Interpretation: Represents age of lava flow.

DIKES

04SAH119A (biotite)

Dike: alkalic; contains biotite, analcime, garnet, and nepheline

One spectrum yielded a plateau age of 107.2 ± 0.6 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

04MBW94A (biotite)

Dike: plagioclase-porphyritic, biotite gabbro

One spectrum yielded a weighted-mean-average age of 80.1 ± 1.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

04MBW384C (biotite)

Dike: biotite gabbro

One spectrum yielded a plateau age of 83.9 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

04MBW525A (biotite)

Dike: biotite gabbro

One spectrum yielded a weighted-mean-average age of 83.5 ± 0.4 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

06RN246A (biotite)

Bluff prospect: DDH 18, between 346 and 352 feet; dike; porphyritic, biotite gabbro

One spectrum yielded a plateau age of 82.6 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

06RN308A (biotite)

Dike: contains biotite, olivine, and plagioclase phenocrysts; biotite gabbro

One spectrum yielded a plateau age of 82.7 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

06Z114A (biotite)

Dike: porphyritic, alkalic, biotite gabbro

One spectrum yielded a plateau age of 82.7 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of dike.

WHITE MICA AND ADULARIA IN HYDROTHERMAL VEINS

04RN351B (white mica)

Vein: cuts across foliation; contains quartz, ankerite, white mica, and plagioclase. Assay of sample does not contain gold (Werdon and others, 2005d).

One spectrum yielded a plateau age of 107.7 ± 0.6 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

04RN355C (white mica)

Vein: contains quartz, plagioclase, and white mica. Assay of sample contains 23 ppb gold (Werdon and others, 2005d).

Two white mica mineral separates were step heated. The two spectra yielded plateau ages of 106.5 ± 0.8 Ma and 106.0 ± 0.7 Ma. A two-run average of the plateau ages yields an average age of 106.2 ± 0.5 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

04RN391A (white mica) [corresponds to incorrect lab sample number 04RN319A]

Vein: contains quartz and white mica

One spectrum yielded a plateau age of 107.5 ± 0.7 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

04RN500C (white mica)

Vein: brecciated; fault zone; contains quartz, plagioclase, and white mica. Assay of sample does not contain gold (Werdon and others, 2005d).

Two white mica mineral separates were step heated. One spectrum yielded a plateau age of 117.7 ± 1.0 Ma, and one spectrum yielded weighted-mean-average age of 116.7 ± 2.1 Ma. The preferred age is 117.7 ± 1.0 Ma.

Interpretation: Represents age of hydrothermal vein.

EF88-42 (white mica)

Big Hurrah mine: vein; contains quartz, white mica, arsenopyrite, and visible gold

Six white mica mineral separates were step heated. Five spectra yielded plateau ages ranging from 114.8 ± 0.9 Ma to 120.4 ± 0.7 Ma, and one spectrum yielded a weighted-mean-average age of 119.5 ± 2.5 Ma. A six-run average of all ages yields an average age of 118.5 ± 0.8 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

04Z156C (white mica) [corresponds to incorrect lab sample number 04Z156]

Vein: contains quartz, iron oxide, and white mica. Assay of sample contains 7 ppb gold (Werdon and others, 2005d).

One spectrum yielded a plateau age of 112.8 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

04Z288A (white mica)

West Creek prospect: vein; contains quartz, arsenopyrite, pyrite, calcite, and white mica. Assay of sample contains 860 ppb gold (Werdon and others, 2005d).

Three white mica mineral separates were step heated. The three spectra yielded weighted-mean-average ages ranging from 130.2 ± 0.7 Ma to 135.1 ± 1.4 Ma. A three-run average of the plateau ages yields an average age of 131.1 ± 1.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

04Z296A (white mica)

West Creek mine dump: vein; contains quartz, white mica, scorodite, arsenopyrite, and pyrite. Assay of sample contains 90 ppb gold (Werdon and others, 2005d).

Three white mica mineral separates were step heated. The three spectra yielded weighted-mean-average ages ranging from 126.7 ± 1.2 Ma to 128.7 ± 2.9 Ma. A three-run average of the plateau ages yields an average age of 127.8 ± 0.6 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

04Z638A (white mica)

Rock Creek mine: DDH RKDC03-169 at 28.96 meters; vein; contains quartz, arsenopyrite, pyrite, white mica, and carbonate

Two white mica mineral separates were step heated. One spectrum yielded a plateau age of 112.3 ± 0.8 Ma and one spectrum yielded a weighted-mean-average age of 112.8 ± 1.4 Ma. The preferred age is 112.3 ± 0.8 Ma.

Interpretation: Represents age of mineralized hydrothermal vein.

04Z641A (white mica) [corresponds to incorrect lab sample number 04Z641]

Rock Creek mine: DDH RKDC03-161 at 84.75–85.31 meters; vein; contains quartz, calcite, arsenopyrite, pyrite, white mica, and iron oxide.

One spectrum yielded a plateau age of 102.3 ± 0.7 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

06JEA706A (white mica)

Koyana Creek prospect: vein; contains quartz, white mica, pyrite, arsenopyrite, and schist inclusions. Assay of sample contains 6.15 ppm gold (Werdon and others, 2007).

Two white mica mineral separates were step heated. The two spectra yielded plateau ages of 108.1 ± 0.4 Ma and 108.1 ± 0.5 Ma. A two-run average of the plateau ages yields an average age of 108.1 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

06RN522B (adularia)

Bluff prospect: DDH 4 at 280–281 feet; vein in altered schist; contains quartz, arsenopyrite, albite, and adularia. Assay of sample 06RN522A from this site contains 8 ppb gold (Werdon and others, 2007).

Eight adularia mineral separates were step heated. The eight spectra yielded plateau ages ranging from 103.7 ± 0.4 Ma to 106.1 ± 0.3 Ma. Seven of the eight plateau ages are statistically identical. The eighth analysis (106.1 ± 0.3 Ma) is significantly older than the other seven. This variance might be geologically significant or it might be analytical. A seven-run average of the statistically identical plateau ages yields an average age of 104.6 ± 0.2 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

06RN556B (white mica)

Montana Creek: vein; contains quartz, albite, white mica, and calcite. Assay of sample does not contain gold (Werdon and others, 2007).

One spectrum yielded a plateau age of 107.4 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

06Z489B (white mica)

Vein: brecciated; contains quartz, white mica, and ankerite. Assay of sample does not contain gold (Werdon and others, 2007).

Two white mica mineral separates were step heated. The two spectrum yielded plateau ages of 111.1 ± 0.4 Ma and 111.8 ± 0.4 Ma. A two-run average of the plateau ages yields an average plateau age of 111.5 ± 0.4 Ma, which is the preferred age for this sample.

Interpretation: Represents age of hydrothermal vein.

06Z492A (white mica)

Idaho lode prospect: vein; contains quartz, white mica, and schist inclusions. Assay of sample contains 7.82 ppm gold (Werdon and others, 2007).

One spectrum yielded a plateau age of 108.7 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

06LF362A (white mica)

Vein: contains quartz, white mica, albite, and chlorite. Assay of sample contains 423 ppb gold (Werdon and others, 2007).

One spectrum yielded a plateau age of 107.2 ± 0.4 Ma, which is the preferred age for this sample.

Interpretation: Represents age of mineralized hydrothermal vein.

PLUTONIC ROCK

2011-SKK-MD051 (amphibole) [corresponds to incorrect lab sample number 2100-SKK-MD1 on amphibole mineral separate]

Cape Denbeigh granite:

The analysis produced a stepping-up age spectrum that is associated with loss/alteration. Due to the documented loss, no isochron age determination was possible. The spectrum yielded a plateau age of 119.3 ± 0.4 Ma, which is the preferred age for this sample because of the documented loss.

Interpretation: Represents closure age of amphibole in the pluton.

2011-SKK-MD051 (feldspar) [corresponds to incorrect lab sample number 2100-SKK-MD1 on feldspar mineral separate]

Cape Denbeigh granite:

One spectrum yielded a plateau age of 112.7 ± 0.8 Ma, which is the preferred age for this sample because of the high atmospheric content of the first two steps. No isochron age determination was possible due to the generally homogenous radiogenic content of the steps used for the plateau age determination.

Interpretation: Represents cooling age of feldspar in the pluton.

METAMORPHIC VEIN MINERALS

03MBW390A (white mica)

Veins cutting schist: veins contain quartz, white mica, chlorite, and magnetite

Fifteen white mica mineral separates were step heated. Seven of the spectra yielded plateau ages ranging from 116.7 ± 0.7 Ma to 129.0 ± 0.8 Ma, and eight of the spectra yielded weighted-mean-average ages ranging from 117.9 ± 2.8 Ma to 132.9 ± 2.8 Ma. The spread of ages likely reflects multiple white mica populations and/or a complex cooling history. The youngest ages record the time of last closure, and likely indicate the age of the latest hydrothermal white micas to crystallize within the vein.

Interpretation: Represents the cooling ages of metamorphic white micas in a vein that cuts foliation.

04RN318A (winchite)

Metamorphic vein: contains white mica and amphibole (winchite) from vein cutting mafic schist

One spectrum yielded a plateau age of 138.6 ± 1.0 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of metamorphic winchite in a vein that cuts foliation.

04RN318B (white mica)

Metamorphic vein: contains white mica and amphibole (winchite) from vein cutting mafic schist

One spectrum yielded a weighted-mean-average age of 127.4 ± 3.4 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of metamorphic white mica in a vein that cuts foliation.

METAMORPHIC MINERALS; POSSIBLE FAULT ZONE

04MBW540A (white mica)

Schist: contains plagioclase porphyroblasts, coarse-grained white mica, and minor carbonate; collected within a possible fault zone.

One spectrum yielded a weighted-mean-average age of 143.7 ± 4.1 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of metamorphic white mica in a possible fault zone.

METAMORPHIC MINERALS

03MBW393A (barroisite)

Metamorphic rock: granofels; contains titanite, garnet, glaucophane, barroisite, chlorite, plagioclase, and clinozoisite

Seven barroisite mineral separates were step heated. The seven spectra yielded weighted-mean-average ages ranging from 140.1 ± 4.4 Ma to 182.4 ± 16.0 Ma, suggesting the barroisite records a complex metamorphic history. There is a Ca/K versus age correlation in this sample (Layer and Newberry, 2004).

Interpretation: No age interpretation could be reliably made.

04RN30A (paragonite) [corresponds to incorrect lab sample number 04RN030A on white mica (paragonite) mineral separate]

Metamorphic rock: granofels; contains glaucophane, garnet, clinozoisite, and paragonite

One spectrum yielded a weighted-mean-average age of 208.7 ± 1.9 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of paragonite.

04RN30B (glaucophane) [corresponds to incorrect lab sample number 04RN030A on glaucophane mineral separate]

Metamorphic rock: granofels; contains glaucophane, garnet, clinozoisite, and paragonite

One run yielded a stairstep-shaped spectrum with an integrated age of 320.5 ± 1.8 Ma.

Interpretation: No age interpretation could be reliably made.

04RN128A (glaucophane)

Metamorphic rock: granofels; contains glaucophane, garnet, and epidote

One spectrum yielded a weighted-mean-average age of 164.1 ± 4.4 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of glaucophane.

04MBW322A (biotite) [corresponds to incorrect lab sample number 04MBW332A]

Semischist: massive, equigranular, contains garnet, plagioclase, quartz, biotite, and white mica

One spectrum yielded a weighted-mean-average age of 186.2 ± 2.0 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of biotite.

04JEA19A (biotite) [corresponds to incorrect lab sample number 06JEA19A]

Orthogneiss: contains quartz, feldspar, and biotite

One spectrum yielded a plateau age of 87.3 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of biotite.

04JEA639A (amphibole) [corresponds to incorrect lab sample number 06JEA639A]

Metamorphic rock: amphibolite; black, blocky, contains plagioclase, trace biotite, amphibole, titanite, and 2-3 percent disseminated sulfide

Two amphibole mineral separates were step heated. The two spectra yielded plateau ages of 83.8 ± 0.4 Ma and 83.9 ± 0.3 Ma. A two-run average of the plateau ages yields an average age of 83.9 ± 0.3 Ma, which is the preferred age for this sample.

Interpretation: Represents cooling age of amphibole.

06LF184A (amphibole)

Metamorphic rock: granofels; contains white mica, chlorite, garnet, and amphibole

Seven amphibole mineral separates were step heated. The seven spectra yielded integrated ages ranging from 209.1 ± 5.1 Ma to 532.3 ± 2.5 Ma, and do not have significant plateau ages. This indicates the amphibole has a complex metamorphic history.

Interpretation: No age interpretation could be reliably made.

ACKNOWLEDGMENTS

Collection of all but one sample was undertaken as part of the DGGS Mineral Resources section's Council project. Three summers of field work (2003, 2004, 2006) were funded through the Alaska Airborne Geophysical/Geological Mineral Inventory Program, authorized by the Alaska State Legislature and managed by the State of Alaska, Department of Natural Resources, DGGS. Supplemental funding for field work was provided by the U.S. Geological Survey (USGS) STATEMAP program (grants 04HQPA0003 and 06HQPA0003). Studies of mineral chemistry and 21 samples for $^{40}Ar/^{39}Ar$ geochronology in the Council map area were funded by Grant 04HQGR0163 from the USGS Mineral Resources External Research Program to the University of Alaska Fairbanks (UAF) (Layer and Newberry, 2004). Samples in this report were collected by Melanie B. Werdon, David J. Szumigala, Jennifer E. Athey, and Lawrence K. Freeman of DGGS, and by Rainer J. Newberry and Shelly A. Hicks of UAF Department of Geology & Geophysics.

The collection of sample 2011-SKK-MD051 was funded with qualified outer continental shelf oil and gas revenues through the Coastal Impact Assistance Program, U.S. Fish and Wildlife Service (USFWS), U.S. Department of the Interior, under USFWS Grant F12AF70098. The sample was collected by Meagan DeRaps of DGGS.

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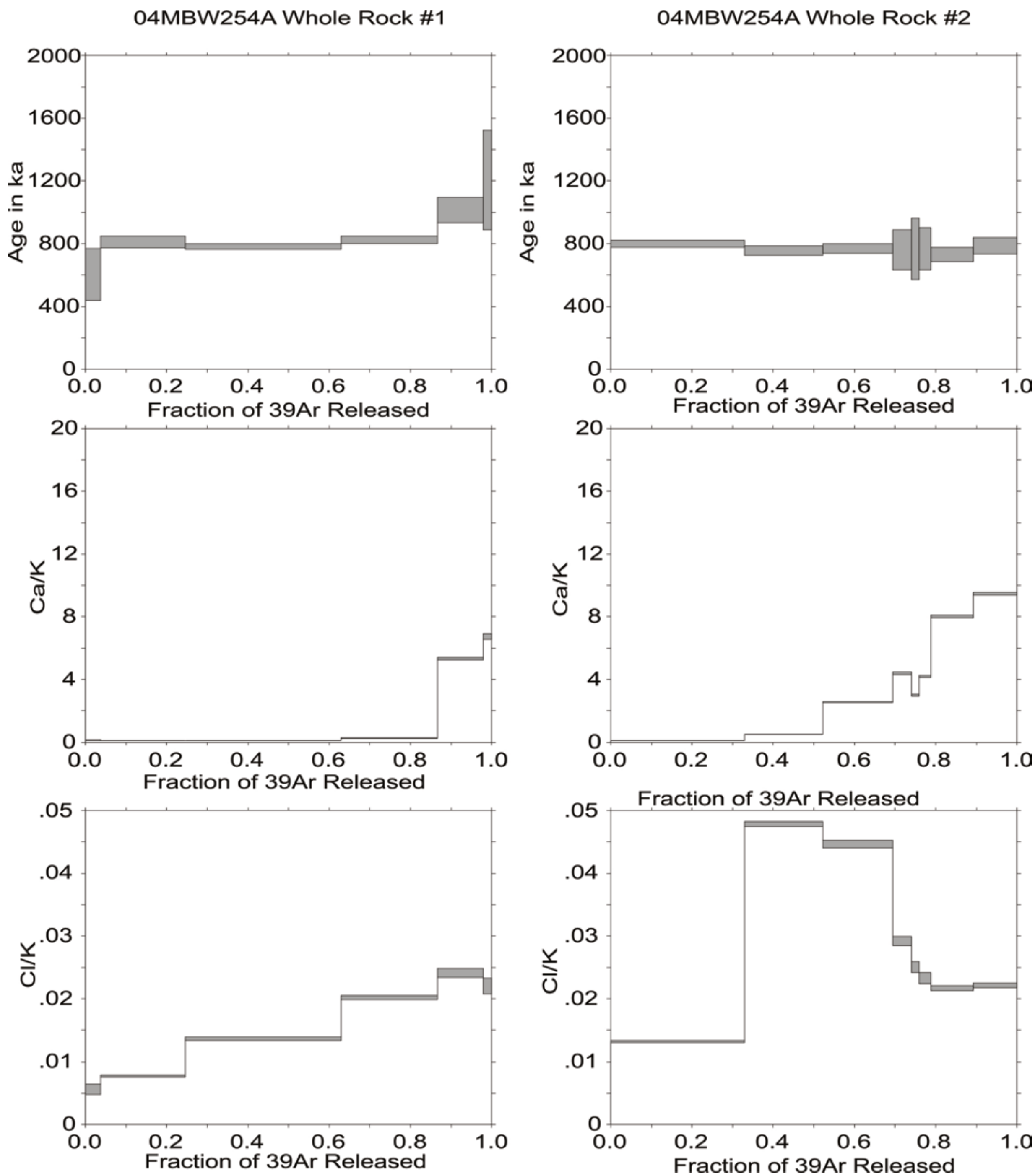
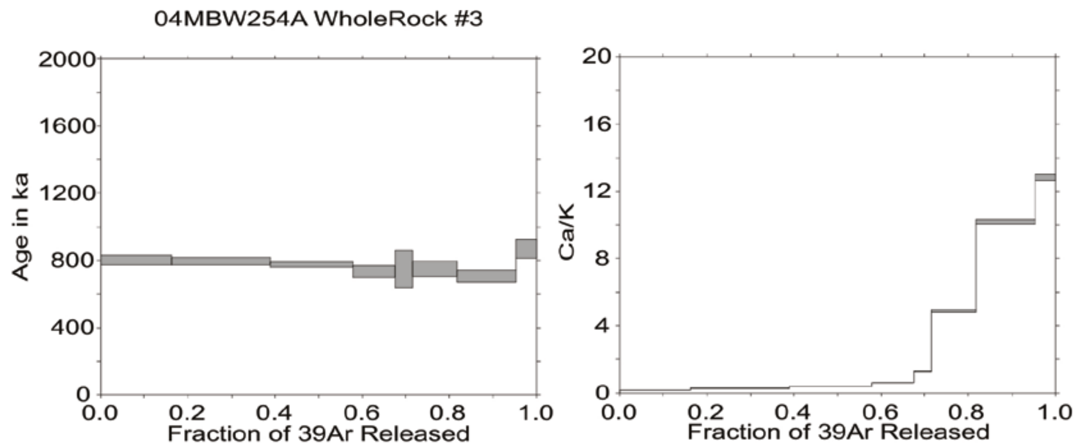
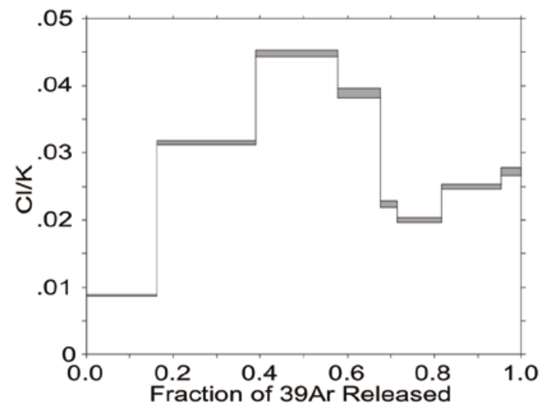
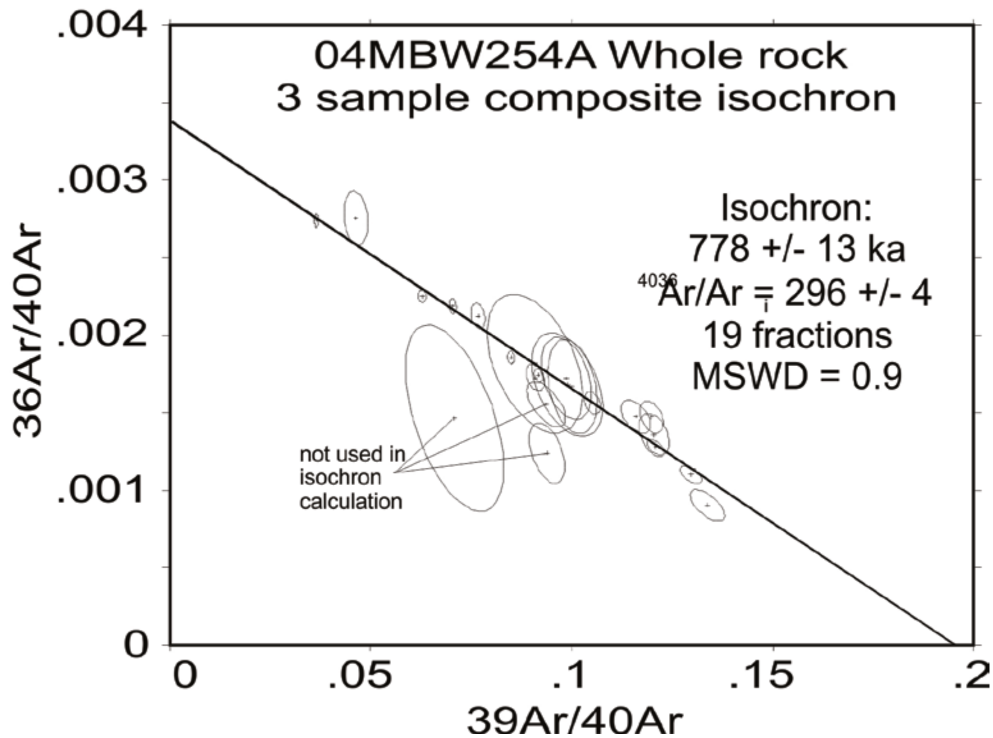
Appendix A-1: $^{40}Ar/^{39}Ar$ Age, Ca/K, and Cl/K Spectra Plots







Isochron from three runs of the basalt. Note that three fractions are excluded from the isochron analysis. They had anomalously old ages which correspond to high Ca/K ratios and may represent excess argon in plagioclase.



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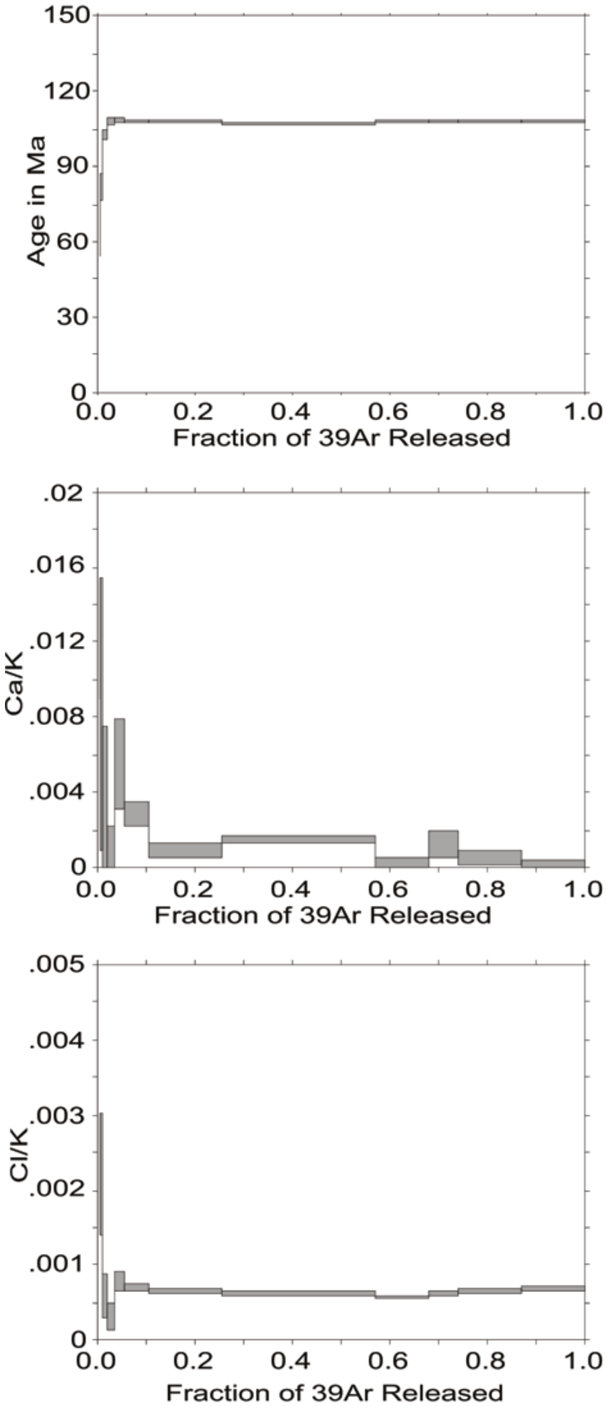

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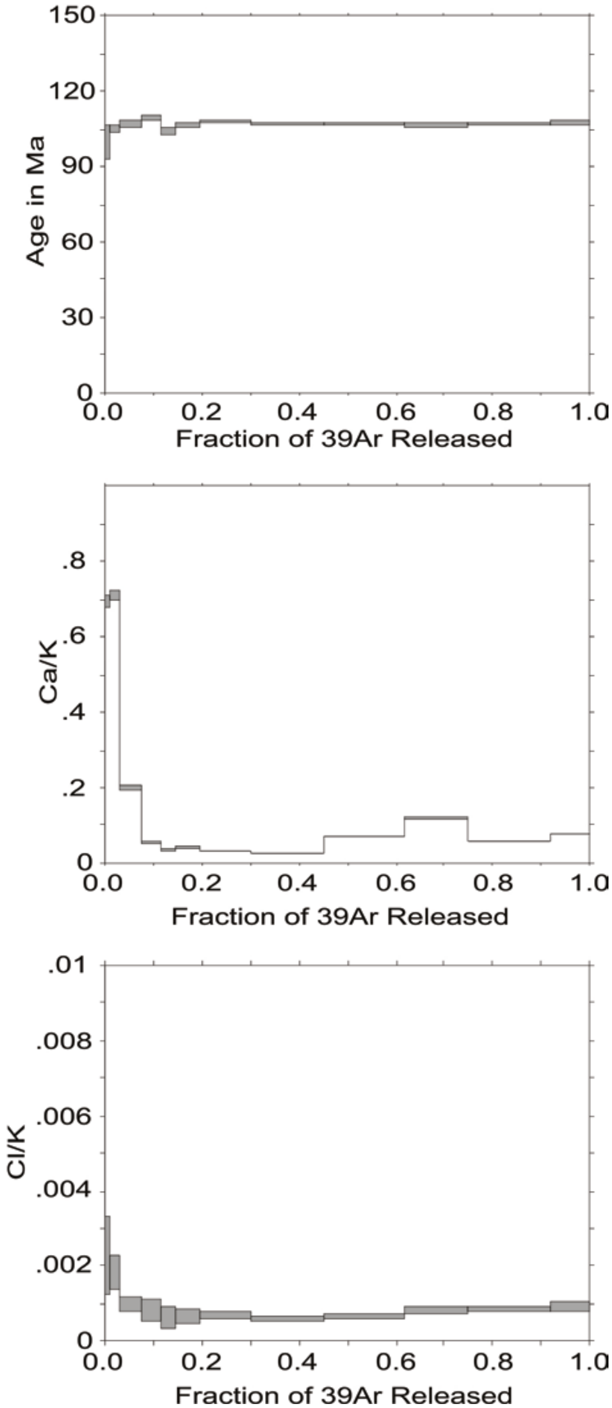

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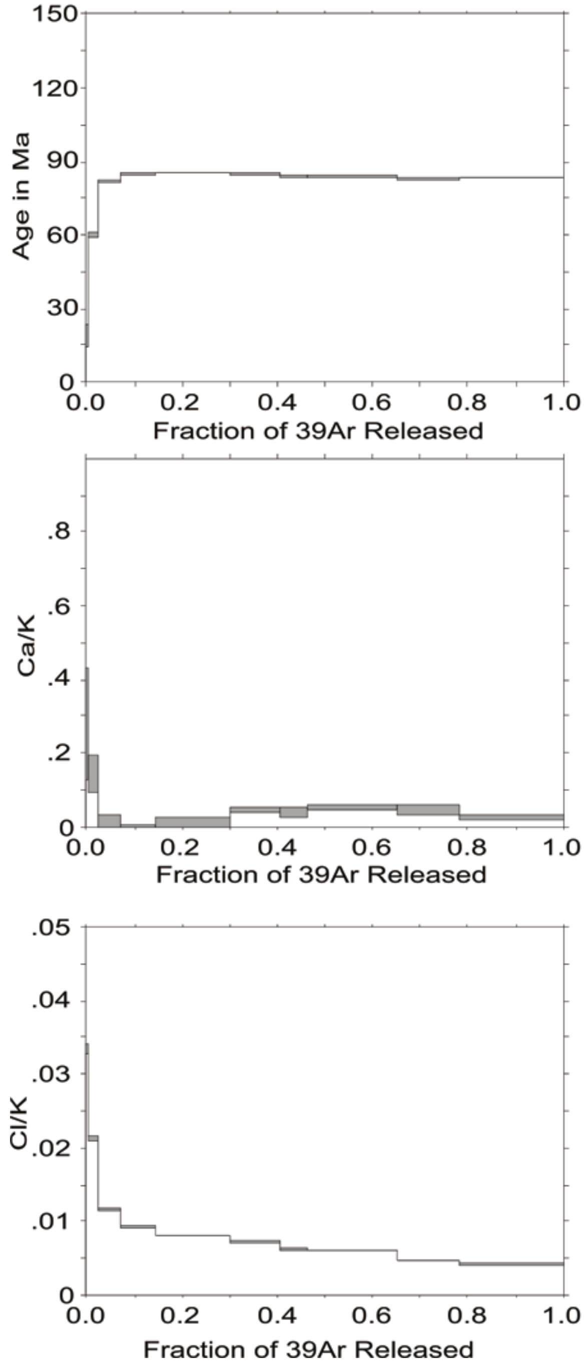

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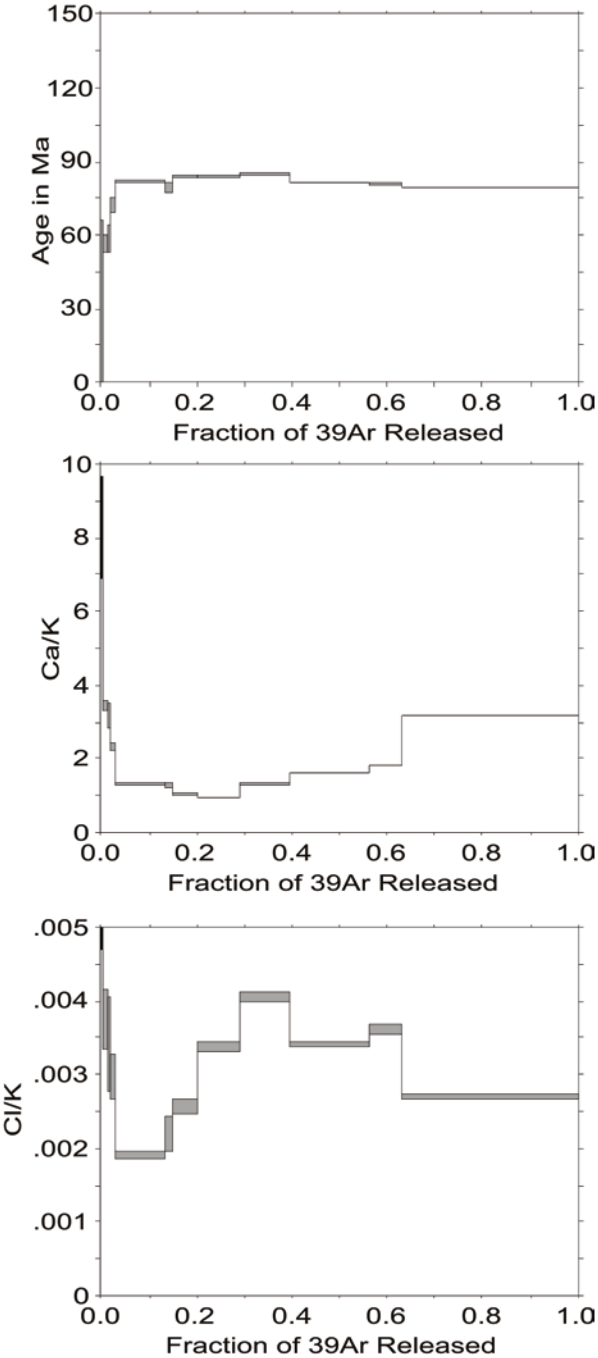

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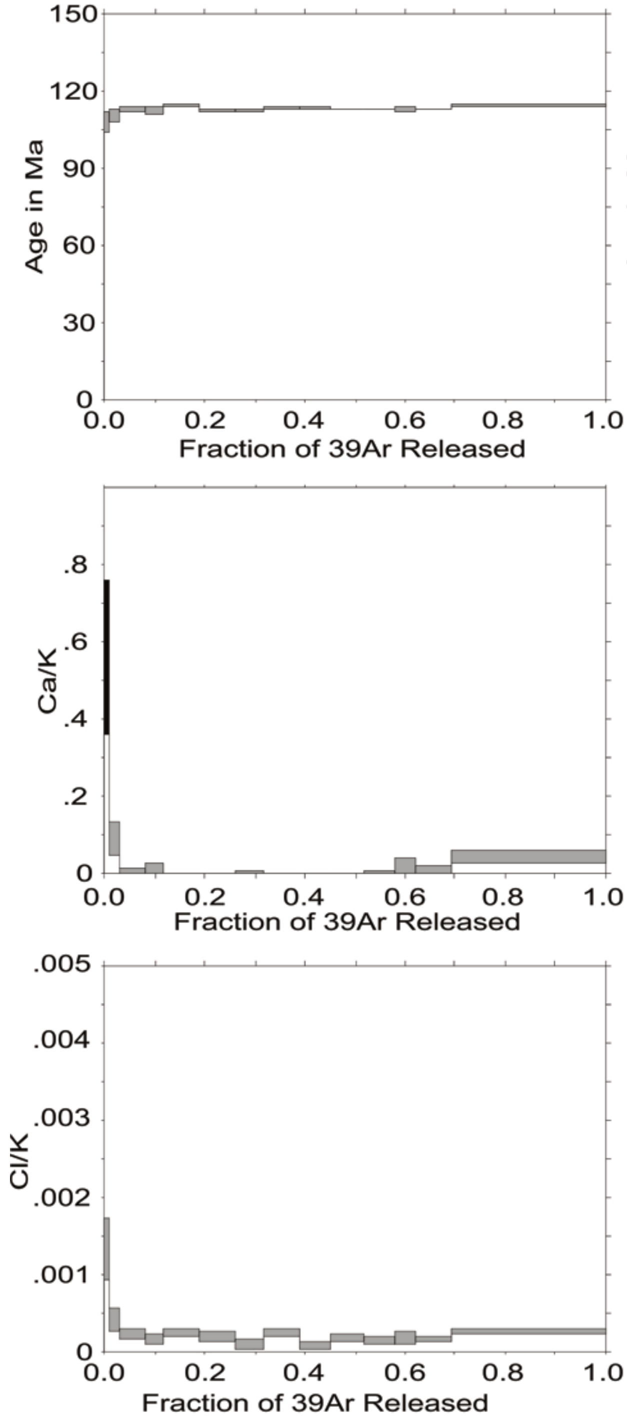

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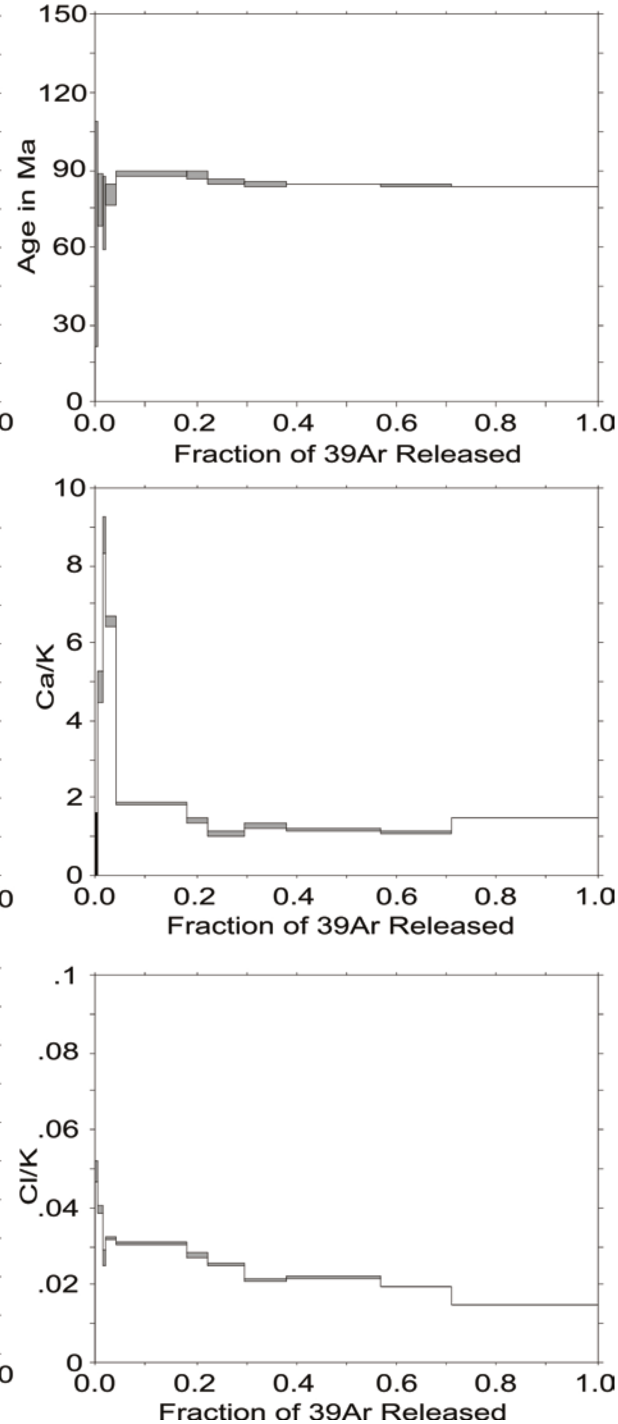

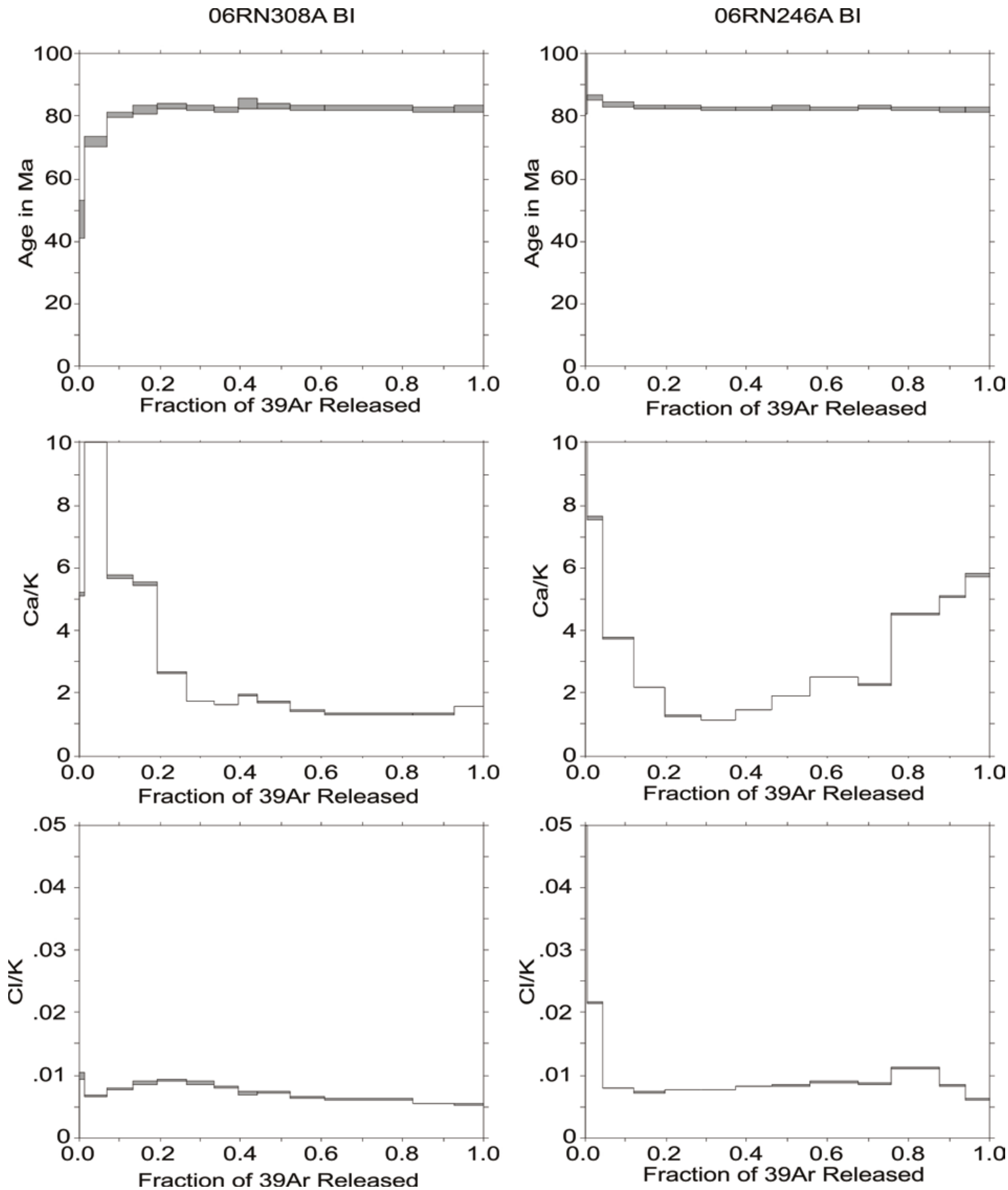
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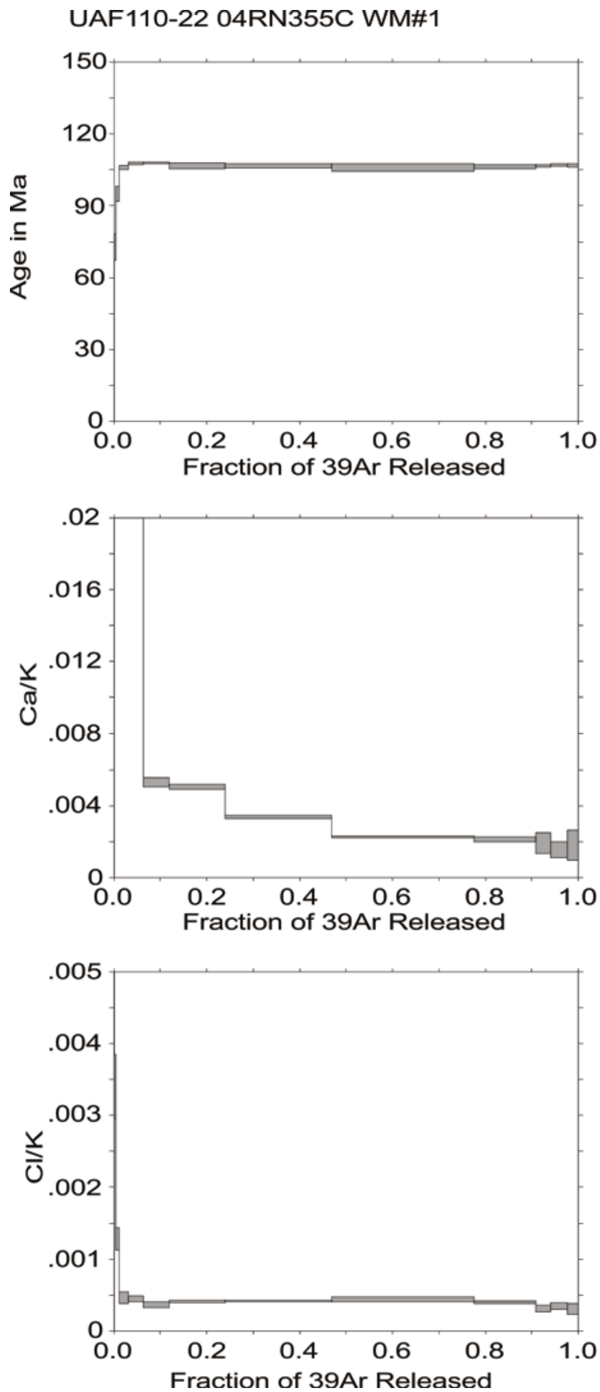
06RN246A BI
Age in Ma
Fraction of 39Ar Released
Ca/K
Cl/K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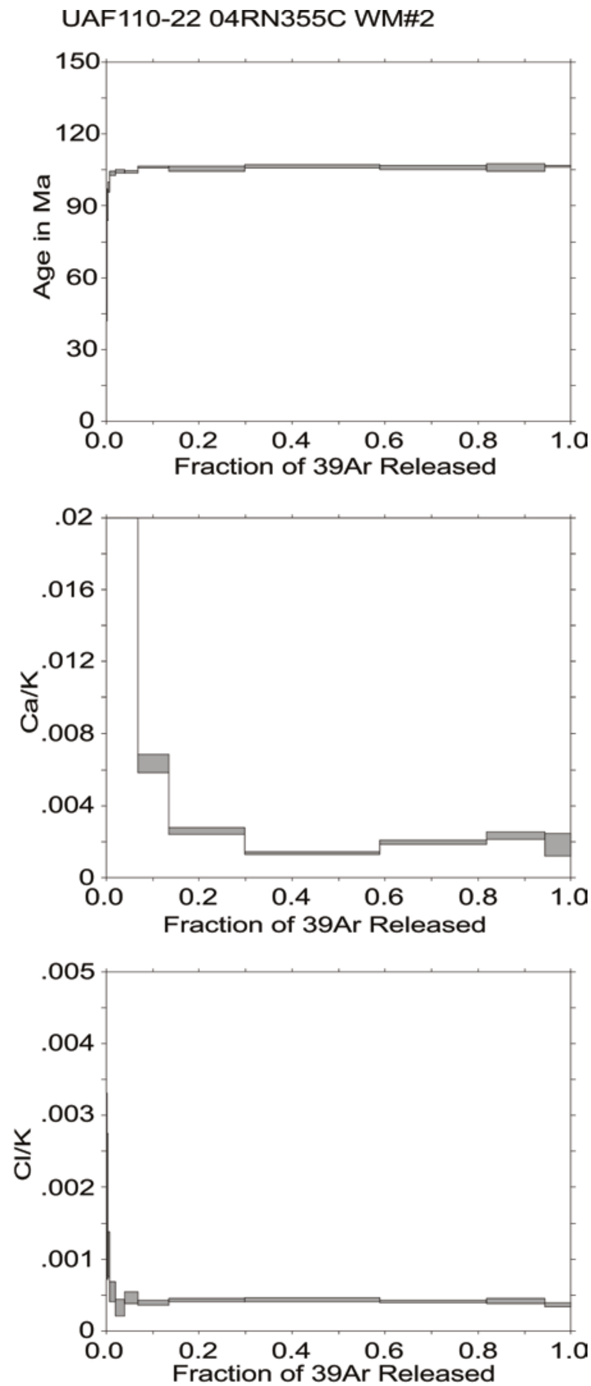
Age in Ma
Fraction of 39Ar Released
Ca/K
Fraction of 39Ar Released
Cl/K
Fraction of 39Ar Released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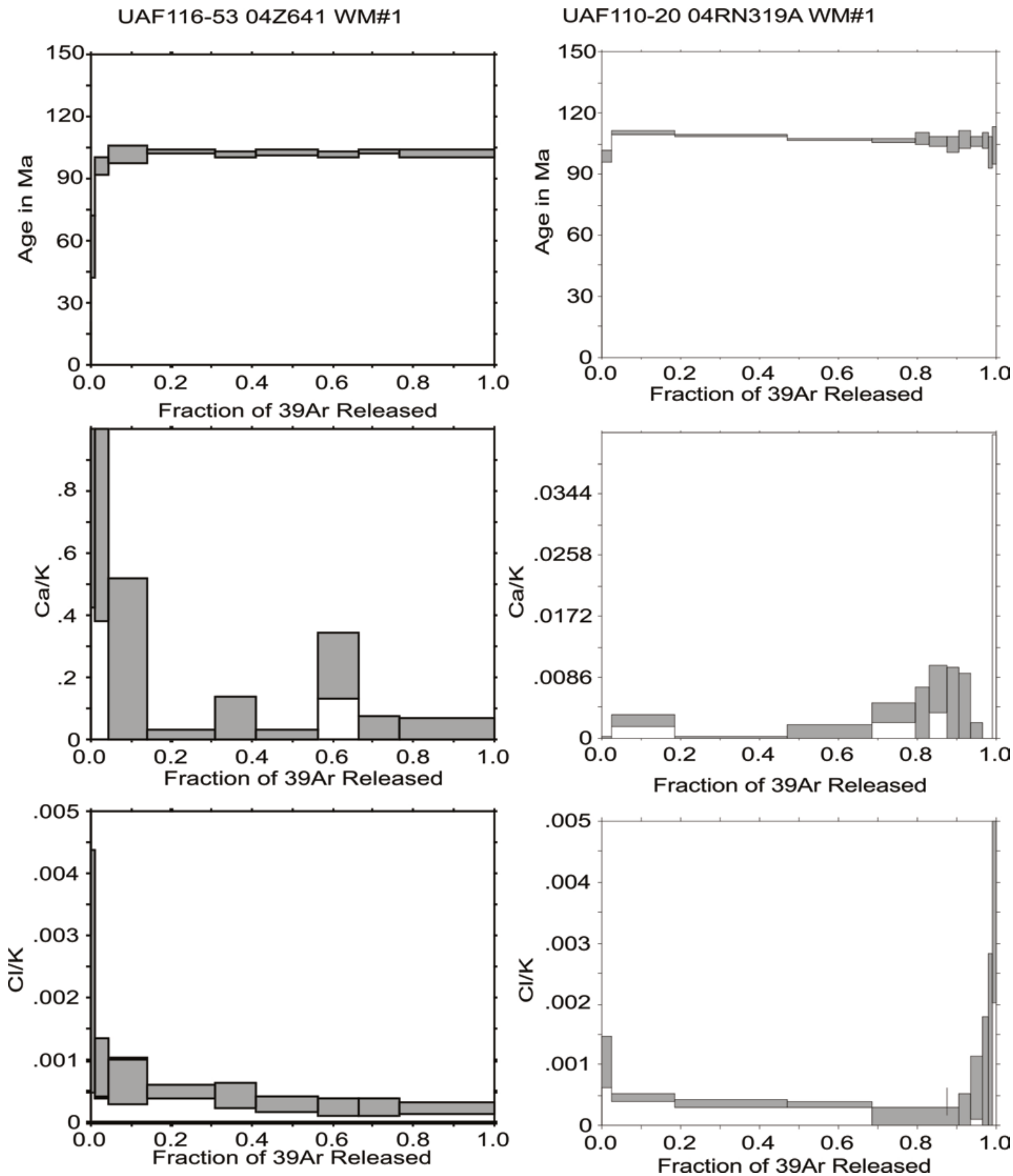
Age in Ma
Fraction of 39Ar Released
Ca/K
Fraction of 39Ar Released
Cl/K
Fraction of 39Ar Released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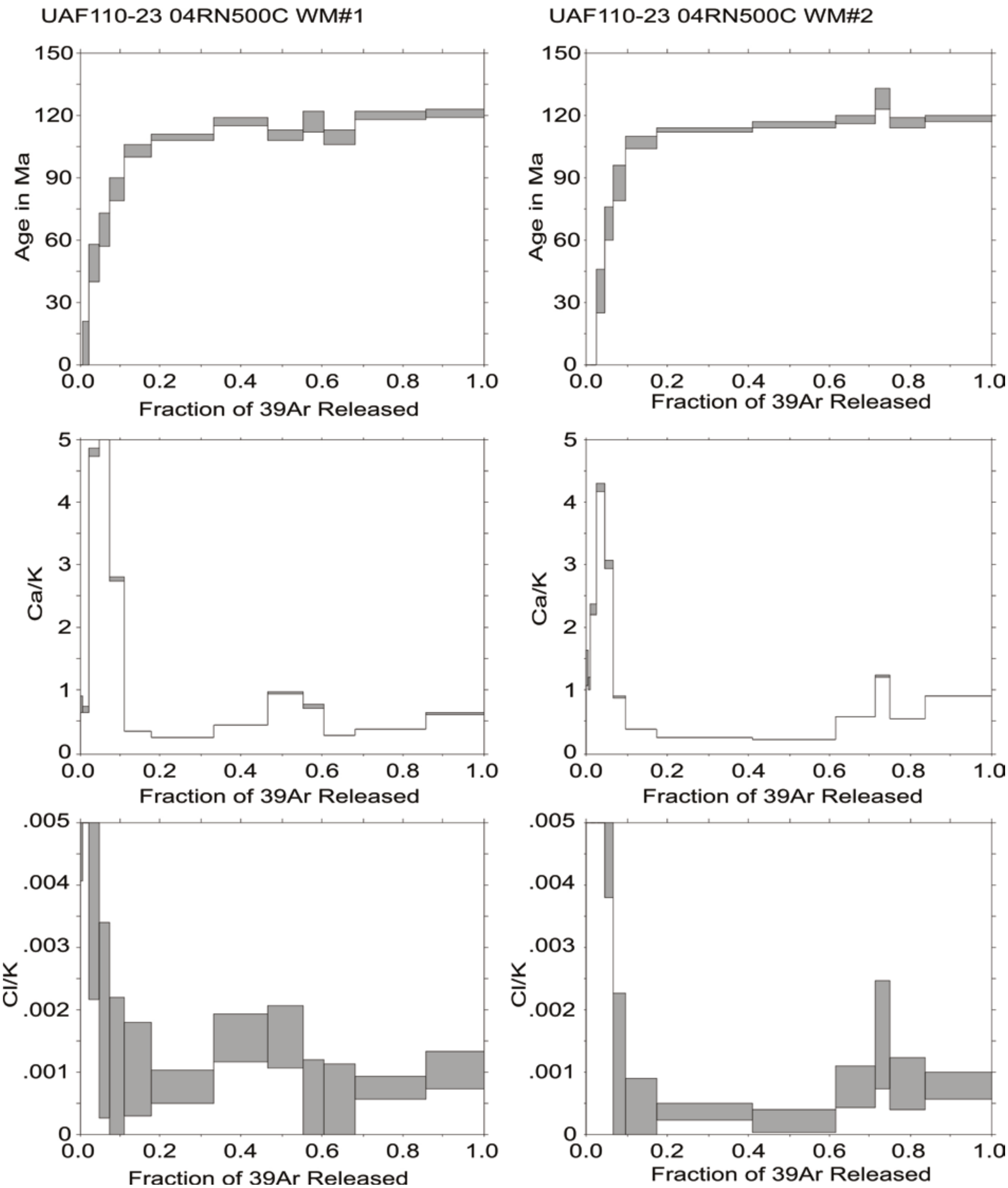
UAF110-20 04RN319A WM#1
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released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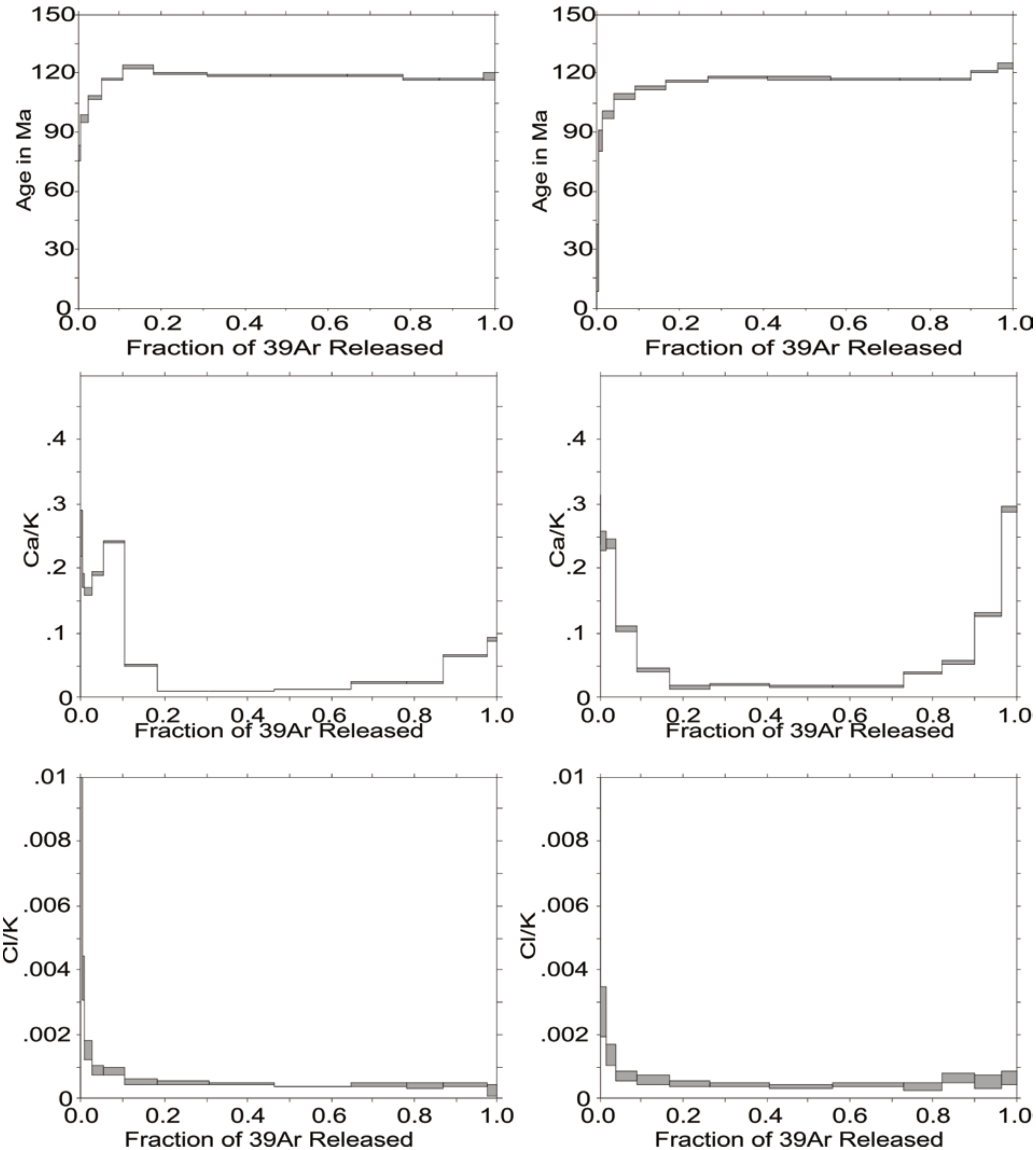
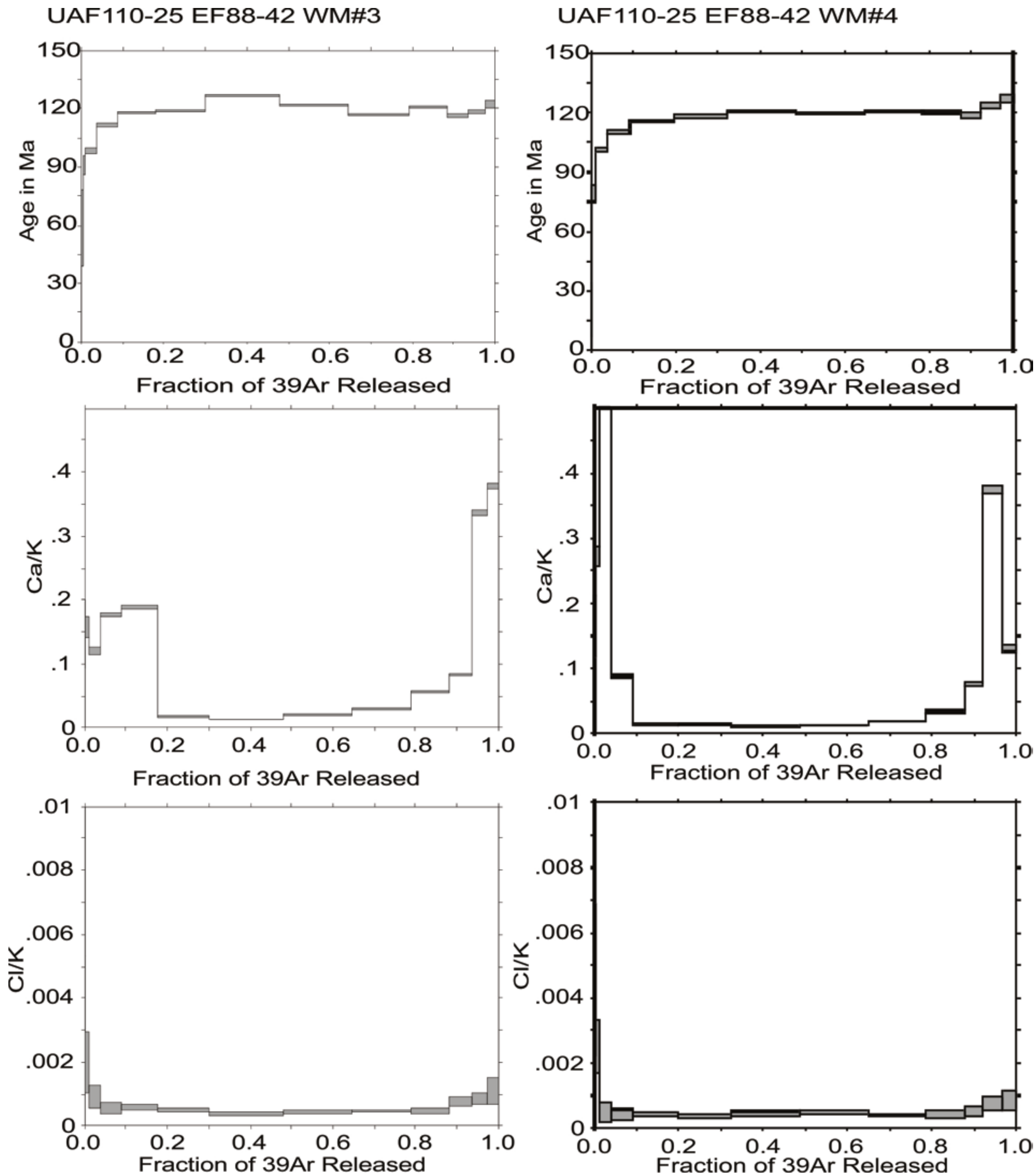
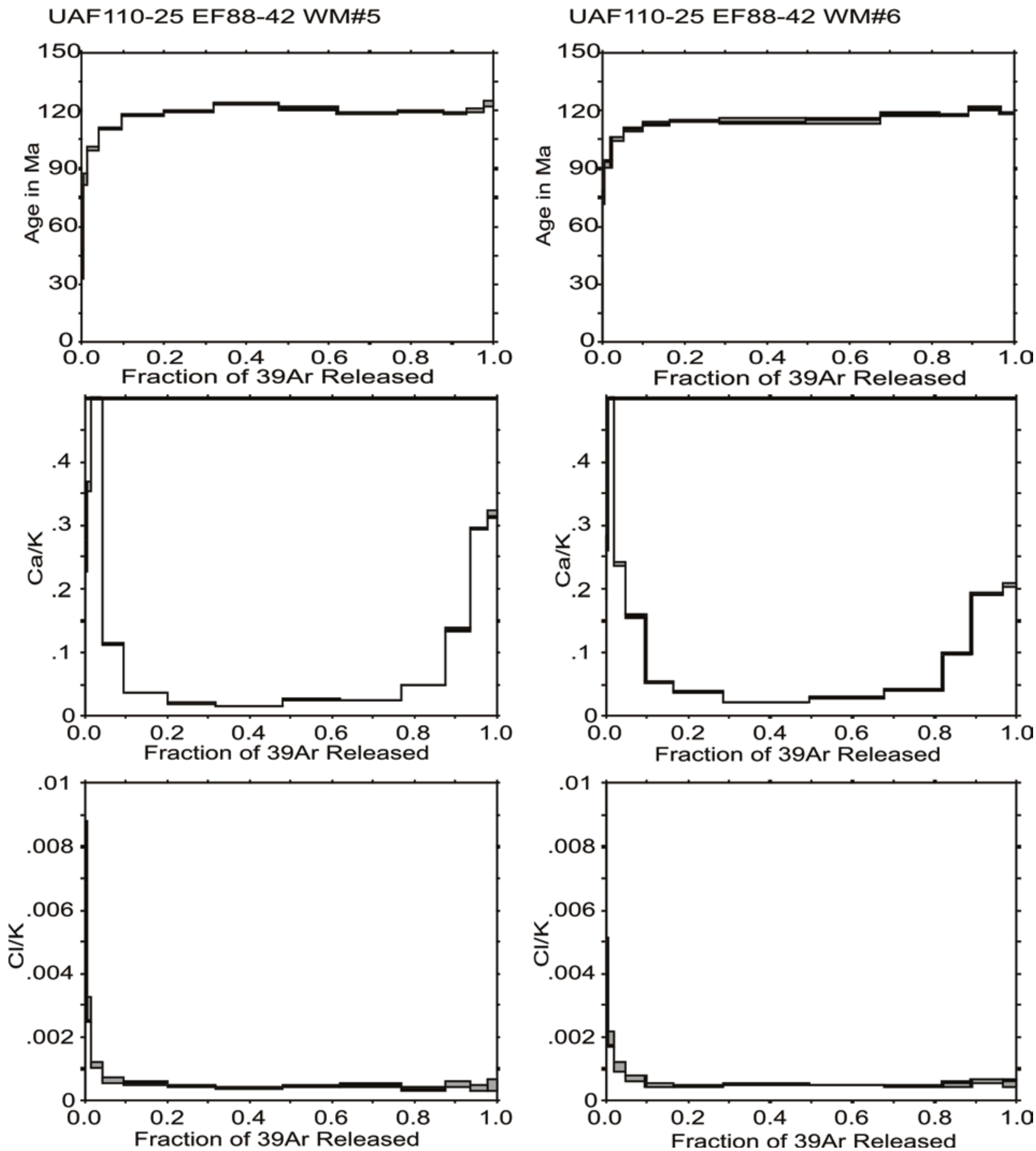
UAF110-23 04RN500C WM#2
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released

UAF110-25 EF88-42 WM#1 UAF110-25 EF88-42 WM#2




UAF110-25 EF88-42 WM#3
UAF110-25 EF88-42 WM#4
Age in Ma
0
30
60
90
120
150
Ca/K
0
.1
.2
.3
.4
Cl/K
0
.002
.004
.006
.008
.01
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


UAF110-25 EF88-42 WM#5
UAF110-25 EF88-42 WM#6
Age in Ma
150
120
90
60
30
0
Ca/K
.4
.3
.2
.1
Cl/K
.01
.008
.006
.004
.002
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released

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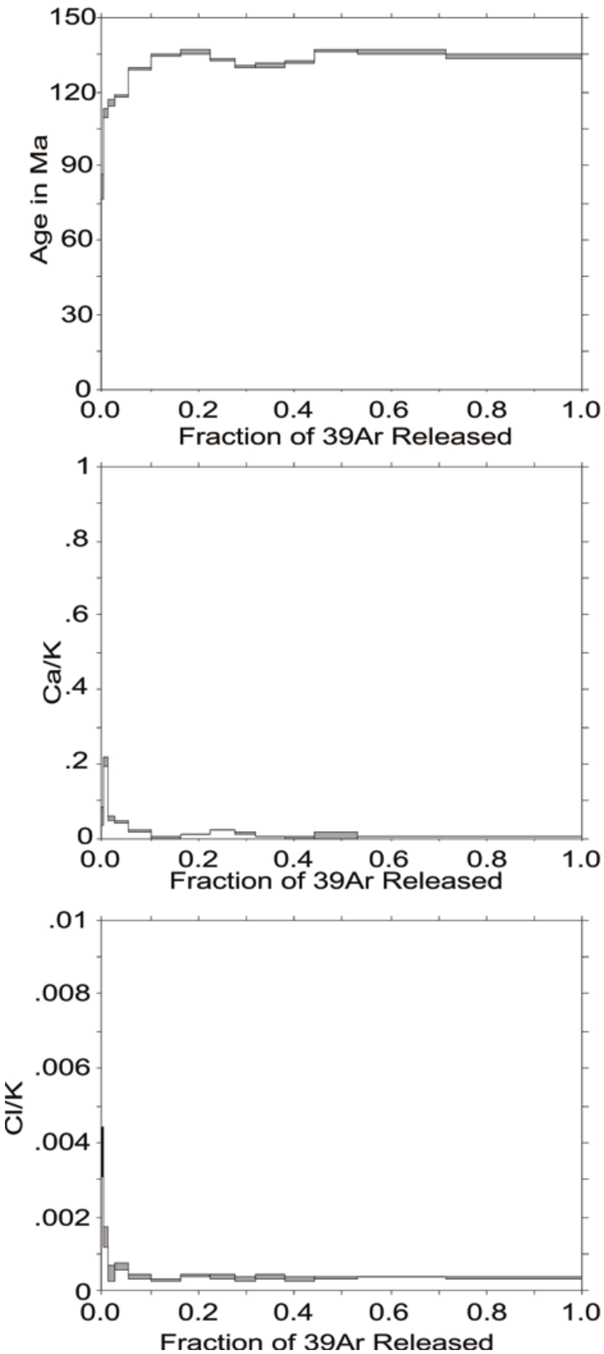

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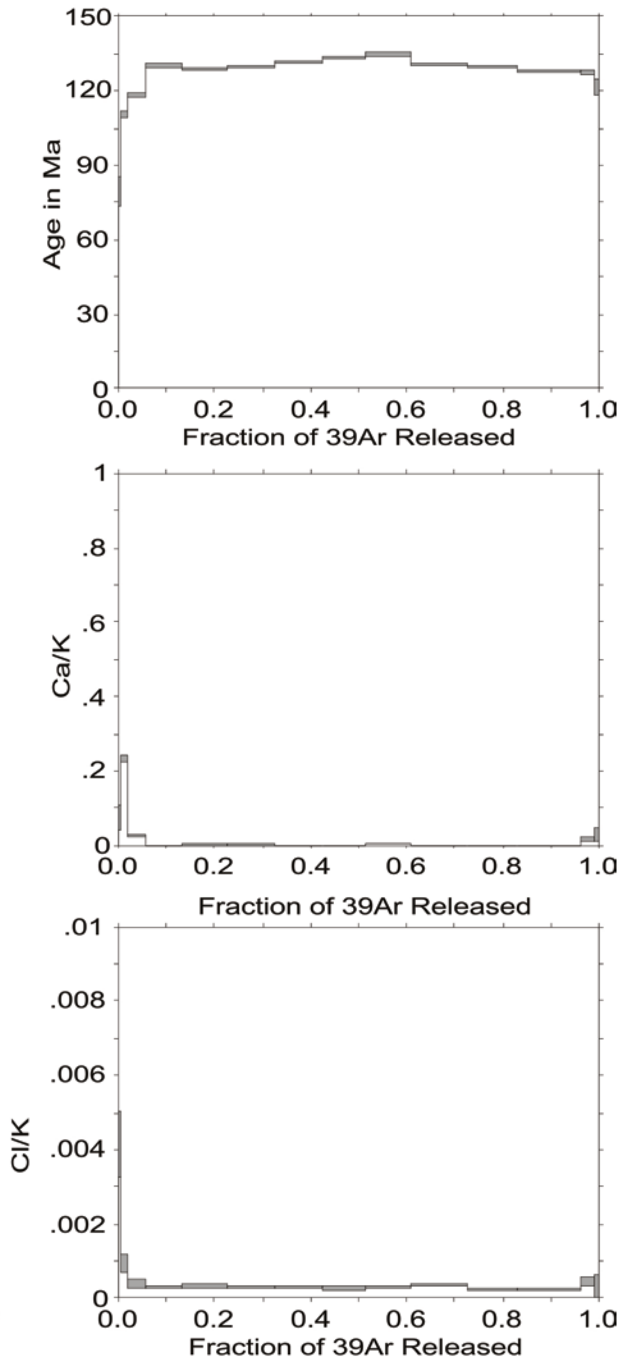

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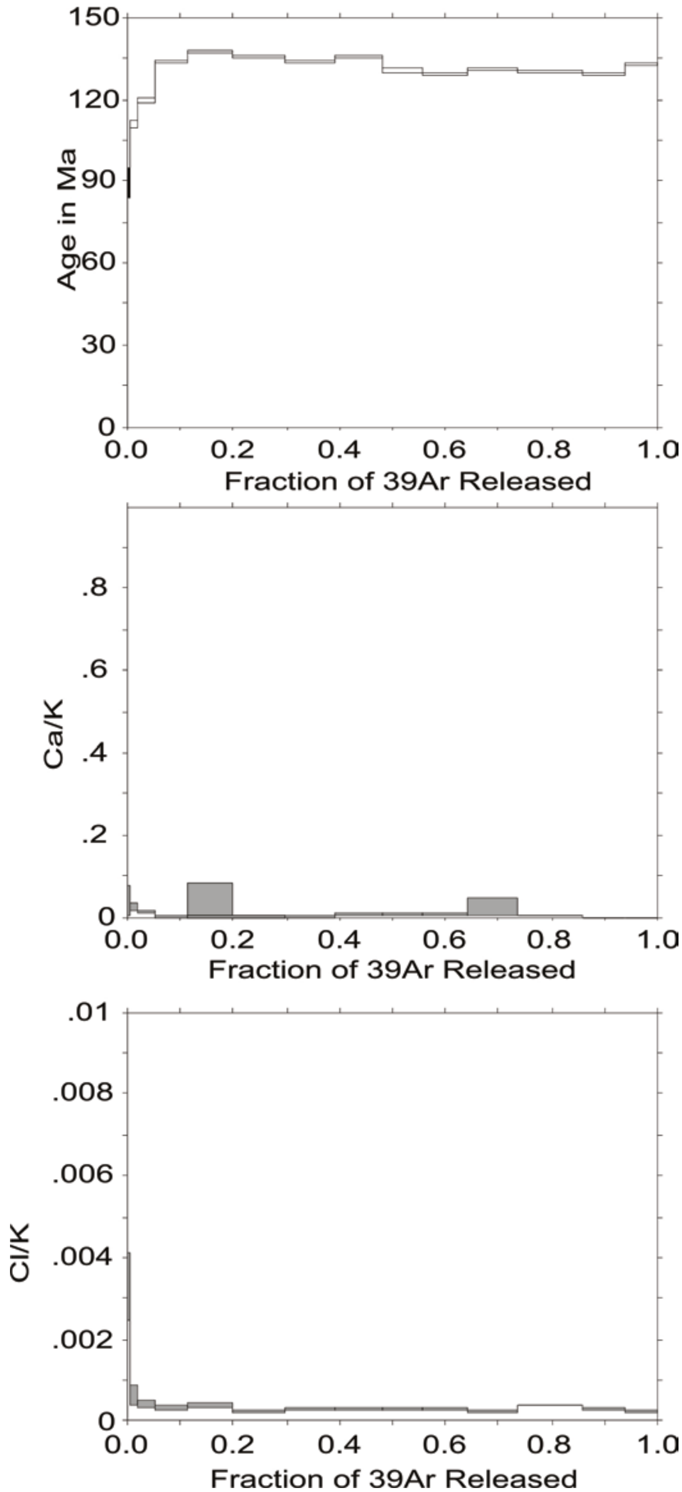

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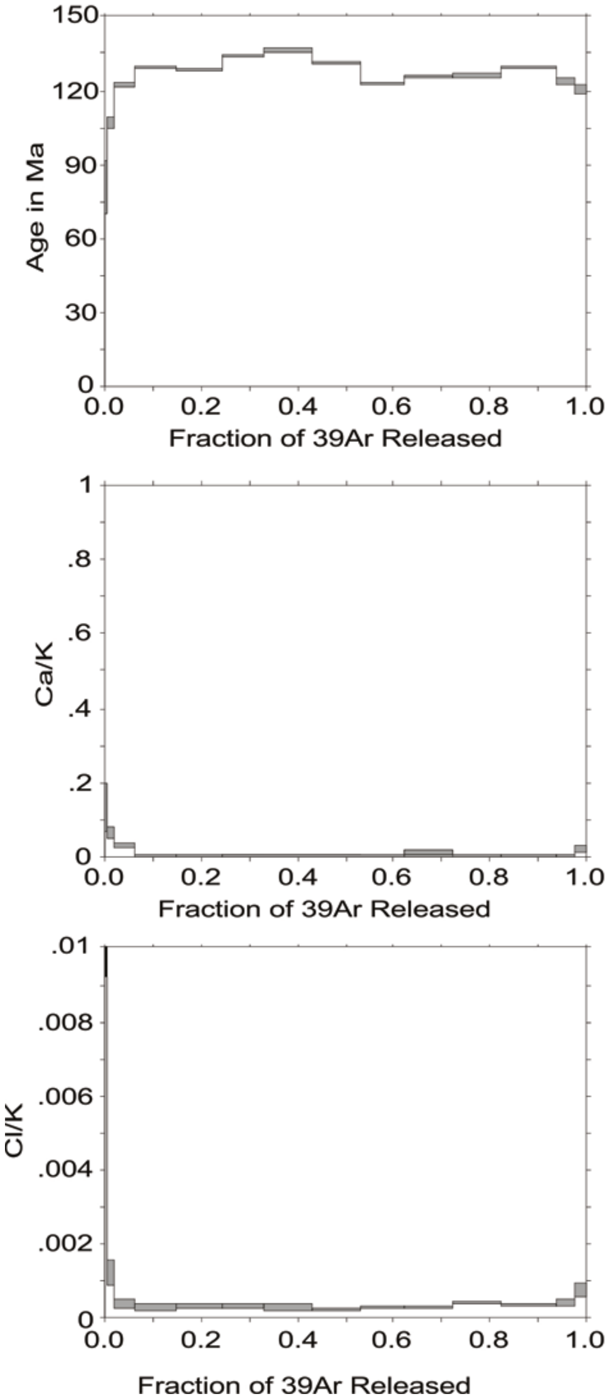

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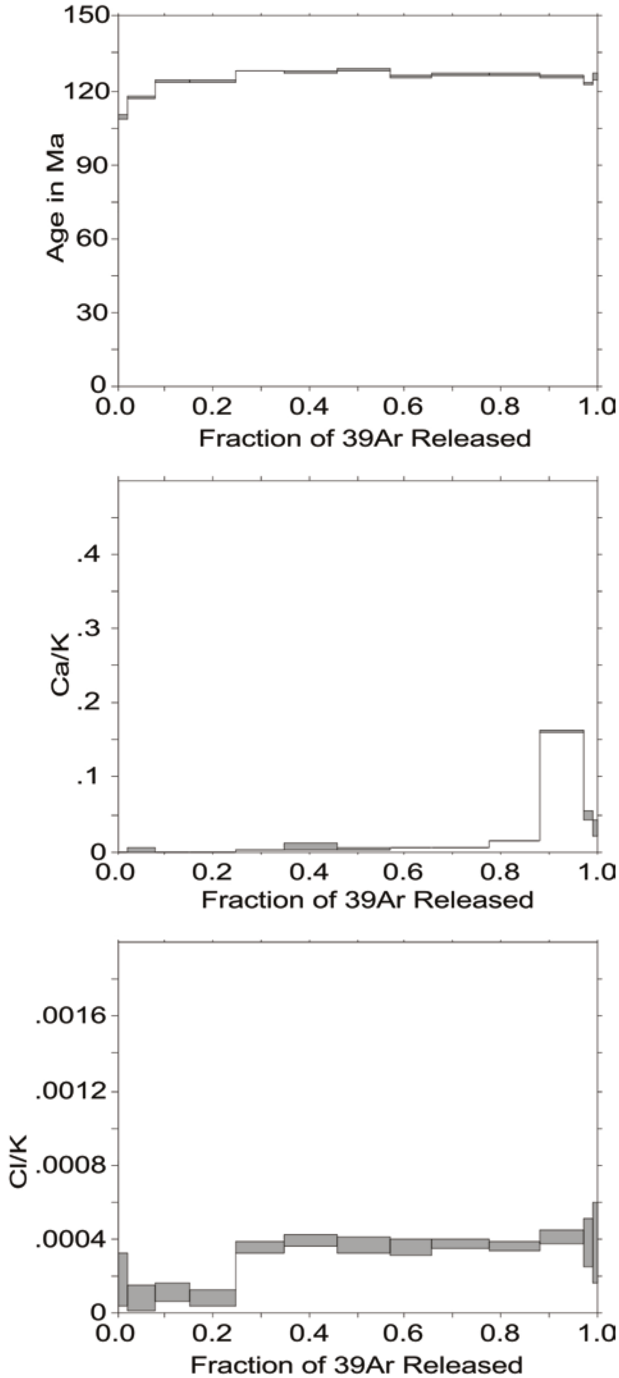

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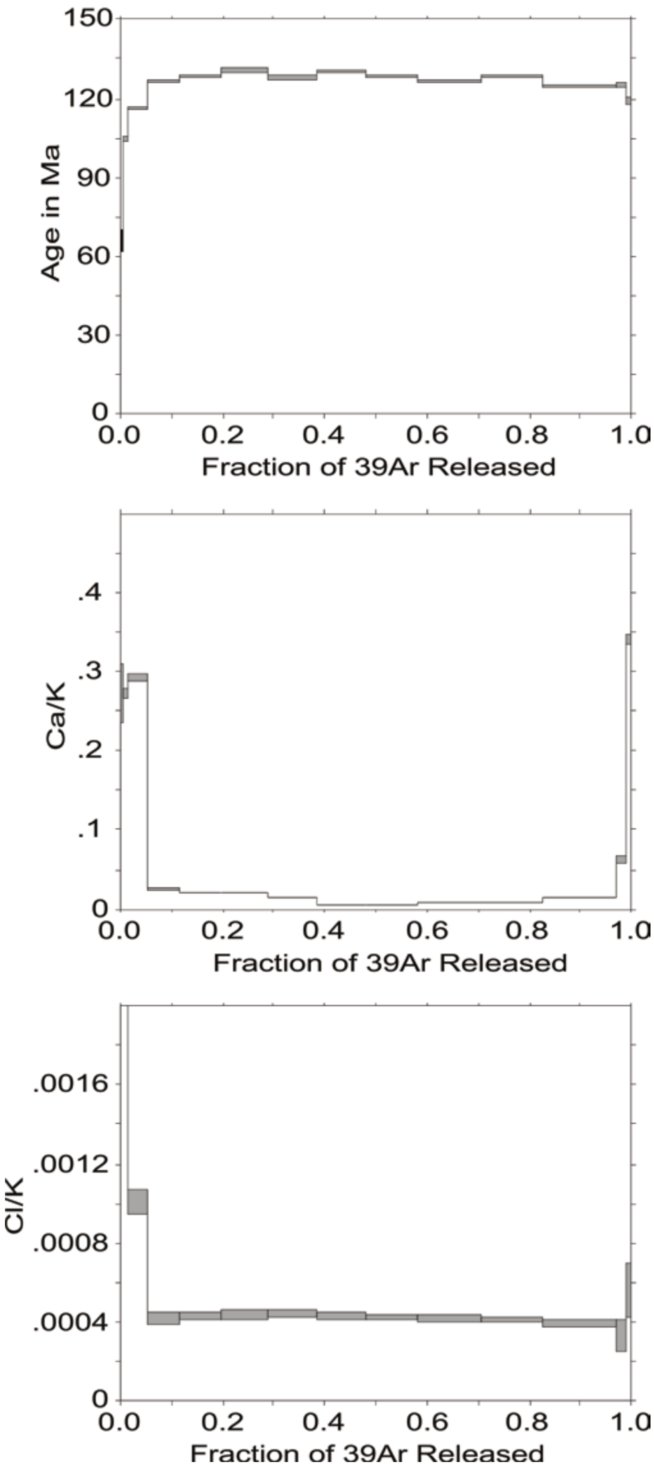
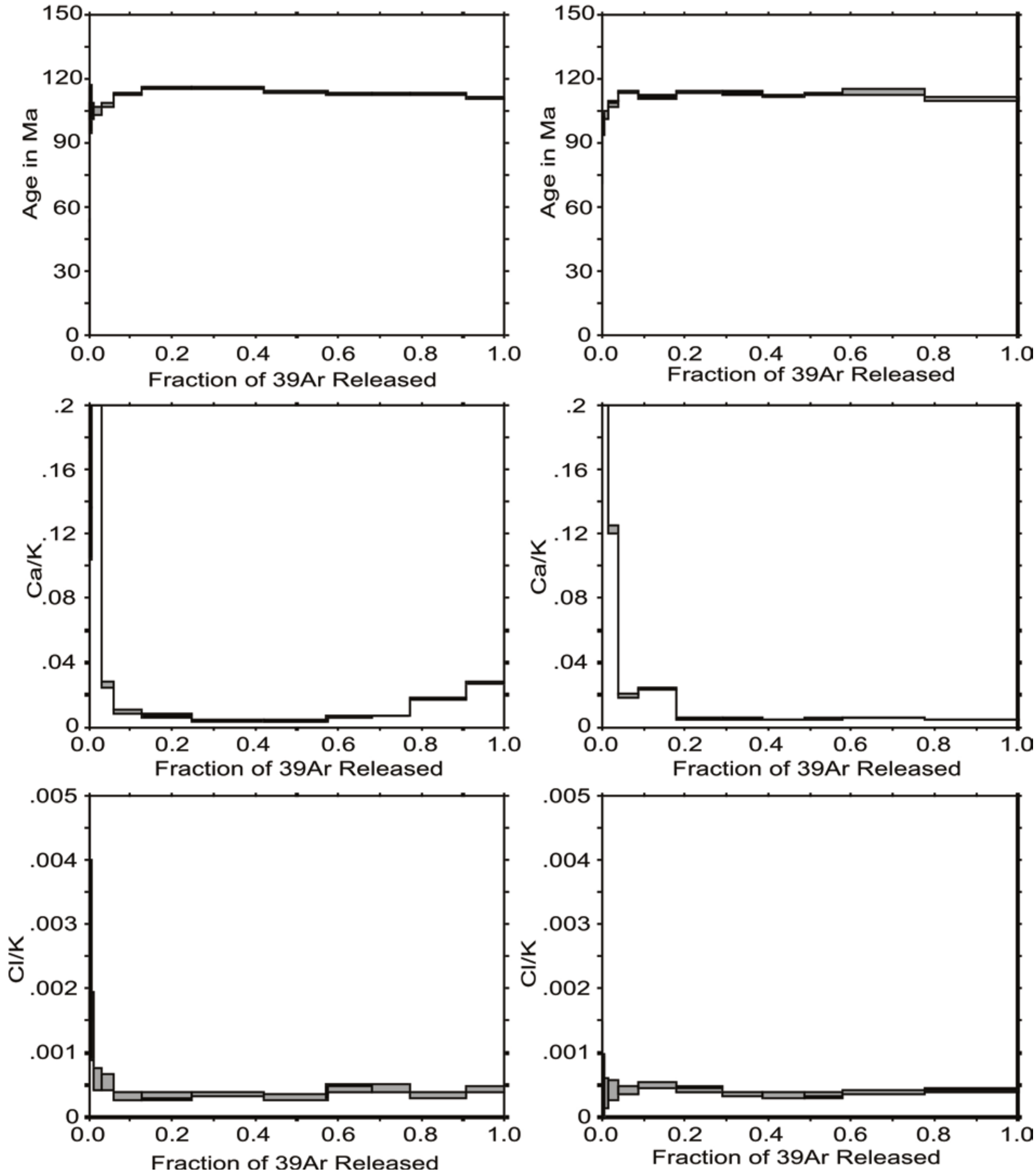
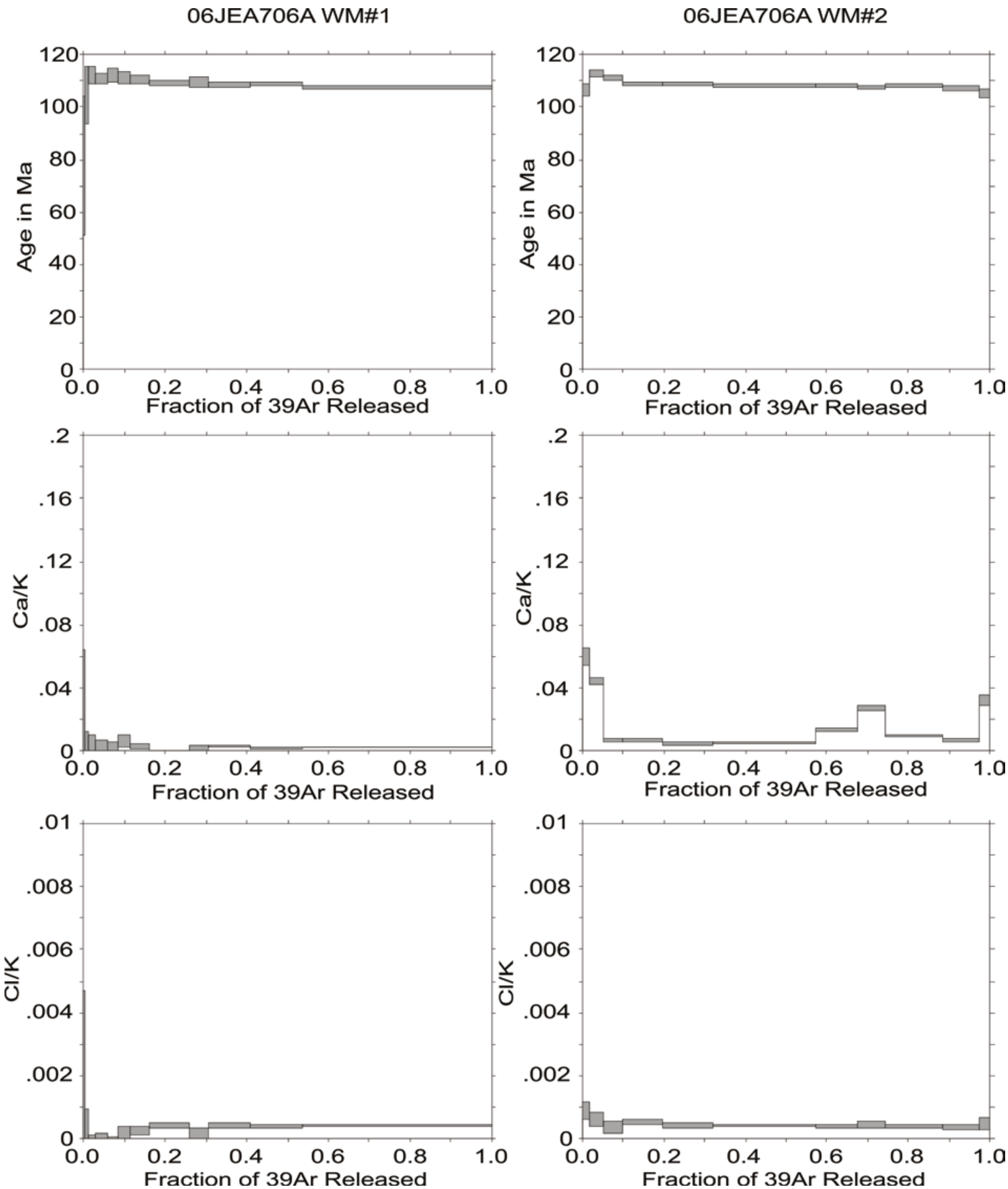


UAF110-24 04Z638A WM#1 UAF110-24 04Z638A WM#2

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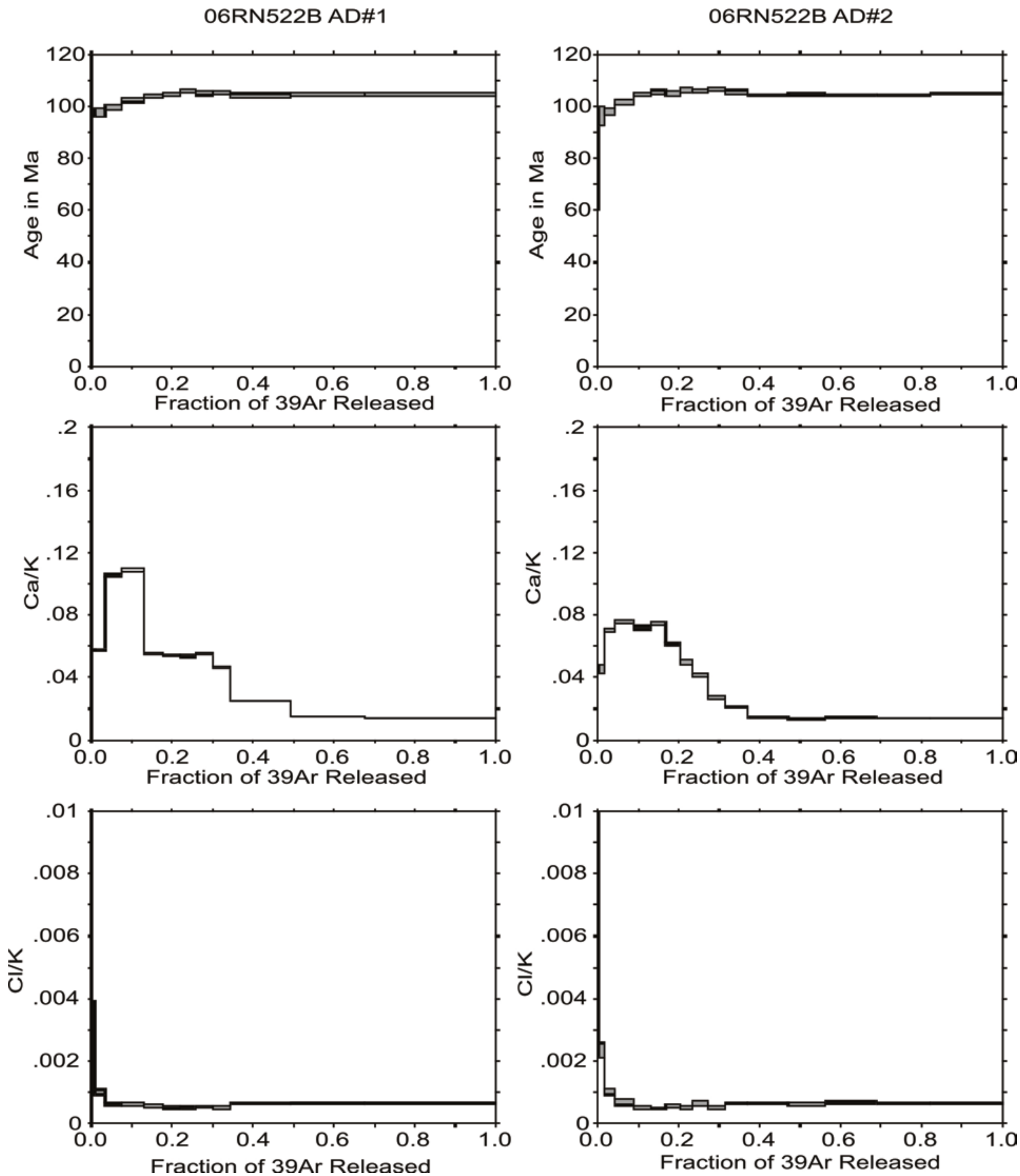
Age in Ma
Fraction of 39Ar Released
Ca/K
Cl/K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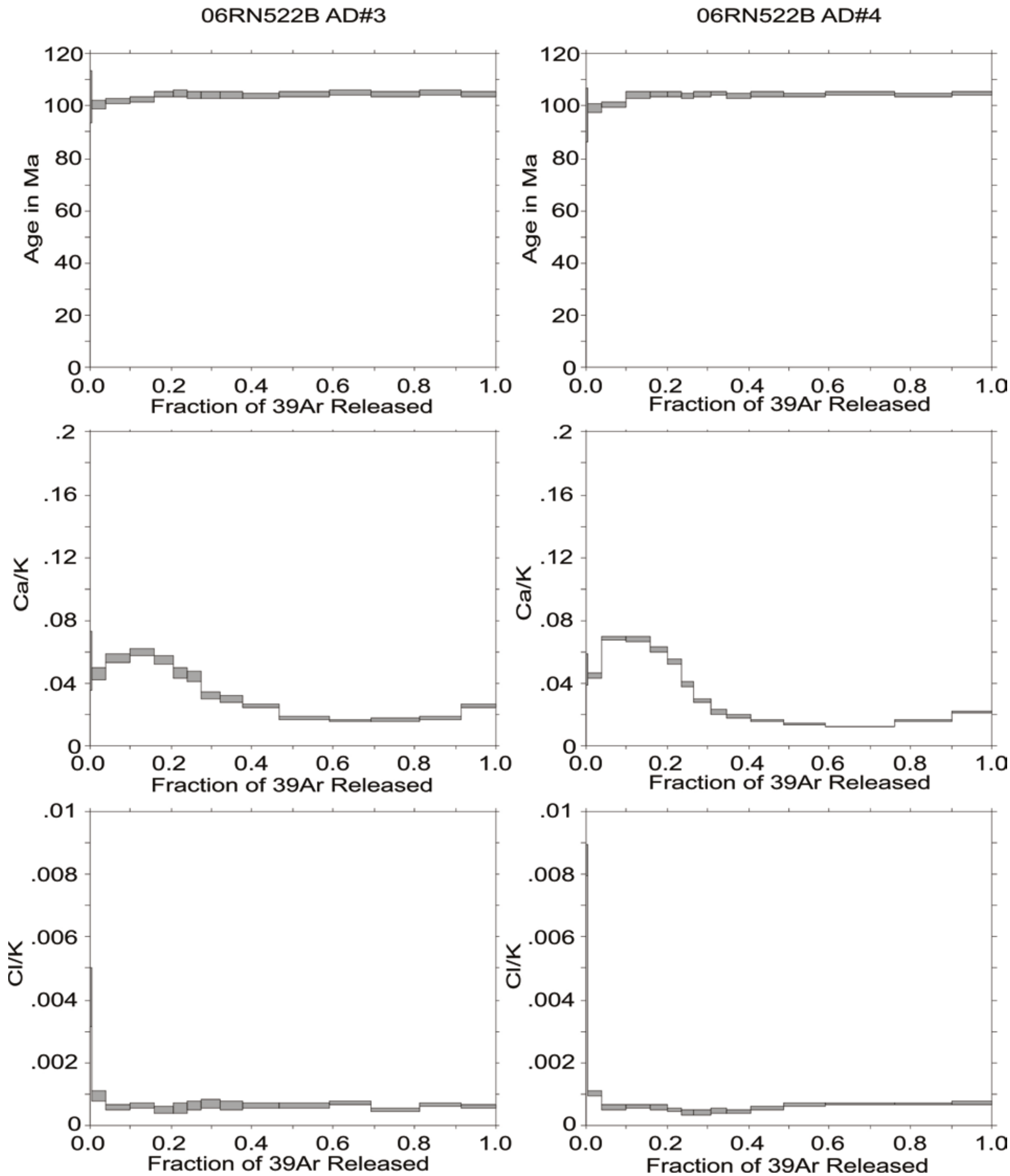
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released


06RN522B AD#3
06RN522B AD#4
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released
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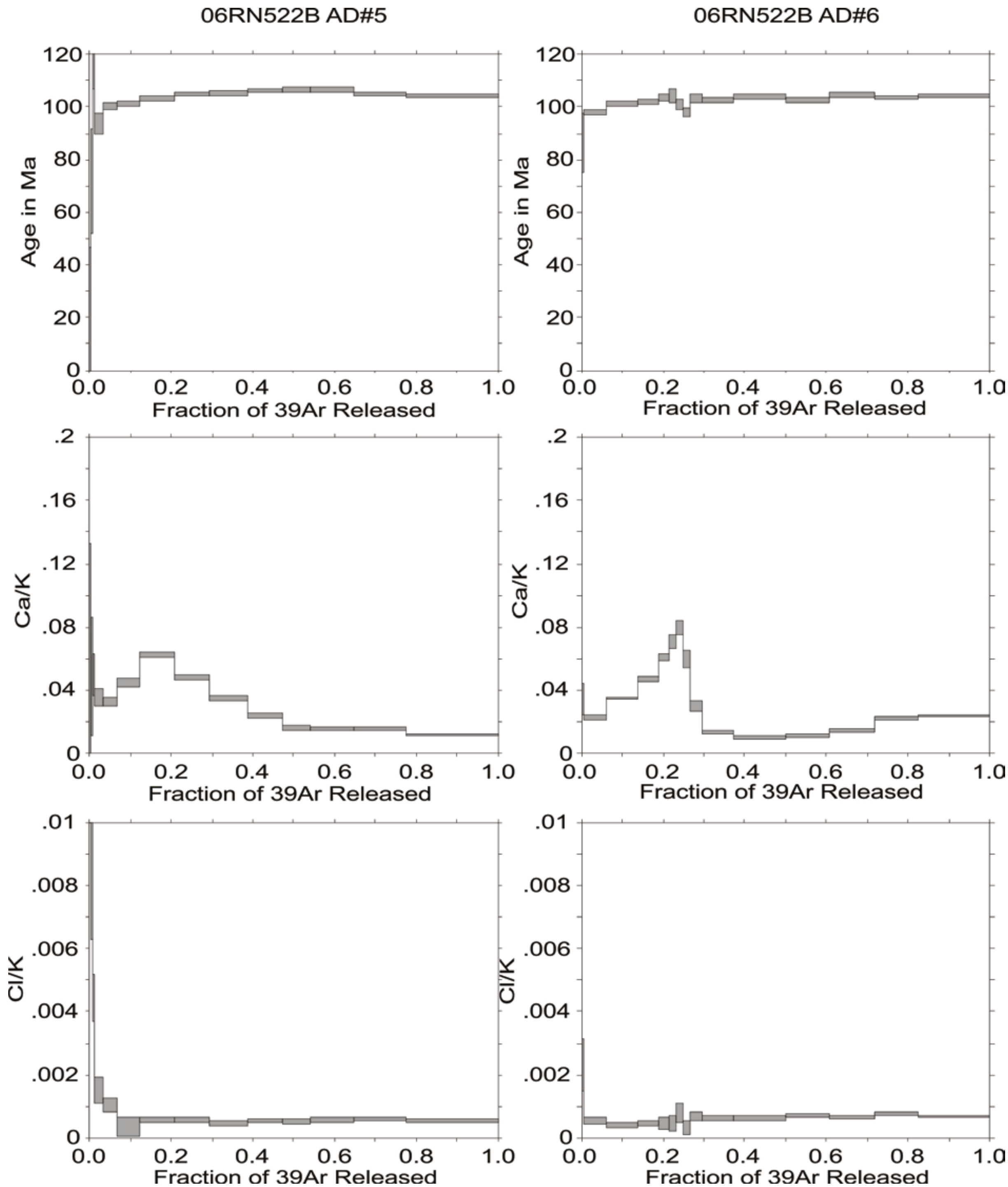
100
80
60
40
20
0
.2
.16
.12
.08
.04
.01
.008
.006
.004
.002
0.0
0.2
0.4
0.6
0.8
1.0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06RN522B AD#6
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released
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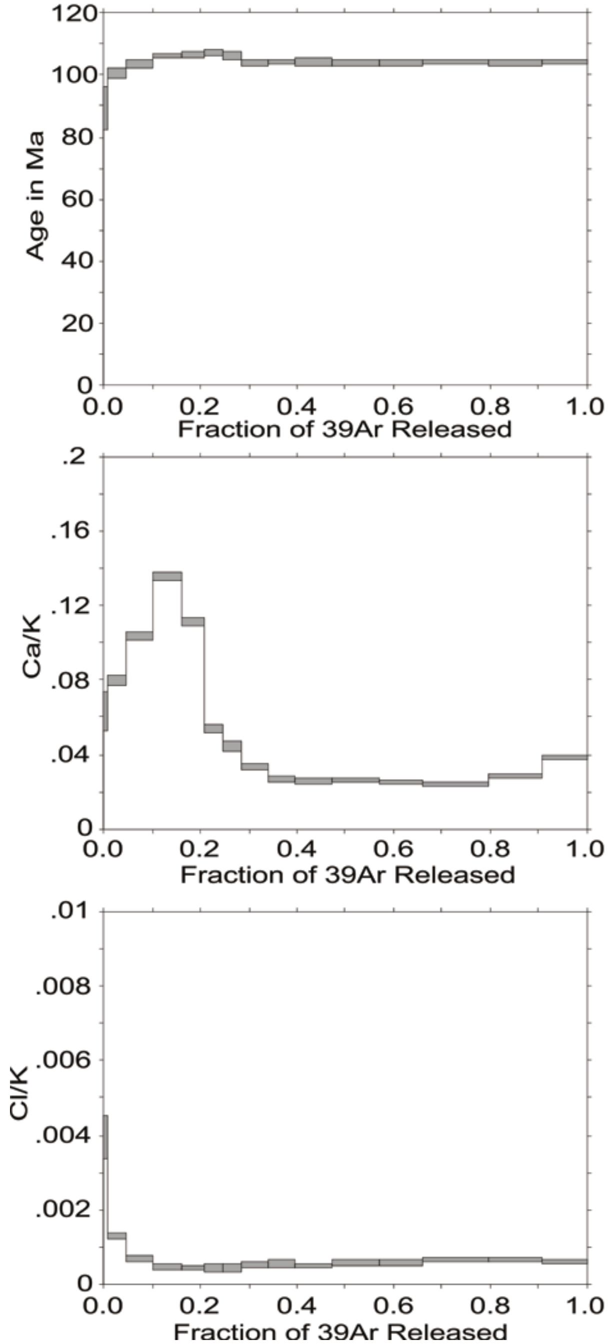
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100
120
.04
.08
.12
.16
.2
.002
.004
.006
.008
.01

06RN522B AD#7



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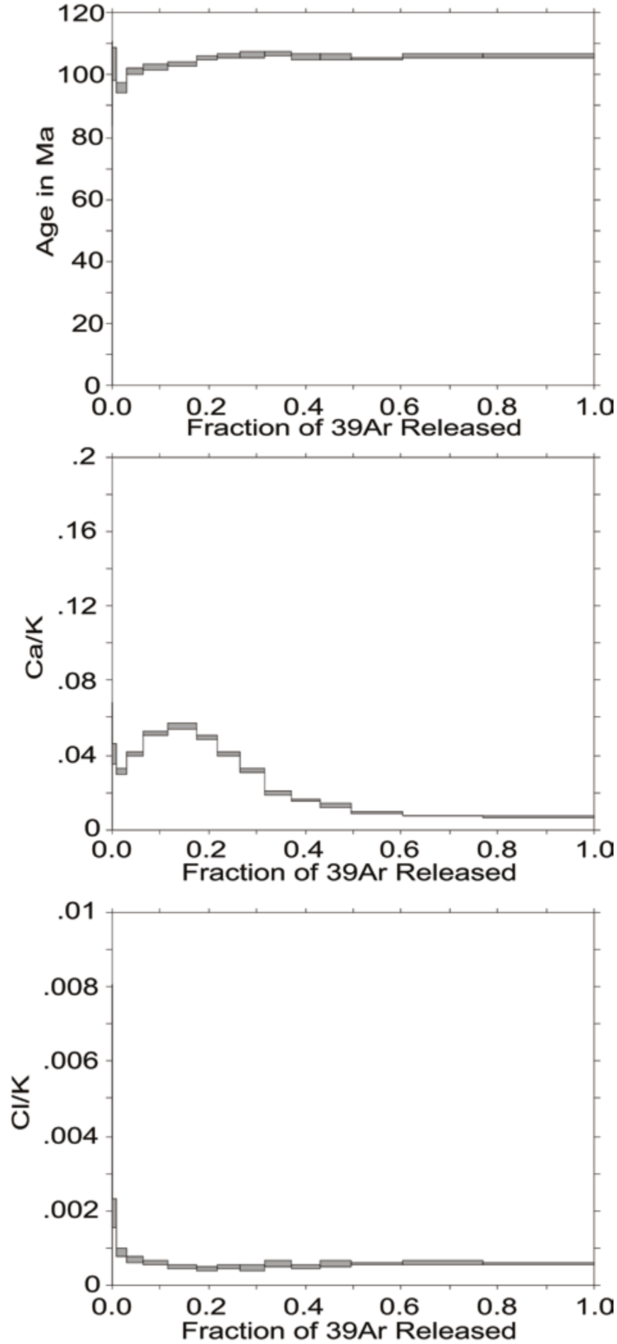

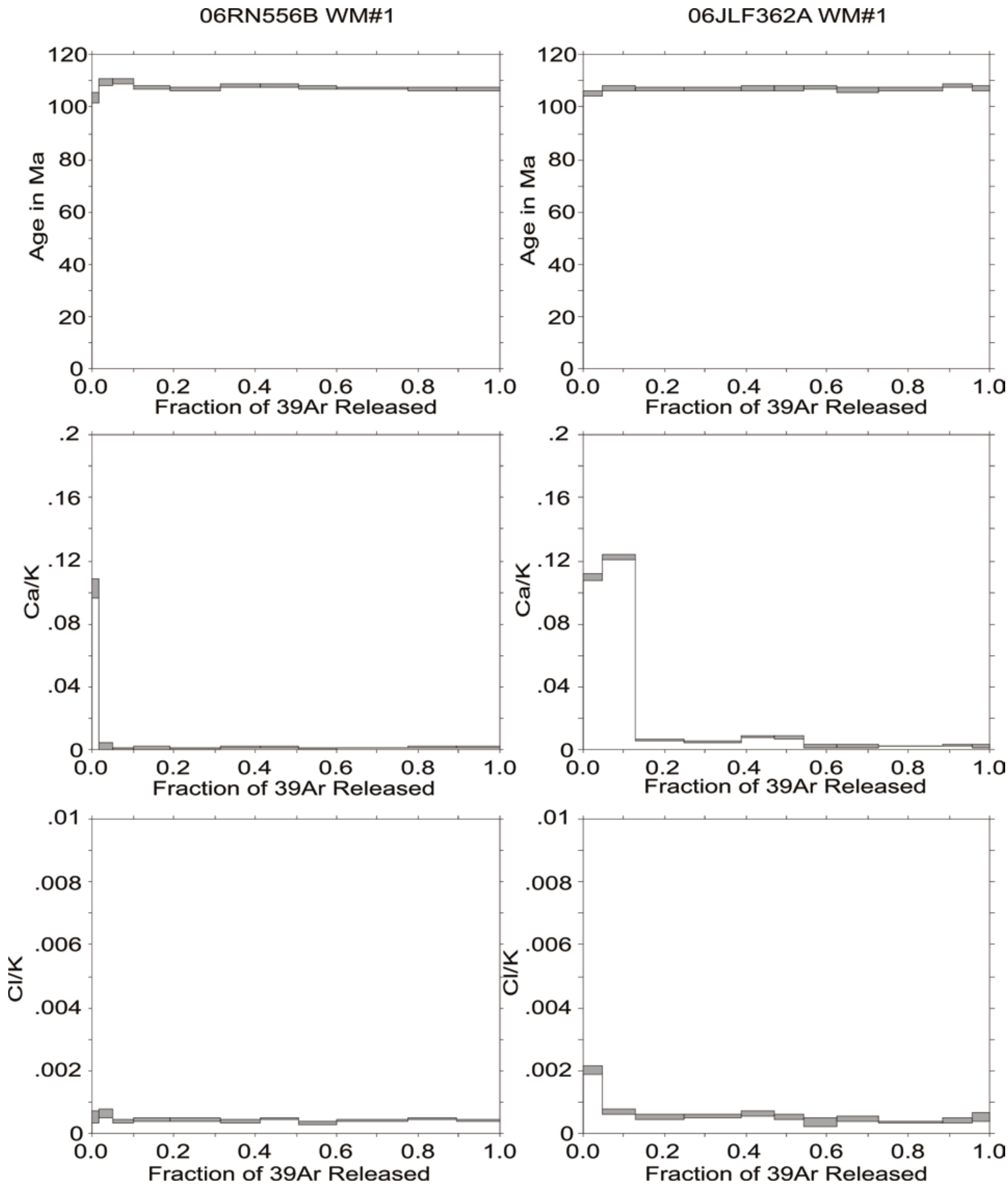
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06JLF362A WM#1
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released
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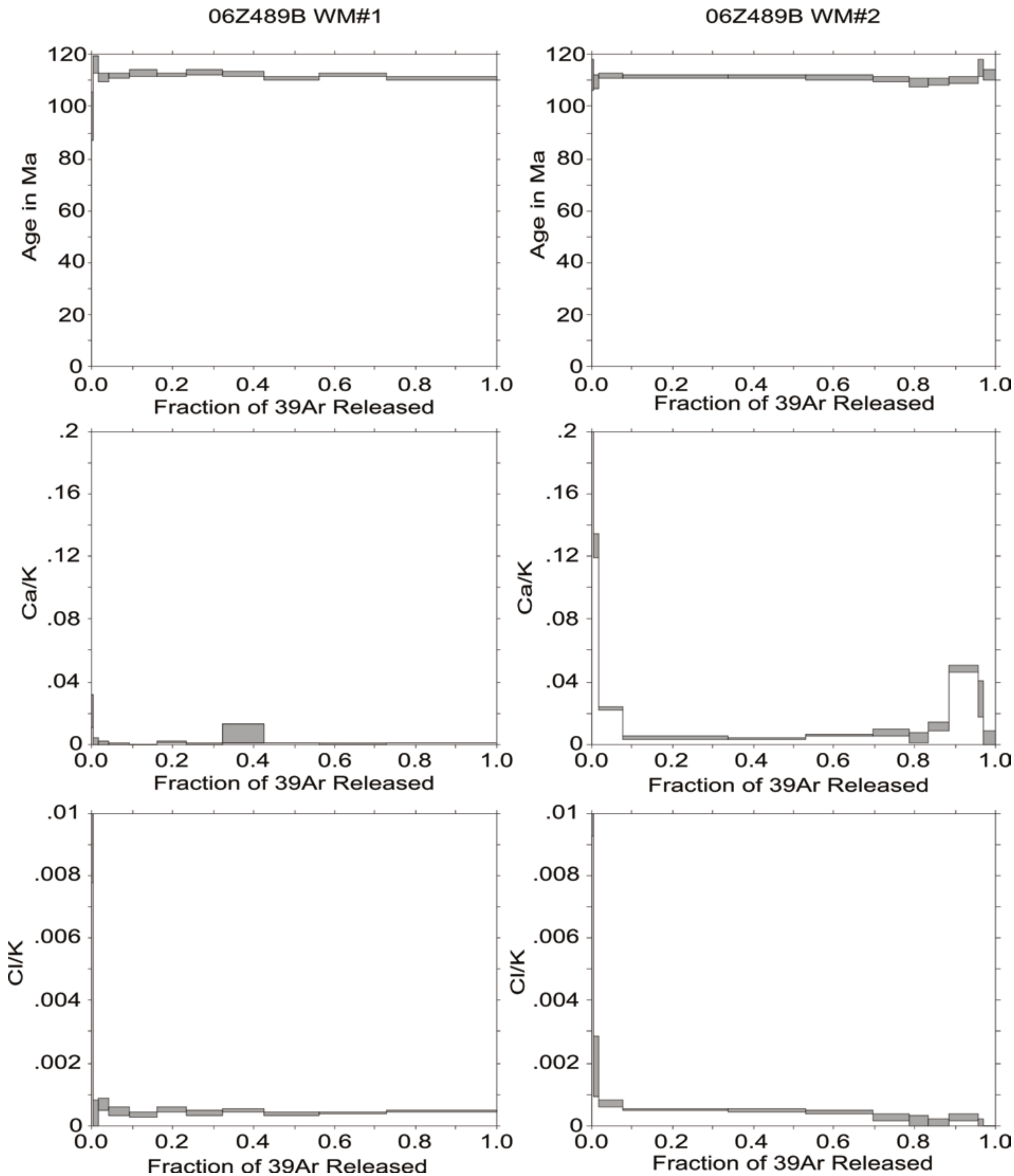
0 .04 .08 .12 .16 .2
0 .002 .004 .006 .008 .01
0.0 0.2 0.4 0.6 0.8 1.0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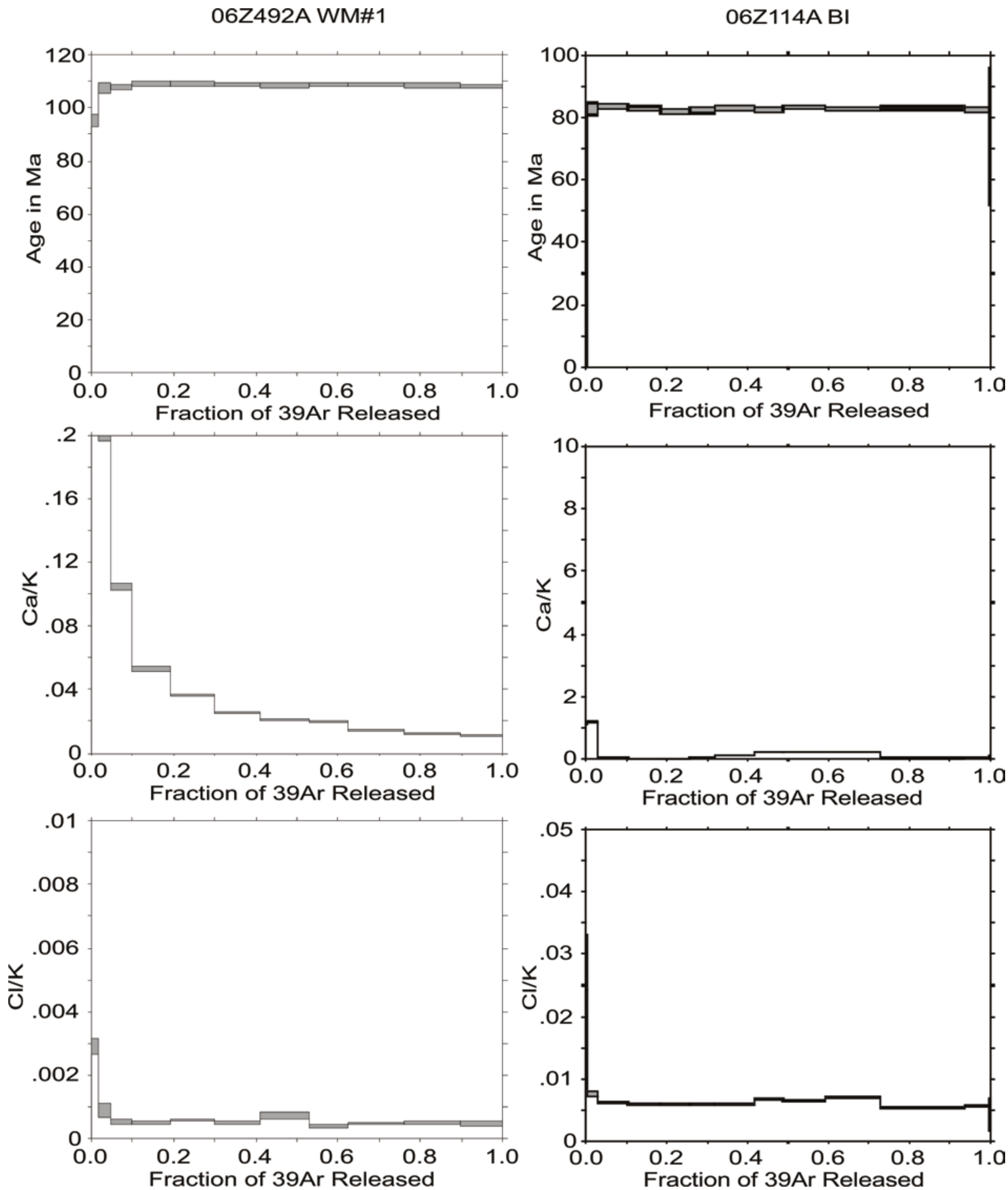
06Z489B WM#2
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released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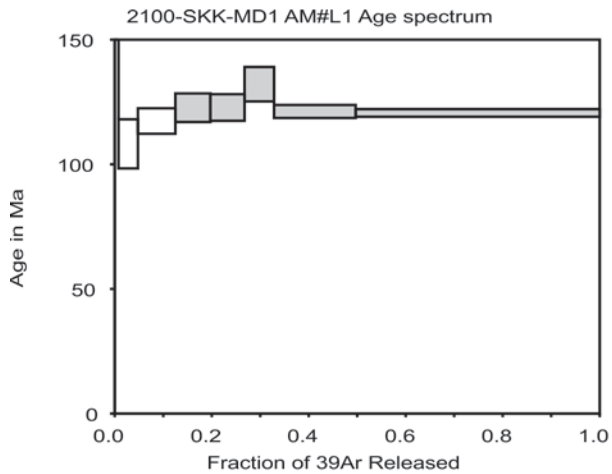
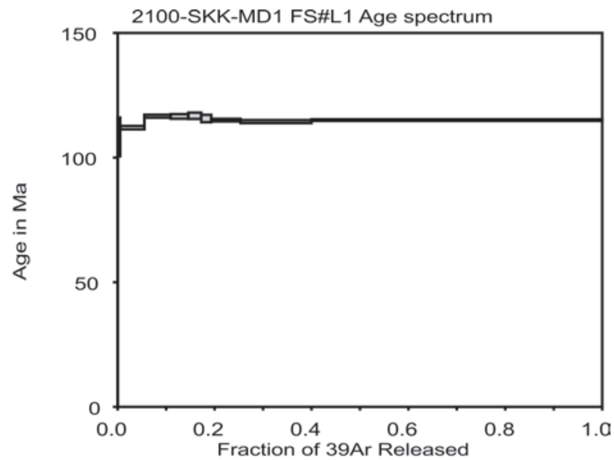
06Z114A BI
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released


2100-SKK-MD1 AM#L1 Age spectrum
Age in Ma
150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released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150
100
50
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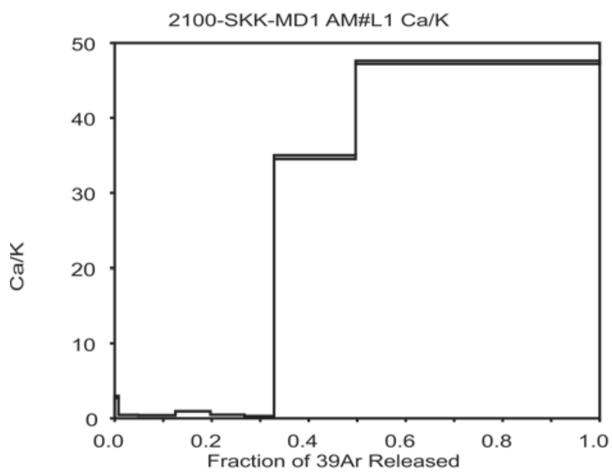
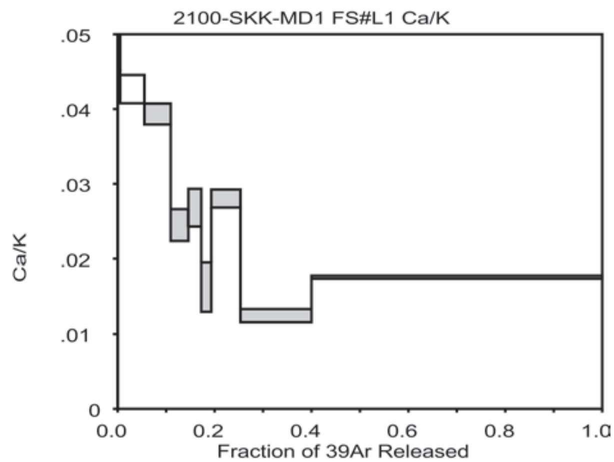
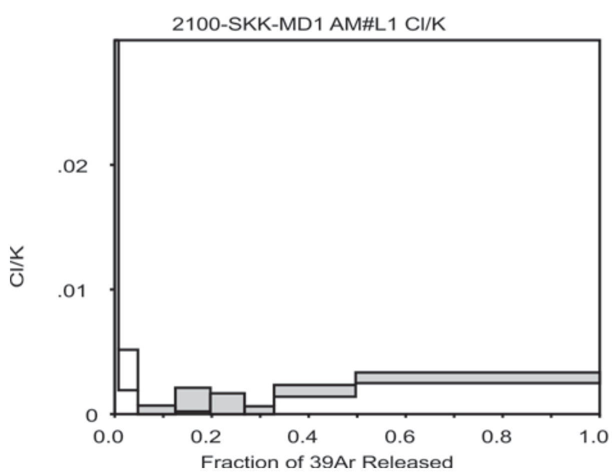
Fraction of 39Ar Released


2100-SKK-MD1 AM#L1 Ca/K
Ca/K
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


2100-SKK-MD1 FS#L1 Ca/K
Ca/K
.05
.04
.03
.02
.01
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


2100-SKK-MD1 AM#L1 Cl/K
Cl/K
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.01
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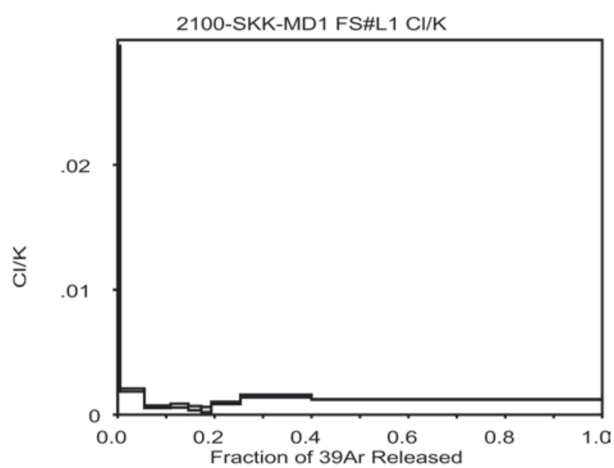
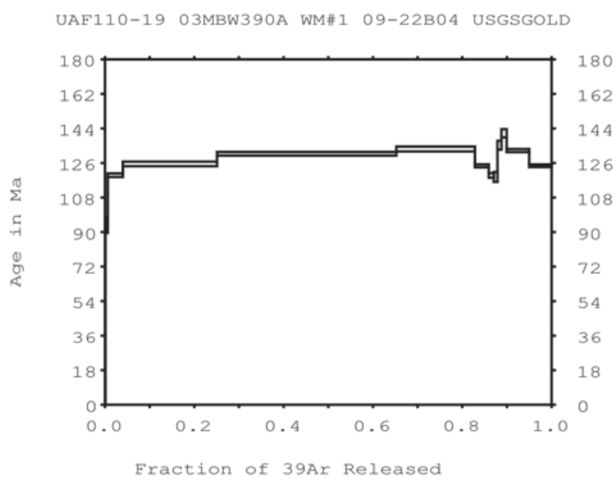
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released


2100-SKK-MD1 FS#L1 Cl/K
Cl/K
.02
.01
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released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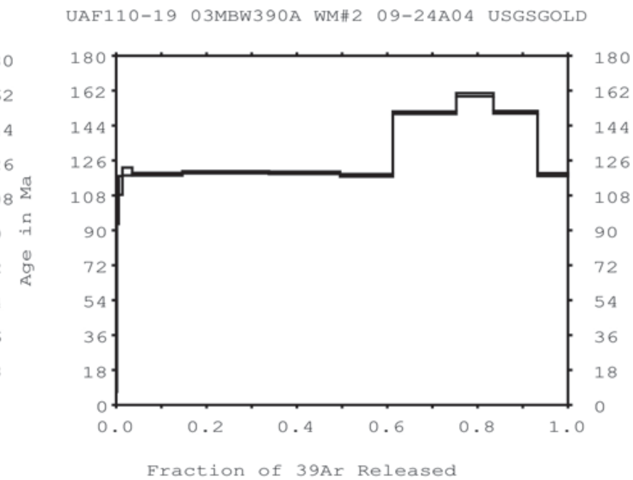
Age in Ma
Fraction of 39Ar Released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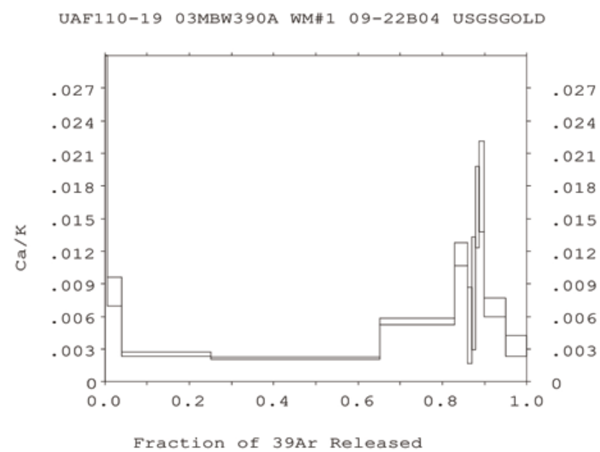
Age in Ma
Fraction of 39Ar Released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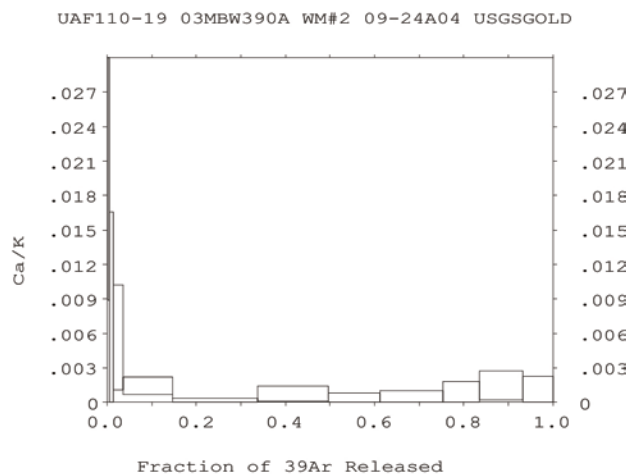
Ca/K
Fraction of 39Ar Released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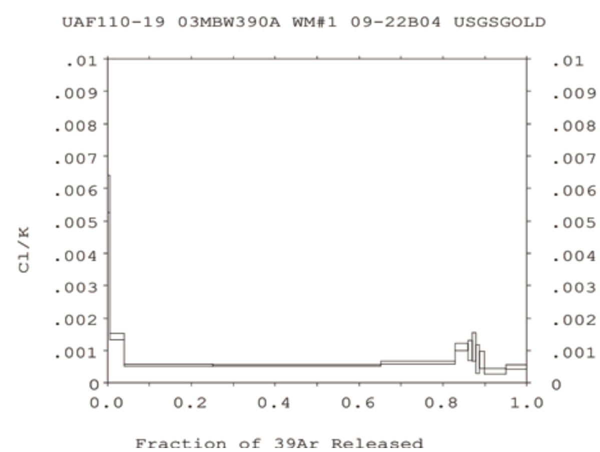
Ca/K
Fraction of 39Ar Released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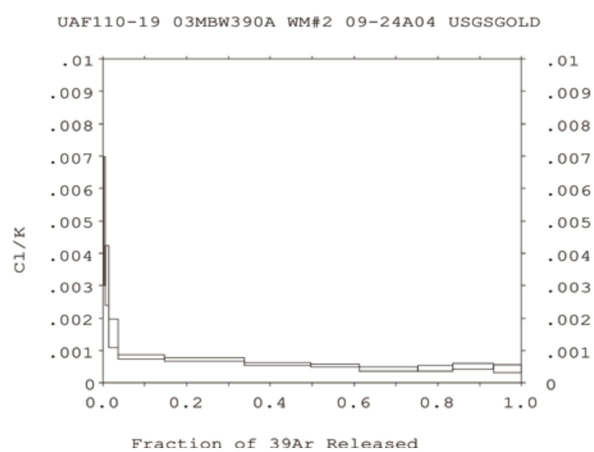
Cl/K
Fraction of 39Ar Released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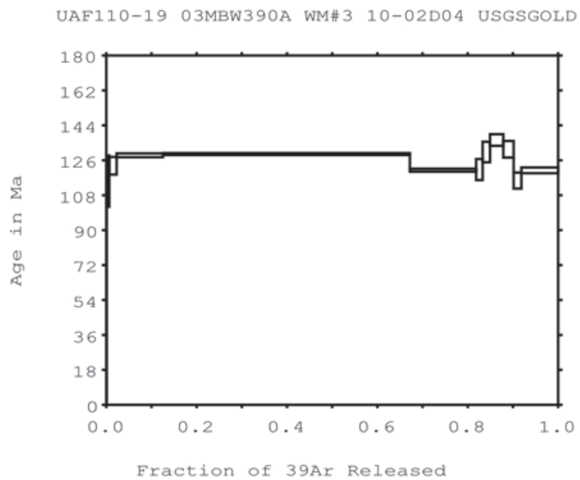
Cl/K
Fraction of 39Ar Released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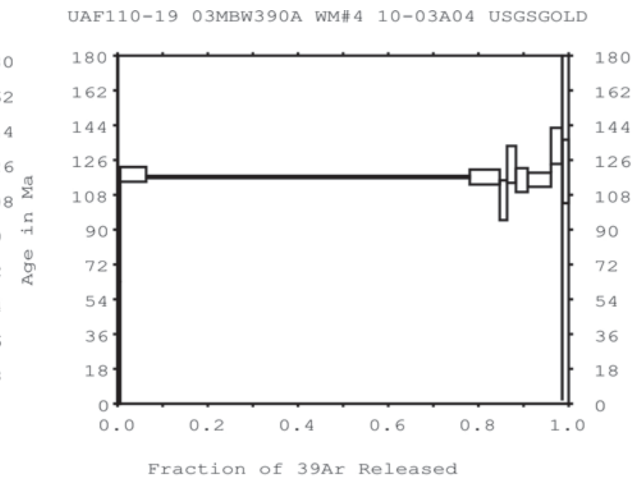
Age in Ma
Fraction of 39Ar Released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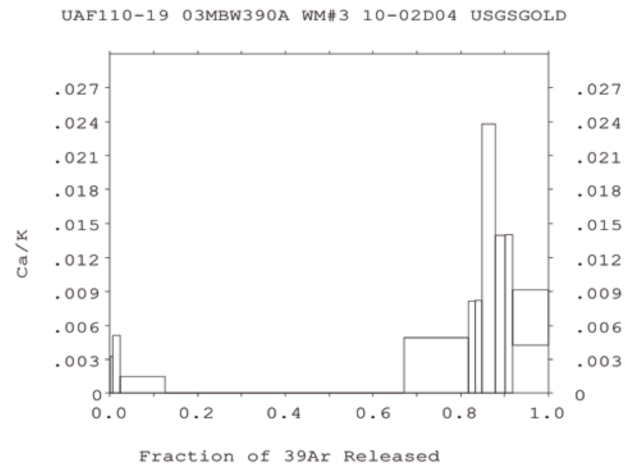
Age in Ma
Fraction of 39Ar Released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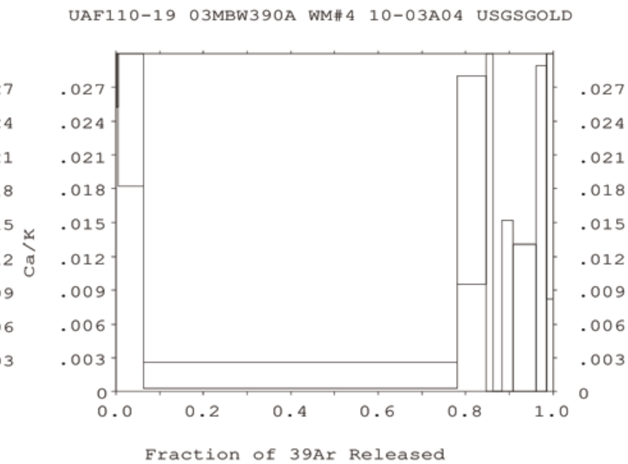
Ca/K
Fraction of 39Ar Released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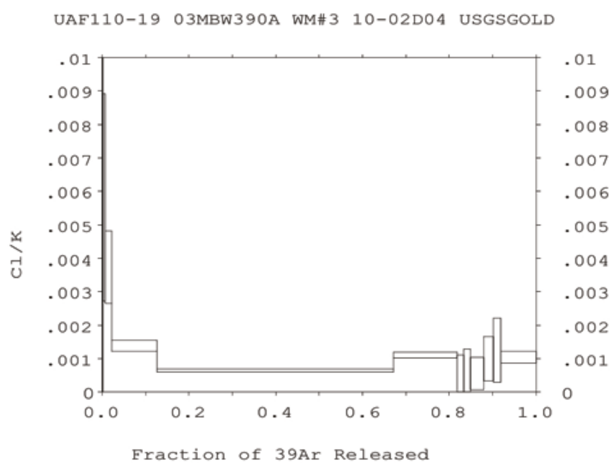
Ca/K
Fraction of 39Ar Released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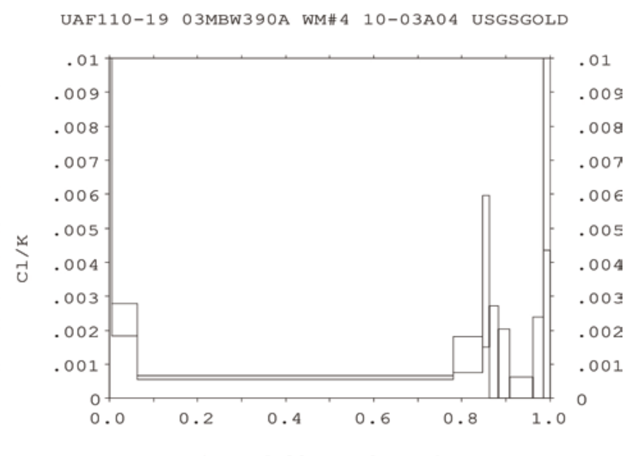
Cl/K
Fraction of 39Ar Released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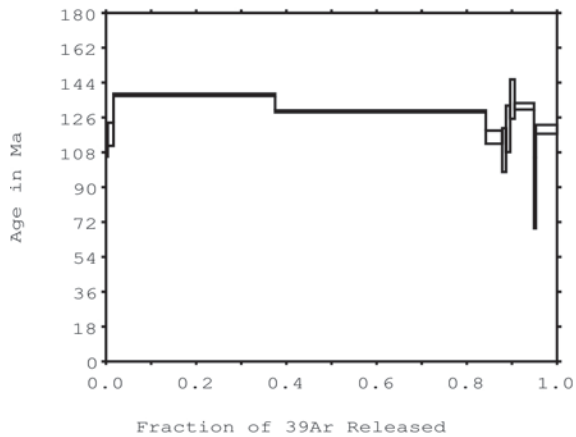
Cl/K
Fraction of 39Ar Released

UAF110-19 03MBW390A WM#5 10-03B04 USGSGOLD



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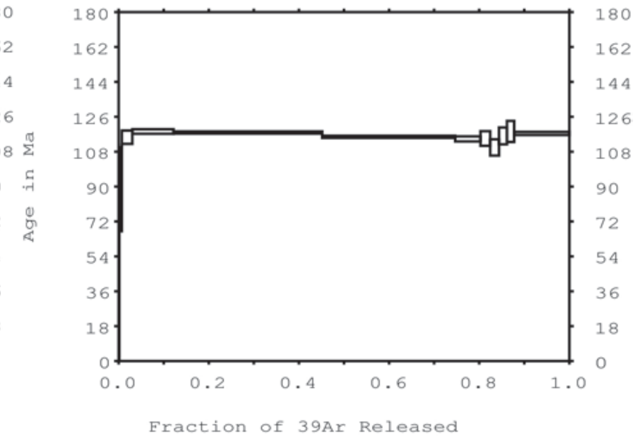

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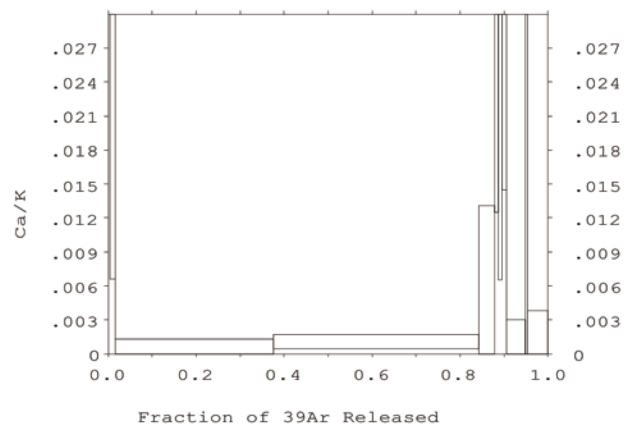

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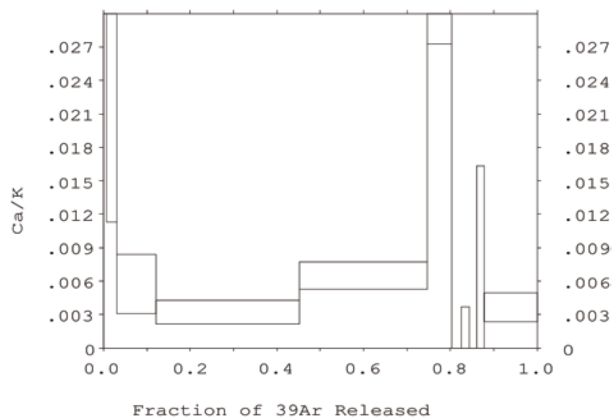

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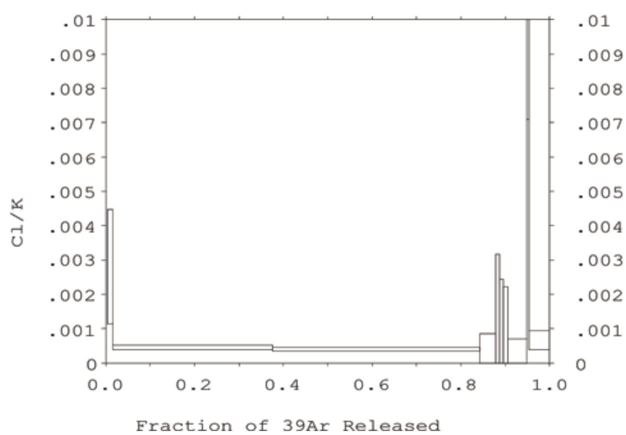

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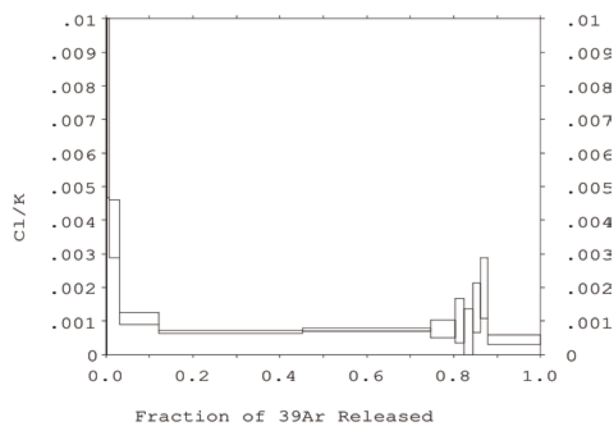

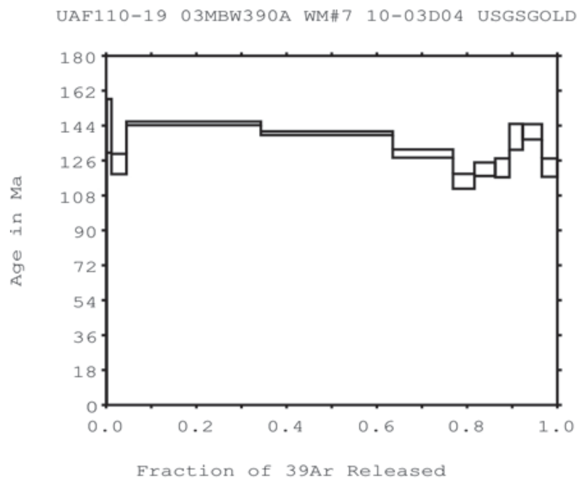
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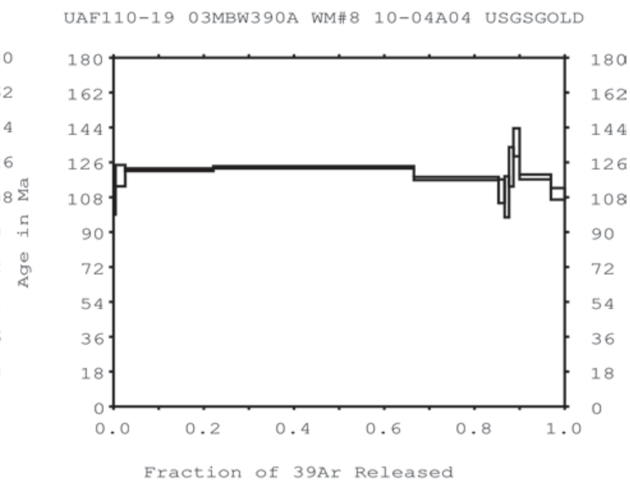
Age in Ma
Fraction of 39Ar Released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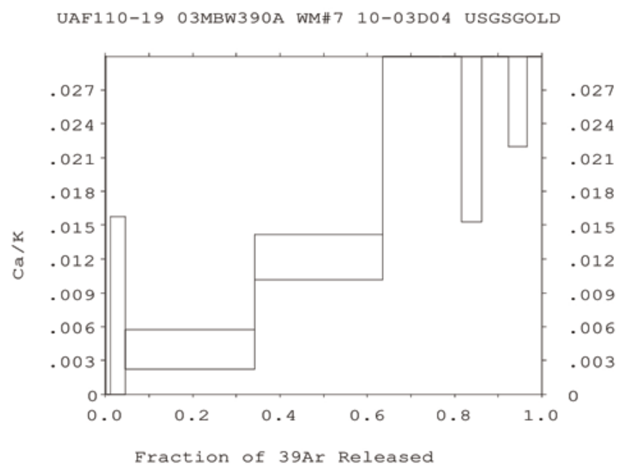
Age in Ma
Fraction of 39Ar Released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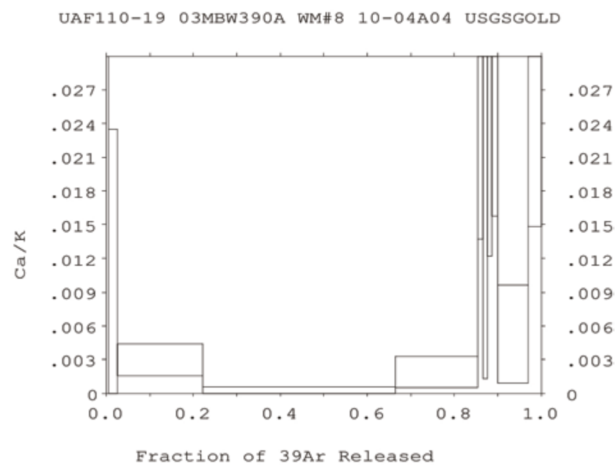
Ca/K
Fraction of 39Ar Released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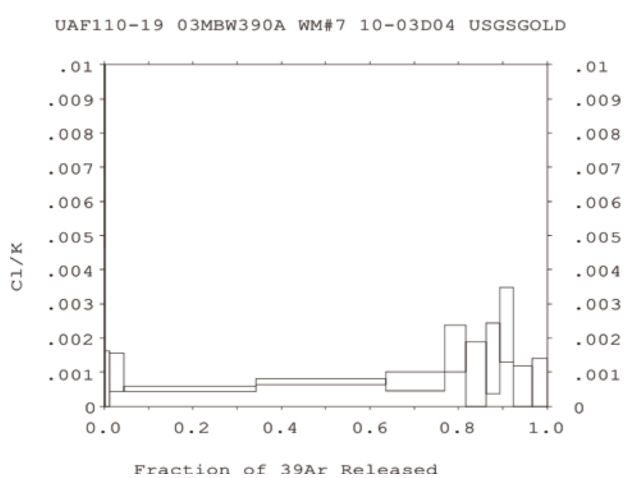
Ca/K
Fraction of 39Ar Released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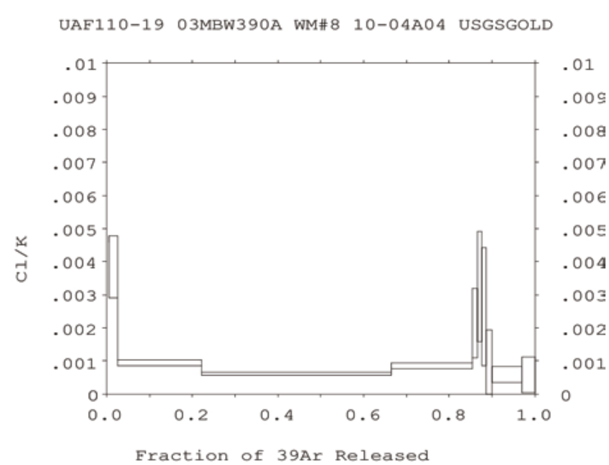
Cl/K
Fraction of 39Ar Released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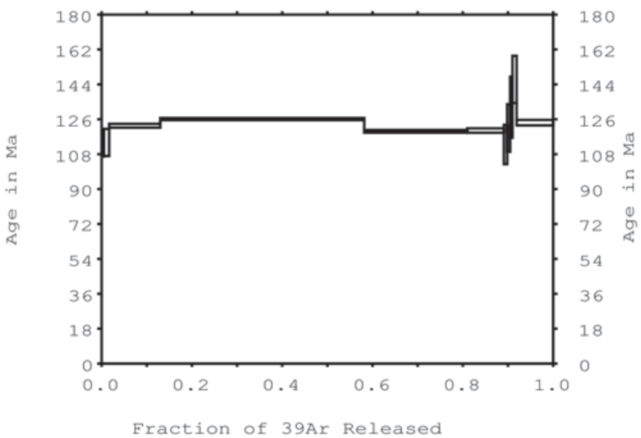
Cl/K
Fraction of 39Ar Released

UAF110-19 03MBW390A WM#9 10-04B04 USGSGOLD



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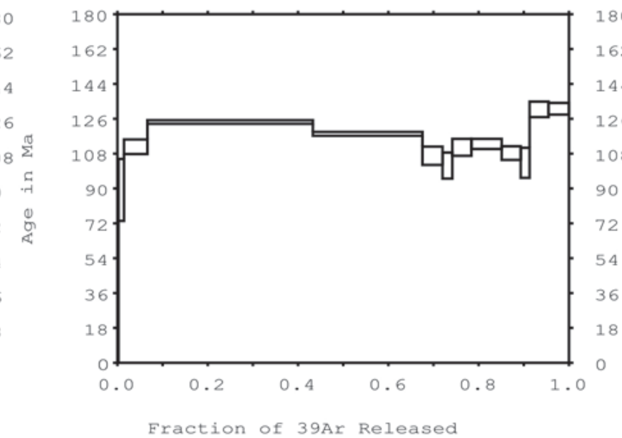

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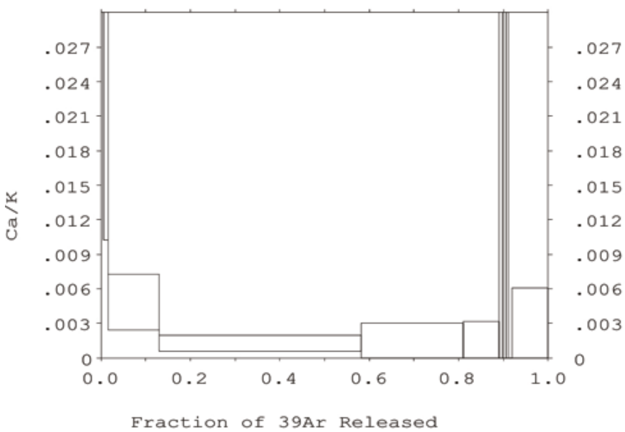

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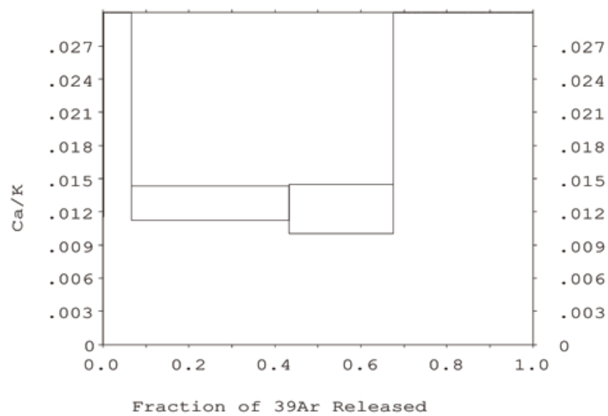

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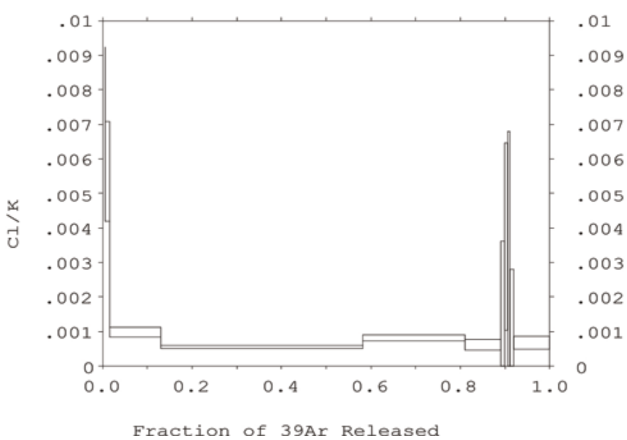

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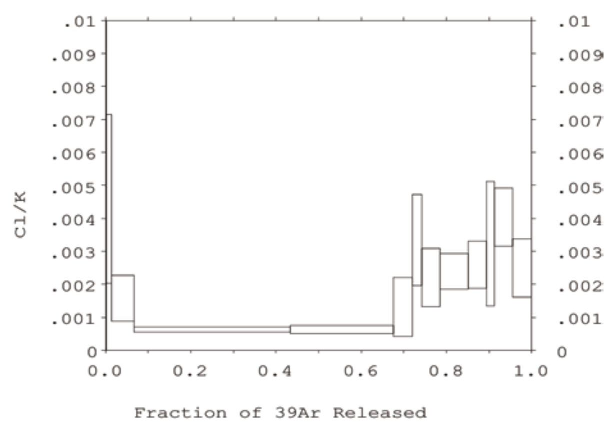

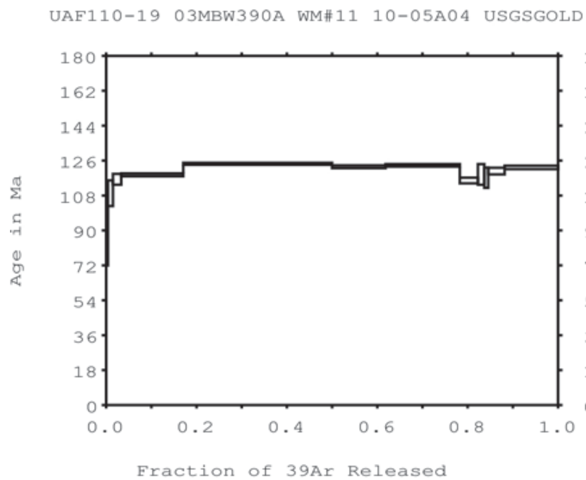
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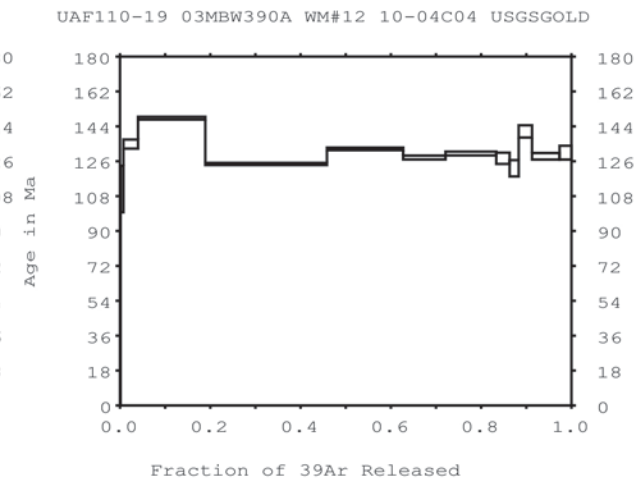
Age in Ma
Fraction of 39Ar Released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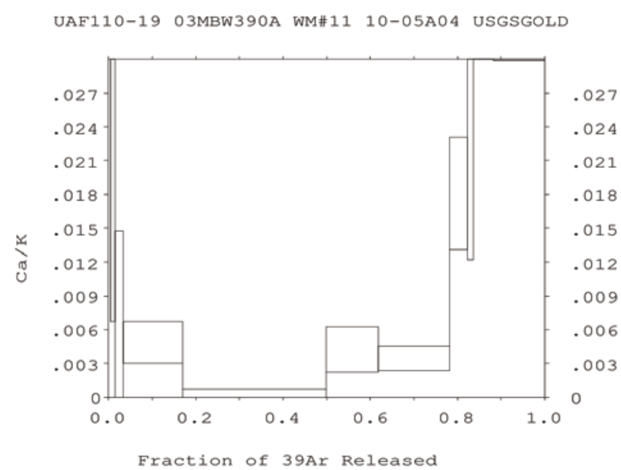
Age in Ma
Fraction of 39Ar Released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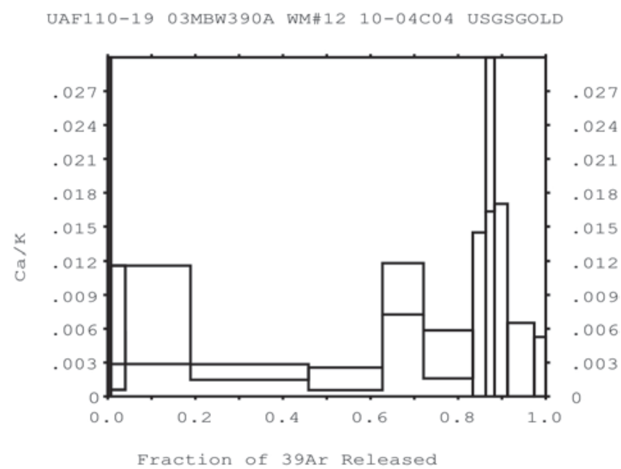
Ca/K
Fraction of 39Ar Released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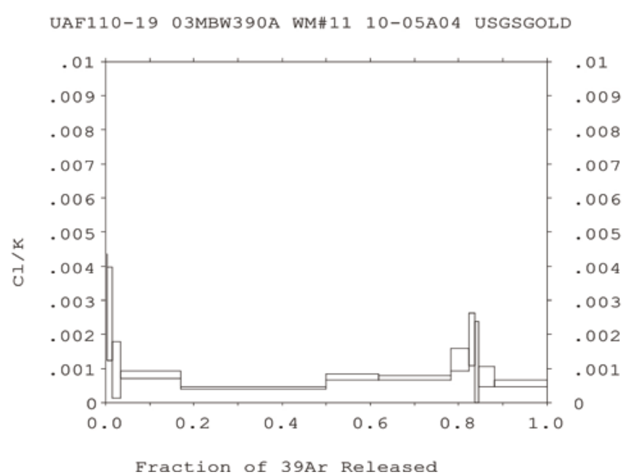
Ca/K
Fraction of 39Ar Released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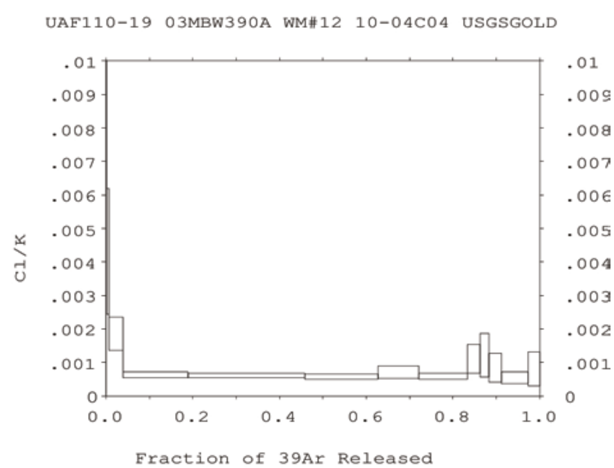
Cl/K
Fraction of 39Ar Released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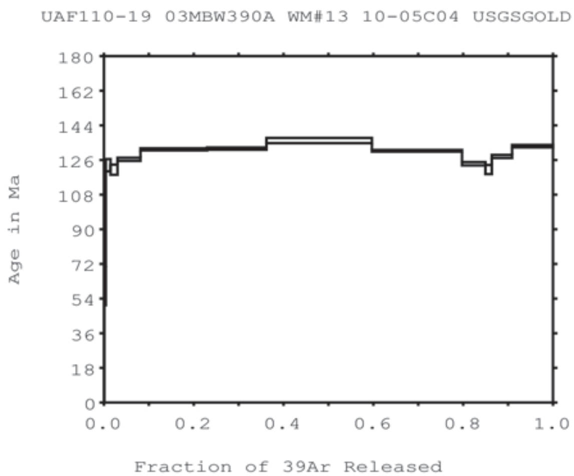
Cl/K
Fraction of 39Ar Released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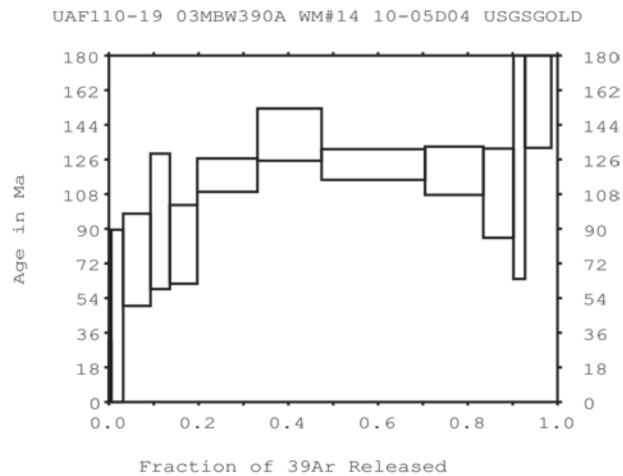
Age in Ma
Fraction of 39Ar Released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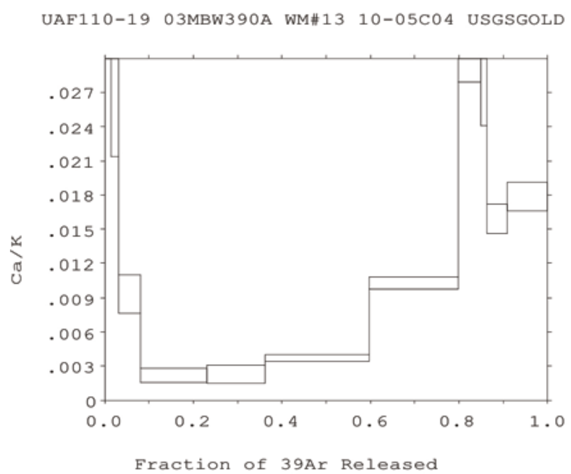
Age in Ma
Fraction of 39Ar Released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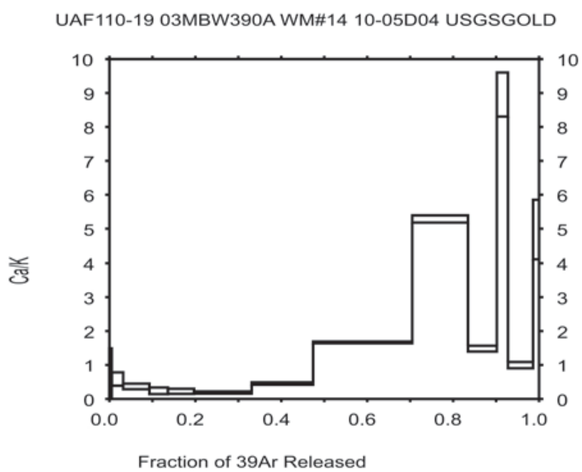
Ca/K
Fraction of 39Ar Released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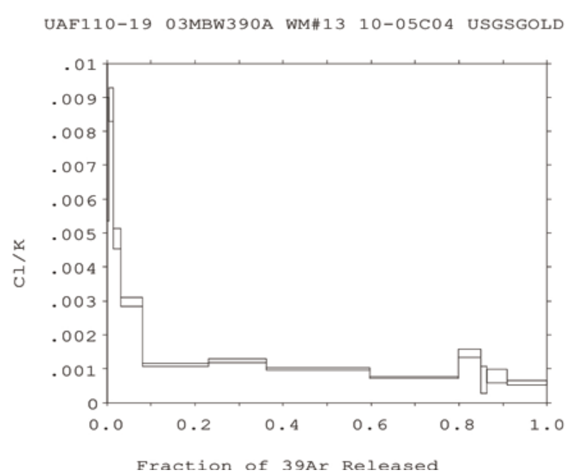
Ca/K
Fraction of 39Ar Released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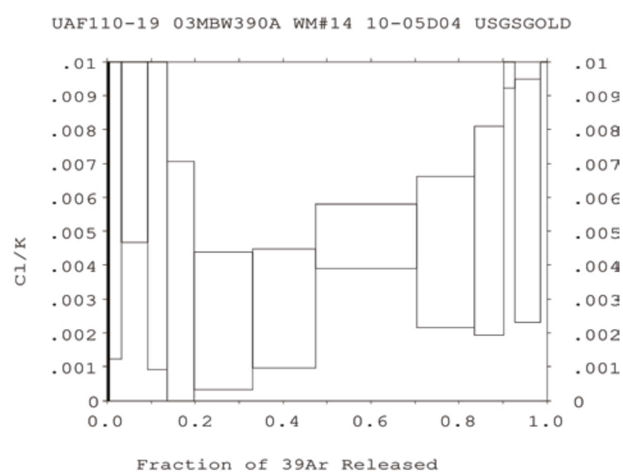
Cl/K
Fraction of 39Ar Released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Cl/K
Fraction of 39Ar Released

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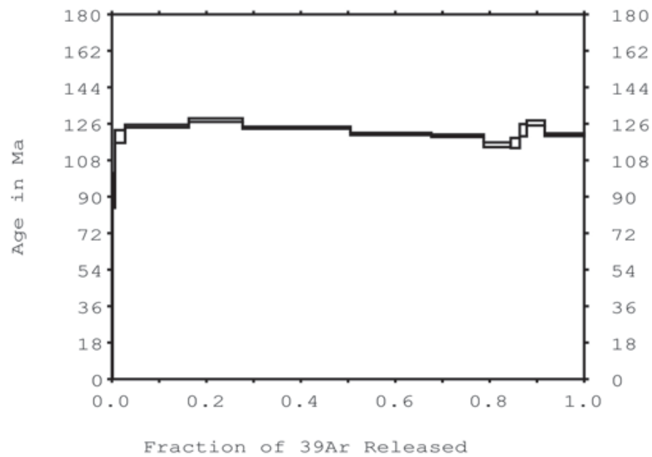

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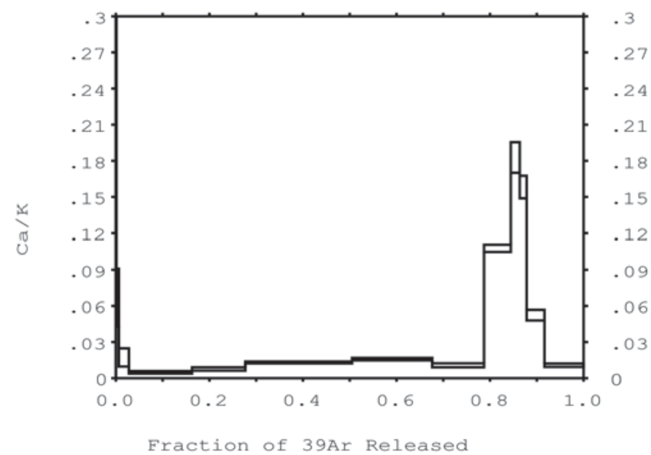

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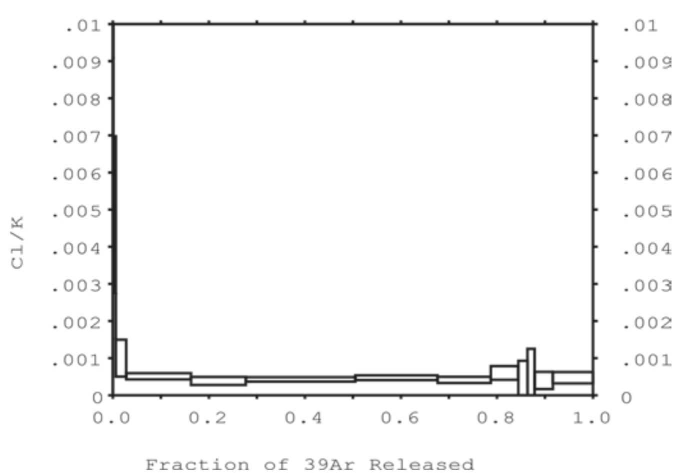

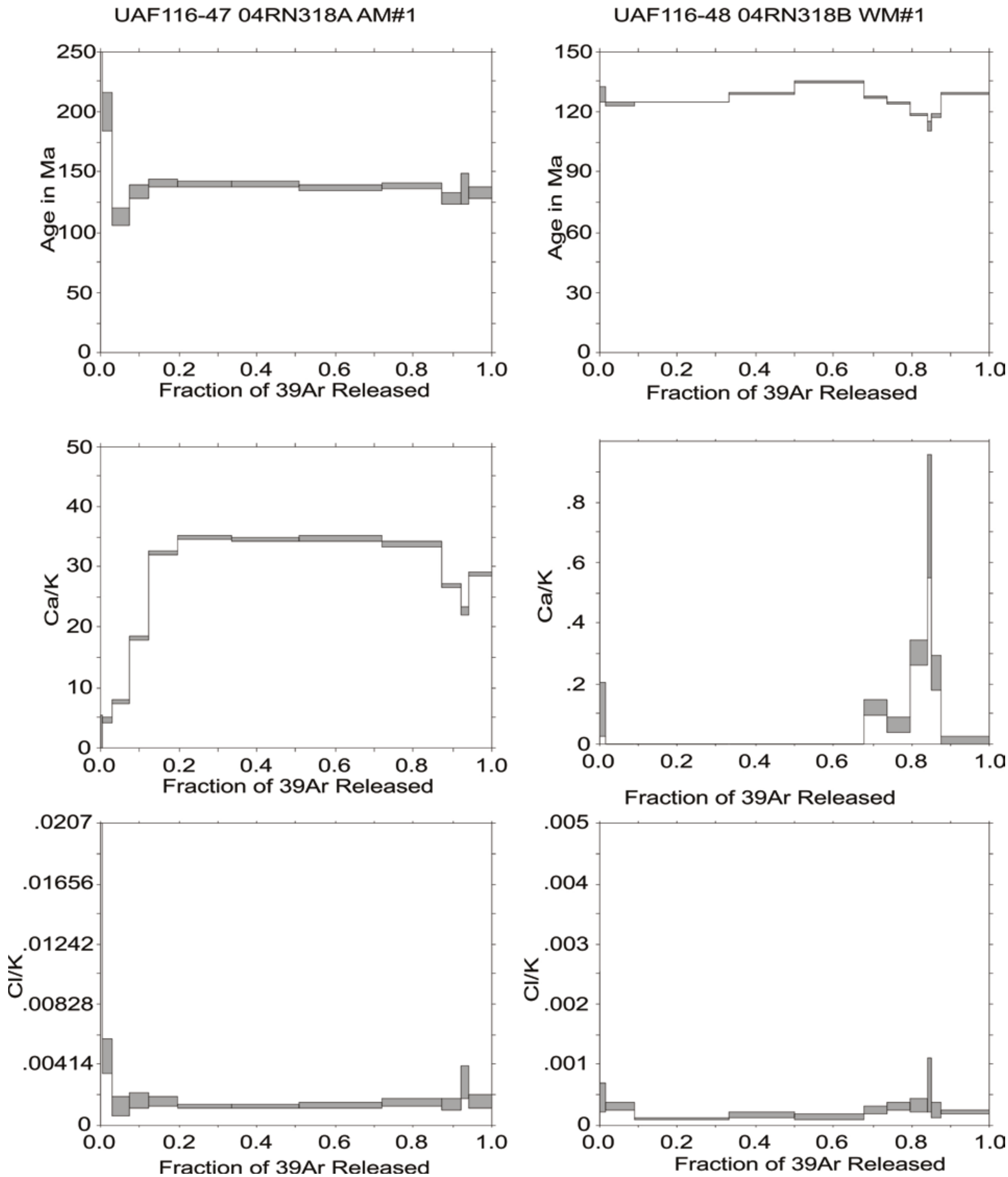
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UAF116-48 04RN318B WM#1
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released
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200
150
100
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90
60
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0.6
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1.0
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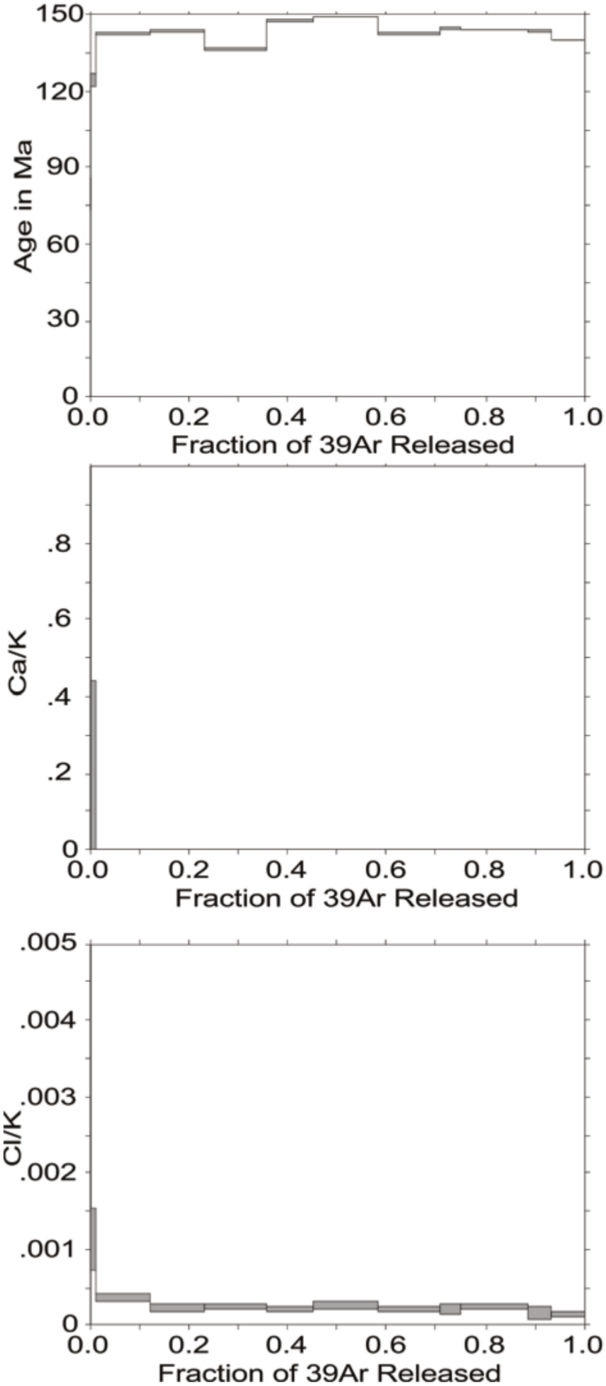
UAF116-42 04MBW540A WM#1



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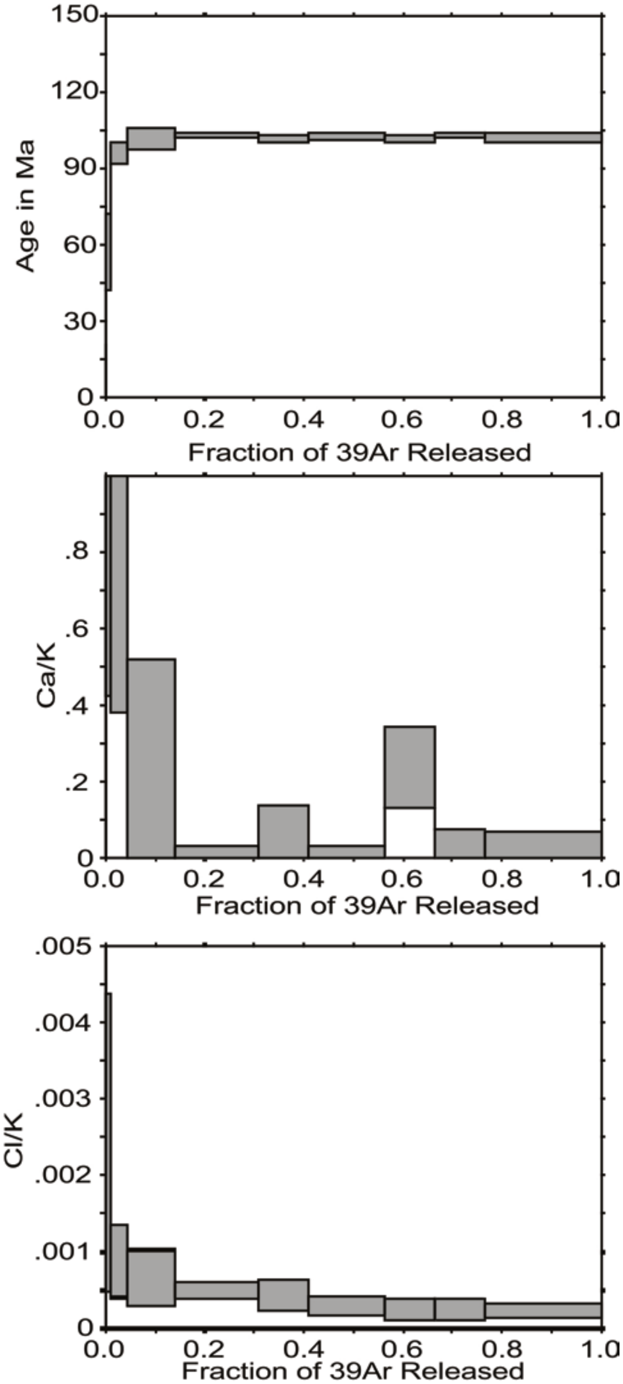

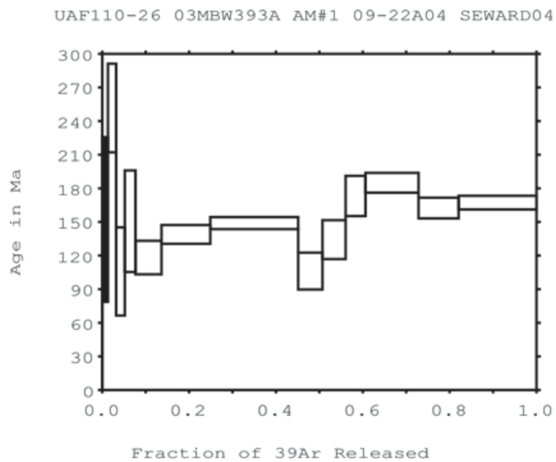
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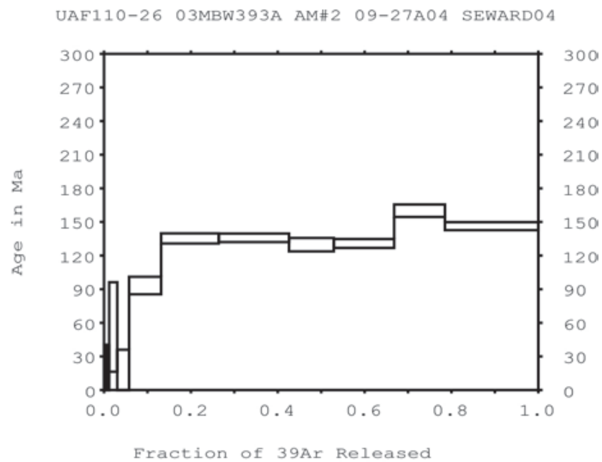
Age in Ma
Fraction of 39Ar Released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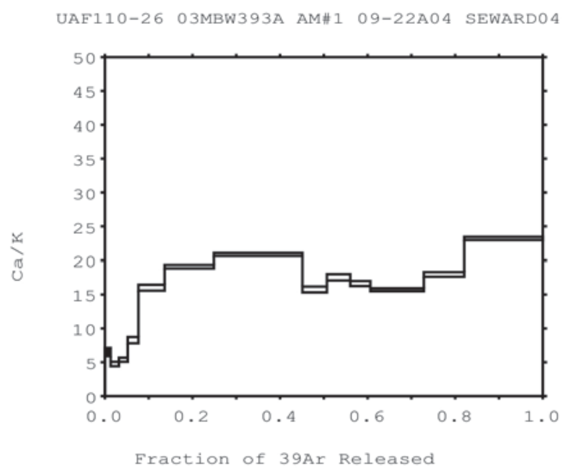
Age in Ma
Fraction of 39Ar Released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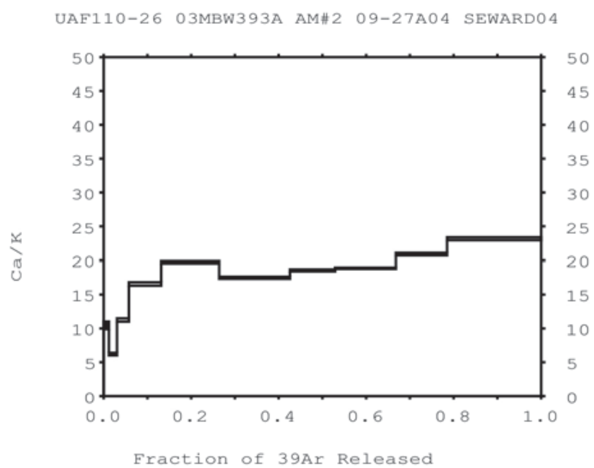
Ca/K
Fraction of 39Ar Released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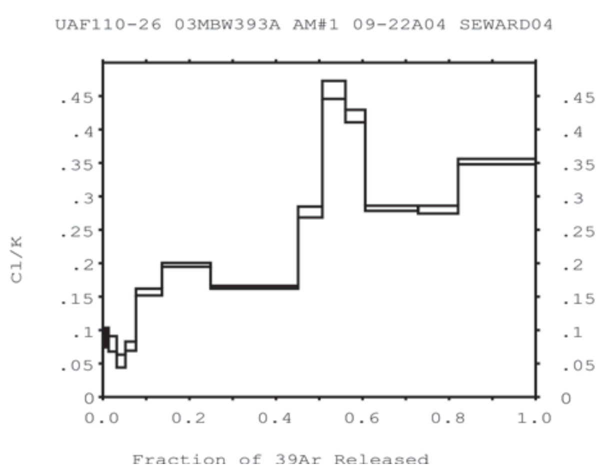
Ca/K
Fraction of 39Ar Released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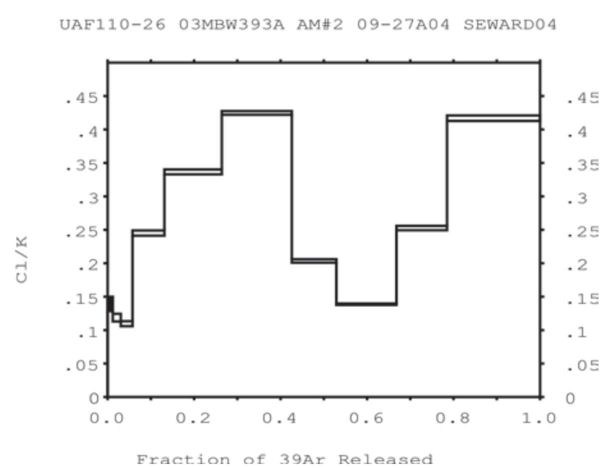
Cl/K
Fraction of 39Ar Released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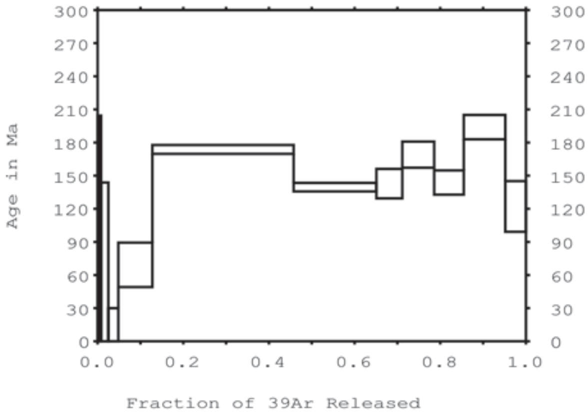
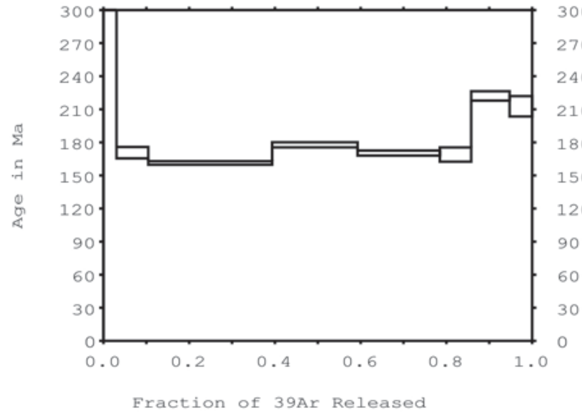
Cl/K
Fraction of 39Ar Released

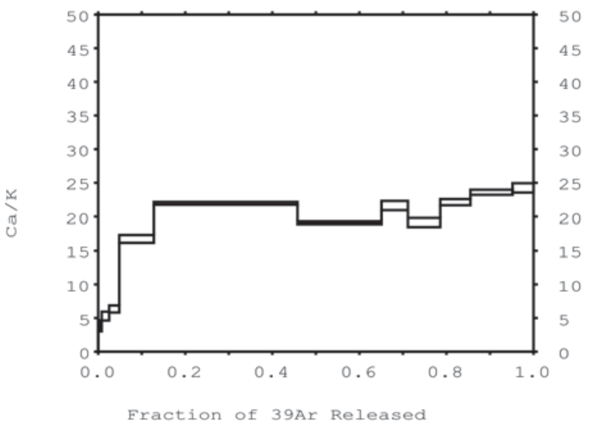
UAF110-26 03MBW393A AM#3 09-30B04 SEWARD04



UAF110-26 03MBW393A AM#4 09-30C04 SEWARD04



UAF110-26 03MBW393A AM#3 09-30B04 SEWARD04



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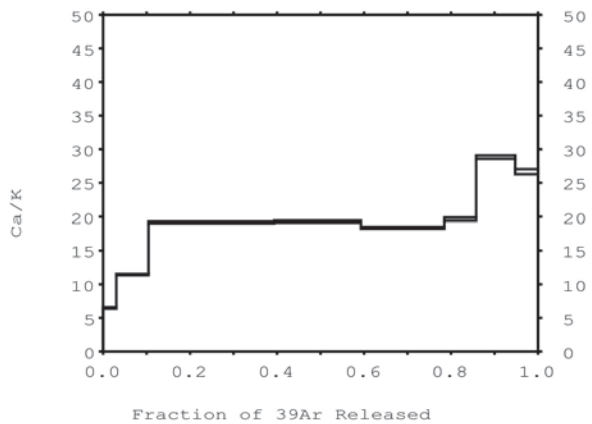

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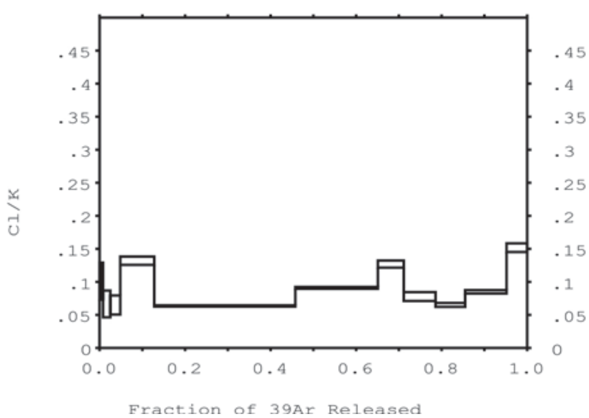

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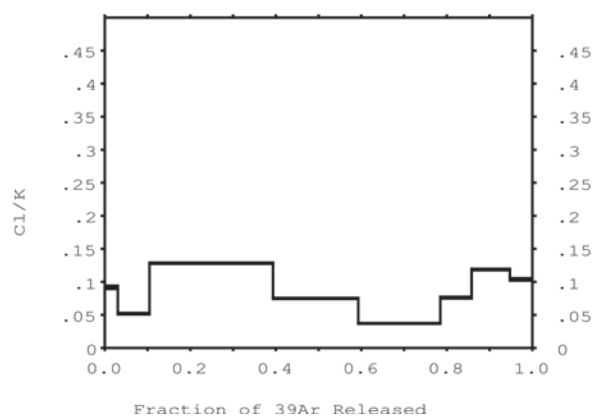
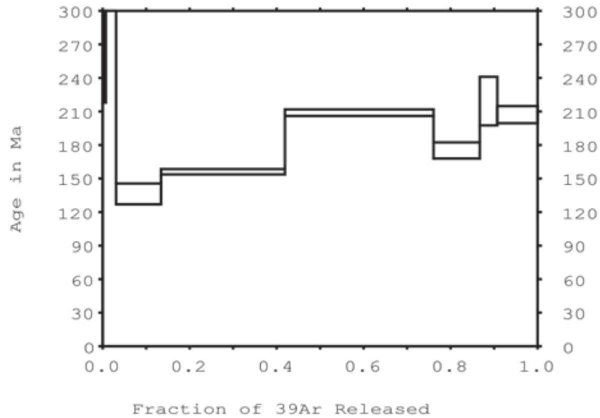
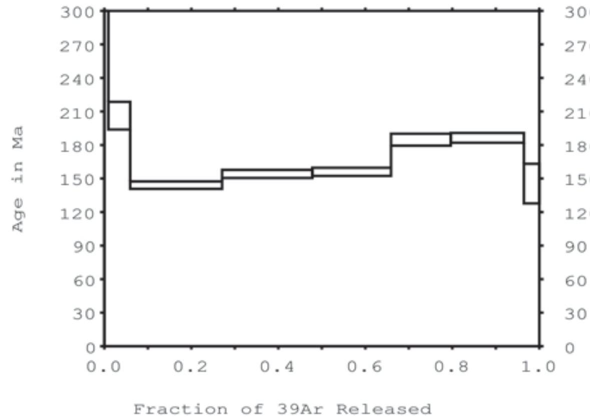


UAF110-26 03MBW393A AM#5 09-30D04 SEWARD04



UAF110-26 03MBW393A AM#6 09-30E04 SEWARD04



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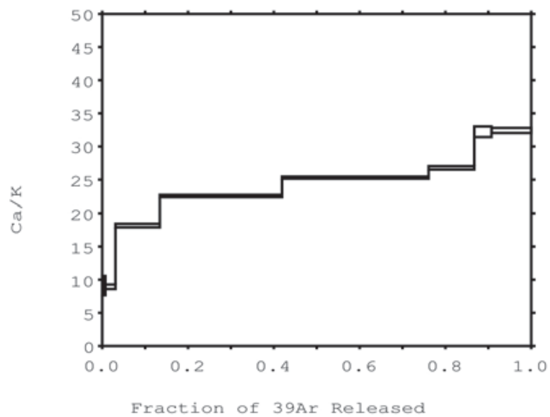

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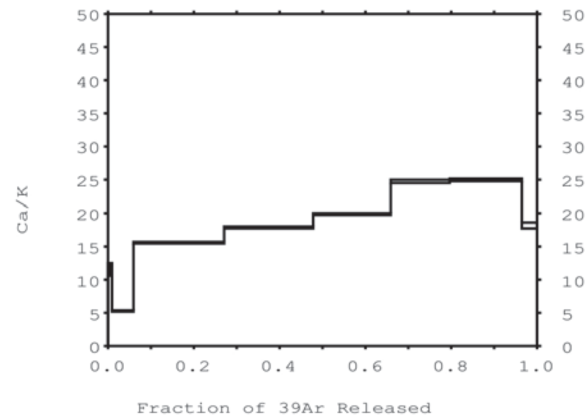

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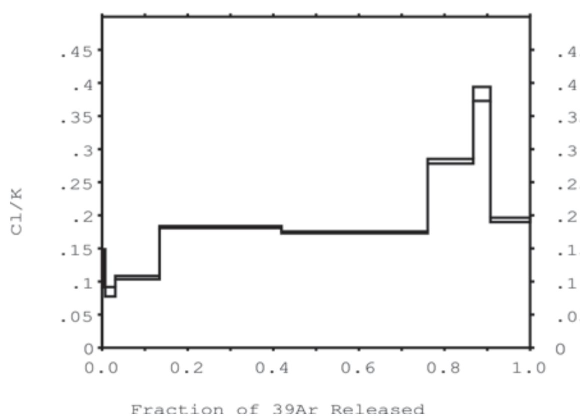

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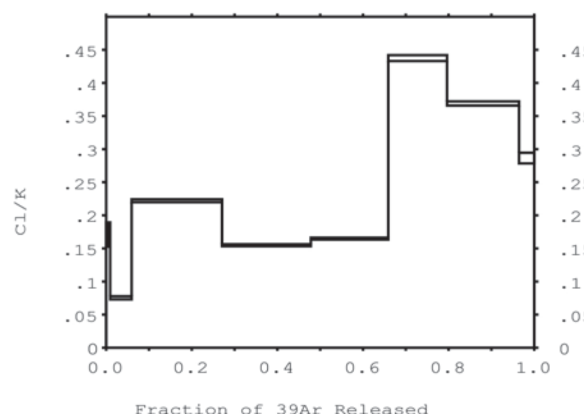

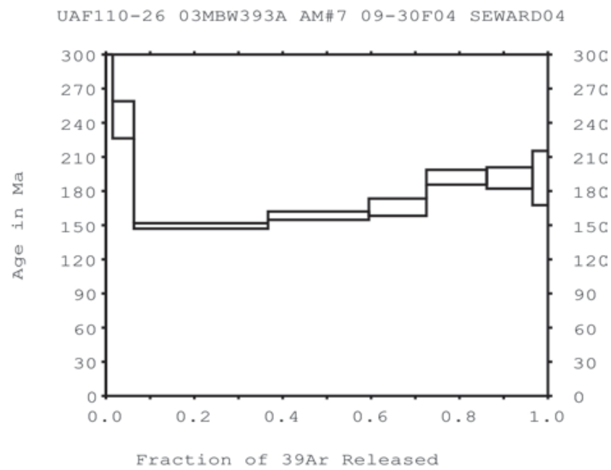
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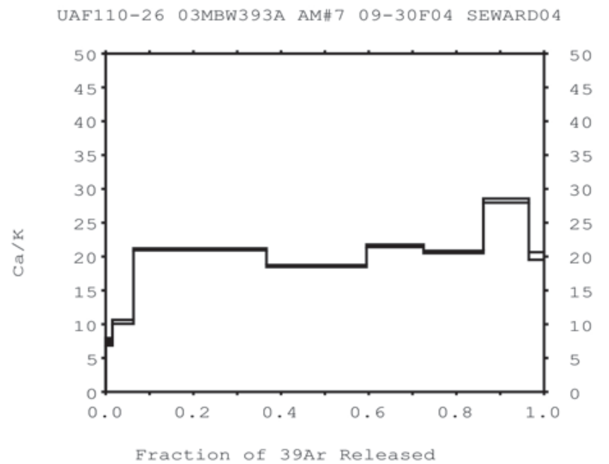
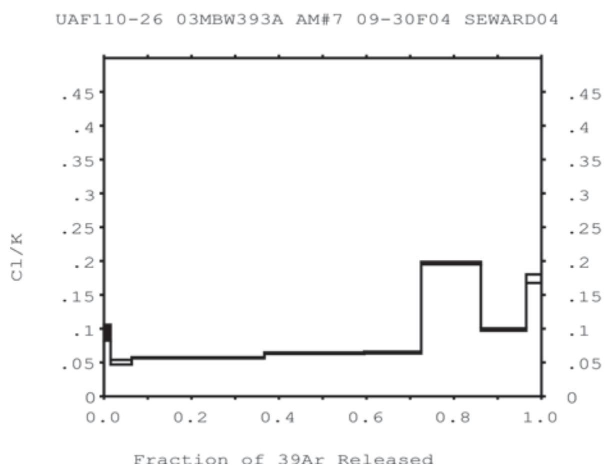
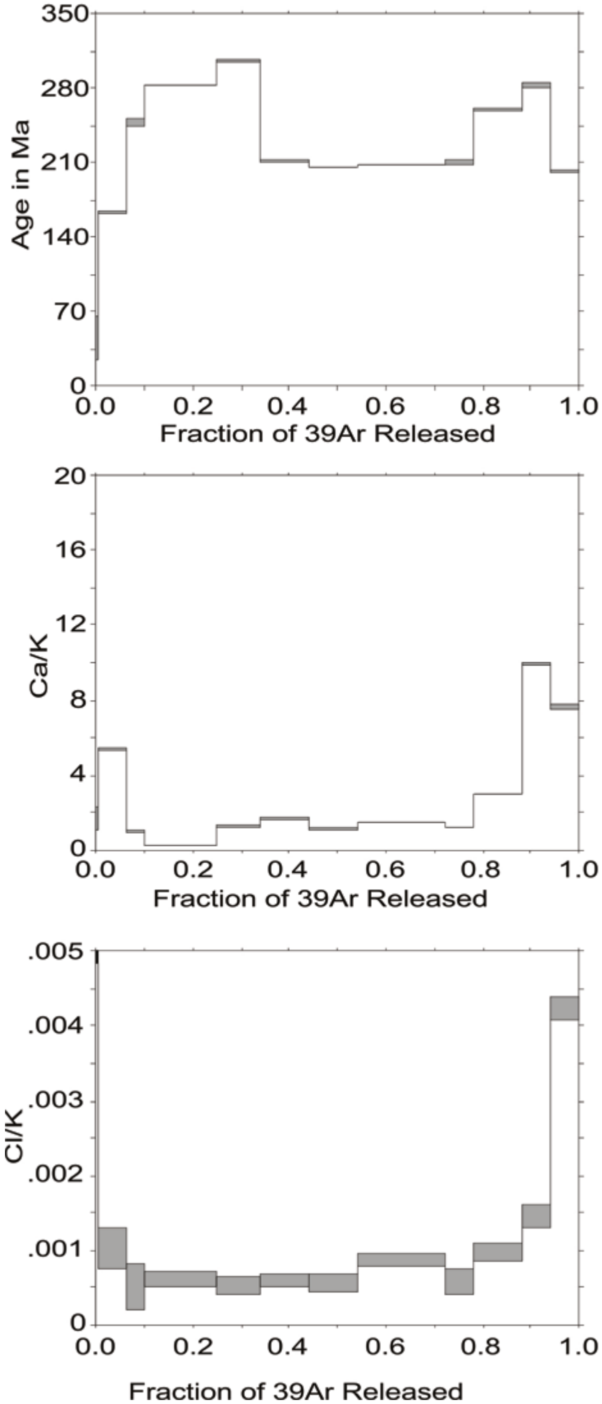
Age in Ma
Fraction of 39Ar Released


UAF110-26 03MBW393A AM#7 09-30F04 SEWARD04
Ca/K
Fraction of 39Ar Released


UAF110-26 03MBW393A AM#7 09-30F04 SEWARD04
Cl/K
Fraction of 39Ar Released

UAF116-44 04RN030A GP#1



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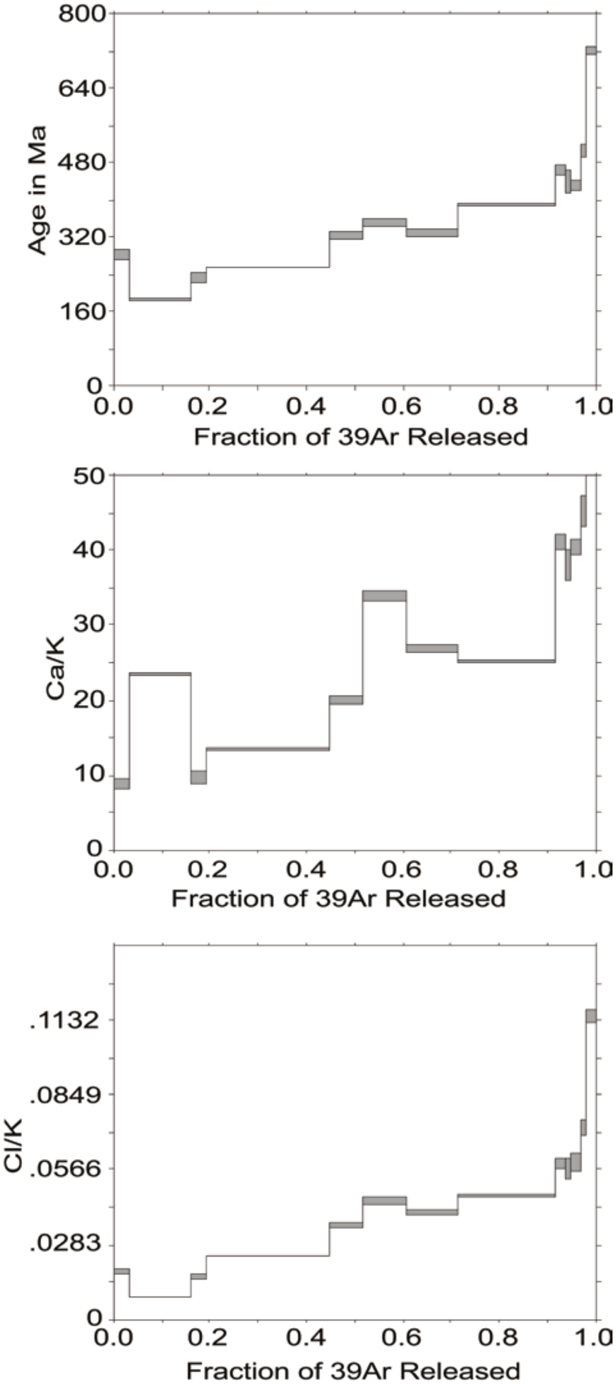
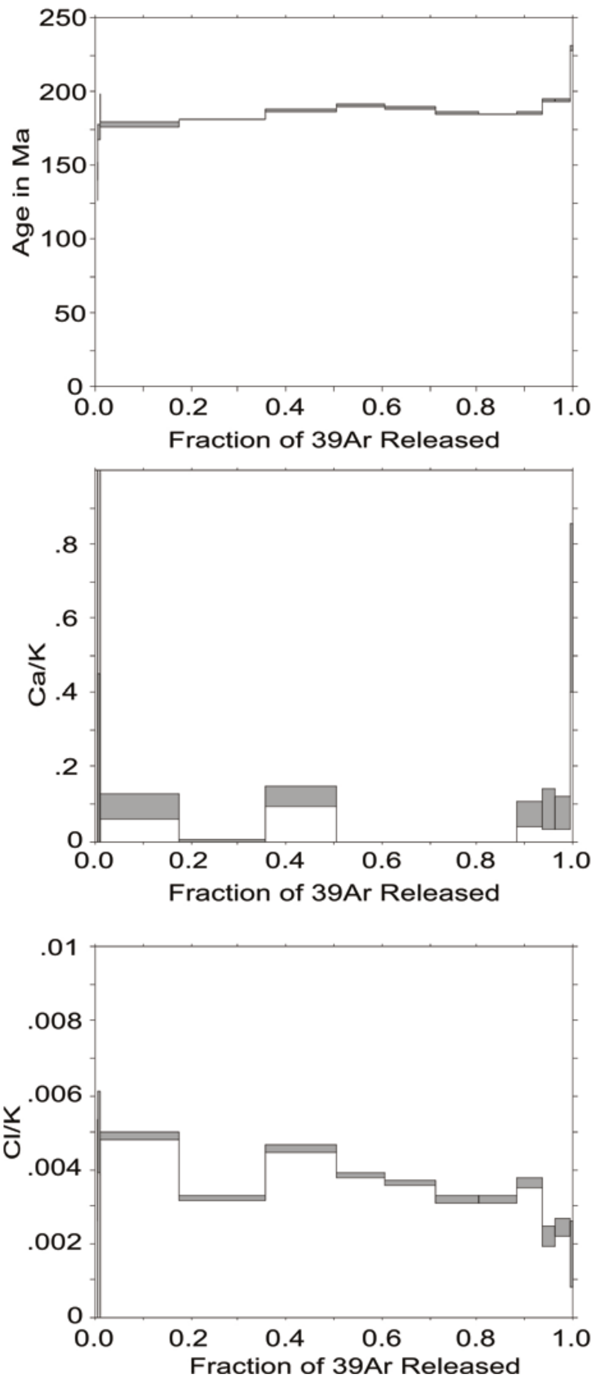
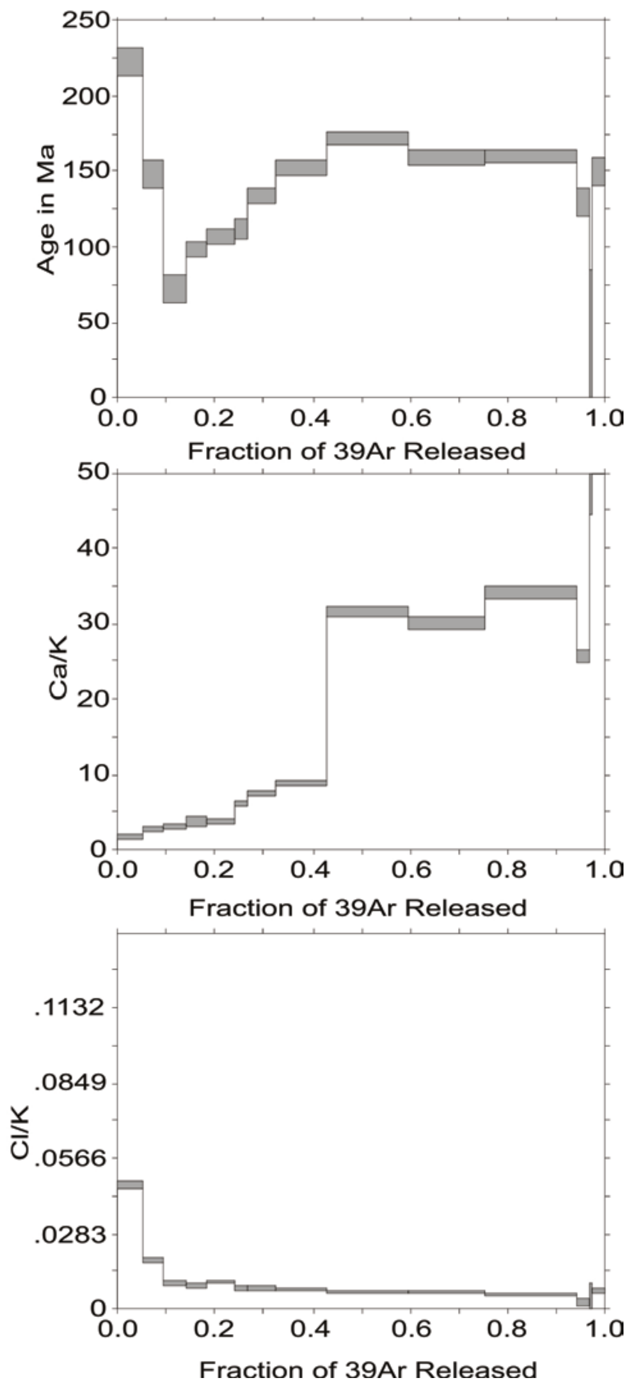
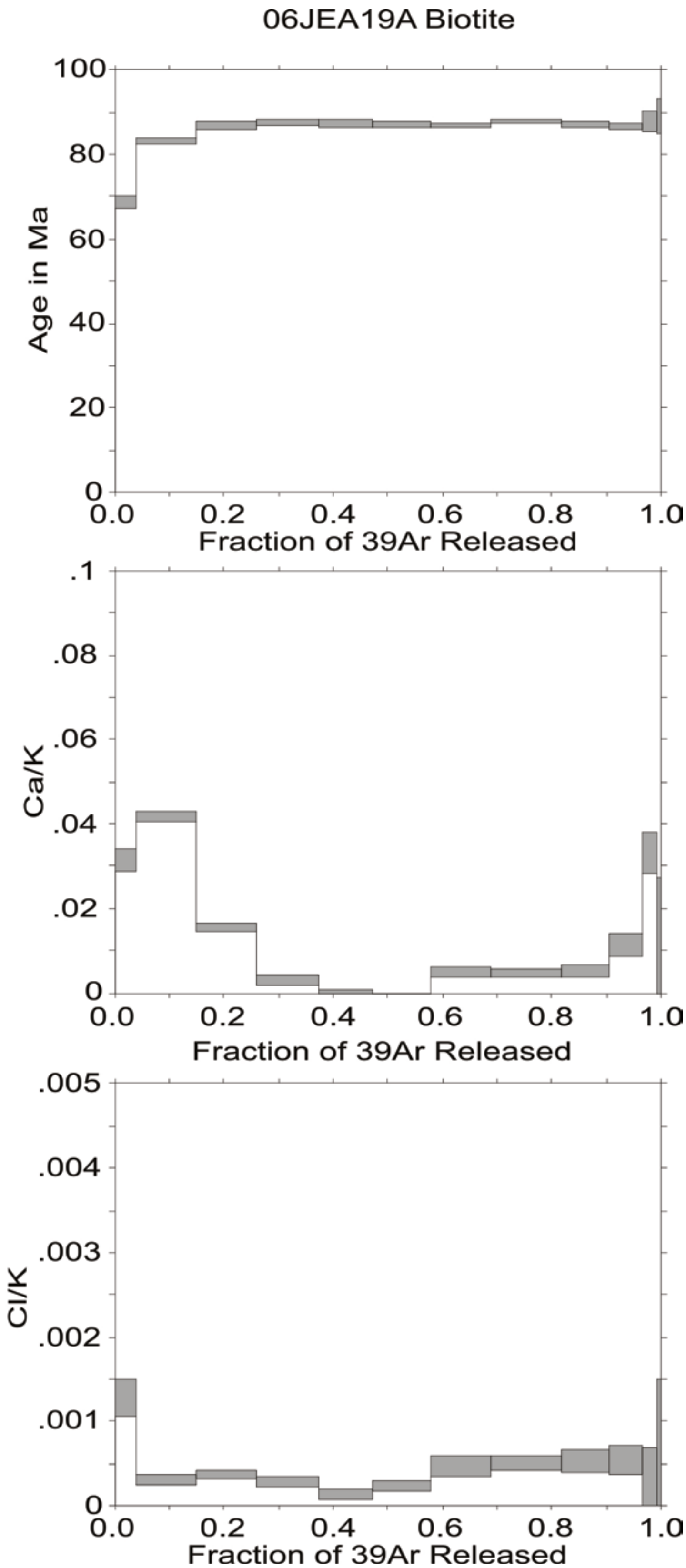


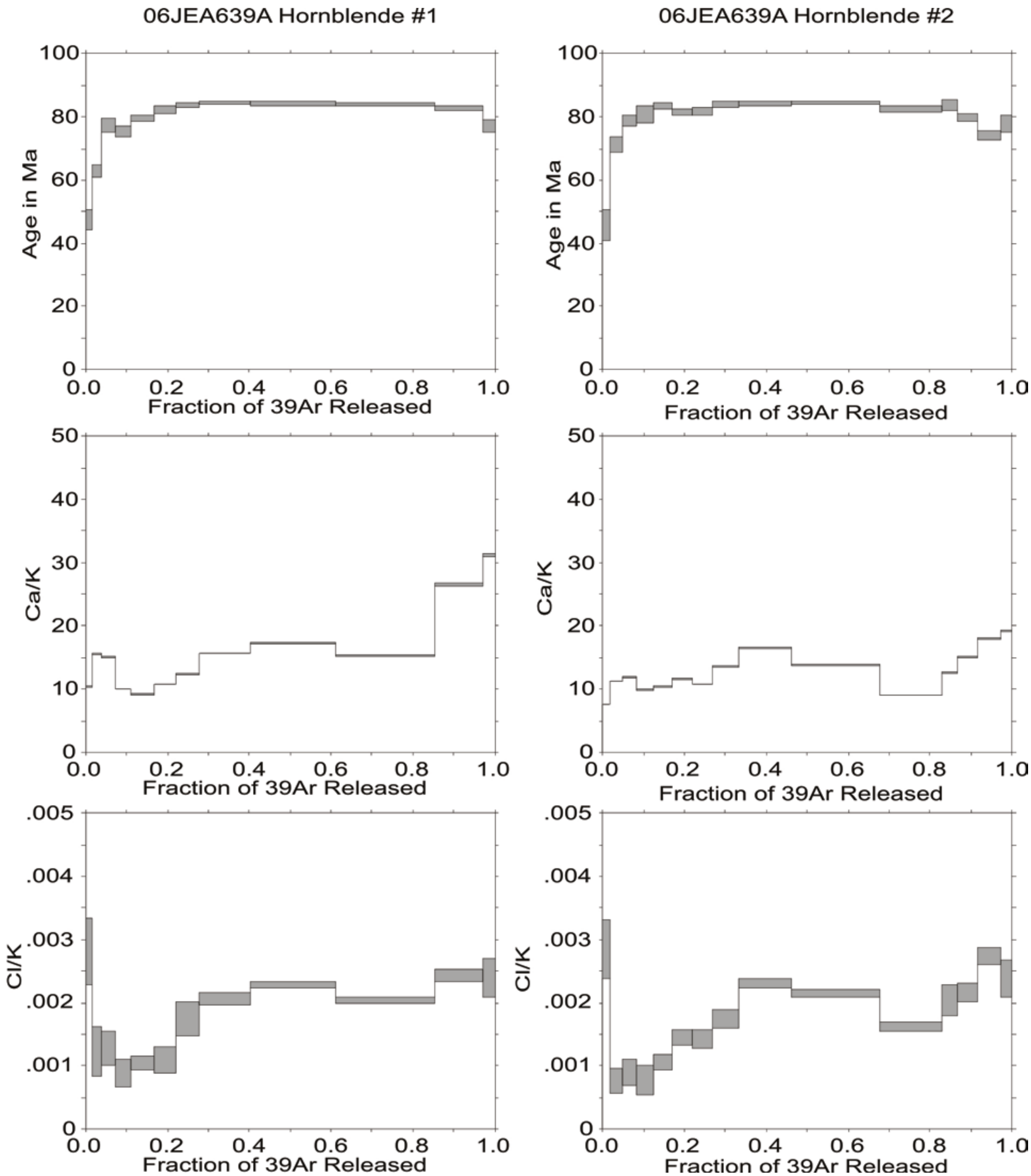
UAF116-39 04MBW332A BI#1

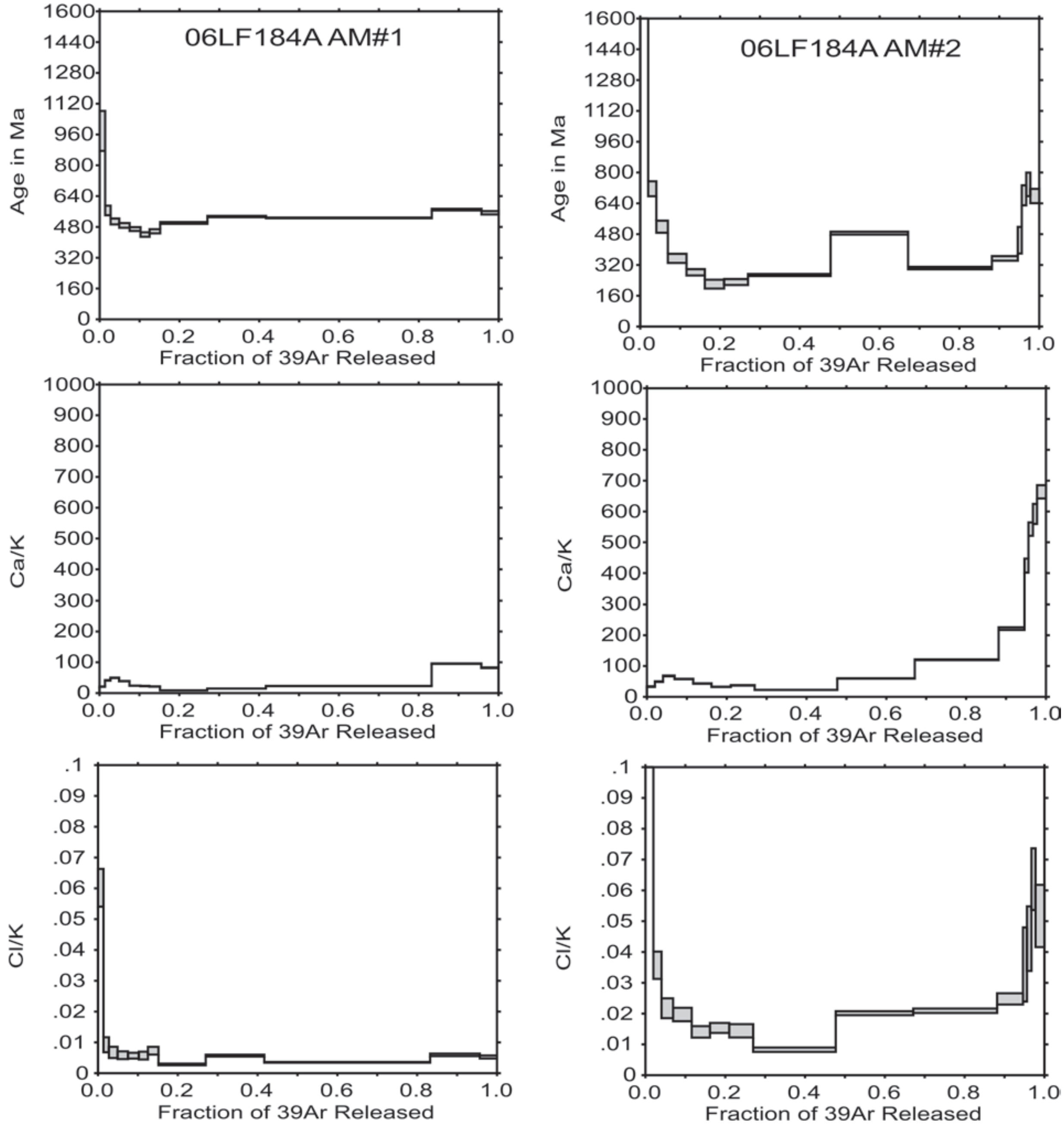


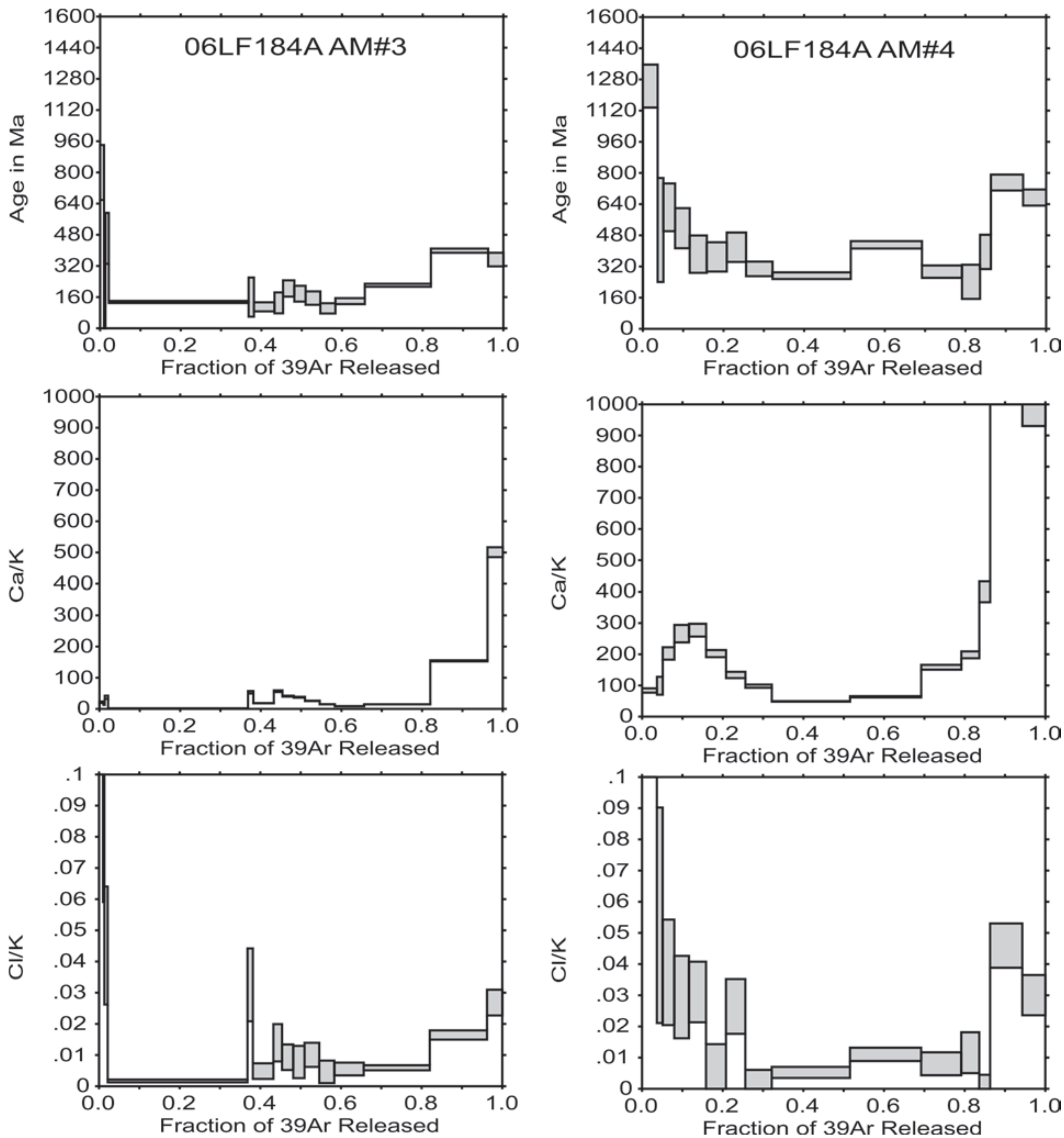
UAF116-46 04RN128A GP#1



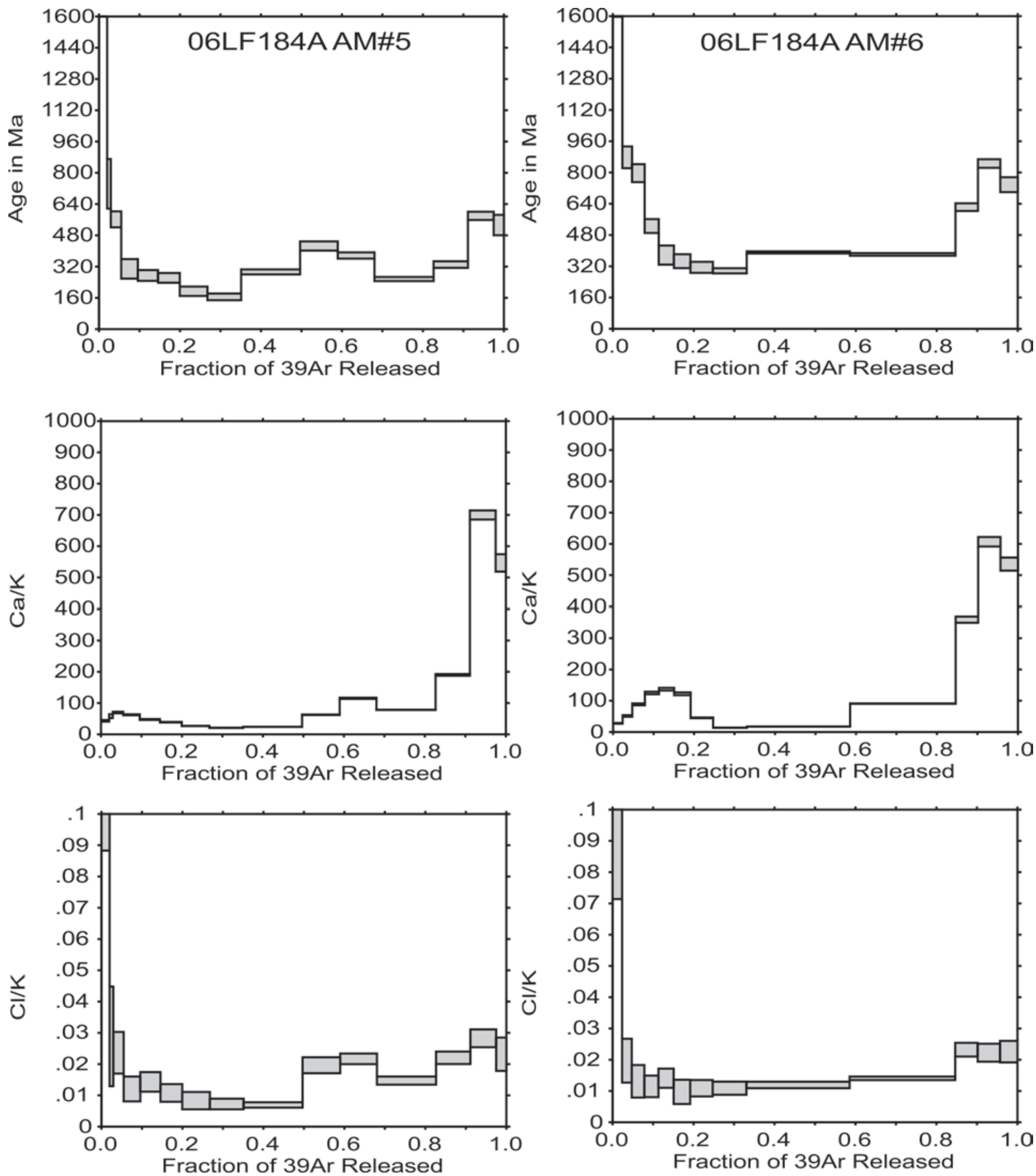

06JEA19A Biotite
Age in Ma
Fraction of 39Ar Released
Ca/K
Fraction of 39Ar Released
Cl/K
Fraction of 39Ar Released

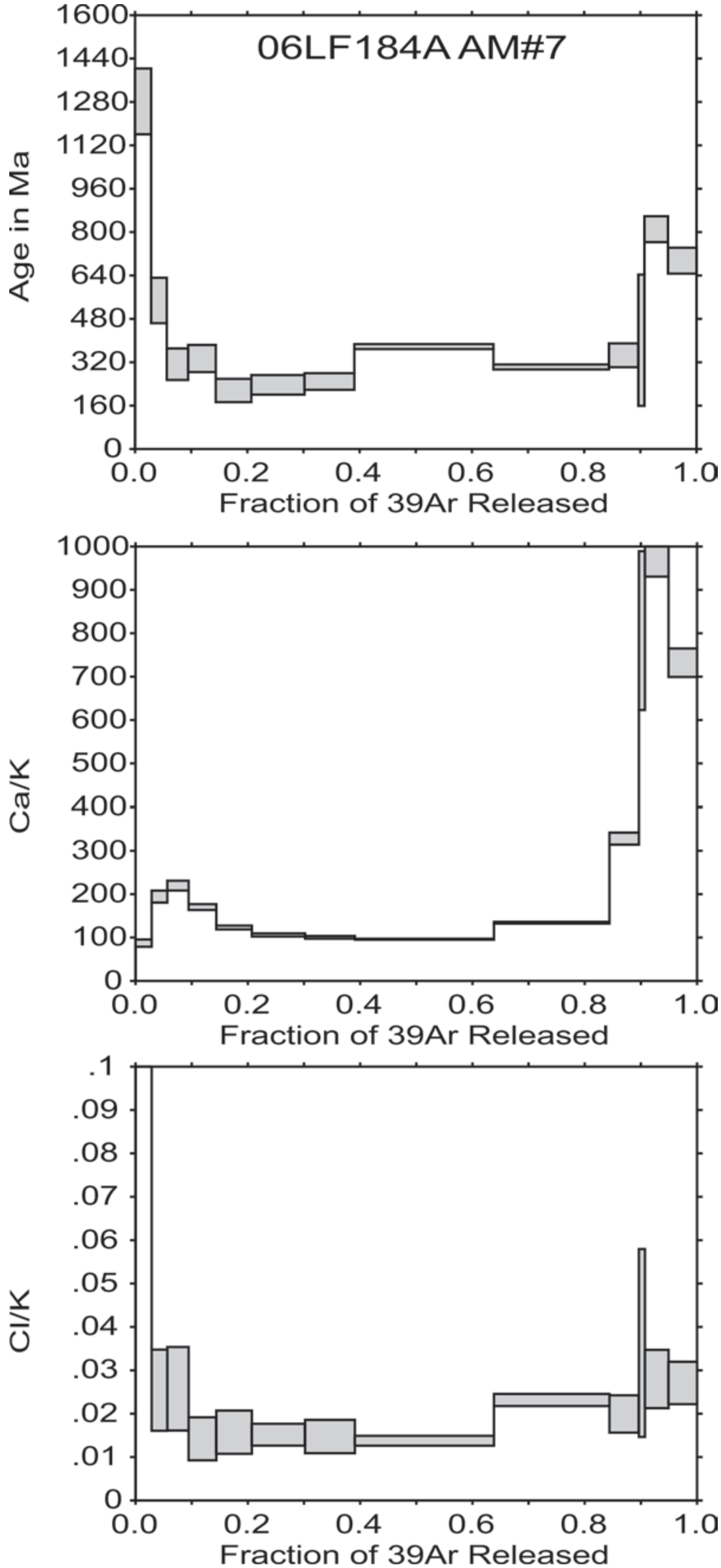

06JEA639A Hornblende #1
06JEA639A Hornblende #2
Age in Ma
Fraction of 39Ar Released
Ca/K
Cl/K


06LF184A AM#1
06LF184A AM#2
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released



06LF184A AM#3
06LF184A AM#4
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released


06LF184A AM#5
06LF184A AM#6
Age in Ma
Ca/K
Cl/K
Fraction of 39Ar Released


06LF184A AM#7
Age in Ma
1600
1440
1280
1120
960
800
640
480
320
160
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released
Ca/K
1000
900
800
700
600
500
400
300
200
100
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released
Cl/K
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of 39Ar Released