$^{40}Ar/^{39}Ar$ Geochronology Results from the Central West, Enterprise, Hebron, and Maple Ridge Quadrangles, Utah

by

Utah Geological Survey and
New Mexico Geochronology Research Laboratory

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This Open-File Report makes available raw analytical data from laboratory procedures completed to determine the age of rock samples collected during geologic mapping funded or partially supported by the Utah Geological Survey (UGS). The references listed in table 1 report the age of the samples and provide additional information such as the sample location, geologic setting, and significance or interpretation of the samples in the context of the area in which they were collected. This report was prepared by the New Mexico Geochronology Research Laboratory under contract to the UGS. These data are highly technical in nature and proper interpretation requires considerable training in the applicable geochronologic techniques.

Table 1. Sample numbers and locations.

Sample #	7.5' quadrangle	Location	Reference
92RB-063B	Central West	SE1/4NE1/4 sec. 3, R17W T39S	Biek and others (2007)
93RB-009A	Enterprise	NE1/4NE1/4 sec. 19, R16W T37S	Rowley and others (2006)
02RB-002	Central West	SE1/4SW1/4 sec. 9, R16W T38S	Biek and others (2007)
02RB-029	Enterprise	SE1/4SE 1/4 sec. 30, R16W T37S	Rowley and others (2006)
02RB-047	Maple Ridge	NE1/4NW1/4 sec. 32, R17W T38S	Biek and others (2007)
03RB-037A	Central West	SE1/4SW1/4 sec. 24, R17W T38S	Biek and others (2007)
03RB-058	Hebron	SE1/4NW1/4 sec. 20, R17W T37S	Rowley and others (2006)

Disclaimer

This open-file release is intended as a data repository for technical analytical information gathered in support of various geologic mapping projects. The data are presented as received from the New Mexico Geochronology Research Laboratory and do not necessarily conform to UGS technical or editorial standards. Therefore, it may be premature for an individual or group to take actions based on the contents of this report.

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References to geologic reports that cite or explain samples analyzed in this report

Biek, R.F., Rowley, P.D., Hacker, D.B., Hayden, J.M., Willis, G.C., Hintze, L.F., Anderson, R.E., and Brown, K.D., 2007, Interim geologic map of the St. George 30' x 60' quadrangle, Washington and Iron Counties, Utah: UGS Open-File Report 478, 70 p., 2 plates., scale 1:100,000.

Rowley, P.D., Williams, V.S., Vice, G.S., Maxwell, D.J., Hacker, D.B., Snee, L.W., and Mackin, J.H., 2006, Interim geologic map of the Cedar City 30' x 60' quadrangle, Iron and Washington Counties, Utah: Utah Geological Survey Open-File Report 476DM, scale 1:100,000.

$^{40}Ar/^{39}Ar$ Geochronology Results

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Introduction

Seven samples from various locations in Utah were submitted for dating by the Utah Geological Survey. The rocks vary in composition therefore a variety of mineral phases or groundmass concentrates were separated and dated (Table 1).

Table 1. Brief summary of results.

Sample	Phase	Unit	Age±2σ (Ma)	Comments
02RB-029	Groundmass Concentrate	Basalt of Twin Spring	5.89±0.11	Isochron age
03RB-058	Sanidine	Ox Valley Tuff	13.93±0.08	single crystal fusion
93RB-009A	Groundmass Concentrate	Isom Formation	21.61±0.14	plateau age
92RB-063B	Biotite	Rencher Formation	22.01±0.08	2 step single crystal
02RB-047	Biotite	Qtz Monz of Bull Valley	21.98±0.10	plateau age
03RB-037A	Biotite	Qtz Monz of Hardscrabble Hollow	22.02±0.11	plateau age
02RB-002	Biotite	Qtz Monz of Big Mountain	22.00±0.07	plateau age

$^{40}Ar/^{39}Ar$ Analytical Methods and Results

Samples prepared as groundmass concentrates were crushed and cleaned with dilute hydrochloric acid. Those prepared for sanidine were crushed and cleaned with dilute hydrofluoric acid, while biotite separates were crushed and cleaned with only water. The analyzed phases were then separated with standard heavy liquid, magnetic

separator and handpicking techniques. The samples were loaded into aluminum discs and irradiated for 10 hours at the Nuclear Science Center in College Station, Texas.

Groundmass concentrates (02RB-029 and 93RB-009A) and biotite from the quartz monzonites (02RB-002, 02RB-047, 03RB-037) were analyzed with the furnace incremental heating age spectrum method. Sanidine from 03RB-58 was analyzed by the single-crystal laser fusion method, whereas biotite from 92RB-063B was step-heated (two steps) as single crystals with a CO_2 laser. The first heating step was employed to remove atmospheric argon and thus increase the radiogenic yields and precision of the second steps. The age data for the more radiogenic, more precise steps from the single crystal biotite analyses and the sanidine total fusion data are displayed on probability distribution diagrams (cf. Deino and Potts, 1992). Abbreviated analytical methods for the dated samples are given in Table 2, and details of the overall operation of the New Mexico Geochronology Research Laboratory are provided in the Appendix. The age results are summarized in Tables 1 and 2 and argon isotopic data are given in Tables 3-6.

93RB-009A Weighted Mean Age=21.61±0.14 Ma n/n_{total}=7/9 MSWD=1.8

93RB-009A groundmass concentrate yielded a well-behaved age spectrum (Figure 1a). The initial 7.3% of the ^{39}Ar released yielded old apparent ages with the remainder of the age spectrum giving a well-defined weighted mean age of 21.61±0.14 Ma. The radiogenic yields rise to 88.8% radiogenic over the initial 40.7% of the age spectrum and then fall to 33.4%. The K/Ca values are somewhat oscillatory, varying from 0.44 to 2.5. Steps C-I were evaluated with the inverse isochron technique and revealed a $^{40}Ar/^{36}Ar$ intercept of 294.2±5.3 (Figure 1b). An inverse isochron age of 21.64±0.22 Ma was calculated.

03RB-037A Weighted Mean Age=22.02±.11 Ma n/n_{total}=8/12 MSWD=2.3

Biotite from 03RB-037A yielded a fairly well-behaved age spectrum (Figure 2a). A weighted mean age of 22.02±0.11 Ma is calculated from 99.2% of the ^{39}Ar released. Radiogenic yields rise to a high of 95.3% with 97.1% of the ^{39}Ar released, after which the radiogenic yields decline to a low of 79.1%. The K/Ca values oscillate between 3.8 and

22.6. Inverse isochron analysis of points B-I (Figure 2b) yields a $^{40}Ar/^{36}Ar$ intercept (298.8±5.1) within error of the atmospheric value. The isochron age (21.98±0.14 Ma) is within error of the weighted mean age calculated from the age spectrum.

02RB-047 Weighted Mean Age=21.98±0.10 Ma n/n_{total}=8/12 MSWD=2.0

Biotite from 02RB-047 yielded a well-behaved age spectrum similar to that of 03RB-037A (Figure 3a). A weighted mean age of 21.98±0.10 Ma is calculated from 97.8% of the ^{39}Ar released. The radiogenic yields rise to a high of 94.4% with 98.1% of the ^{39}Ar released and then decrease slightly to 92.5% radiogenic. The K/Ca values oscillate between 2.8 and 14.6. Inverse isochron analysis of points A-J reveals a $^{40}Ar/^{36}Ar$ intercept (297.0±3.8) within error of the atmospheric value and an isochron age of 21.98±0.17 Ma (Figure 3b).

02RB-002 Weighted Mean Age=22.00±0.07 n/n_{total}=4/12 MSWD=1.2

Biotite from 02RB-002 reveals an age spectrum slightly more disturbed than the previous two age spectra (Figure 4a), however a well-defined weighted mean age of 22.00±0.07 Ma is calculated from steps G-J that comprise ~70% of the ^{39}Ar released. The radiogenic yields rise to >93% by 9.5% of the ^{39}Ar released and remain fairly constant for the remainder of the age spectrum. The K/Ca values rise and fall in a similar manner to the other biotites with values ranging from 4.8 to 20.6. Points G-J are evaluated with the inverse isochron technique but cluster near the $^{39}Ar/^{40}Ar$ intercept due to the consistent high radiogenic yields (Figure 4b). An imprecise $^{40}Ar/^{36}Ar$ ratio of 310±76 is calculated. The calculated isochron age of 21.98±0.15 Ma agrees within error to the weighted mean calculated from the age spectrum.

02RB-029 Isochron Age=5.89±0.11 Ma n/n_{total}=7/9 MSWD=3.5

02RB-029 groundmass concentrate yielded a disturbed, saddle-shaped age spectrum with old apparent ages in the early and late heating steps (Figure 5a). A weighted mean age of 5.95±0.06 Ma is calculated from heating steps E-G that contain 39.9% of the ^{39}Ar released. The radiogenic yields are inversely correlated to the apparent ages, rising to a high of 66.8% as the apparent ages decrease and then falling to 10.7% radiogenic as the apparent ages rise. The K/Ca values are quite consistent (0.22 to 0.38) until the final heating step where they drop by an order of magnitude. Inverse isochron analysis of steps B-H reveals a $^{40}Ar/^{36}Ar$ intercept of 302.1±3.4 and an isochron age of 5.89±0.11 Ma (Figure 5b).

03RB-58 Weighted Mean Age=13.93±0.08 Ma n/n_{total}=9/12 MSWD=1.7

Eight of the ten 03RB-058 sanidine crystals yield a normal distribution of ages and have a weighted mean of 13.93±0.08 Ma (Figure 6). The remaining two sanidine crystals with ages of ca 16 Ma as well as five plagioclase analyses were eliminated from the weighted mean age calculation. The K/Ca values of the crystals included in the weighted mean age range from 28.7 to 58.3, and the radiogenic yields are high and range from 91.0% to 100.5%.

92RB-063B Weighted Mean Age=22.01±0.08 Ma n/n_{total}=9/10 MSWD=1.0

The biotite from the Rencher Formation tuff (92RB-063B) was analyzed as single crystals to evaluate possible xenocrystic contamination. In addition, the single crystals were heated in two steps with the first step consistently yielding lower radiogenic yields and precision compared to the fusion step. Typically A-steps are less than 14% radiogenic, whereas B-steps are greater than 59%. Nine of the ten precise B-step ages yield a well-defined population that gives a weighted mean of 22.01±0.08 Ma (Figure 7).

Discussion

The weighted mean ages assigned to the 93RB-009A (21.61±0.14 Ma), 03RB-037A (22.02±0.11 Ma), 02RB-047 (21.98±0.10 Ma) and 02RB-002 (22.00±0.07 Ma) age spectra provide precise, reliable ages for the eruption of the basalts or cooling of the biotite below its closure temperature of (300-350°C). The saddle-shaped 02RB-029 age spectrum is suggestive of excess Ar ($^{40}Ar/^{36}Ar > 295.5$), this is confirmed by the trapped $^{40}Ar/^{36}Ar$ ratio of 302.1±3.4 calculated from the inverse isochron analysis (Harrison and McDougall, 1981; Zeitler and Fitzgerald, 1986). We have therefore, assigned the isochron age of 5.89±0.11 Ma as the eruption age of the basalt of Twin Spring. The single crystal data for 03RB-058 sanidine (13.93±0.08 Ma) provides an eruption age for the Ox Valley Tuff. The weighted mean age calculated from the B steps of 92RB-063B biotite (22.01±0.08 Ma) provides an eruption age for the lower outflow tuff member found within the Rencher Formation and a deposition age for the Rencher Formation.

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Table 2. Summary of $^{40}Ar/^{39}Ar$ results and analytical methods

Sample	Lab #	Irradiation	mineral	age analysis	steps	Age	±2σ	MSWD	40Ar/36Ar intercept	comments
02RB-029	55175	NM-182	groundmass concentrate	furnace step-heat	3	5.89	0.11	3.5	302.1±3.4	isochron age
03RB-058	55203	NM-182	sanidine	laser total fusion	10	13.93	0.08	1.7	-	
93RB-009A	55172	NM-182	groundmass concentrate	furnace step-heat	7	21.61	0.14	1.8	-	
92RB-063B	55168	NM-182	biotite	laser step-heat	9	22.01	0.08	1.0	-	
02RB-047	55165	NM-182	biotite	furnace step-heat	8	21.98	0.10	2.0	-	
03RB-037A	55169	NM-182	biotite	furnace step-heat	8	22.02	0.11	2.3	-	
02RB-002	55164	NM-182	biotite	furnace step-heat	4	22.00	0.07	1.2	-	

Sample preparation and irradiation:
Minerals separated with standard heavy liquid, Franz Magnetic and hand-picking techniques.
Samples were loaded into a machined Al disc and irradiated for 10 hours in D-3 position, Nuclear Science Center, College Station, TX.
Neutron flux monitor Fish Canyon Tuff sanidine (FC-2). Assigned age = 28.02 Ma (Renne et al, 1998).

Instrumentation:
Mass Analyzer Products 215-50 mass spectrometer on line with automated all-metal extraction system.
Groundmass concentrates and biotite step-heated for 10 or 9 minutes, respectively using a Mo double-vacuum resistance furnace.
Reactive gases removed during furnace analysis by reaction with 3 SAES GP-50 getters, 2 operated at ~450°C and
1 at 20°C. Gas also exposed to a W filiment operated at ~2000°C.
92RB-063B step-heated by a 50 watt Synrad CO_2 laser equipped with top-hat lens for 20 seconds.
Reactive gases removed during a 4 minute reaction with 2 SAES GP-50 getters, 1 operated at ~450°C and
1 at 20°C. Gas also exposed to a W filament operated at ~2000°C and a cold finger operated at -140°C.
Sanidine fused by a 50 watt Synrad CO_2 laser.
Reactive gases removed during a 2 minute reaction with 2 SAES GP-50 getters, 1 operated at ~450°C and
1 at 20°C. Gas also exposed to a W filament operated at ~2000°C and a cold finger operated at -140°C.

Analytical parameters:
Electron multiplier sensitivity averaged 2.13 x 10^{-16} moles/pA for furance analyses and 1.22 x 10^{-16} moles/pA for laser analyses.
Total system blank and background averaged 4650, 13.4, 3.6, 1.4, 16.9 x 10^{-18} moles at masses 40, 39, 38, 37 and 36, respectively for the furnace analyses.
Total system blank and background averaged 2430, 6.4, 2.9, 1.4, 9.3 x 10^{-18} moles at masses 40, 39, 38, 37 and 36, respectively for the laser analyses.
J-factors determined to a precision of ± 0.1% by CO_2 laser-fusion of 6 single crystals from each of 6 or 10 radial positions around the irradiation tray.
Correction factors for interfering nuclear reactions were determined using K-glass and CaF_2 and are as follows:
$(^{40}Ar/^{39}Ar)_K = 0.0000\pm0.0004$; $(^{36}Ar/^{37}Ar)_{Ca} = 0.00028\pm0.00001$; and $(^{39}Ar/^{37}Ar)_{Ca} = 0.0007\pm0.00005$.

Table 3. $^{40}Ar/^{39}Ar$ analytical data.

	ID	Power (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
	93RB-009A, Groundmass Concentrate, J=0.0011047±0.24%, D=1.0063±0.001, NM-182J, Lab#=55172-01										
#	A	650	528.4	0.3021	1713.9	5.21	1.7	4.2	3.3	43.23	4.24
#	B	725	24.42	0.3358	44.49	6.27	1.5	46.3	7.3	22.39	0.21
	C	775	13.74	0.3755	10.03	2.65	1.4	78.7	8.9	21.42	0.29
	D	825	13.46	0.4573	8.859	8.3	1.1	80.8	14.2	21.56	0.13
	E	900	13.57	0.4095	8.876	14.9	1.2	80.9	23.6	21.76	0.08
	F	1000	12.32	0.3010	4.746	27.0	1.7	88.8	40.7	21.67	0.05
	G	1100	13.69	0.2047	9.718	38.1	2.5	79.1	64.8	21.47	0.06
	H	1275	18.03	0.3314	24.27	40.1	1.5	60.4	90.2	21.57	0.10
	I	1725	32.58	1.155	73.71	15.5	0.44	33.4	100.0	21.59	0.25
	Integrated age ± 2σ		n=9			158.0	1.4 ±1.2		K2O=2.81%	22.33	0.43
	Plateau ± 2σ	**steps C-I**	**n=7**	**MSWD=1.8**		**146.5**	**1.4 ±1.2**		**92.7**	**21.61**	**0.14**
	Isochron±2σ	steps C-I	n=7	MSWD=2.4		$^{40}Ar/^{36}Ar$=294±16				21.64	0.22
	03RB-037A, Biotite, J=0.0010368±0.12%, D=1.0063±0.001, NM-182H, Lab#=55169-02										
#	*A*	*650*	*147.3*	*0.1325*	*468.2*	*1.96*	*3.8*	*6.1*	*0.8*	*16.78*	*1.36*
	B	750	43.75	0.0725	108.5	2.17	7.0	26.7	1.6	21.75	0.61
	C	850	23.29	0.0424	38.56	7.38	12.0	51.1	4.6	22.12	0.23
	D	920	20.23	0.0290	28.37	18.7	17.6	58.6	12.0	22.02	0.14
	E	1000	17.07	0.0226	17.11	23.7	22.6	70.4	21.4	22.33	0.11
	F	1075	14.21	0.0237	7.932	31.3	21.5	83.5	33.8	22.06	0.08
	G	1110	12.66	0.0428	3.011	13.3	11.9	93.0	39.1	21.89	0.09
	H	1180	12.39	0.0398	1.976	146.2	12.8	95.3	97.1	21.96	0.04
	I	1210	15.10	0.0302	10.67	7.44	16.9	79.1	100.0	22.21	0.13
	Integrated age ± 2σ		n=9			252.2	15.3 ±10.6		K2O=9.75%	21.98	0.12
	Plateau ± 2σ	**steps B-I**	**n=8**	**MSWD=2.3**		**250.3**	**15.3 ±10.6**		**99.2**	**22.02**	**0.11**
	Isochron±2σ	steps B-I	n=8	MSWD=2.0		$^{40}Ar/^{36}Ar$=298.8±5.1				21.98	0.14
	02RB-047, Biotite, J=0.0011994±0.10%, D=1.0063±0.001, NM-182H, Lab#=55165-01										
#	A	650	1304.5	0.1803	4303.0	0.765	2.8	2.5	0.3	69.91	12.02
	B	750	221.8	0.1919	710.4	1.57	2.7	5.4	0.9	25.57	2.74
	C	850	52.36	0.1309	144.3	3.54	3.9	18.6	2.3	20.95	0.68
	D	920	28.02	0.0681	60.97	7.44	7.5	35.7	5.2	21.53	0.30
	E	1000	16.91	0.0349	22.78	16.7	14.6	60.2	11.8	21.89	0.14
	F	1075	14.46	0.0376	14.50	25.4	13.6	70.4	21.7	21.90	0.11
	G	1110	12.12	0.0519	6.401	21.3	9.8	84.4	30.1	22.01	0.09
	H	1180	11.52	0.0817	4.550	74.9	6.2	88.4	59.5	21.90	0.05
	I	1210	10.88	0.0584	2.091	98.4	8.7	94.4	98.1	22.08	0.05
#	J	1250	11.38	0.0957	2.911	4.72	5.3	92.5	100.0	22.63	0.21
	Integrated age ± 2σ		n=10			254.8	8.4 ±8.5		K2O=10.01%	22.14	0.20
	Plateau ± 2σ	**steps B-I**	**n=8**	**MSWD=2.0**		**249.3**	**8.4 ±8.5**		**97.8**	**21.98**	**0.10**
	Isochron±2σ	steps A-J	n=10	MSWD=4.4		$^{40}Ar/^{36}Ar$=297.0±3.8				21.98	0.17

	ID	Power (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
	02RB-002, Biotite, J=0.0011905±0.11%, D=1.0063±0.001, NM-182H, Lab#=55164-01										
#	A	650	404.5	0.1073	1346.8	0.654	4.8	1.6	0.2	14.07	5.05
#	B	750	80.75	0.0455	249.0	0.584	11.2	8.9	0.4	15.34	1.85
#	C	850	18.42	0.0440	28.27	8.61	11.6	54.6	3.5	21.49	0.19
#	D	920	11.18	0.0248	2.575	16.7	20.6	93.2	9.5	22.25	0.07
#	E	1000	10.89	0.0309	1.726	13.5	16.5	95.3	14.4	22.15	0.07
#	F	1075	10.82	0.0460	1.383	41.7	11.1	96.3	29.4	22.23	0.04
	G	1110	10.65	0.0442	1.249	26.4	11.5	96.6	38.9	21.95	0.05
	H	1180	10.76	0.0907	1.471	58.9	5.6	96.0	60.0	22.05	0.04
	I	1210	10.45	0.0672	0.4741	76.3	7.6	98.7	87.4	22.02	0.05
	J	1250	10.48	0.0561	0.6620	35.0	9.1	98.2	100.0	21.97	0.05
	Integrated age ± 2σ			n=10		278.2	8.5 ±5.0		K2O=10.05%	22.02	0.10
	Plateau ± 2σ steps G-J			**n=4**	**MSWD=1.2**	**196.5**	**8.5 ±5.0**		**70.6**	**22.00**	**0.07**
	Isochron±2σ steps G-J			n=4	MSWD=1.6		$^{40}Ar/^{36}Ar$=310±76			21.98	0.15
	02RB-029, Groundmass Concentrate, J=0.0011227±0.25%, D=1.0063±0.001, NM-182J, Lab#=55175-01										
#	A	650	2713.5	1.920	8455.4	20.8	0.27	7.9	4.9	390.66	21.78
#	B	725	66.93	1.728	213.3	52.3	0.30	6.0	17.2	8.18	0.57
#	C	775	16.79	2.423	46.68	60.1	0.21	19.0	31.4	6.48	0.14
#	D	825	6.668	1.842	12.76	95.8	0.28	45.7	54.0	6.17	0.05
	E	900	4.422	1.446	5.367	79.5	0.35	66.8	72.7	5.98	0.03
	F	1000	4.389	1.346	5.339	60.9	0.38	66.6	87.0	5.91	0.03
	G	1100	9.106	2.269	21.50	29.1	0.22	32.3	93.9	5.95	0.09
#	H	1275	37.02	18.96	117.2	26.0	0.027	10.7	100.0	8.11	0.34
	Integrated age ± 2σ			n=8		424.5	0.32 ±0.17		K2O=1.37%	27.4	2.8
	Plateau ± 2σ steps E-G			n=3	MSWD=1.1	169.5	0.32 ±0.17		39.9	5.95	0.06
	Isochron±2σ steps B-H			**n=7**	**MSWD=3.5**		**$^{40}Ar/^{36}Ar$=302.1±3.4**			**5.89**	**0.11**

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Errors quoted for individual analyses include analytical error only, without interferring reaction or J uncertainties.
Integrated age is volume-weighted mean of all steps.
Integrated age calculated by recombining isotopic measurements of all steps.
Integrated age error calculated by recombining errors of isotopic measurements of all steps.
Plateau age is inverse-variance-weighted mean of selected steps.
Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.
Decay constants and isotopic abundances after Steiger and Jäeger (1977).
symbol preceding sample ID denotes analyses excluded from plateau age calculations.
Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.02 Ma
Decay Constant (LambdaK (total)) = 5.543e-10/a
Discrimination = 1.0063 ± 0.001
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 5e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 1e-05
$(^{38}Ar/^{39}Ar)_{K}$ = 0.0133
$(^{40}Ar/^{39}Ar)_{K}$ = 0 ± 0.0004

Table 4. $^{40}Ar/^{39}Ar$ analytical data.

	ID	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	Age (Ma)	±1σ (Ma)
	03RB-058, Sanidine, J=0.0010924±0.11%, D=1.0063±0.001, NM-182N, Lab#=55203								
#	14	7.614	1.065	3.558	0.769	0.48	87.3	13.07	0.61
	06	7.423	0.0140	1.341	3.255	36.4	94.7	13.80	0.15
	11	7.348	0.0104	1.083	11.333	49.1	95.7	13.80	0.06
	07	7.751	0.0180	2.365	10.996	28.4	91.0	13.85	0.11
	04	7.240	0.0088	0.4867	6.688	58.3	98.0	13.93	0.09
	08	7.281	0.0088	0.6175	5.526	57.8	97.5	13.94	0.12
	05	7.346	0.0178	0.7729	16.957	28.7	96.9	13.98	0.05
	15	7.259	0.0149	0.2727	11.402	34.2	98.9	14.10	0.08
	03	7.248	0.0120	-0.1224	2.199	42.5	100.5	14.30	0.29
	13	7.206	0.9236	-0.2492	0.806	0.55	102.1	14.45	0.65
#	*09*	*8.223*	*0.0277*	*0.5644*	*7.870*	*18.4*	*98.0*	*15.81*	*0.10*
#	*10*	*8.382*	*0.0070*	*0.6938*	*9.463*	*72.5*	*97.6*	*16.04*	*0.10*
#	*02*	*10.94*	*3.415*	*3.654*	*0.937*	*0.15*	*92.7*	*19.93*	*0.67*
#	*01*	*9.904*	*3.591*	*-3.3780*	*0.725*	*0.14*	*113.1*	*21.99*	*0.90*
#	*12*	*19.58*	*3.573*	*27.37*	*1.095*	*0.14*	*60.2*	*23.14*	*0.74*
	Mean age ± 2σ		n=9	MSWD =1.7		37.3 ±35.6		13.93	0.08

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Errors quoted for individual analyses include analytical error only, without interferring reaction or J uncertainties.
Mean age is weighted mean age of Taylor (1982). Mean age error is weighted error of the mean (Taylor, 1982), multiplied by the root of the MSWD where MSWD>1, and also incorporates uncertainty in J factors and irradiation correction uncertainties.
Decay constants and isotopic abundances after Steiger and Jäeger (1977).
symbol preceding sample ID denotes analyses excluded from mean age calculations.
Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.02 Ma
Decay Constant (LambdaK (total)) = 5.543e-10/a
Discrimination = 1.0063 ± 0.001
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 5e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 1e-05
$(^{38}Ar/^{39}Ar)_K$ = 0.0133
$(^{40}Ar/^{39}Ar)_K$ = 0 ± 0.0004

Table 5. $^{40}Ar/^{39}Ar$ analytical data.

	ID	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	Age (Ma)	±1σ (Ma)
	92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168								
#	*03B*	*13.34*	*0.0683*	*7.289*	*8.140*	*7.5*	*83.9*	*21.60*	*0.08*
	09B	12.63	0.0457	4.411	5.164	11.2	89.7	21.88	0.13
	10B	15.60	0.0580	14.32	10.727	8.8	72.9	21.95	0.09
	07B	14.13	0.0726	9.371	19.121	7.0	80.4	21.95	0.07
	06B	12.15	0.0624	2.626	6.162	8.2	93.7	21.97	0.08
	08B	12.06	0.0566	2.305	9.644	9.0	94.4	21.97	0.07
	05B	13.96	0.0451	8.659	21.538	11.3	81.7	22.02	0.06
	01B	13.27	0.0488	6.231	11.888	10.5	86.2	22.06	0.07
	02B	19.35	0.0601	26.76	6.221	8.5	59.2	22.10	0.13
	04B	13.97	0.0559	8.379	10.921	9.1	82.3	22.19	0.09
	Mean age ± 2σ		n=9	MSWD=1.04		9.3 ±2.9		22.01	0.08

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.

Errors quoted for individual analyses include analytical error only, without interferring reaction or J uncertainties.

Mean age is weighted mean age of Taylor (1982). Mean age error is weighted error of the mean (Taylor, 1982), multiplied by the root of the MSWD where MSWD>1, and also incorporates uncertainty in J factors and irradiation correction uncertainties.

Decay constants and isotopic abundances after Steiger and Jäeger (1977).

symbol preceding sample ID denotes analyses excluded from mean age calculations.

Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.02 Ma

Decay Constant (LambdaK (total)) = 5.543e-10/a

Discrimination = 1.0063 ± 0.001

Correction factors:

$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 5e-05

$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 1e-05

$(^{38}Ar/^{39}Ar)_K$ = 0.0133

$(^{40}Ar/^{39}Ar)_K$ = 0 ± 0.0004

Table 6. $^{40}Ar/^{39}Ar$ analytical data.

ID	Power (Watts)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-01										
A	1	588.7	0.4556	1977.9	0.109	1.1	0.7	0.9	8.2	10.2
B	4	13.27	0.0488	6.231	11.9	10.5	86.2	100.0	22.060	0.065
Integrated age ± 2σ			n=2		12.0	5.8 ±13.2			21.93	0.26
Plateau ± 2σ	steps A-B		n=2	MSWD=1.85	12.0	5.8 ±13.2		100.0	22.06	0.19
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-02										
A	1	558.1	1.449	1927.1	0.094	0.35	-2.0	1.5	-21.9	12.6
B	4	19.35	0.0601	26.76	6.22	8.5	59.2	100.0	22.10	0.13
Integrated age ± 2σ			n=2		6.31	4.4 ±11.5			21.46	0.50
Plateau ± 2σ	steps A-B		n=2	MSWD=12.13	6.31	4.4 ±11.5		100.0	22.10	0.94
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-03										
A	1	354.3	0.5810	1153.4	0.109	0.88	3.8	1.3	26.1	7.5
B	4	13.34	0.0683	7.289	8.14	7.5	83.9	100.0	21.605	0.082
Integrated age ± 2σ			n=2		8.25	4.2 ±9.3			21.66	0.28
Plateau ± 2σ	steps A-B		n=2	MSWD=0.35	8.25	4.2 ±9.3		100.0	21.61	0.17
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-04										
A	2	486.2	0.7314	1587.3	0.438	0.70	3.6	3.9	33.3	5.2
B	4	13.97	0.0559	8.379	10.9	9.1	82.3	100.0	22.187	0.086
Integrated age ± 2σ			n=2		11.4	4.9 ±11.9			22.62	0.49
Plateau ± 2σ	steps A-B		n=2	MSWD=4.54	11.4	4.9 ±11.9		100.0	22.19	0.37
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-05										
A	2	1191.9	0.7169	3991.1	0.374	0.71	1.1	1.7	24.4	10.6
B	4	13.96	0.0451	8.659	21.5	11.3	81.7	100.0	22.018	0.064
Integrated age ± 2σ			n=2		21.9	6.0 ±15.0			22.06	0.45
Plateau ± 2σ	steps A-B		n=2	MSWD=0.05	21.9	6.0 ±15.0		100.0	22.02	0.14
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-06										
A	2	100.7	0.1076	302.0	1.02	4.7	11.4	14.3	22.2	1.1
B	4	12.15	0.0624	2.626	6.16	8.2	93.7	100.0	21.966	0.082
Integrated age ± 2σ			n=2		7.19	6.5 ±4.9			22.00	0.38
Plateau ± 2σ	steps A-B		n=2	MSWD=0.03	7.19	6.5 ±4.9		100.0	21.97	0.17

ID	Power (Watts)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-07										
A	2	202.8	0.4224	658.6	1.33	1.2	4.0	6.5	15.8	2.1
B	4	14.13	0.0726	9.371	19.1	7.0	80.4	100.0	21.946	0.070
Integrated age ± 2σ			n=2		20.5	4.1 ±8.2			21.55	0.36
Plateau ± 2σ	steps A-B		n=2	MSWD=8.46	20.5	4.1 ±8.2		100.0	21.94	0.41
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-08										
A	2	117.4	0.2364	360.7	0.890	2.2	9.2	8.4	20.9	1.2
B	4	12.06	0.0566	2.305	9.64	9.0	94.4	100.0	21.970	0.070
Integrated age ± 2σ			n=2		10.5	5.6 ±9.7			21.88	0.27
Plateau ± 2σ	steps A-B		n=2	MSWD=0.78	10.5	5.6 ±9.7		100.0	21.97	0.15
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-09										
A	2	220.9	0.2557	709.9	0.190	2.0	5.1	3.6	21.6	4.5
B	4	12.63	0.0457	4.411	5.16	11.2	89.7	100.0	21.88	0.13
Integrated age ± 2σ			n=2		5.35	6.6 ±13.0			21.87	0.42
Plateau ± 2σ	steps A-B		n=2	MSWD=0.00	5.35	6.6 ±13.0		100.0	21.88	0.26
92RB-063, Biotite, J=0.0010764±0.13%, D=1.0063±0.001, NM-182H, Lab#=55168-10										
A	2	135.7	0.0462	414.0	1.01	11.0	9.9	8.6	25.8	1.5
B	4	15.60	0.0580	14.32	10.7	8.8	72.9	100.0	21.945	0.092
Integrated age ± 2σ			n=2		11.7	9.9 ±3.2			22.27	0.36
Plateau ± 2σ	steps A-B		n=2	MSWD=6.89	11.7	9.9 ±3.2		100.0	21.96	0.48

Notes:
Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Errors quoted for individual analyses include analytical error only, without interferring reaction or J uncertainties.
Integrated age is volume-weighted mean of all steps.
Integrated age calculated by recombining isotopic measurements of all steps.
Integrated age error calculated by recombining errors of isotopic measurements of all steps.
Plateau age is inverse-variance-weighted mean of selected steps.
Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.
Decay constants and isotopic abundances after Steiger and Jäeger (1977).
symbol preceding sample ID denotes analyses excluded from plateau age calculations.
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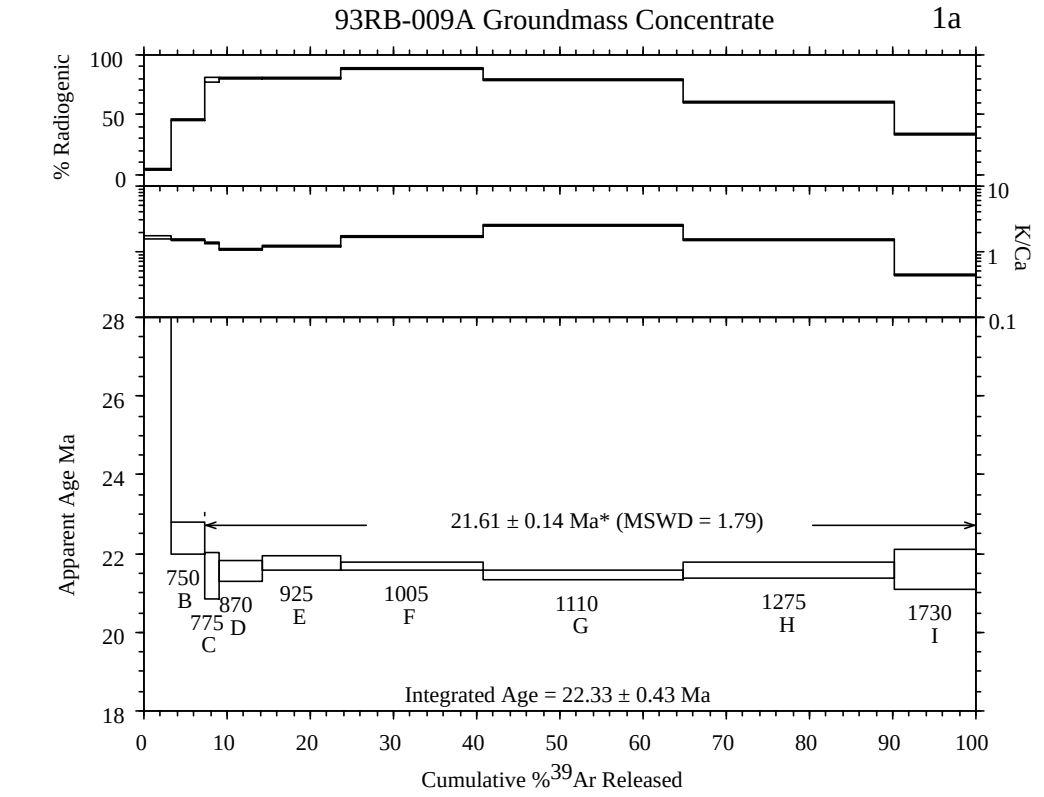
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 5e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 1e-05
$(^{38}Ar/^{39}Ar)_{K}$ = 0.0133
$(^{40}Ar/^{39}Ar)_{K}$ = 0 ± 0.0004



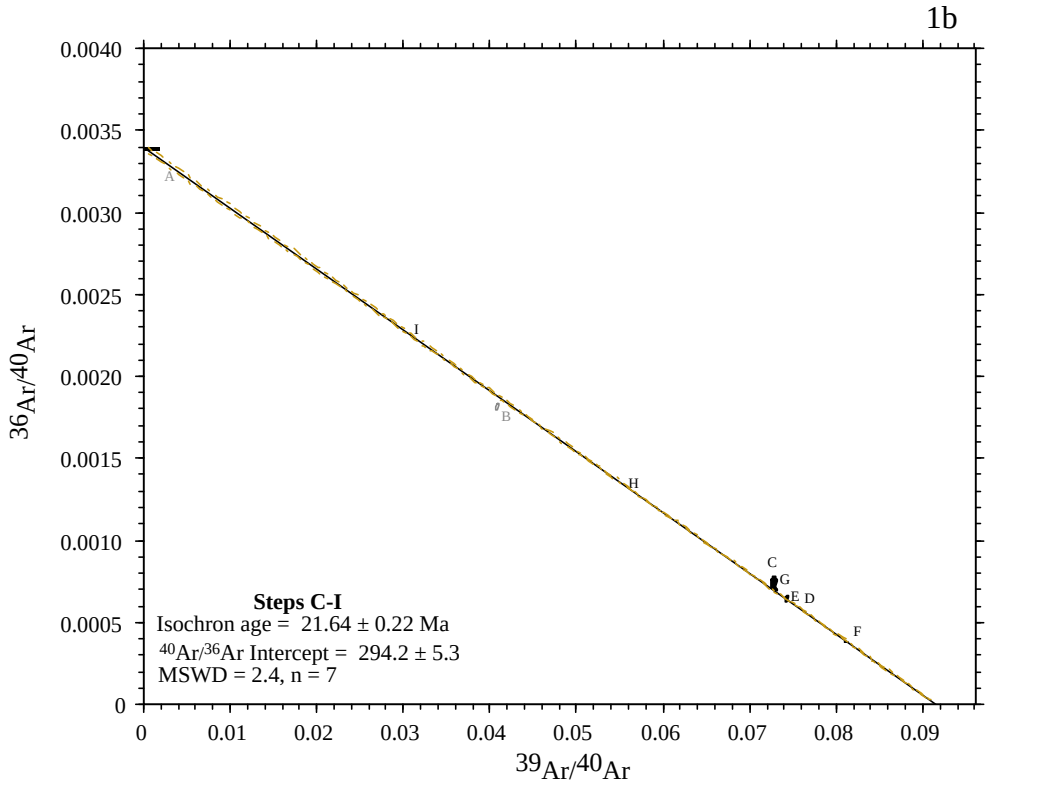


Figure 1. Age spectrum (1a) and isochron (1b) for 93RB-009A groundmass concentrate. Points shown in gray not included in isochron. All errors quoted at two sigma.

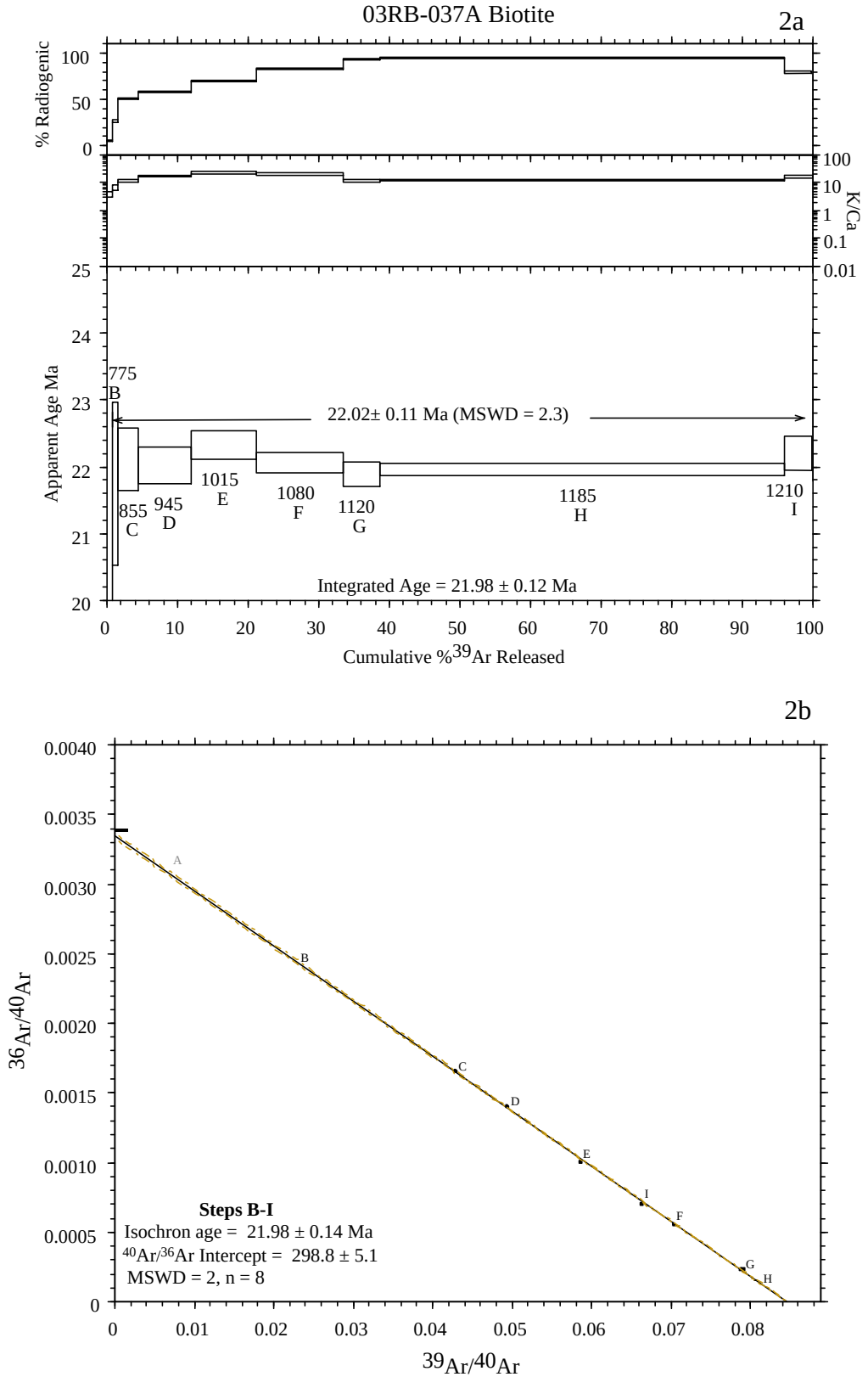


Figure 2. Age spectrum (2a) and isochron (2b) for 03RB-37A biotite. Points shown in gray not included in isochron. All errors quoted at two sigma.

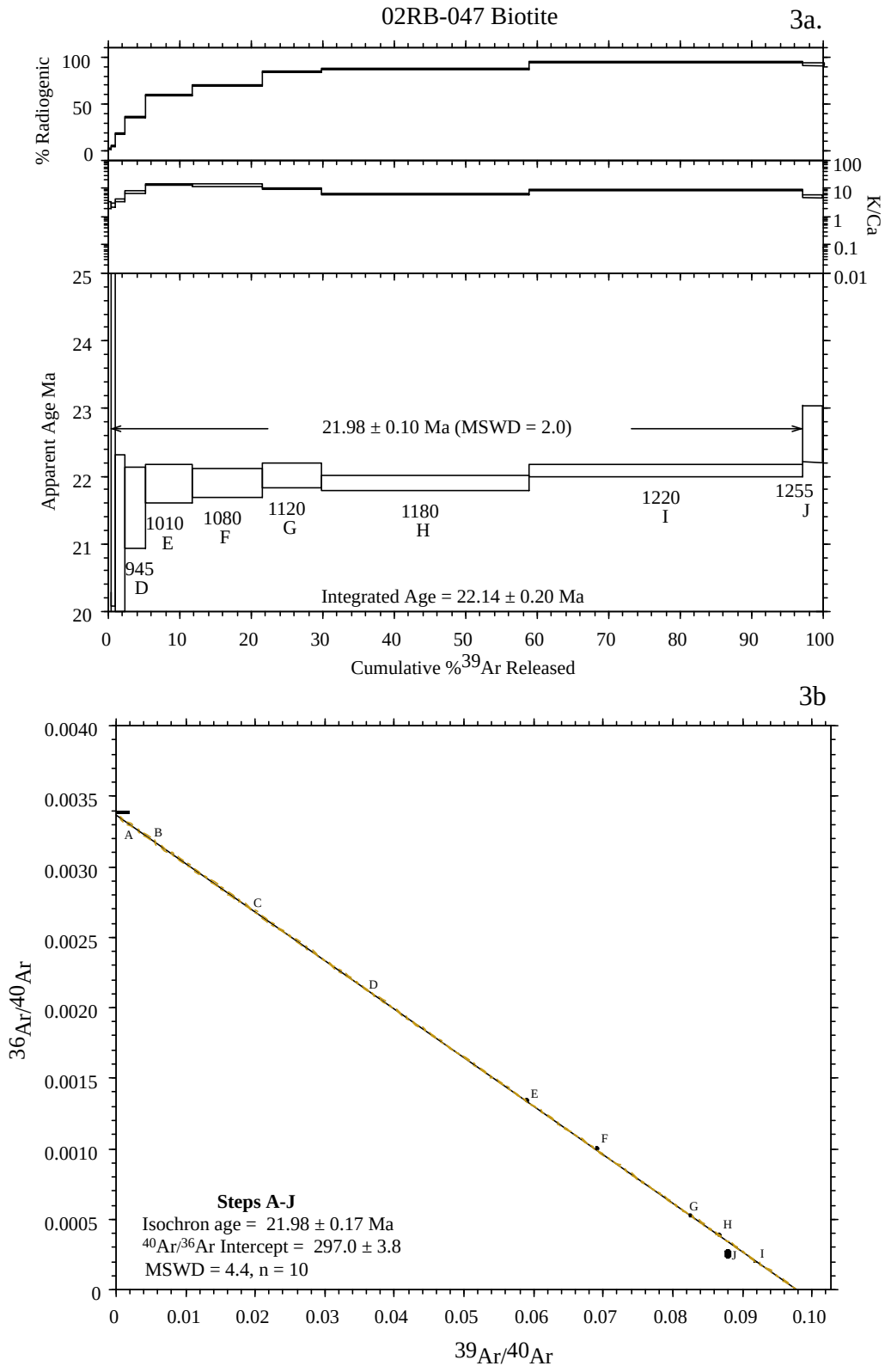


Figure 3. Age spectrum (3a) and isochron (3b) for 02RB-047 biotite. All errors quoted at two sigma.

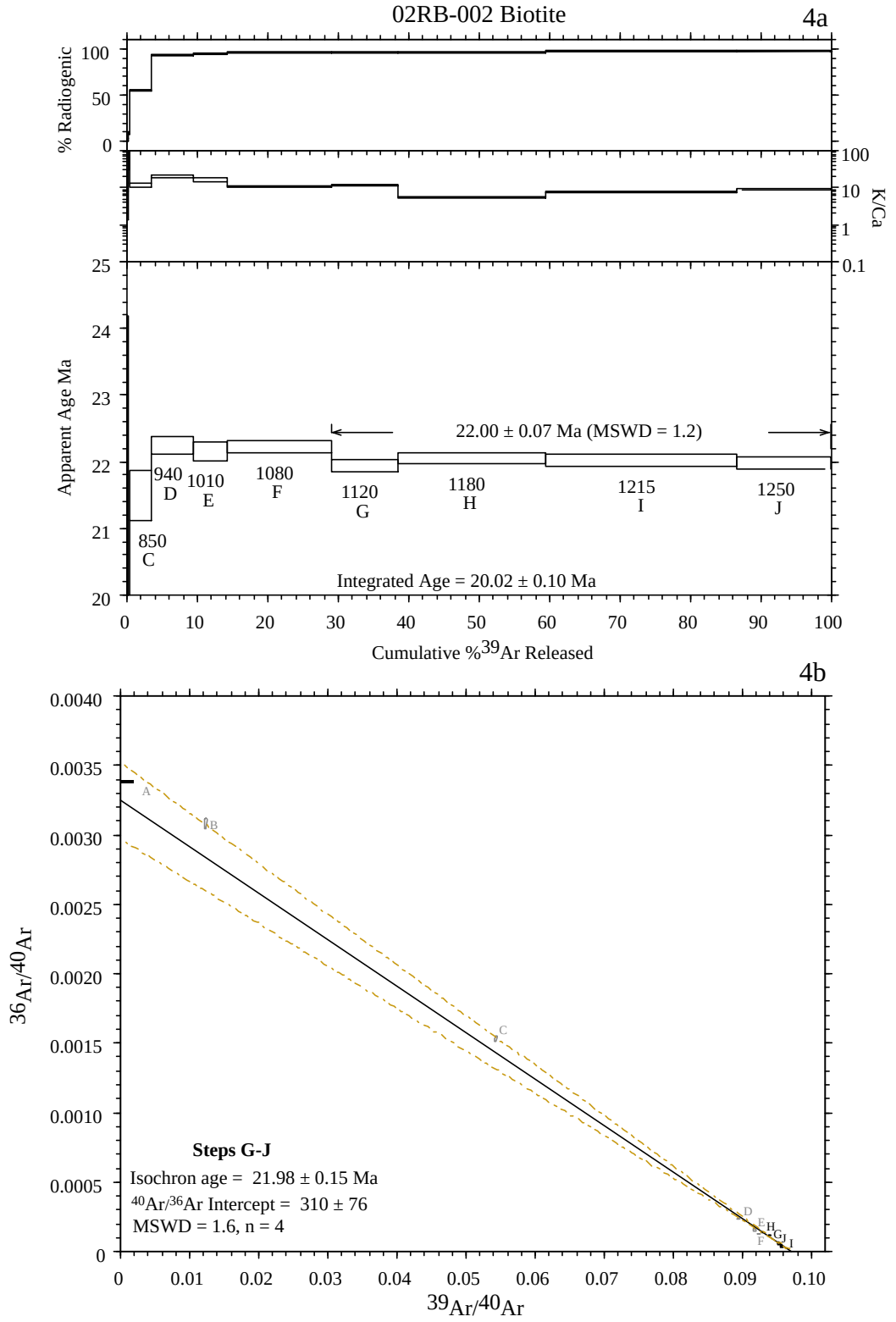


Figure 4. Age spectrum (4a) and isochron (4b) for 02RB-002 biotite.
Points shown in gray not included in isochron. All errors quoted at two sigma.

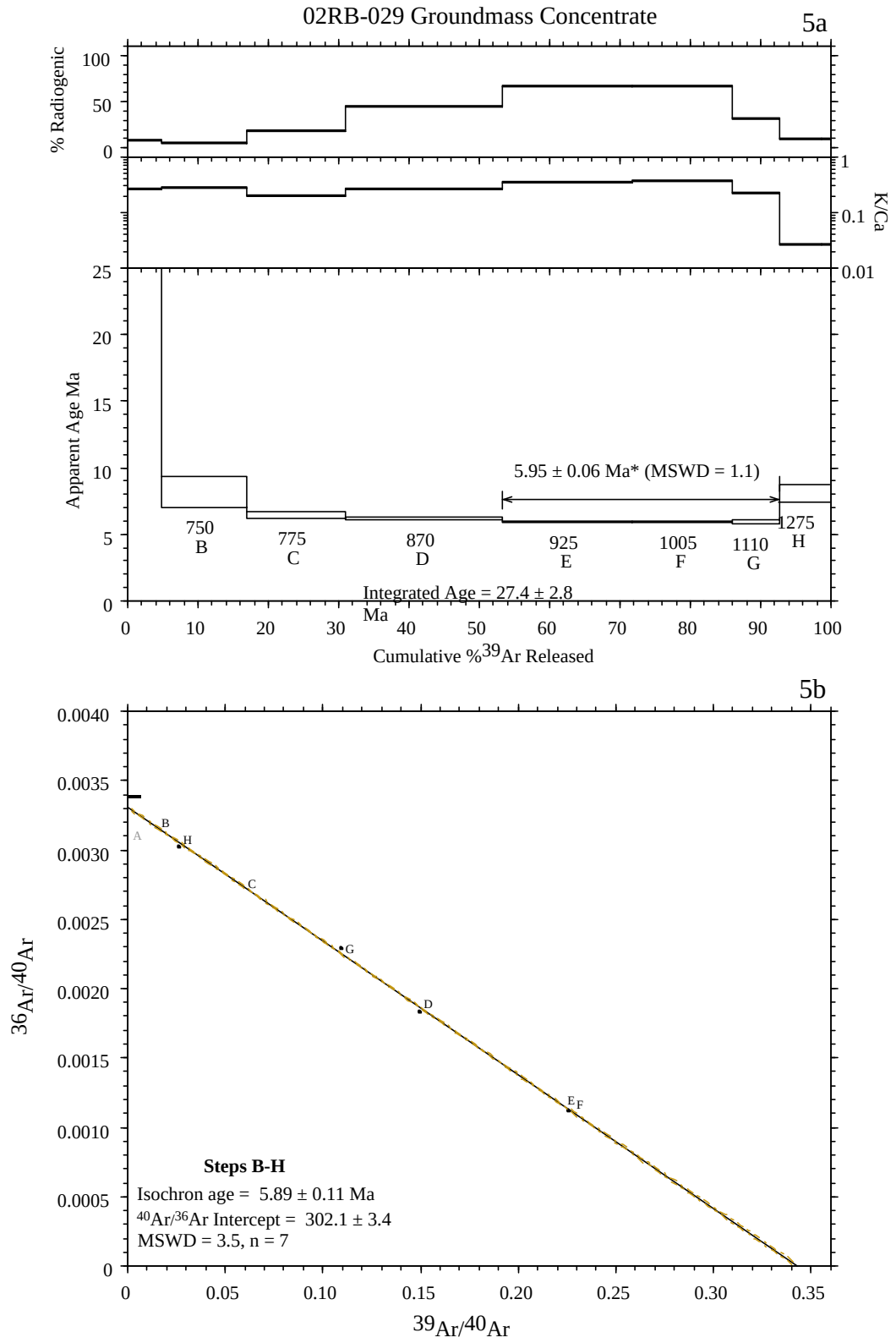


Figure 5. Age spectrum (5a) and isochron (5b) for 02RB-029 groundmass concentrate. Points shown in gray not included in isochron. All errors quoted at two sigma.

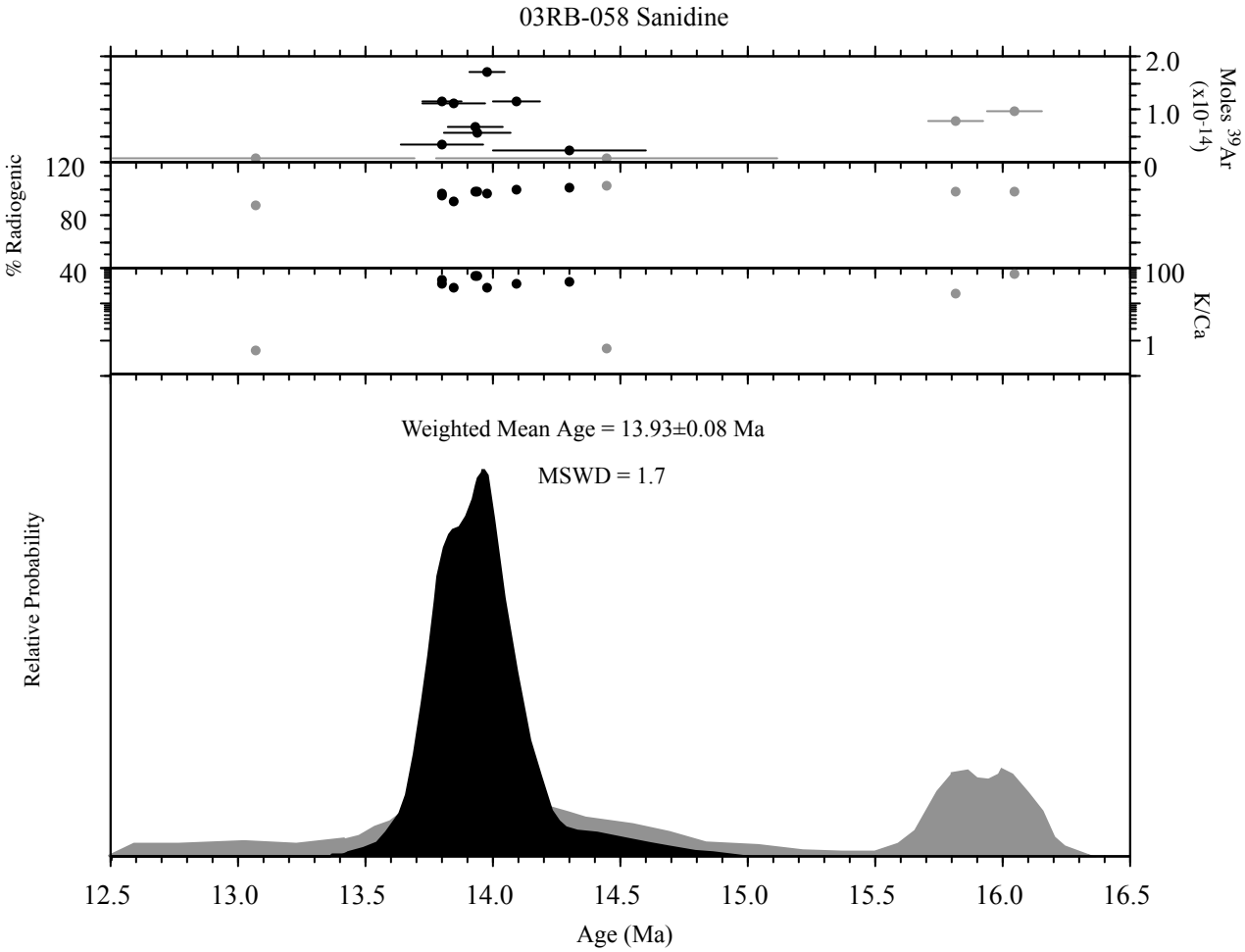


Figure 6. Age probability distribution diagram of 03RB-058 sanidine. Points in gray not included in weighted mean age. All errors quoted at 2 sigma.

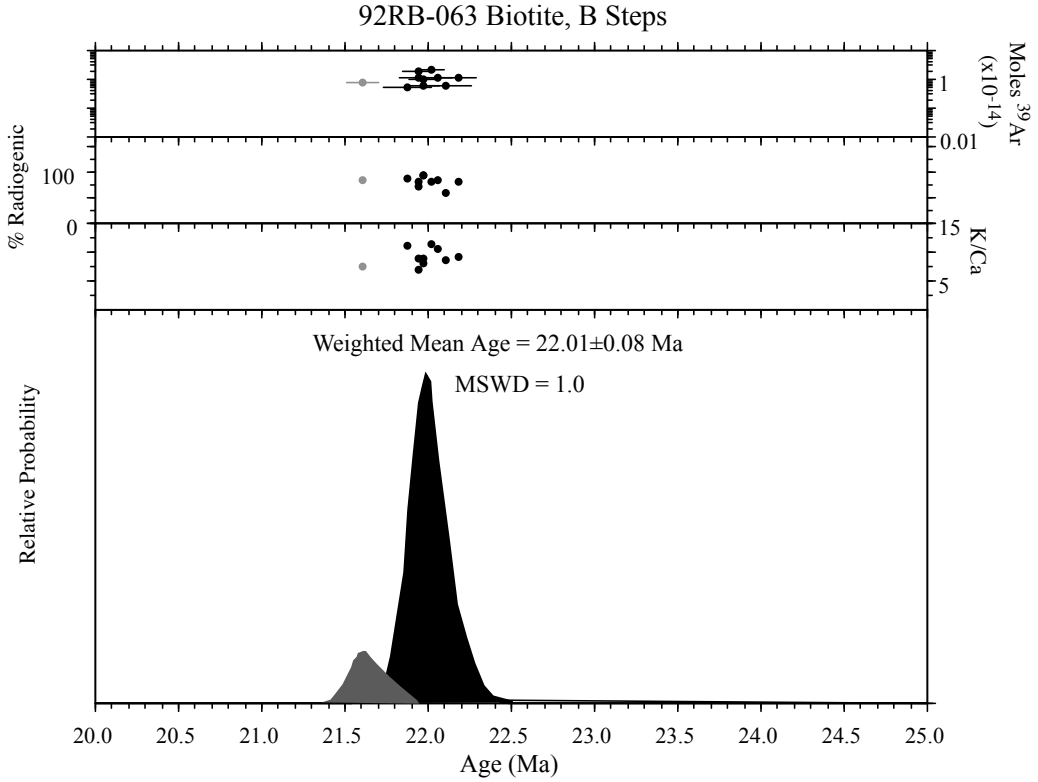


Figure 7. Age probability distribution diagram of 92RB-063 biotite. Points in gray not included in weighted mean age. All errors quoted at 2 sigma.

New Mexico Bureau of Mines and Mineral Resources

Procedures of the New Mexico Geochronology Research Laboratory

For the Period June 1998 – present

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$^{40}Ar/^{39}Ar$ and K-Ar dating

Often, large bulk samples (either minerals or whole rocks) are required for K-Ar dating and even small amounts of xenocrystic, authigenic, or other non-ideal behavior can lead to inaccuracy. The K-Ar technique is susceptible to sample inhomogeneity as separate aliquots are required for the potassium and argon determinations. The need to determine absolute quantities (i.e. moles of $^{40}Ar^*$ and ^{40}K) limits the precision of the K-Ar method to approximately 1% and also, the technique provides limited potential to evaluate underlying assumptions. In the $^{40}Ar/^{39}Ar$ variant of the K-Ar technique, a sample is irradiated with fast neutrons thereby converting ^{39}K to ^{39}Ar through a (n,p) reaction. Following irradiation, the sample is either fused or incrementally heated and the gas analyzed in the same manner as in the conventional K-Ar procedure, with one exception, no argon spike need be added.

Some of the advantages of the $^{40}Ar/^{39}Ar$ method over the conventional K-Ar technique are:

1. A single analysis is conducted on one aliquot of sample thereby reducing the sample size and eliminating sample inhomogeneity.
2. Analytical error incurred in determining absolute abundances is reduced by measuring only isotopic ratios. This also eliminates the need to know the exact weight of the sample.
3. The addition of an argon spike is not necessary.
4. The sample does not need to be completely fused, but rather can be incrementally heated. The $^{40}Ar/^{39}Ar$ ratio (age) can be measured for each fraction of argon released and this allows for the generation of an age spectrum.

The age of a sample as determined with the $^{40}Ar/^{39}Ar$ method requires comparison of the measured $^{40}Ar/^{39}Ar$ ratio with that of a standard of known age. Also, several isotopes of other elements (Ca, K, Cl, Ar) produce argon during the irradiation procedure and must be corrected for. Far more in-depth details of the determination of an apparent age via the $^{40}Ar/^{39}Ar$ method are given in Dalrymple et al. (1981) and McDougall and Harrison (1988).

Analytical techniques

Sample Preparation and irradiation details

Mineral separates are obtained in various fashions depending upon the mineral of interest, rock type and grain size. In almost all cases the sample is crushed in a jaw crusher and ground in a disc grinder and then sized. The size fraction used generally corresponds to the largest size possible which will permit obtaining a pure mineral separate. Following sizing, the sample is washed and dried. For plutonic and metamorphic rocks and lavas, crystals are separated using standard heavy liquid, Franz magnetic and hand-picking techniques. For volcanic sanidine and plagioclase, the sized sample is reacted with 15% HF acid to remove glass and/or matrix and then thoroughly washed prior to heavy liquid and magnetic separation. For groundmass concentrates, rock fragments are selected which do not contain any visible phenocrysts.

The NMGRL uses either the Ford reactor at the University of Michigan or the Nuclear Science Center reactor at Texas A&M University. At the Ford reactor, the L67 position is used (unless otherwise noted) and the D-3 position is always used at the Texas A&M reactor. All of the Michigan irradiations are carried out underwater without any shielding for thermal neutrons, whereas the Texas irradiations are in a dry location which is shielded with B and Cd. Depending upon the reactor used, the mineral separates are loaded into either holes drilled into Al discs or into 6 mm I.D. quartz tubes. Various Al discs are used. For Michigan, either six hole or twelve hole, 1 cm diameter discs are used and all holes are of equal size. Samples are placed in the 0, 120 and 240° locations and standards in the 60, 180 and 300° locations for the six hole disc. For the twelve hole disc, samples are located at 30, 60, 120, 150, 210, 240, 300, and 330° and standards at 0, 90, 180 and 270 degrees. If samples are loaded into the quartz tubes, they are wrapped in Cu foil with standards interleaved at ~0.5 cm intervals. For Texas, 2.4 cm diameter discs contain either sixteen or six sample holes with smaller holes used to hold the standards. For the six hole disc, sample locations are 30, 90, 150, 210, 270 and 330° and standards are at 0, 60, 120, 180, 240 and 300°. Samples are located at 18, 36, 54, 72, 108, 126, 144, 162, 198, 216, 234, 252, 288, 306, 324, 342 degrees and standards at 0, 90, 180 and 270 degrees in the sixteen hole disc. Following sample loading into the discs, the discs are stacked, screwed together and sealed

in vacuo in either quartz (Michigan) or Pyrex (Texas) tubes.

Extraction Line and Mass Spectrometer details

The NMGRL argon extraction line has both a double vacuum Mo resistance furnace and a CO_2 laser to heat samples. The Mo furnace crucible is heated with a W heating element and the temperature is monitored with a W-Re thermocouple placed in a hole drilled into the bottom of the crucible. A one inch long Mo liner is placed in the bottom of the crucible to collect the melted samples. The furnace temperature is calibrated by either/or melting Cu foil or with an additional thermocouple inserted in the top of the furnace down to the liner. The CO_2 laser is a Synrad 10W laser equipped with a He-Ne pointing laser. The laser chamber is constructed from a 3 3/8" stainless steel conflat and the window material is ZnS. The extraction line is a two stage design. The first stage is equipped with a SAES GP-50 getter, whereas the second stage houses two SAES GP-50 getters and a tungsten filament. The first stage getter is operated at 450°C as is one of the second stage getters. The other second stage getter is operated at room temperature and the tungsten filament is operated at ~2000°C. Gases evolved from samples heated in the furnace are reacted with the first stage getter during heating. Following heating, the gas is expanded into the second stage for two minutes and then isolated from the first stage. During second stage cleaning, the first stage and furnace are pumped out. After gettering in the second stage, the gas is expanded into the mass spectrometer. Gases evolved from samples heated in the laser are expanded through a cold finger operated at -140°C and directly into the second stage. Following cleanup, the gas in the second stage and laser chamber is expanded into the mass spectrometer for analysis.

The NMGRL employs a MAP-215-50 mass spectrometer which is operated in static mode. The mass spectrometer is operated with a resolution ranging between 450 to 600 at mass 40 and isotopes are detected on a Johnston electron multiplier operated at ~2.1 kV with an overall gain of about 10,000 over the Faraday collector. Final isotopic intensities are determined by linear regression to time zero of the peak height versus time following gas introduction for each mass. Each mass intensity is corrected for mass spectrometer baseline and background and the extraction system blank.

Blanks for the furnace are generally determined at the beginning of a run while the furnace is cold and then between heating steps while the furnace is cooling. Typically, a blank is

run every three to six heating steps. Periodic furnace hot blank analysis reveals that the cold blank is equivalent to the hot blank for temperatures less than about 1300°C. Laser system blanks are generally determined between every four analyses. Mass discrimination is measured using atmospheric argon which has been dried using a Ti-sublimation pump. Typically, 10 to 15 replicate air analyses are measured to determine a mean mass discrimination value. Air pipette analyses are generally conducted 2-3 times per month, but more often when samples sensitive to the mass discrimination value are analyzed. Correction factors for interfering nuclear reactions on K and Ca are determined using K-glass and CaF_2, respectively. Typically, 3-5 individual pieces of the salt or glass are fused with the CO_2 laser and the correction factors are calculated from the weighted mean of the individual determinations.

Data acquisition, presentation and age calculation

Samples are either step-heated or fused in a single increment (total fusion). Bulk samples are often step-heated and the data are generally displayed on an age spectrum or isochron diagram. Single crystals are often analyzed by the total fusion method and the results are typically displayed on probability distribution diagrams or isochron diagrams.

The Age Spectrum Diagram

Age spectra plot apparent age of each incrementally heated gas fraction versus the cumulative % $^{39}Ar_K$ released, with steps increasing in temperature from left to right. Each apparent age is calculated assuming that the trapped argon (argon not produced by *in situ* decay of ^{40}K) has the modern day atmospheric $^{40}Ar/^{36}Ar$ value of 295.5. Additional parameters for each heating step are often plotted versus the cumulative $\%^{39}Ar_K$ released. These auxiliary parameters can aid age spectra interpretation and may include radiogenic yield (percent of ^{40}Ar which is not atmospheric), K/Ca (determined from measured Ca-derived ^{37}Ar and K-derived ^{39}Ar) and/or K/Cl (determined from measured Cl-derived ^{38}Ar and K-derived ^{39}Ar). Incremental heating analysis is often effective at revealing complex argon systematics related to excess argon, alteration, contamination, ^{39}Ar recoil, argon loss, etc. Often low-temperature heating steps have low radiogenic yields and apparent ages with relatively high errors due mainly to

loosely held, non-radiogenic argon residing on grain surfaces or along grain boundaries. An entirely or partially flat spectrum, in which apparent ages are the same within analytical error, may indicate that the sample is homogeneous with respect to K and Ar and has had a simple thermal and geological history. A drawback to the age spectrum technique is encountered when hydrous minerals such as micas and amphiboles are analyzed. These minerals are not stable in the ultra-high vacuum extraction system and thus step-heating can homogenize important details of the true ^{40}Ar distribution. In other words, a flat age spectrum may result even if a hydrous sample has a complex argon distribution.

The Isochron Diagram

Argon data can be plotted on isotope correlation diagrams to help assess the isotopic composition of Ar trapped at the time of argon closure, thereby testing the assumption that trapped argon isotopes have the composition of modern atmosphere which is implicit in age spectra. To construct an "inverse isochron" the $^{36}Ar/^{40}Ar$ ratio is plotted versus the $^{39}Ar/^{40}Ar$ ratio. A best fit line can be calculated for the data array which yields the value for the trapped argon (Y-axis intercept) and the $^{40}Ar^*/^{39}Ar_K$ value (age) from the X-axis intercept. Isochron analysis is most useful for step-heated or total fusion data which have a significant spread in radiogenic yield. For young or low K samples, the calculated apparent age can be very sensitive to the composition of the trapped argon and therefore isochron analysis should be preformed routinely on these samples (cf. Heizler and Harrison, 1988). For very old (>Mesozoic) samples or relatively old sanidines (>mid-Cenozoic) the data are often highly radiogenic and cluster near the X-axis thereby making isochron analysis of little value.

The Probability Distribution Diagram

The probability distribution diagram, which is sometimes referred to as an ideogram, is a plot of apparent age versus the summation of the normal distribution of each individual analysis (Deino and Potts, 1992). This diagram is most effective at displaying single crystal laser fusion data to assess the distribution of the population. The K/Ca, radiogenic yield, and the moles of ^{39}Ar for each analysis are also often displayed for each sample as this allows for visual ease in identifying apparent age correlations between, for instance, plagioclase contamination, signal size and/or radiogenic concentrations. The error (1σ) for each age analysis is generally shown by the horizontal lines in the moles of ^{39}Ar section. Solid symbols represent the analyses used for the weighted mean age calculation and the generation of the solid line on the ideogram, whereas open symbols represent data omitted from the age calculation. If shown, a dashed line represents the probability distribution of all of the displayed data. The diagram is most effective for displaying the form of the age distribution (i.e. gaussian, skewed, etc.) and for identifying xenocrystic or other grains which fall outside of the main population.

Error Calculations

For step-heated samples, a plateau for the age spectrum is defined by the steps indicated. The plateau age is calculated by weighting each step on the plateau by the inverse of the variance and the error is calculated by either the method of Samson and Alexander (1987) or Taylor (1982). A mean sum weighted deviates (MSWD) value is determined by dividing the Chi-squared value by n-1 degrees of freedom for the plateau ages. If the MSWD value is outside the 95% confidence window (cf. Mahon, 1996; Table 1), the plateau or preferred age error is multiplied by the square root of the MSWD.

For single crystal fusion data, a weighted mean is calculated using the inverse of the variance to weight each age determination (Taylor, 1982). Errors are calculated as described for the plateau ages above.

Isochron ages, $^{40}Ar/^{36}Ar_i$ values and MSWD values are calculated from the regression results obtained by the York (1969) method.

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