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^{40}Ar/^{39}Ar Geochronology results From the Upper Tesuque Formation in Northern Espanola Basin

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Introduction

Twelve samples from the lower coarse white tephra series of the upper Tesuque Formation and one stratigraphically higher tuffaceous sample possibly from the lower Chamita tuffaceous zone were submitted for dating by Dan Koning of the NMBMMR. It was noted during the mineral separation process that all samples were altered. Sanidine was not present in any of the samples so biotite was separated from four of the least altered lower coarse white tephras (SCV-948-251102-djk, SCV-318-230702-djk, SCV-1014-051202-djk, and FW1-CWA-Encinos-djk) and from the possible lower Chamita tuffaceous zone sample (SCV-1154-160103-djk). This report presents results from these samples. This information is briefly summarized in Table 1.

Table 1. Brief summary of results.

Sample	Phase	Unit	Age±2σ(Ma)
SCV-1154-160103-djk	biotite	lower Chamita tuffaceous Zone	9.40±0.46
SCV-948-251102-djk	biotite	lower coarse white ash	11.98±0.67
SCV-318-230702-djk	biotite	lower coarse white ash	12.63±0.74
SCV-1014-051202	biotite	lower ccoarse white ash	12.7±2.1
FW1-CWA-Encinos-djk	biotite	lower coarse white ash	15.6±2.4

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

The submitted samples were crushed and cleaned with distilled water. The biotite was separated with standard magnetic separator and handpicking techniques. The mineral separates were then loaded into aluminum discs and irradiated for 7 hours at the Nuclear Science Center in College Station, Texas.

The biotite separates were heated as single crystals in two steps with a CO_2 laser. The lower power A steps were used to drive off the atmospheric Ar and thereby increase the precision of the B steps. The age data are displayed on probability distribution diagrams (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 argon isotopic results are summarized in Tables 1 and 2 and listed in Tables 3 and 4. It is noted that the undefined K/Ca ratios for these biotites are due to the length of time between irradiation and analysis. 37Ar, which is used as a proxy for calcium, has a half-life of 35.1 days. These samples were analyzed ~5 months after irradiation and the 37Ar has decayed to undectectable levels.

These biotite samples from the lower coarse white tephra series yield results very similar to the results from the first suit of tephras submitted by Dan Koning and included in report IR#365. As with the others, the A step ^{40}Ar signal sizes are up to 2 orders of magnitude larger than the B steps and are very non-radiogenic (<5%, Table 2). The B steps are more radiogenic but not as radiogenic as typical biotite samples of this age (<26.6%, SCV-1154-160103-djk; <32.3%, SCV-948-251102-djk; <28.9%, SCV-318-230702-djk; <25.6%, SCV-1014-051202-djk; <6.3%, FW1-CWA-Encinos-djk). Unaltered biotite from mid-Tertiary tuffs commonly have radiogenic yields >90%. These low radiogenic yields have resulted in age uncertainties one to two orders of magnitude larger than uncertainties of typical unaltered biotite. Weighted-mean ages have been calculated by eliminating suspected xenocrystic contaminants and analytical outliers that have ^{40}Ar signal sizes one to two orders of magnitude smaller than the majority of the other analyses (9.40±0.46 Ma, SCV-1154-160103-djk; 11.98±0.67 Ma, SCV-948-251102; 12.63±0.74 Ma, CSV-318-230702-djk; 12.7±2.1 Ma, SCV-1014-051202-djk; 15.6±2.4 Ma, FW1-CWA-Encinos-djk). These populations are shown plotted on Figures 1-5 and a summary figure with these five and a previously dated sample of the lower coarse white tephra series are shown on Figure 6.

Discussion

The weighted mean ages calculated from the B steps are assigned as eruption ages of the lower coarse white ashes (11.98±0.67 Ma, SCV-948-251102; 12.63±0.74 Ma, SCV-318-230702-djk; 12.7±2.1 Ma, SCV-1014-051202-djk; 15.6±2.4 Ma, FW1-CWA-Encinos-djk). We note that all agree within error to the more precise age assigned to SCV-946FV-251102-djk (13.03±0.40 Ma, also from the Lower Coarse White Ashes) that was dated as part of a group of samples submitted previously by Dan Koning. We also note that the age assigned to SCV-1154-160103-djk (9.40±0.46 Ma), which is stratigraphically higher than the lower coarse white ash tephras, yields a younger age than any of the lower coarse white ashes. This adds to our confidence in the low precision ages we have assigned to these samples. We do caution that with radiogenic yields as low as those from these samples and atmospheric ^{40}Ar signal sizes as large as those seen in the A steps, the possibility of alteration and accompanying Ar loss is very high. This would have the effect of lowering the apparent ages of the biotites. The agreement of the assigned lower coarse white ash ages to each other and the relatively young apparent age assigned to the stratigraphically higher SCV-1154-160103-djk add to our confidence in these ages.

References Cited

Deino, A., and Potts, R., 1990. Single-Crystal $^{40}Ar/^{39}Ar$ dating of the Olorgesailie Formation, Southern Kenya Rift, J. Geophys. Res., 95, 8453-8470.

Deino, A., and Potts, R., 1992. Age-probability spectra from examination of single-crystal $^{40}Ar/^{39}Ar$ dating results: Examples from Olorgesailie, Southern Kenya Rift, Quat. International, 13/14, 47-53.

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

Sample	Lab #	Irradiation	mineral	age analysis	# of crystals	Age	±2σ	comments
SCV-1154-160103	54445	NM-172	biotite	single crystal step-heat	14	9.40	0.46	
SCV-948-251102-djk	54435	NM-172	biotite	single crystal step-heat	10	11.98	0.67	
SCV-318-230702-djk	54436	NM-172	biotite	single crystal step-heat	14	12.63	0.74	
SCV-1014-051202-djk	54437	NM-172	biotite	single crystal step-heat	12	12.7	2.1	
FW1-CWA-Encinos-djk	54438	NM-172	biotite	single crystal step-heat	7	15.6	2.4	

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 7 hours in D-3 position, Nuclear Science Center, College Station, TX.
Neutron flux monitor Fish Canyon Tuff sanidine (FC-1). Assigned age = 27.84 Ma (Deino and Potts, 1990) relative to Mmhb-1 at 520.4 Ma (Samson and Alexander, 1987).

Instrumentation:
Mass Analyzer Products 215-50 mass spectrometer on line with automated all-metal extraction system.
Single crystal biotite were step-heated by a 50 watt Synrad CO_2 laser.
Reactive gases removed during a 6 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 1.55 x 10^{-16} moles/pA.
Total system blank and background averaged 4750, 24.1, 7.6, 3.9, 1.8 x 10^{-18} moles at masses 40, 39, 38, 37 and 36, respectively for the biotite analyses.
J-factors determined to a precision of ± 0.1% by CO_2 laser-fusion of 4 single crystals from each of 4 radial positions around the irradiation tray.
Correction factors for interfering nuclear reactions were determined using K-glass and CaF_2 and are as follows:
$(^{40}Ar/^{39}Ar)_K$ = 0.00020±0.0003; $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028±0.000005; and $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007±0.00002.

Table 3. $^{40}Ar/^{39}Ar$ 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)
	SCV-1154-160103-djk, G12:172, single crystal biotite J=0.0007514, D=1.005, NM-172, Lab#=54445								
	08B	138.0	0.1330	448.0	2.200	3.8	4.1	7.66	0.89
	06B	60.23	0.1886	183.7	0.817	2.7	9.9	8.09	0.55
	07B	123.0	0.0739	396.0	1.557	6.9	4.9	8.11	0.81
	04B	98.73	0.6000	313.0	2.525	0.85	6.4	8.49	0.64
	11B	53.43	0.2938	159.2	3.022	1.7	12.0	8.66	0.40
	13B	39.09	0.1371	110.2	2.273	3.7	16.7	8.83	0.29
	02B	86.50	0.1156	270.6	2.070	4.4	7.6	8.87	0.57
	01B	92.88	0.2874	291.3	1.395	1.8	7.3	9.23	0.72
	10B	42.29	0.1649	120.0	1.162	3.1	16.1	9.23	0.44
	12B	32.82	0.1508	87.35	2.096	3.4	21.4	9.50	0.24
	03B	115.2	0.2693	365.4	1.529	1.9	6.3	9.79	0.75
	14B	28.89	0.0201	71.79	0.464	25.4	26.6	10.39	0.52
	15B	31.81	0.0311	81.66	1.027	16.4	24.2	10.39	0.33
	05B	57.36	0.2471	166.5	1.838	2.1	14.3	11.06	0.41
†	*09B*	*128.3*	*0.0782*	*181.5*	*0.397*	*6.5*	*58.2*	*98.52*	*0.90*
	Mean age ± 2σ		n=14	MSWD=4.02		5.6 ±13.8		9.40	0.46
	SCV-948-251102-djk, G1:172, singlecrystal biotite J=0.0007536, D=1.005, NM-172, Lab#=54435								
†	*12B*	*483.2*	*11.59*	*1716.6*	*0.009*	*0.044*	*-4.8*	*-31.9*	*22.3*
†	*09B*	*394.1*	*-210.1472*	*1322.2*	*0.017*	*-*	*-3.5*	*-16.6*	*10.9*
†	*04B*	*651.5*	*-147.9266*	*2172.8*	*0.023*	*-*	*-0.4*	*-3.5*	*10.5*
	03B	1178.1	-14.6551	3979.0	0.204	-	0.1	1.5	7.6
	15B	658.0	-344.2798	2109.0	0.011	-	1.0	6.9	14.0
	05B	46.22	0.8854	129.4	0.703	0.58	17.4	10.93	0.54
	07B	206.1	-5.4862	667.9	0.550	-	4.0	11.2	1.5
	01B	58.65	-0.7929	168.5	3.233	-	15.0	11.92	0.35
	11B	64.58	-1.5794	188.2	1.578	-	13.7	11.95	0.45
	14B	29.82	0.7563	68.50	0.183	0.67	32.3	13.07	0.86
	02B	289.1	-55.9174	923.2	0.055	-	4.1	15.3	4.9
	13B	80.69	-163.0441	184.3	0.021	-	15.8	15.5	6.5
	08B	101.5	1.606	305.2	0.370	0.32	11.3	15.5	1.1
†	*06B*	*257.7*	*4.302*	*822.3*	*0.037*	*0.12*	*5.9*	*20.4*	*5.7*
†	*10B*	*127.6*	*3.362*	*372.4*	*0.026*	*0.15*	*14.0*	*24.2*	*6.3*
	Mean age ± 2σ		n=10	MSWD=2.15		0.52 ±0.20		11.98	0.67

	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)
	SCV-318-230702-djk, G2:172, single crystal biotite, J=0.0007532, D=1.005, NM-172, Lab#=54436								
	04B	28.62	-4.9755	67.47	0.605	-	28.9	11.16	0.36
	17B	74.25	-17.9887	217.3	0.195	-	11.5	11.5	1.2
	06B	84.95	-2.1201	257.9	1.260	-	10.1	11.57	0.59
	10B	146.1	-2.3238	462.7	1.205	-	6.3	12.46	0.96
	05B	143.3	-0.6337	453.7	1.917	-	6.4	12.50	0.89
	13B	102.5	-1.9158	315.1	1.409	-	9.0	12.54	0.69
	07B	121.7	-0.8026	379.7	3.091	-	7.8	12.77	0.72
	18B	67.57	-9.7917	193.0	0.339	-	14.4	13.09	0.93
	03B	135.7	-4.6780	423.4	0.618	-	7.5	13.83	0.95
	08B	76.38	-5.7816	221.9	0.500	-	13.5	13.94	0.72
	02B	141.7	-1.2271	443.9	1.679	-	7.3	14.07	0.84
	01B	80.58	1.617	238.0	0.300	0.32	12.9	14.08	0.93
	09B	127.6	-0.0411	396.0	5.098	-	8.3	14.27	0.71
	12B	141.3	-0.4438	439.5	5.032	-	8.1	15.46	0.80
†	*16B*	*82.98*	*1.706*	*235.6*	*0.164*	*0.30*	*16.3*	*18.3*	*1.5*
†	*15B*	*359.4*	*-14.3189*	*1165.2*	*0.203*	*-*	*3.9*	*18.6*	*2.8*
†	*11B*	*395.7*	*4.374*	*1259.3*	*0.075*	*0.12*	*6.0*	*32.3*	*5.9*
†	*14B*	*212.8*	*-18.4930*	*584.8*	*0.165*	*-*	*18.1*	*50.9*	*2.7*
	Mean age ± 2σ		n=14	MSWD=3.85		0.32 ±0.00		12.63	0.74
	SCV-1014-051202-djk, G#:172, single crystal biotite, J=0.0007527, D=1.005, NM-172, Lab#=54437								
†	*13B*	*2904.3*	*-2.7004*	*9847.8*	*0.008*	*-*	*-0.2*	*-8.1*	*44.0*
	14B	92.61	0.7402	290.3	0.078	0.69	7.5	9.4	2.7
	12B	99.06	0.1737	310.9	0.075	2.9	7.3	9.7	2.4
	06B	198.5	3.499	647.6	0.030	0.15	3.7	10.0	5.2
	08B	49.34	1.005	140.9	0.154	0.51	15.8	10.54	0.95
	15B	71.29	0.3083	209.3	0.111	1.7	13.3	12.8	1.7
	03B	272.6	4.553	889.6	0.028	0.11	3.7	13.7	7.4
	07B	119.7	1.932	367.4	0.039	0.26	9.4	15.2	4.0
	10B	65.63	0.9355	183.8	0.078	0.55	17.3	15.4	2.9
	09B	117.5	2.290	354.2	0.068	0.22	11.1	17.6	2.6
	01B	178.1	2.490	559.4	0.061	0.20	7.3	17.6	3.9
	02B	114.4	2.245	339.2	0.036	0.23	12.5	19.4	4.0
	04B	62.91	2.170	159.0	0.056	0.24	25.6	21.8	2.6
†	*11B*	*214.4*	*0.6020*	*647.4*	*0.015*	*0.85*	*10.8*	*31.2*	*8.5*
†	*05B*	*258.0*	*7.009*	*787.6*	*0.009*	*0.073*	*10.0*	*35.0*	*17.0*
	Mean age ± 2σ		n=12	MSWD=2.74		0.65 ±1.67		12.7	2.1
	FW1-CWA-Encinos-djk, G4:172, single crystal biotite, J=0.000752, D=1.005, NM-172, Lab#=54438								
†	*08B*	*272.8*	*-5.0435*	*947.0*	*0.008*	*-*	*-2.7*	*-10.0*	*21.9*
	06B	216.3	0.1191	702.9	1.777	4.3	4.0	11.7	1.4
	04B	223.9	0.0623	724.8	0.234	8.2	4.4	13.2	2.2
	03B	580.2	0.2994	1923.4	0.174	1.7	2.0	16.1	4.5
	01B	195.8	0.1769	620.9	1.694	2.9	6.3	16.7	1.2
	05B	244.5	0.0912	783.5	0.379	5.6	5.3	17.6	1.8
	02B	896.6	0.2921	2983.6	0.529	1.7	1.7	20.3	5.3
	07B	362.3	0.1915	1175.4	1.646	2.7	4.1	20.3	2.1
	09B	*-138.6154*	*-47.6641*	*-734.1714*	*0.001*	*-*	*-53.7*	*95.2*	*263.1*
†	**Mean age ± 2σ**		n=7	MSWD=2.89		3.9 ±4.7		15.6	2.4

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)

Notes:

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

Ages calculated ralative to FC-1 Fish Canyon Tuff sanidine interlaboratory standard at 27.84 Ma.

Errors quoted for individual analyses include analytical error only, without interfering 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 square 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 Jäger (1977).

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

Discrimination = 1.005 ± 0.001

Correction factors:

$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 2e-05

$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 5e-06

$(^{38}Ar/^{39}Ar)_K$ = 0.01077

$(^{40}Ar/^{39}Ar)_K$ = 0.0002 ± 0.0003

Table 4. $^{40}Ar/^{39}Ar$ 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)
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-01										
A	1	4402.0	0.8313	14875.1	1.22	0.61	0.1	17.8	8.8	27.0
B	10	92.88	0.2874	291.3	5.63	1.8	7.3	100.0	9.23	0.72
Integrated age ± 2σ			n=2		6.84				9.1	10.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.00	6.84	1.6		100.0	9.2	1.4
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-02										
A	1	836.5	0.1025	2816.1	2.76	5.0	0.5	24.8	5.9	5.3
B	10	86.50	0.1156	270.6	8.35	4.4	7.6	100.0	8.87	0.57
Integrated age ± 2σ			n=2		11.1				8.1	3.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.32	11.1	4.6		100.0	8.8	1.1
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-03										
A	1	1529.9	0.2339	5189.1	1.18	2.2	-0.2	16.1	-4.7	9.4
B	10	115.2	0.2693	365.4	6.17	1.9	6.3	100.0	9.79	0.75
Integrated age ± 2σ			n=2		7.35				7.5	4.0
Plateau ± 2σ	steps A-B		n=2	MSWD=2.37	7.35	1.9		100.0	9.7	2.3
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-04										
A	1	3276.5	0.1932	11032.0	1.19	2.6	0.5	10.5	22.3	19.1
B	10	98.73	0.6000	313.0	10.2	0.85	6.4	100.0	8.49	0.64
Integrated age ± 2σ			n=2		11.4				9.9	4.9
Plateau ± 2σ	steps A-B		n=2	MSWD=0.52	11.4	1.0		100.0	8.5	1.3
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-05										
A	1	3050.5	0.2927	10404.0	1.09	1.7	-0.8	12.8	-32.7	18.7
B	10	57.36	0.2471	166.5	7.41	2.1	14.3	100.0	11.06	0.41
Integrated age ± 2σ			n=2		8.50				5.5	5.2
Plateau ± 2σ	steps A-B		n=2	MSWD=5.46	8.50	2.0		100.0	11.0	1.9
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-06										
A	1	1775.9	0.1738	6015.7	1.18	2.9	-0.1	26.3	-2.3	11.1
B	10	60.23	0.1886	183.7	3.29	2.7	9.9	100.0	8.09	0.55
Integrated age ± 2σ			n=2		4.47				5.4	6.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.87	4.47	2.8		100.0	8.1	1.1
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-07										
A	1	469.9	0.0767	1578.9	2.31	6.7	0.7	26.9	4.5	3.0
B	10	123.0	0.0739	396.0	6.28	6.9	4.9	100.0	8.11	0.81
Integrated age ± 2σ			n=2		8.59				7.1	2.5
Plateau ± 2σ	steps A-B		n=2	MSWD=1.36	8.59	6.8		100.0	7.9	1.8

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)
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-08										
A	1	2389.6	0.3028	8081.3	2.11	1.7	0.1	19.2	2.1	14.3
B	10	138.0	0.1330	448.0	8.87	3.8	4.1	100.0	7.66	0.89
Integrated age ± 2σ		n=2			11.0				6.6	6.6
Plateau ± 2σ	steps A-B	n=2	MSWD=0.15		11.0	3.4		100.0	7.6	1.8
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-09										
A	1	151.8	0.2618	282.8	1.18	1.9	45.0	42.5	90.3	1.2
B	10	128.3	0.0782	181.5	1.60	6.5	58.2	100.0	98.52	0.90
Integrated age ± 2σ		n=2			2.78				95.0	1.6
Plateau ± 2σ	steps A-B	n=2	MSWD=29.77		2.78	4.6		100.0	95.6	7.9
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-10										
A	1	675.2	0.0303	2265.3	1.08	16.8	0.9	18.7	7.9	4.4
B	10	42.29	0.1649	120.0	4.69	3.1	16.1	100.0	9.23	0.44
Integrated age ± 2σ		n=2			5.77				9.0	2.0
Plateau ± 2σ	steps A-B	n=2	MSWD=0.09		5.77	5.7		100.0	9.22	0.87
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-11										
A	1	565.5	0.0375	1916.8	1.26	13.6	-0.2	9.3	-1.2	3.9
B	10	53.43	0.2938	159.2	12.2	1.7	12.0	100.0	8.66	0.40
Integrated age ± 2σ		n=2			13.4				7.7	1.3
Plateau ± 2σ	steps A-B	n=2	MSWD=6.24		13.4	2.8		100.0	8.6	2.0
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-12										
A	1	485.5	0.1789	1624.6	2.01	2.9	1.1	19.2	7.4	3.3
B	10	32.82	0.1508	87.35	8.45	3.4	21.4	100.0	9.50	0.24
Integrated age ± 2σ		n=2			10.5				9.1	1.5
Plateau ± 2σ	steps A-B	n=2	MSWD=0.41		10.5	3.3		100.0	9.48	0.48
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-13										
A	1	910.8	0.0455	3062.0	2.06	11.2	0.7	18.4	8.1	5.5
B	10	39.09	0.1371	110.2	9.17	3.7	16.7	100.0	8.83	0.29
Integrated age ± 2σ		n=2			11.2				8.7	2.3
Plateau ± 2σ	steps A-B	n=2	MSWD=0.02		11.2	5.1		100.0	8.82	0.58
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-14										
A	1	441.0	0.0806	1480.6	1.01	6.3	0.8	35.1	4.7	3.4
B	10	28.89	0.0201	71.79	1.87	25.4	26.6	100.0	10.39	0.52
Integrated age ± 2σ		n=2			2.88				8.4	2.6
Plateau ± 2σ	steps A-B	n=2	MSWD=2.83		2.88	18.7		100.0	10.3	1.7
SCV-1154-160103-djkbi, G12:172, single xtal bi, J=0.0007514±0.10%, D=1.005±0.001, NM-172, Lab#=54445-15										
A	1	219.6	0.0704	719.4	1.79	7.2	3.2	30.1	9.6	1.7
B	10	31.81	0.0311	81.66	4.14	16.4	24.2	100.0	10.39	0.33
Integrated age ± 2σ		n=2			5.92				10.1	1.2
Plateau ± 2σ	steps A-B	n=2	MSWD=0.24		5.92	13.6		100.0	10.36	0.65

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)
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-01										
A	2	786.6	-1.5384	2637.6	7.49	-	0.9	36.5	9.6	4.5
B	10	58.65	-0.7929	168.5	13.0	-	15.0	100.0	11.92	0.35
Integrated age ± 2σ		n=2			20.5				11.1	3.6
Plateau ± 2σ	steps A-B	n=2	MSWD=0.27		20.5	0.000		100.0	11.91	0.70
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-02										
A	2	362.9	-1.6288	1205.1	7.13	-	1.8	97.0	9.0	2.1
B	10	289.1	-55.9174	923.2	0.223	-	4.1	100.0	15.3	4.9
Integrated age ± 2σ		n=2			7.35				9.2	4.2
Plateau ± 2σ	steps A-B	n=2	MSWD=1.34		7.35	0.000		100.0	10.0	4.6
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-03										
A	2	5565.3	-667.5564	18951.2	0.027	-	-1.6	3.2	-85.4	49.8
B	10	1178.1	-14.6551	3979.0	0.823	-	0.1	100.0	1.5	7.6
Integrated age ± 2σ		n=2			0.850				-1.2	16.1
Plateau ± 2σ	steps A-B	n=2	MSWD=2.97		0.850	0.000		100.0	-0.5	25.9
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-04										
A	2	269.0	-3.6560	887.1	3.38	-	2.4	97.3	8.9	1.8
B	10	651.5	-147.9266	2172.8	0.093	-	-0.4	100.0	-3.5	10.5
Integrated age ± 2σ		n=2			3.47				8.6	3.7
Plateau ± 2σ	steps A-B	n=2	MSWD=1.36		3.47	0.000		100.0	8.5	4.2
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-05										
A	2	828.1	-2.3011	2772.5	5.04	-	1.0	64.0	11.7	4.7
B	10	46.22	0.8854	129.4	2.84	0.58	17.4	100.0	10.93	0.54
Integrated age ± 2σ		n=2			7.87				11.4	6.2
Plateau ± 2σ	steps A-B	n=2	MSWD=0.02		7.87	0.58		100.0	10.9	1.1
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-06										
A	2	329.6	-3.2762	1098.8	3.68	-	1.4	96.1	6.3	2.0
B	10	257.7	4.302	822.3	0.150	0.12	5.9	100.0	20.4	5.7
Integrated age ± 2σ		n=2			3.83				6.8	4.0
Plateau ± 2σ	steps A-B	n=2	MSWD=5.45		3.83	0.12		100.0	7.8	8.8
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-07										
A	2	441.7	-2.5040	1468.4	4.84	-	1.7	68.6	10.3	2.7
B	10	206.1	-5.4862	667.9	2.22	-	4.0	100.0	11.2	1.5
Integrated age ± 2σ		n=2			7.06				10.6	4.3
Plateau ± 2σ	steps A-B	n=2	MSWD=0.10		7.06	0.000		100.0	11.0	2.5
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-08										
A	2	256.8	-1.9814	849.2	6.04	-	2.2	80.2	7.7	1.6
B	10	101.5	1.606	305.2	1.49	0.32	11.3	100.0	15.5	1.1
Integrated age ± 2σ		n=2			7.53				9.3	2.8
Plateau ± 2σ	steps A-B	n=2	MSWD=16.41		7.53	0.32		100.0	13.1	7.2

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)
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-09										
A	2	544.1	-3.2361	1811.4	3.73	-	1.6		11.6	3.1
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-9B										
	10	394.1	-210.1472	1322.2	0.069	-	-3.5		-16.6	10.9
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-10										
A	2	288.8	-3.3979	949.8	3.66	-	2.7	97.3	10.6	1.9
B	10	127.6	3.362	372.4	0.103	0.15	14.0	100.0	24.2	6.3
Integrated age ± 2σ			n=2		3.77				11.0	3.8
Plateau ± 2σ		steps A-B	n=2	MSWD=4.29	3.77	0.15		100.0	11.7	7.6
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-11										
A	2	873.4	-2.4109	2942.7	4.78	-	0.4	42.9	4.9	5.1
B	10	64.58	-1.5794	188.2	6.37	-	13.7	100.0	11.95	0.45
Integrated age ± 2σ			n=2		11.2				8.9	4.7
Plateau ± 2σ		steps A-B	n=2	MSWD=1.90	11.2	0.000		100.0	11.9	1.2
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-12										
A	2	1097.3	-12.1184	3675.7	1.01	-	0.9	96.5	13.6	7.4
B	10	483.2	11.59	1716.6	0.036	0.044	-4.8	100.0	-31.9	22.3
Integrated age ± 2σ			n=2		1.04				12.0	14.5
Plateau ± 2σ		steps A-B	n=2	MSWD=3.74	1.04	0.044		100.0	9.1	27.2
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-13										
A	2	192.7	-2.8414	626.6	4.23	-	3.8	98.0	9.9	1.2
B	10	80.69	-163.0441	184.3	0.085	-	15.8	100.0	15.5	6.5
Integrated age ± 2σ			n=2		4.32				10.0	2.3
Plateau ± 2σ		steps A-B	n=2	MSWD=0.70	4.32	0.000		100.0	10.1	2.3
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-14										
A	2	157.9	-1.7492	507.4	6.72	-	4.9	90.1	10.57	0.99
B	10	29.82	0.7563	68.50	0.737	0.67	32.3	100.0	13.07	0.86
Integrated age ± 2σ			n=2		7.45				10.8	1.8
Plateau ± 2σ		steps A-B	n=2	MSWD=3.60	7.45	0.67		100.0	12.0	2.5
SCV-948-251102-djk, G1:172, single xtal bi, J=0.0007536±0.10%, D=1.005±0.001, NM-172, Lab#=54435-15										
A	2	208.9	-4.8152	683.3	2.48	-	3.2	98.3	8.9	1.5
B	10	658.0	-344.2798	2109.0	0.044	-	1.0	100.0	6.9	14.0
Integrated age ± 2σ			n=2		2.53				8.9	3.1
Plateau ± 2σ		steps A-B	n=2	MSWD=0.02	2.53	0.000		100.0	8.9	3.0
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-01										
A	2	545.2	-1.2192	1812.3	7.77	-	1.8	86.5	12.9	3.2
B	10	80.58	1.617	238.0	1.21	0.32	12.9	100.0	14.08	0.93
Integrated age ± 2σ			n=2		8.98				13.1	5.6
Plateau ± 2σ		steps A-B	n=2	MSWD=0.12	8.98	0.32		100.0	14.0	1.8

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)
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-02										
A	2	1893.0	-1.3514	6376.8	5.38	-	0.5	44.3	11.6	10.8
B	10	141.7	-1.2271	443.9	6.77	-	7.3	100.0	14.07	0.84
Integrated age ± 2σ			n=2		12.2				13.0	10.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.05	12.2	0.000		100.0	14.1	1.7
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-03										
A	2	962.1	-1.6925	3206.7	6.34	-	1.5	71.8	19.4	5.5
B	10	135.7	-4.6780	423.4	2.49	-	7.5	100.0	13.83	0.95
Integrated age ± 2σ			n=2		8.83				17.8	8.2
Plateau ± 2σ	steps A-B		n=2	MSWD=1.00	8.83	0.000		100.0	14.0	1.9
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-04										
A	2	642.7	-1.9953	2149.8	5.96	-	1.1	70.9	9.9	3.7
B	10	28.62	-4.9755	67.47	2.44	-	28.9	100.0	11.16	0.36
Integrated age ± 2σ			n=2		8.40				10.2	5.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.12	8.40	0.000		100.0	11.15	0.71
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-05										
A	2	876.7	-0.7251	2952.1	5.49	-	0.5	41.5	5.9	5.0
B	10	143.3	-0.6337	453.7	7.73	-	6.4	100.0	12.50	0.89
Integrated age ± 2σ			n=2		13.2				9.7	5.0
Plateau ± 2σ	steps A-B		n=2	MSWD=1.69	13.2	0.000		100.0	12.3	2.3
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-06										
A	2	571.6	-0.7495	1912.0	6.68	-	1.1	56.8	8.8	3.2
B	10	84.95	-2.1201	257.9	5.08	-	10.1	100.0	11.57	0.59
Integrated age ± 2σ			n=2		11.8				10.0	4.0
Plateau ± 2σ	steps A-B		n=2	MSWD=0.70	11.8	0.000		100.0	11.5	1.2
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-07										
A	2	2007.6	-1.1141	6728.3	9.50	-	1.0	43.2	26.0	11.5
B	10	121.7	-0.8026	379.7	12.5	-	7.8	100.0	12.77	0.72
Integrated age ± 2σ			n=2		22.0				18.5	10.6
Plateau ± 2σ	steps A-B		n=2	MSWD=1.32	22.0	0.000		100.0	12.8	1.7
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-08										
A	2	891.3	-1.0840	2975.9	8.74	-	1.3	81.3	16.0	5.1
B	10	76.38	-5.7816	221.9	2.02	-	13.5	100.0	13.94	0.72
Integrated age ± 2σ			n=2		10.8				15.6	8.4
Plateau ± 2σ	steps A-B		n=2	MSWD=0.16	10.8	0.000		100.0	14.0	1.4
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-09										
A	2	1332.4	-0.4210	4451.5	11.6	-	1.3	36.0	22.9	7.5
B	10	127.6	-0.0411	396.0	20.6	-	8.3	100.0	14.27	0.71
Integrated age ± 2σ			n=2		32.1				17.4	6.2
Plateau ± 2σ	steps A-B		n=2	MSWD=1.32	32.1	0.000		100.0	14.3	1.6

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)
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-10										
A	2	2651.5	-8.1941	8921.0	1.47	-	0.6	23.2	19.7	15.2
B	10	146.1	-2.3238	462.7	4.86	-	6.3	100.0	12.46	0.96
Integrated age ± 2σ			n=2		6.33				14.1	8.2
Plateau ± 2σ	steps A-B		n=2	MSWD=0.22	6.33	0.000		100.0	12.5	1.9
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-11										
A	2	0.7300	8.441	22.67	-0.038	0.060	-717.2	-14.5	-7.2	24.3
B	10	395.7	4.374	1259.3	0.303	0.12	6.0	100.0	32.3	5.9
Integrated age ± 2σ			n=2		0.264				38.0	16.2
Plateau ± 2σ	steps A-B		n=2	MSWD=2.49	0.264	0.12		100.0	30.1	18.1
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-12										
A	2	3113.2	-0.9988	10390.0	10.5	-	1.4	34.2	57.3	17.7
B	10	141.3	-0.4438	439.5	20.3	-	8.1	100.0	15.46	0.80
Integrated age ± 2σ			n=2		30.8				29.9	13.1
Plateau ± 2σ	steps A-B		n=2	MSWD=5.60	30.8	0.000		100.0	15.5	3.8
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-13										
A	2	907.4	-1.3955	3038.5	8.19	-	1.0	59.0	12.7	5.0
B	10	102.5	-1.9158	315.1	5.68	-	9.0	100.0	12.54	0.69
Integrated age ± 2σ			n=2		13.9				12.6	6.4
Plateau ± 2σ	steps A-B		n=2	MSWD=0.00	13.9	0.000		100.0	12.5	1.4
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-14										
A	2	841.5	-0.7592	2782.6	4.35	-	2.3	86.7	25.9	4.7
B	10	212.8	-18.4930	584.8	0.666	-	18.1	100.0	50.9	2.7
Integrated age ± 2σ			n=2		5.02				29.2	8.4
Plateau ± 2σ	steps A-B		n=2	MSWD=21.31	5.02	0.000		100.0	44.6	21.8
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-15										
A	2	846.5	-1.4324	2821.4	3.10	-	1.5	79.1	17.1	4.8
B	10	359.4	-14.3189	1165.2	0.819	-	3.9	100.0	18.6	2.8
Integrated age ± 2σ			n=2		3.92				17.4	8.4
Plateau ± 2σ	steps A-B		n=2	MSWD=0.07	3.92	0.000		100.0	18.3	4.9
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-16										
A	2	721.9	-1.6306	2418.2	7.60	-	1.0	92.0	9.8	4.1
B	10	82.98	1.706	235.6	0.661	0.30	16.3	100.0	18.3	1.5
Integrated age ± 2σ			n=2		8.26				10.5	7.6
Plateau ± 2σ	steps A-B		n=2	MSWD=3.86	8.26	0.30		100.0	17.3	5.4
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-17										
A	2	506.6	-2.0981	1670.9	5.98	-	2.5	88.4	17.1	2.8
B	10	74.25	-17.9887	217.3	0.786	-	11.5	100.0	11.5	1.2
Integrated age ± 2σ			n=2		6.77				16.5	5.1
Plateau ± 2σ	steps A-B		n=2	MSWD=3.43	6.77	0.000		100.0	12.3	4.0

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)
SCV-318-230702-djk, G2:172, single xtal bi, J=0.0007532±0.10%, D=1.005±0.001, NM-172, Lab#=54436-18										
A	2	785.1	-1.3322	2610.7	9.26	-	1.7	87.2	18.3	4.3
B	10	67.57	-9.7917	193.0	1.37	-	14.4	100.0	13.09	0.93
Integrated age ± 2σ			n=2		10.6				17.6	7.6
Plateau ± 2σ		steps A-B	n=2	MSWD=1.36	10.6	0.000		100.0	13.3	2.1
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-01										
A	2	230.0	-3.9584	750.6	3.29	-	3.4	93.1	10.7	1.5
B	10	178.1	2.490	559.4	0.246	0.20	7.3	100.0	17.6	3.9
Integrated age ± 2σ			n=2		3.54				11.2	2.9
Plateau ± 2σ		steps A-B	n=2	MSWD=2.83	3.54	0.20		100.0	11.6	4.6
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-02										
A	2	455.3	-3.0855	1508.2	4.22	-	2.0	96.7	12.6	2.8
B	10	114.4	2.245	339.2	0.143	0.23	12.5	100.0	19.4	4.0
Integrated age ± 2σ			n=2		4.37				12.8	5.4
Plateau ± 2σ		steps A-B	n=2	MSWD=1.93	4.37	0.23		100.0	14.8	6.4
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-03										
A	2	399.8	-8.8058	1307.5	1.49	-	3.2	93.0	17.1	2.9
B	10	272.6	4.553	889.6	0.113	0.11	3.7	100.0	13.7	7.4
Integrated age ± 2σ			n=2		1.60				16.9	5.6
Plateau ± 2σ		steps A-B	n=2	MSWD=0.18	1.60	0.11		100.0	16.7	5.4
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-04										
A	2	304.9	-1.9254	998.7	5.00	-	3.2	95.7	13.0	1.8
B	10	62.91	2.170	159.0	0.225	0.24	25.6	100.0	21.8	2.6
Integrated age ± 2σ			n=2		5.22				13.4	3.4
Plateau ± 2σ		steps A-B	n=2	MSWD=7.80	5.22	0.24		100.0	15.9	8.2
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-05										
A	2	282.1	-3.7668	927.1	2.68	-	2.8	98.6	10.6	1.9
B	10	258.0	7.009	787.6	0.037	0.073	10.0	100.0	35.0	17.0
Integrated age ± 2σ			n=2		2.72				11.0	3.8
Plateau ± 2σ		steps A-B	n=2	MSWD=2.03	2.72	0.073		100.0	10.9	5.4
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-06										
A	2	176.7	-2.6234	572.8	3.76	-	4.1	96.8	9.8	1.3
B	10	198.5	3.499	647.6	0.123	0.15	3.7	100.0	10.0	5.2
Integrated age ± 2σ			n=2		3.89				9.8	2.6
Plateau ± 2σ		steps A-B	n=2	MSWD=0.00	3.89	0.15		100.0	9.8	2.5
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-07										
A	2	221.6	3.397	718.8	2.35	0.15	4.3	93.7	12.8	1.6
B	10	119.7	1.932	367.4	0.159	0.26	9.4	100.0	15.2	4.0
Integrated age ± 2σ			n=2		2.51				13.0	3.1
Plateau ± 2σ		steps A-B	n=2	MSWD=0.32	2.51	0.16		100.0	13.1	2.9

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)
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-08										
A	2	257.2	-2.2523	839.3	4.18	-	3.5	87.1	12.2	1.7
B	10	49.34	1.005	140.9	0.619	0.51	15.8	100.0	10.54	0.95
Integrated age ± 2σ			n=2		4.79				12.0	3.0
Plateau ± 2σ	steps A-B		n=2	MSWD=0.70	4.79	0.51		100.0	10.9	1.7
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-09										
A	2	402.6	-4.4647	1336.4	2.78	-	1.8	91.0	9.8	2.5
B	10	117.5	2.290	354.2	0.276	0.22	11.1	100.0	17.6	2.6
Integrated age ± 2σ			n=2		3.06				10.5	4.7
Plateau ± 2σ	steps A-B		n=2	MSWD=4.56	3.06	0.22		100.0	13.6	7.8
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-10										
A	2	297.4	-3.2808	980.4	3.72	-	2.5	92.2	10.1	2.0
B	10	65.63	0.9355	183.8	0.314	0.55	17.3	100.0	15.4	2.9
Integrated age ± 2σ			n=2		4.03				10.5	3.7
Plateau ± 2σ	steps A-B		n=2	MSWD=2.34	4.03	0.55		100.0	11.8	5.0
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-11										
A	2	414.8	0.1960	1387.7	2.86	2.6	1.2	97.9	6.5	2.8
B	10	214.4	0.6020	647.4	0.063	0.85	10.8	100.0	31.2	8.5
Integrated age ± 2σ			n=2		2.93				7.0	5.6
Plateau ± 2σ	steps A-B		n=2	MSWD=7.56	2.93	2.6		100.0	8.9	14.8
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-12										
A	2	456.6	0.2310	1509.7	3.55	2.2	2.3	92.1	14.2	3.0
B	10	99.06	0.1737	310.9	0.304	2.9	7.3	100.0	9.7	2.4
Integrated age ± 2σ			n=2		3.85				13.8	5.6
Plateau ± 2σ	steps A-B		n=2	MSWD=1.32	3.85	2.3		100.0	11.5	4.3
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-13										
A	2	436.1	0.4213	1446.4	2.13	1.2	2.0	98.6	11.8	3.0
B	10	2904.3	-2.7004	9847.8	0.030	-	-0.2	100.0	-8.1	44.0
Integrated age ± 2σ			n=2		2.16				11.5	6.4
Plateau ± 2σ	steps A-B		n=2	MSWD=0.20	2.16	1.2		100.0	11.7	6.0
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-14										
A	2	378.6	0.1543	1257.6	4.92	3.3	1.8	94.0	9.4	2.3
B	10	92.61	0.7402	290.3	0.313	0.69	7.5	100.0	9.4	2.7
Integrated age ± 2σ			n=2		5.23				9.4	4.4
Plateau ± 2σ	steps A-B		n=2	MSWD=0.00	5.23	3.2		100.0	9.4	3.5
SCV-1014-051202-djk, G#:172, single xtal bi, J=0.0007527±0.10%, D=1.005±0.001, NM-172, Lab#=54437-15										
A	2	350.5	0.4001	1166.4	3.60	1.3	1.7	88.9	8.0	2.1
B	10	71.29	0.3083	209.3	0.448	1.7	13.3	100.0	12.8	1.7
Integrated age ± 2σ			n=2		4.05				8.5	3.8
Plateau ± 2σ	steps A-B		n=2	MSWD=3.24	4.05	1.3		100.0	11.0	4.7

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)
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-01										
A	2	1251.8	0.1244	4190.7	6.05	4.1	1.1	46.9	18.2	7.1
B	10	195.8	0.1769	620.9	6.83	2.9	6.3	100.0	16.7	1.2
Integrated age ± 2σ			n=2		12.9				17.4	7.7
Plateau ± 2σ		steps A-B	n=2	MSWD=0.04	12.9	3.5		100.0	16.8	2.3
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-02										
A	2	2151.2	0.3737	7180.7	1.01	1.4	1.4	32.1	39.4	15.8
B	10	896.6	0.2921	2983.6	2.13	1.7	1.7	100.0	20.3	5.3
Integrated age ± 2σ			n=2		3.14				26.4	15.8
Plateau ± 2σ		steps A-B	n=2	MSWD=1.33	3.14	1.6		100.0	22.2	11.6
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-03										
A	2	1370.9	0.2465	4608.0	3.23	2.1	0.7	82.1	12.5	7.8
B	10	580.2	0.2994	1923.4	0.702	1.7	2.0	100.0	16.1	4.5
Integrated age ± 2σ			n=2		3.93				13.1	13.9
Plateau ± 2σ		steps A-B	n=2	MSWD=0.15	3.93	2.0		100.0	15.2	7.8
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-04										
A	2	1571.4	0.0650	5284.5	6.53	7.8	0.6	87.4	13.3	9.2
B	10	223.9	0.0623	724.8	0.945	8.2	4.4	100.0	13.2	2.2
Integrated age ± 2σ			n=2		7.47				13.3	16.3
Plateau ± 2σ		steps A-B	n=2	MSWD=0.00	7.47	7.9		100.0	13.2	4.3
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-05										
A	2	1847.2	0.0796	6230.6	4.56	6.4	0.3	74.9	8.2	11.1
B	10	244.5	0.0912	783.5	1.53	5.6	5.3	100.0	17.6	1.8
Integrated age ± 2σ			n=2		6.09				10.6	17.2
Plateau ± 2σ		steps A-B	n=2	MSWD=0.69	6.09	6.2		100.0	17.4	3.6
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-06										
A	2	1594.9	0.1043	5346.3	4.50	4.9	0.9	38.6	20.3	8.9
B	10	216.3	0.1191	702.9	7.17	4.3	4.0	100.0	11.7	1.4
Integrated age ± 2σ			n=2		11.7				15.0	8.3
Plateau ± 2σ		steps A-B	n=2	MSWD=0.91	11.7	4.5		100.0	11.9	2.7
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-07										
A	2	911.7	0.1631	3059.4	2.98	3.1	0.8	31.0	10.4	5.2
B	10	362.3	0.1915	1175.4	6.64	2.7	4.1	100.0	20.3	2.1
Integrated age ± 2σ			n=2		9.62				17.2	5.9
Plateau ± 2σ		steps A-B	n=2	MSWD=3.06	9.62	2.8		100.0	18.9	6.8
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-08										
A	2	892.4	0.0339	2990.4	2.57	15.0	1.0	98.8	11.8	5.4
B	10	272.8	-5.0435	947.0	0.032	-	-2.7	100.0	-10.0	21.9
Integrated age ± 2σ			n=2		2.60				11.6	10.7
Plateau ± 2σ		steps A-B	n=2	MSWD=0.94	2.60	14.8		100.0	10.6	10.4

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)
FW1-CWA-Encinos-djk, G4:172, single xtal bi, J=0.000752±0.10%, D=1.005±0.001, NM-172, Lab#=54438-09										
A	2	620.3	0.0801	2074.8	1.35	6.4	1.2	99.8	9.7	4.6
B	10	-138.6154	-47.6641	-734.1714	0.003	-	-53.7	100.0	95.2	263.1
Integrated age ± 2σ			n=2		1.35				9.9	9.3
Plateau ± 2σ	steps A-B		n=2	MSWD=0.11	1.35	6.4		100.0	9.7	9.3

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Ages calculated ralative to FC-1 Fish Canyon Tuff sanidine interlaboratory standard at 27.84 Ma.
Errors quoted for individual analyses include analytical error only, without interfering reaction or J uncertainties.
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 aquare root MSWD where MSWD>1.
Plateau and integrated ages incorporate uncertainties in interfering reaction corrections and J factors.
Decay constants and isotopic abundances after Steiger and Jäger (1977).
# symbol preceding sample ID denotes analyses excluded from plateau age calculations.
Discrimination = 1.005 ± 0.001
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007 ± 2e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 5e-06
$(^{38}Ar/^{39}Ar)_K$ = 0.01077
$(^{40}Ar/^{39}Ar)_K$ = 0.0002 ± 0.0003

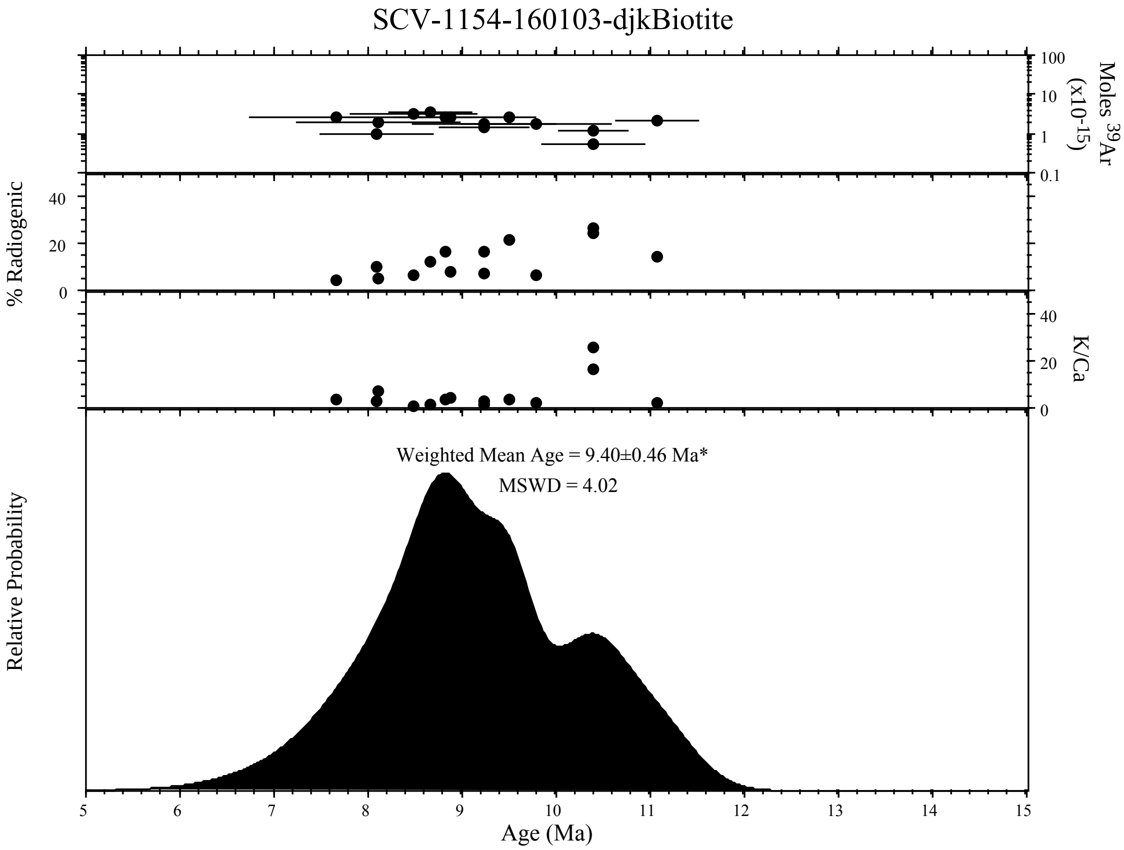

Figure 1. Age probability distribution diagram of SCV-1154-160103-djk single crystal biotite B steps. *2 sigma

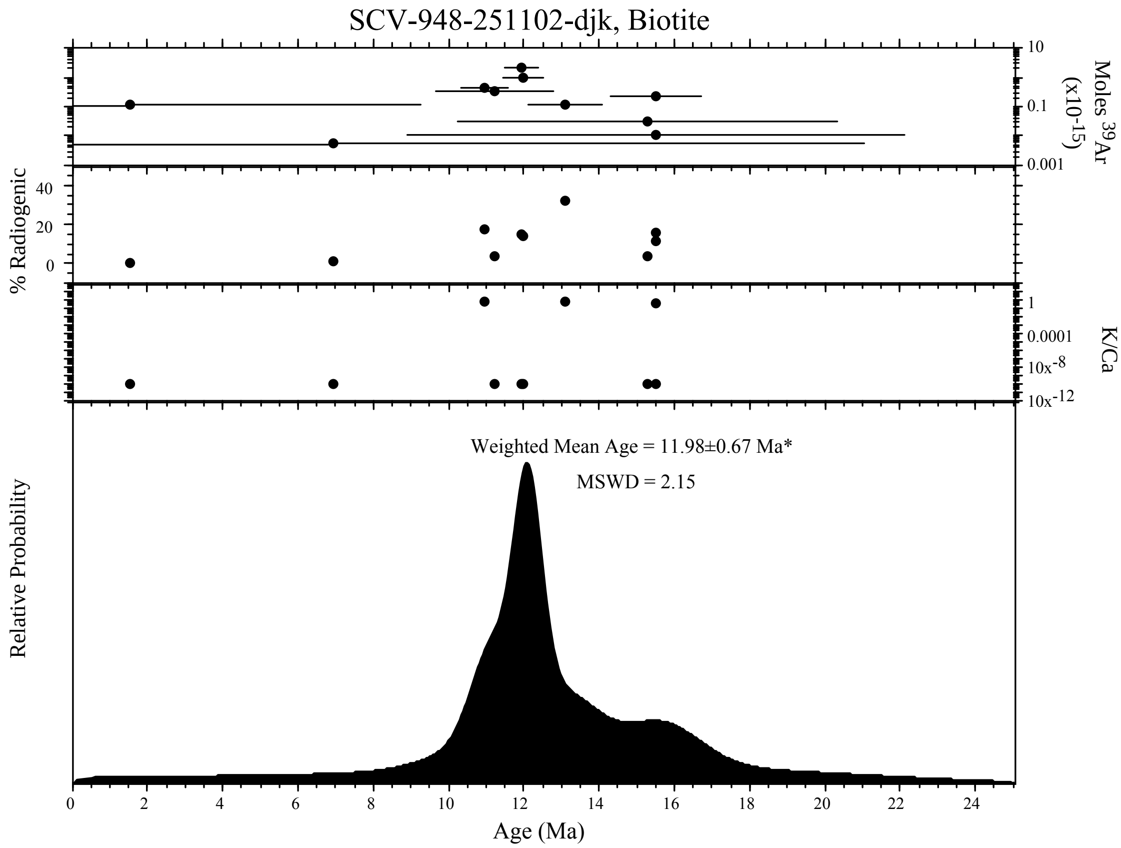

Figure 2. Age probability distribution diagram of SCV-948-251102-djk single crystal biotite B steps. *2 sigma

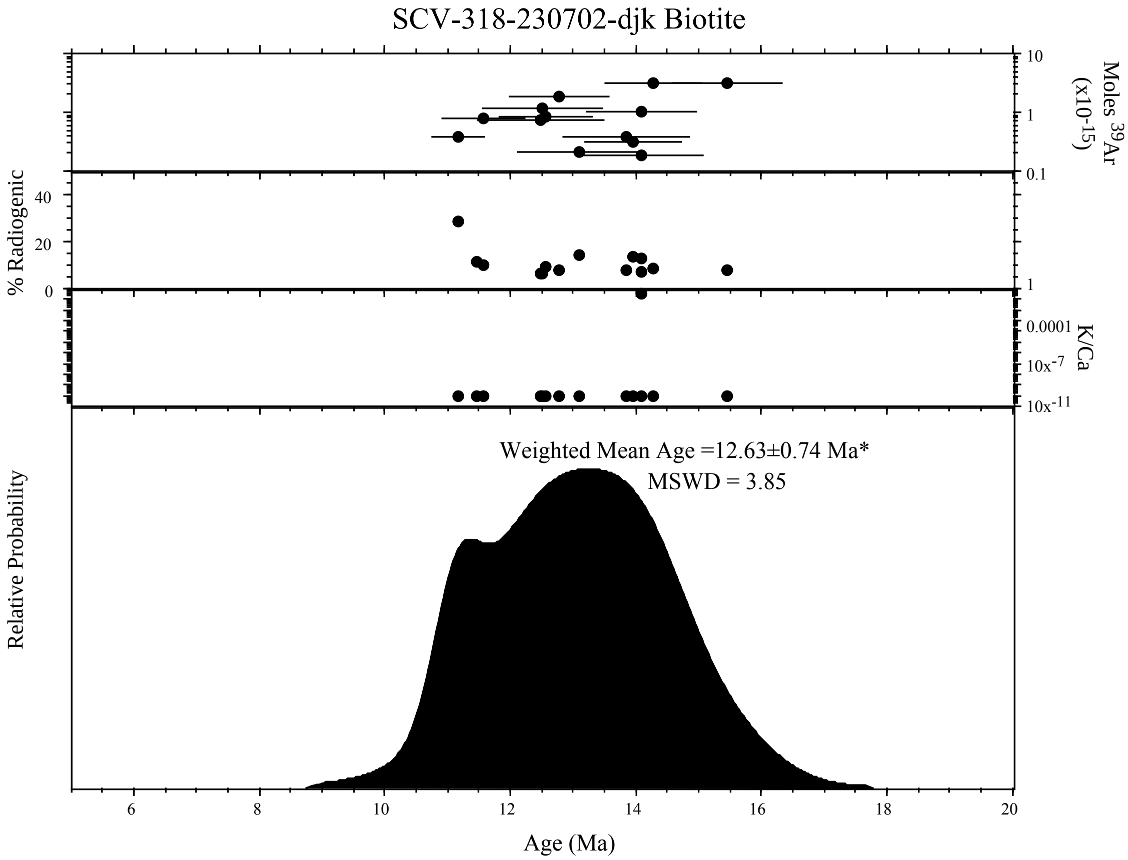

Figure 3. Age probability distribution diagram of SCV-318-230702-djk single crystal biotite B steps. *2 sigma

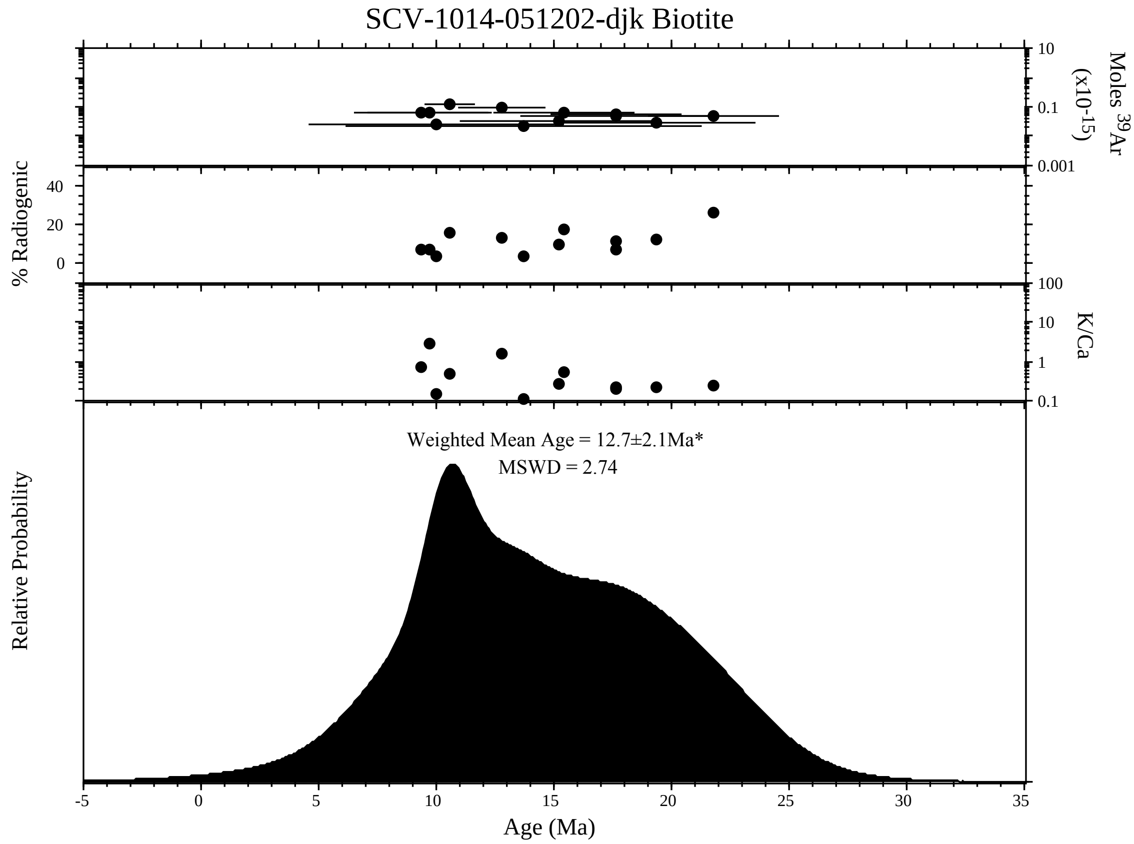

Figure 4. Age probability distribution diagram of SCV-1014-05122-djk single crystal biotite B steps. *2 sigma

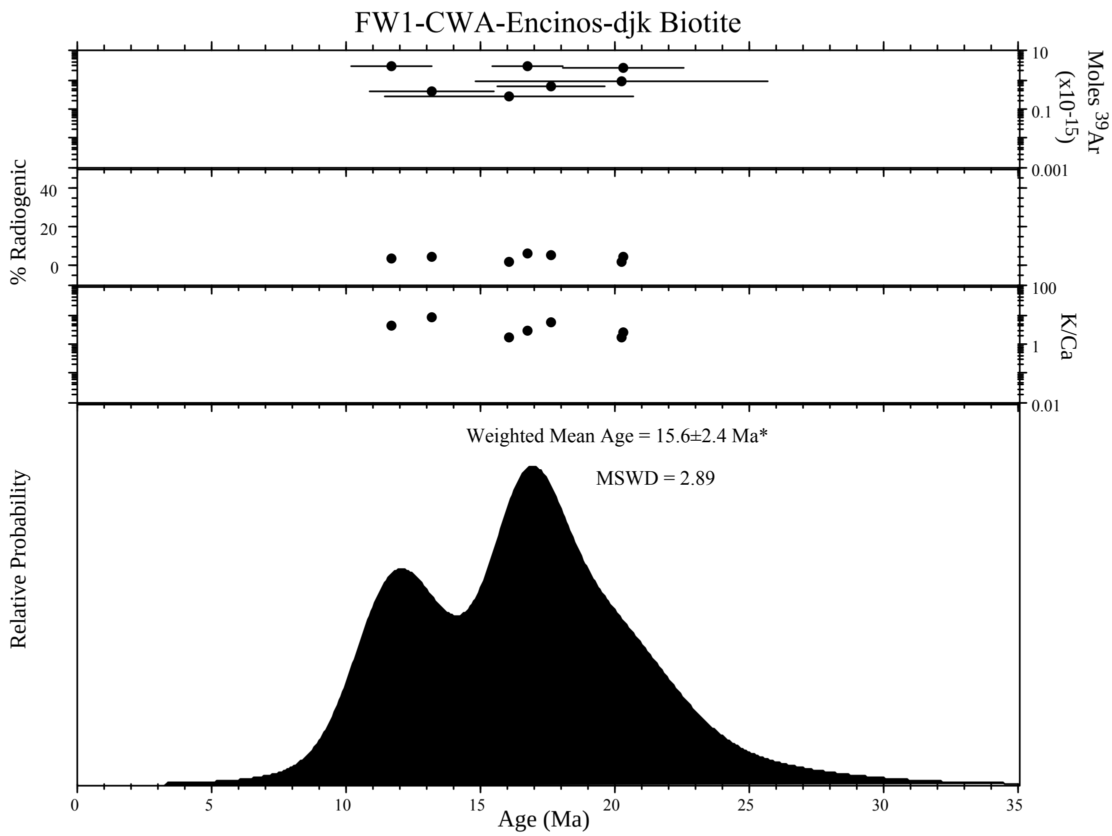

Figure 5. Age probability distribution diagram of FW1-CWA-Encinos-djk single crystal biotite B steps. *2 sigma

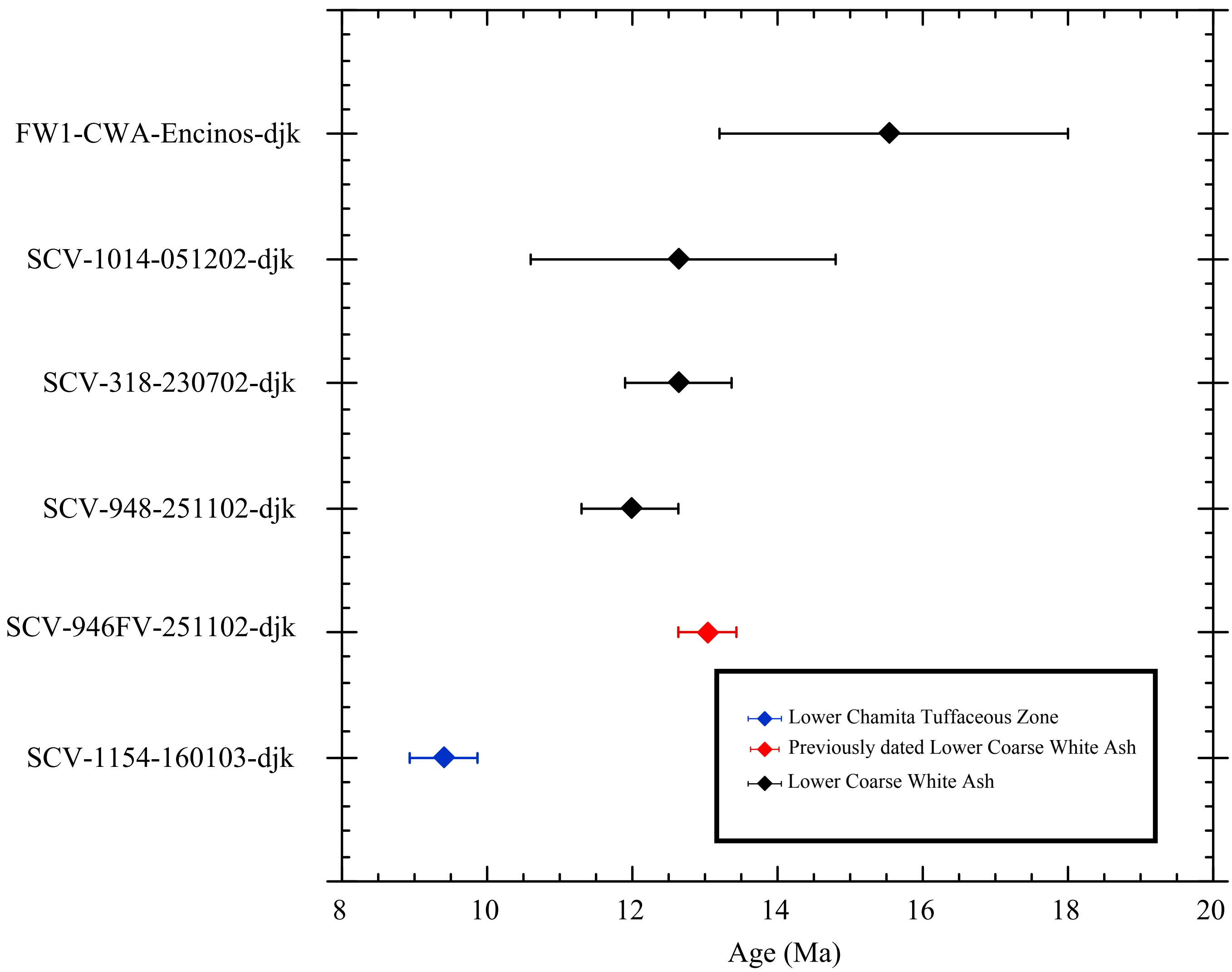

Figure 6. Summary of Lower Coarse White Ashes and possible Lower Chamita Tuffaceous Zone sample, analyzed with single crystal biotite.

New Mexico Bureau of Mines and Mineral Resources

Procedures of the New Mexico Geochronology Research Laboratory

For the Period June 1998 – present

Matthew Heizler
William C. McIntosh
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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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