$^{40}Ar/^{39}Ar$ Geochronology Results for the Cottonwood Mountain, Panguitch NW, and Sigurd Quadrangles, Utah

by

Utah Geological Survey and New Mexico Geochronology Research Laboratory

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INTRODUCTION

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 provide additional information such as the 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	Easting UTM NAD83	Northing UTM NAD83	Reference
PNW080913-1	Panguitch NW	369369	4195381	Biek and others (2015)
CM081413-2	Cottonwood Mountain	350335	4203177	Biek and others (2015)
CM081513-1	Cottonwood Mountain	350098	4195381	Biek and others (2015)
SIG22812-1	Sigurd	415565	4297514	Doelling and others (in prep.)

DISCLAIMER

REFERENCES

Biek, R.F., Rowley, P.D., Anderson, J.J., Maldonado, F., Moore, D.W., Hacker, D.B., Eaton, J.G., Hereford, R., Filkorn, H.F., and Matyjasik, B., 2015, Geologic map of the Panguitch 30′ x 60′ quadrangle, Garfield, Iron, and Kane Counties, Utah: Utah Geological Survey Map 270DM, 162 p., 3 plates, scale 1:62,500.

Doelling, H.H., Willis, G.C., and Kuehne, P.A., in preparation, Interim geologic map of the west half of the Salina 30′ x 60′ quadrangle, Sevier, Emery, and Piute Counties, Utah: Utah Geological Survey Open-File Report, scale 1:62,500.

$^{40}Ar/^{39}Ar$ Geochronology Results From the Marysvale Volcanic Field

By

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JANUARY 21, 2015

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Introduction

Five volcanic samples from the Marysvale volcanic field were submitted for dating by Bob Biek of the Utah Geological Survey (CM081413-2, CM081513-1, PNW080913-1, PNW080913-2 and SIG22812-1). These samples were specifically chosen to help constrain the age of the Markagunt Megabreccia. PNW080913-1 and PNW080913-2 are pseudotachylite associated with the bedding-plane of the gravity slide; we were to choose the "best" of the two. We analyzed PNW080913-1.

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

Groundmass concentrates were prepared by treating crushed material with dilute HCl and then removing the phenocrysts. The mineral separates and monitors (Fish Canyon tuff sanidine, 28.201, Kuiper et al., 2008) were loaded into aluminum discs and irradiated for 8 hours at the USGS TRIGA reactor in Denver Colorado.

The samples were step-heated with a Photon Machines Diode laser and analyzed with a Thermo Argus VI mass spectrometer. Abbreviated analytical methods for the dated samples are given in Table 1, and details of the overall operation of the New Mexico Geochronology Research Laboratory is provided in the Appendix. The age results are summarized in Table 1 and the argon isotopic data are given in Table 2.

Groundmass concentrate from samples CM081513-1 and SIG22812-1 yielded fairly flat age spectra (Figures 1 and 2). Over 85% of the ^{39}Ar released has been used to calculate a weighted mean age for these samples (23.66±0.05 Ma-CM081513-1 and 25.32±0.06 Ma-SIG22812-1). Both revealed increasing radiogenic ^{40}Ar over the initial ~30% of the ^{39}Ar released to over 50% radiogenic ^{40}Ar and K/Ca ratios ranging from 0.1-1.5. Radiogenic yields and K/Ca values typical for basalts of this age. Inverse isochron analysis of this data yields $^{40}Ar/^{36}Ar$ intercepts within error of atmosphere (295.5) and intercept ages that agree within error with the weighted mean ages.

The psuedotachylitic glass from PNW080913-1 yielded an imprecise but nearly concordant age spectrum (Figure 3) and a weighted mean age of (28.13±0.78 Ma) is calculated from 96.9% of the ^{39}Ar released. The radiogenic yields for this sample are very low and slowly increase throughout the heating of the sample, reaching only ~10% radiogenic for the last few steps. For the first 75% of the age spectra the radiogenic yields are below 5%. Inverse isochron analysis of this sample reveals an atmospheric intercept (295.3±0.8).

CM081413-2 groundmass concentrate yielded a disturbed hump-shaped age spectrum (Figure 4). The apparent ages increase from 19.93 Ma to 24.67 Ma over the initial 33.1% of the ^{39}Ar released and then decrease in age to 19.56 Ma over the remainder of the heating steps. This rise and fall in apparent ages correlates to a rise and fall in radiogenic yield; increasing from 5.6% radiogenic to 76.1% and then decreasing to 29.6% radiogenic. This data fails to form a well-defined linear array when plotted on an isochron.

Discussion

The nearly flat age spectra for the groundmass concentrates from samples CM081513-1 and SIG22812-1 yield precise, robust ages that we interpret as accurate eruption or emplacement ages (23.66±0.05 Ma and 25.32±0.06 Ma, respectively). The apparent age calculated from the pseudotachylyte glass of sample PNW080913-1 yielded an imprecise but relatively flat spectrum with low radiogenic yields and a weighted mean age of 28.13±0.78 Ma. We do not have great confidence that this represents an accurate age of the formation of the basal shear plane of the Markagunt Megabreccia. Although there is no obvious excess ^{40}Ar ($^{40}Ar/^{36}Ar$ intercept of the isochron is 295.3±0.9, within error of the atmospheric intercept of 295.5) and the spectrum does not show obvious

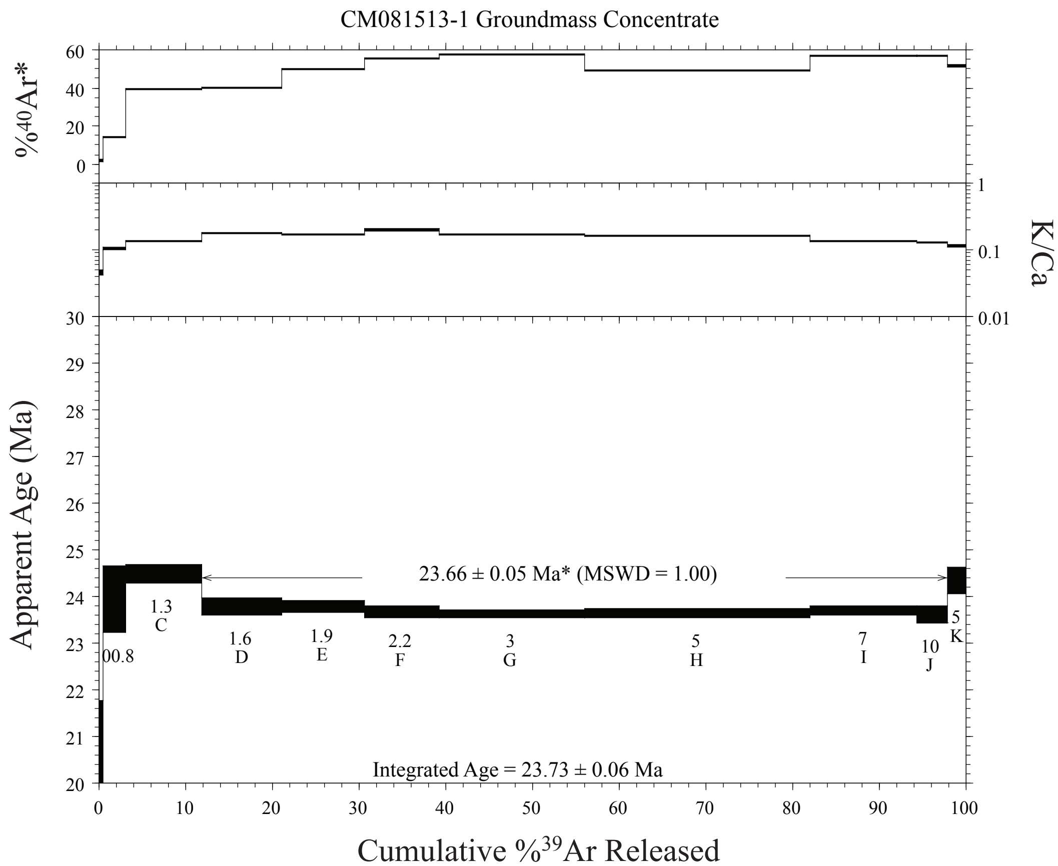
Ar loss (increasing apparent ages correlated to increasing radiogenic yields), the radiogenic yields are extremely low for a sample of this age (see those of other samples in this study). Because of the very low radiogenic yields, the apparent age of this sample is highly sensitive to contamination by materials that were not completely reset during heating during displacement of the gravity slide. The highly disturbed age spectrum from the deeply weathered basalt sample CM081413-2, is probably affected by both ^{39}Ar recoil and Ar loss related to alteration. In multi-phase samples, such as a basalt, the ^{39}Ar isotopes produced at the reactor jump (or recoil) from higher K phases into lower K phases (or completely out of the sample). If these phases degas at different temperatures, the result is an increase in apparent age of the portion of the age spectrum that is controlled by the high K phase and a decrease in age of the portion of the age spectrum that is controlled by the lower K phase (Figure 5). We have assigned the integrated age as our best estimate of this samples age but have very low confidence that this age represents an accurate emplacement age.

References Cited

Kuiper, K. F., Deino, A., Hilgen, F. J., Krijgsman, W., Renne, P. R., and Wijbrans, J. R., 2008, Synchronizing rock clocks of earth history: Science, v. 320, p. 500-504.

Min, K., Mundil, R., Renne, P. L., and Ludwig, K.R., 2000, A test for systematic errors in $^{40}Ar/^{39}Ar$ geochronology through comparison with U/Pb analysis of a 1.1-Ga rhyolite: Geochimica et Cosmochimica Acta, v. 64, p. 73-98.

Taylor, J.R., 1982. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements,. Univ. Sci. Books, Mill Valley, Calif., 270 p.



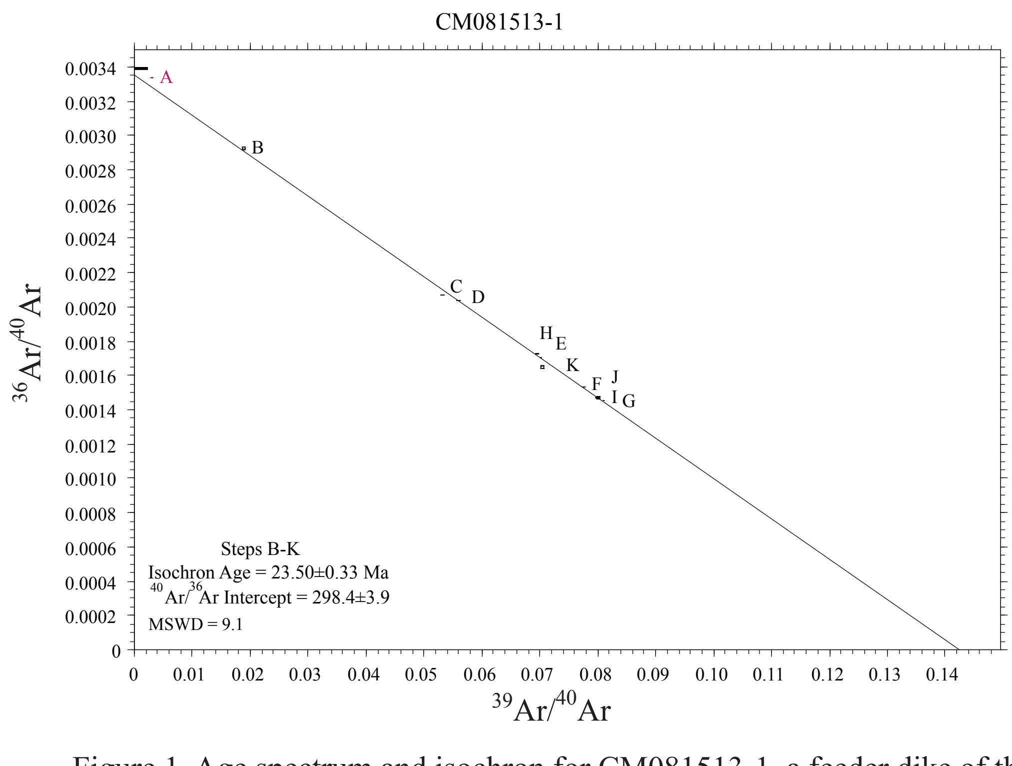
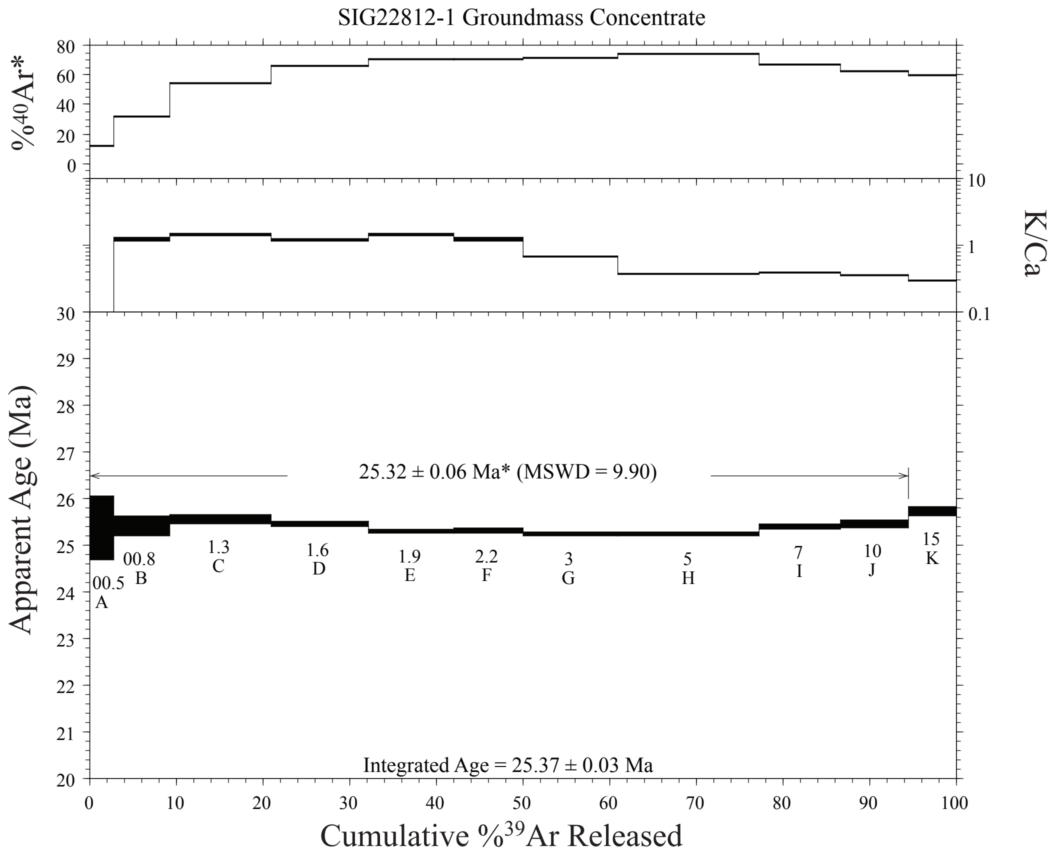


Figure 1. Age spectrum and isochron for CM081513-1, a feeder dike of the Iron Peak laccolith.



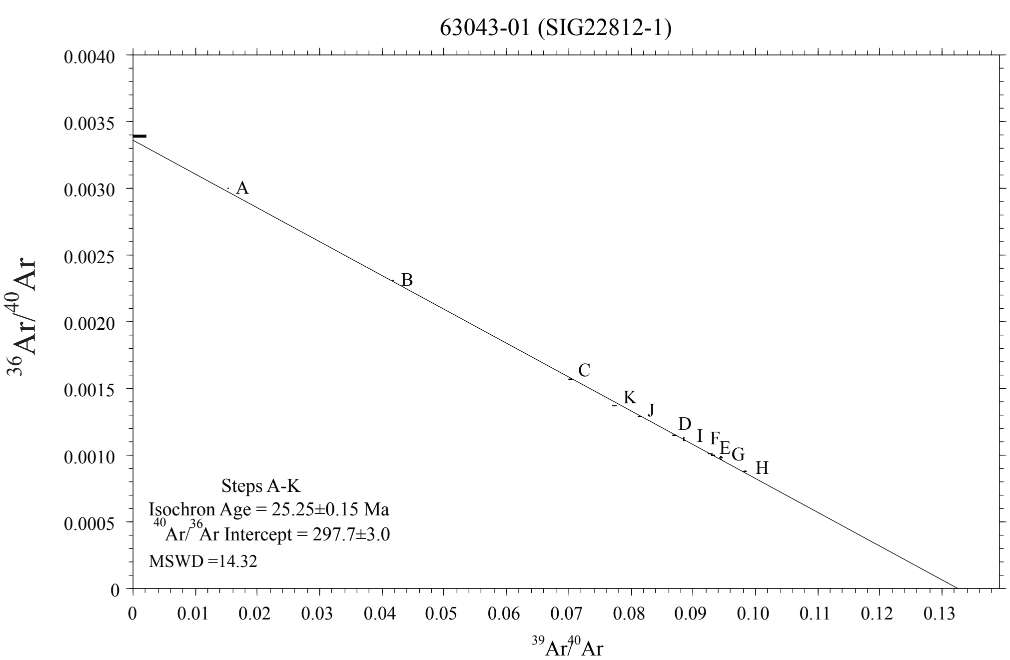


Figure 2. Age spectrum and isochron for SIG22812-1.

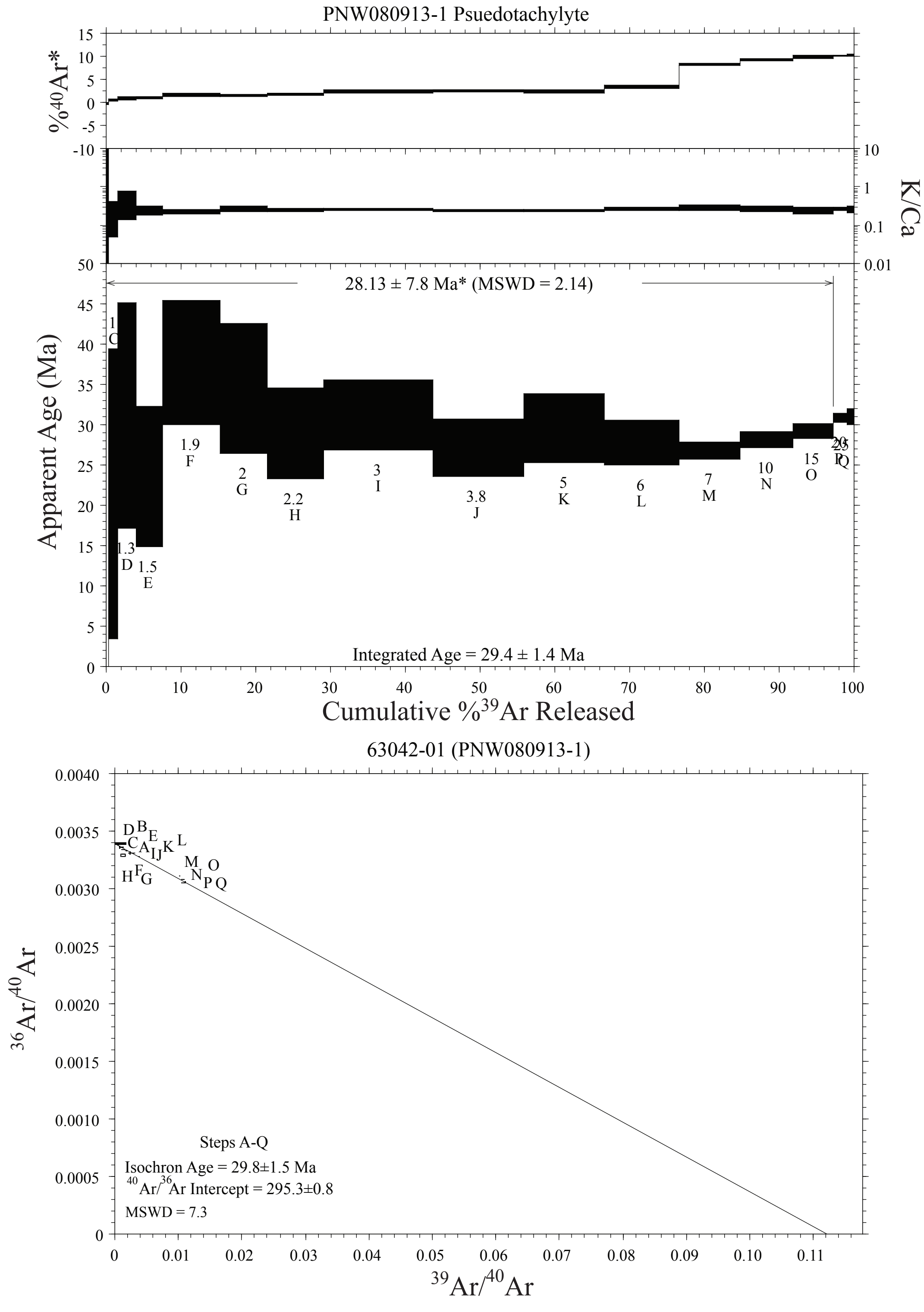
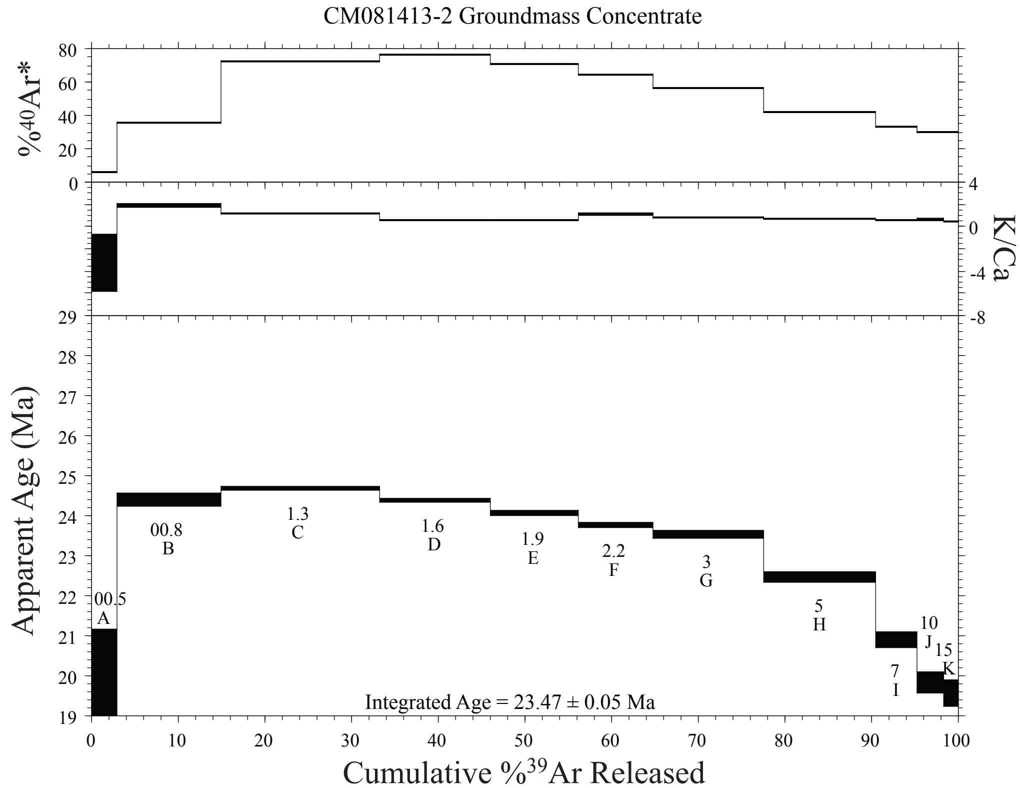


Figure 3. Age spectrum and isochron for PNW080913-1 pseudotachylyte associated with the basal plane of the Markagunt Meggabreccia.



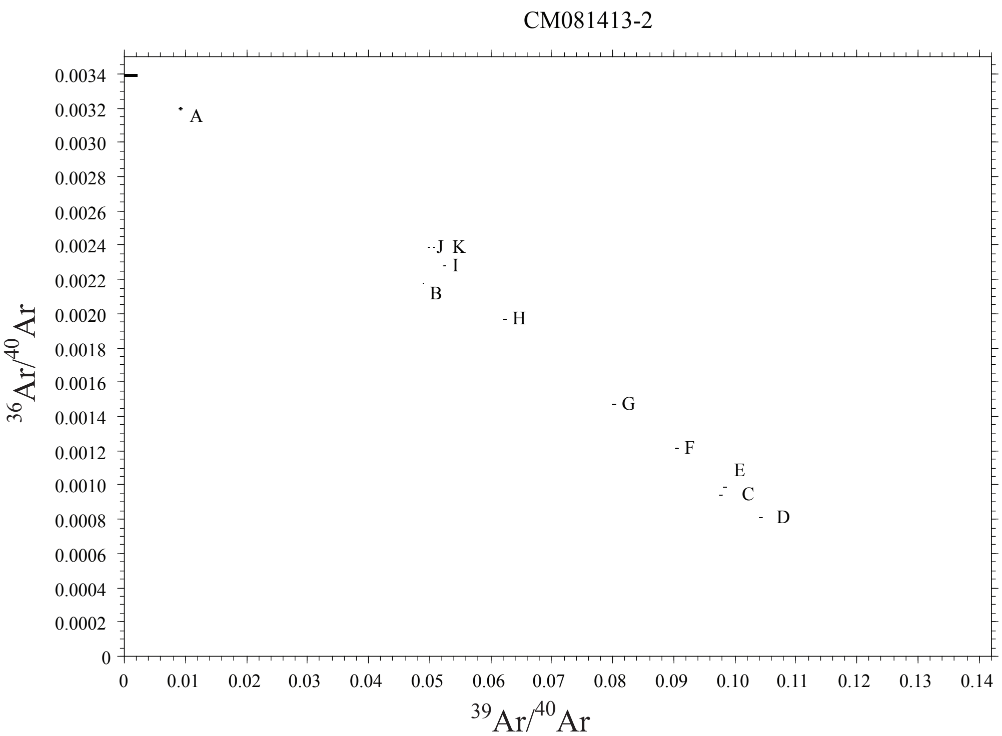


Figure 4. Age spectrum and isochron for CM081413-2, a deeply weathered dike that cut the Markagunt Meggabreccia.

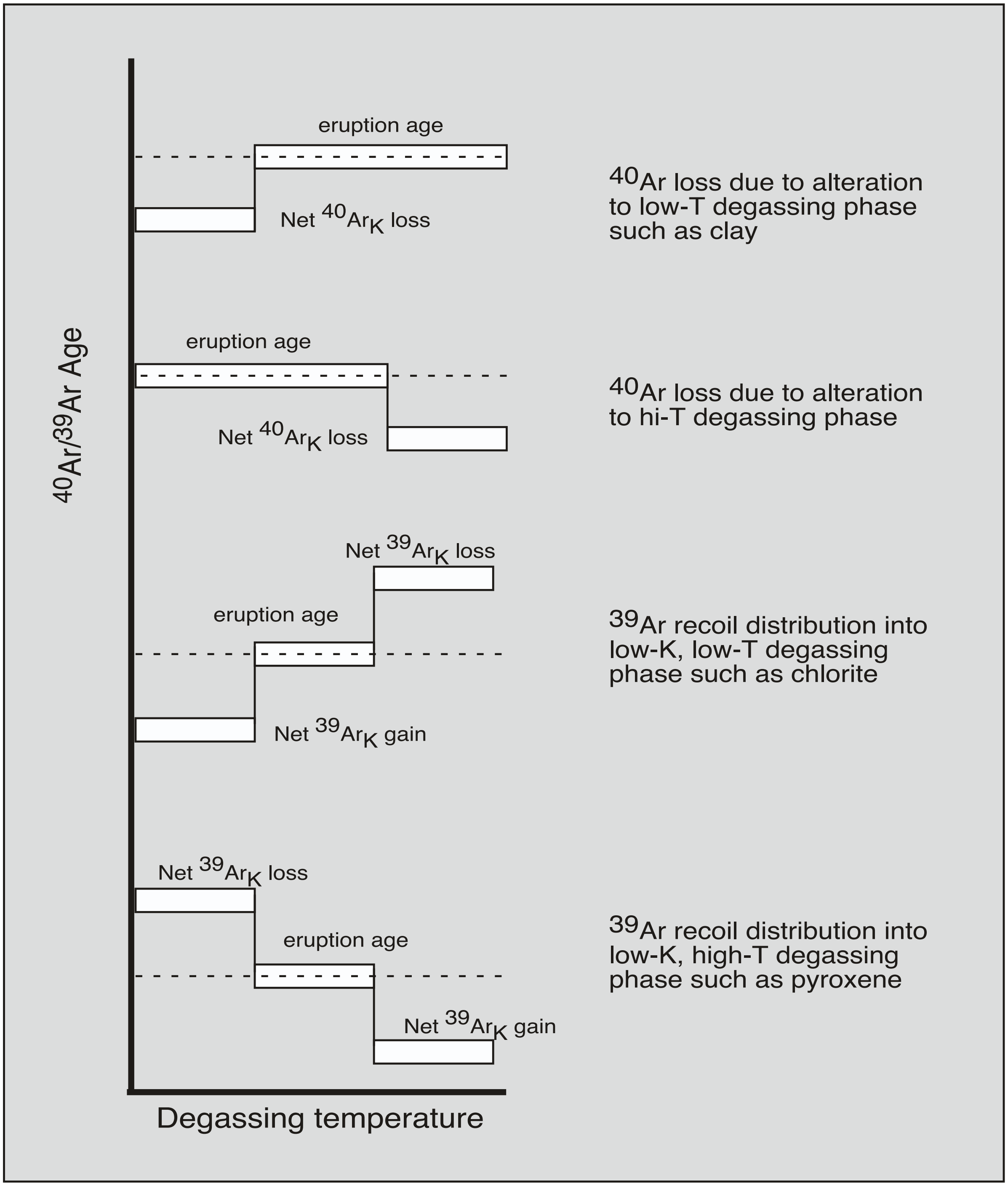


Figure 5. Cartoon showing potential effects of ^{39}Ar recoil and alteration induced ^{40}Ar loss on an otherwise flat age spectrum.

Table 1. Summary of $^{40}Ar/^{39}Ar$ results and analytical methods

Sample	Lab #	Irradiation	mineral	age analysis	steps/analyses	Age	±2σ	MSWD	comments
CM081513-1	63040	268	groundmass concentrate	bulk step-heat	7	23.66	0.05	1.00	
SIG22812-1	63043	268	groundmass concentrate	bulk step-heat	10	25.32	0.06	9.9	
PNW08913-1	63042	268	glass	bulk step-heat	13	28.13	0.78	2.14	
CM081413-2	62267	268	weathered basalt	bulk step-heat	11	23.47	0.05	-	very low confidence

Sample preparation and irradiation:

Minerals separated with standard heavy liquid, Franz Magnetic and hand-picking techniques.

Samples in NM-268 irradiated in a machined Aluminum tray for 8 hours in C.T. position, USGS TRIGA, Denver, Colorado.

Neutron flux monitor Fish Canyon Tuff sanidine (FC-2). Assigned age = 28.201 Ma (Kuiper et al., 2008).

Instrumentation:

Total fusion analyses performed on a Argus VI mass spectrometer on line with automated all-metal extraction system. System = Jan

Step-heat analyses performed on a Argus VI mass spectrometer on line with automated all-metal extraction system. System = Obama

Multi-collector configuration: 40Ar-H1, 39Ar-Ax, 38Ar-L1, 37Ar-L2, 36Ar-CDD

Flux monitors fused with a Photon Machines Inc. CO_2 laser. Groundmass concentrate and glass step-heated with a Photon Machine Inc. Diode laser.

Analytical parameters:

Sensitivity for the Argus VI with the Diode laser (step-heated samples) is 9.84e-17 moles/fA.

Sensitivty for the Argus VI with the CO2 laser (fused monitors)is 4.62 e-17 moles/fA.

Total system blank and background averaged 404, 2.45, 1.08, 1.18, 1.38 x 10^{-18} moles at masses 40, 39, 38, 37 and 36, respectively for the laser analyses.

J-factors determined by CO_2 laser-fusion of 6 single crystals from each of 8 radial positions around the irradiation tray.

Decay constants and isotopic abundances after Minn et al., (2000).

Table 2. $^{40}Ar/^{39}Ar$ 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)
	CM081513-1, gm, 8.04 mg, J=0.0018406±0.02%, D=1±0, NM-268J, Lab#=63040-01										
Xi	A	1	320.3	11.51	1069.8	0.160	0.044	1.6	0.5	17.23	2.26
X	B	1	52.32	4.933	154.3	0.783	0.10	13.6	3.2	23.93	0.36
X	C	1	18.73	3.879	39.71	2.63	0.13	39.0	11.9	24.48	0.10
	D	2	17.80	2.917	37.05	2.77	0.17	39.8	21.2	23.77	0.09
	E	2	14.21	3.092	24.94	2.86	0.17	49.9	30.7	23.78	0.07
	F	2	12.85	2.618	20.33	2.55	0.19	54.9	39.3	23.65	0.06
	G	3	12.32	3.057	18.68	5.03	0.17	57.2	56.1	23.62	0.05
	H	5	14.33	3.155	25.51	7.77	0.16	49.2	82.0	23.63	0.05
	I	7	12.47	3.826	19.35	3.69	0.13	56.6	94.3	23.68	0.05
	J	10	12.43	4.047	19.34	1.048	0.13	56.6	97.8	23.60	0.10
X	K	15	14.13	4.555	24.48	0.644	0.11	51.3	100.0	24.33	0.14
	Integrated age ± 2σ			n=11		29.9	0.15	K2O=0.78%		23.73	0.06
	Plateau ± 2σ		**steps D-J**	**n=7**	**MSWD=1.00**	**25.7**	**0.16 ±0.05**		**85.9**	**23.66**	**0.05**
	Isochron±2σ		steps B-K	n=10	MSWD=9.13		$^{40}Ar/^{36}Ar$=	298.4±3.9		23.50	0.33
	CM081413-2, gm, 6.85 mg, J=0.0018374±0.02%, D=1±0, NM-268J, Lab#=63041-01										
X	A	1	106.8	-0.1534	341.3	1.574	-	5.6	3.0	19.93	0.60
X	B	1	20.43	0.2828	44.49	6.35	1.8	35.7	15.1	24.39	0.09
X	C	1	10.23	0.4681	9.737	9.59	1.1	72.2	33.3	24.67	0.02
X	D	2	9.588	0.8276	7.964	6.72	0.62	76.1	46.1	24.37	0.02
X	E	2	10.15	0.9097	10.21	5.36	0.56	70.9	56.2	24.06	0.03
X	F	2	11.05	0.4745	13.45	4.49	1.1	64.3	64.8	23.75	0.04
X	G	3	12.44	0.6557	18.45	6.79	0.78	56.6	77.7	23.51	0.04
X	H	5	16.02	0.7426	31.68	6.74	0.69	41.9	90.5	22.45	0.06
X	I	7	19.03	0.9499	43.53	2.55	0.54	32.8	95.3	20.87	0.10
X	J	10	20.04	0.8775	47.99	1.601	0.58	29.6	98.4	19.83	0.13
X	K	15	19.71	1.369	47.28	0.853	0.37	29.6	100.0	19.56	0.17
	Integrated age ± 2σ			**n=11**		**52.6**	**0.81**	**K2O=1.61%**		**23.47**	**0.05**
	Isochron±2σ		steps A-K	n=11	MSWD=294.04		$^{40}Ar/^{36}Ar$=	281±10		24.70	0.07

	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)
	PNW080913-1, gm, 6.85 mg, J=0.0018376±0.02%, D=1±0, NM-268J, Lab#=63042-01										
X	A	1	700.5	11.93	2306.8	0.030	0.043	2.8	0.1	65.84	14.18
X	B	1	2586.8	-0.4410	8786.5	0.198	-	-0.4	0.4	-32.79	15.06
	C	1	1631.5	2.258	5500.3	0.598	0.23	0.4	1.6	21.33	9.01
	D	1	1294.2	1.177	4348.5	1.314	0.43	0.7	4.0	31.08	7.01
	E	2	801.4	2.123	2688.9	1.933	0.24	0.9	7.7	23.54	4.37
	F	2	717.7	2.331	2391.1	4.10	0.22	1.6	15.4	37.64	3.83
	G	2	755.1	1.937	2520.9	3.30	0.26	1.4	21.6	34.46	4.05
	H	2	525.0	2.113	1748.0	4.00	0.24	1.6	29.1	28.84	2.82
	I	3	408.6	2.029	1351.6	7.82	0.25	2.3	43.8	31.10	2.17
	J	4	333.0	2.174	1100.3	6.42	0.23	2.4	55.9	27.03	1.78
	K	5	402.0	2.191	1331.2	5.73	0.23	2.2	66.6	29.45	2.15
	L	6	259.6	1.939	850.9	5.32	0.26	3.2	76.6	27.73	1.38
	M	7	97.82	1.836	304.5	4.33	0.28	8.2	84.8	26.71	0.51
	N	10	92.20	1.996	284.1	3.82	0.26	9.1	92.0	28.04	0.48
	O	15	90.14	2.115	276.0	2.83	0.24	9.7	97.3	29.18	0.48
X	P	20	91.93	1.998	280.4	0.991	0.26	10.0	99.2	30.79	0.32
X	Q	25	91.21	1.979	277.8	0.446	0.26	10.2	100.0	30.95	0.48
	Integrated age ± 2σ		n=17			53.2	0.25	K2O=1.62%		29.4	1.4
	Plateau ± 2σ	**steps C-O**	**n=13**	**MSWD=2.14**		**51.5**	**0.25 ±0.11**		**96.9**	**28.13**	**0.78**
	Isochron±2σ	steps A-Q	n=17	MSWD=7.31			$^{40}Ar/^{36}Ar$= 295.3±0.8			29.8	1.5

	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)
	SIG22812-1, gm, 8.69 mg, J=0.0018412±0.02%, D=1±0, NM-268J, Lab#=63043-01										
	A	1	65.60	-0.1232	196.3	2.64	-	11.6	2.9	25.36	0.35
	B	1	23.90	0.4216	55.29	5.83	1.2	31.8	9.3	25.40	0.10
	C	1	14.20	0.3545	22.31	10.67	1.4	53.8	21.0	25.55	0.04
	D	2	11.48	0.4392	13.22	10.20	1.2	66.2	32.3	25.44	0.03
	E	2	10.77	0.3614	10.94	8.96	1.4	70.2	42.1	25.29	0.03
	F	2	10.72	0.4195	10.77	7.17	1.2	70.6	50.0	25.31	0.03
	G	3	10.58	0.7542	10.47	10.02	0.68	71.3	61.0	25.23	0.03
	H	5	10.16	1.383	9.237	14.84	0.37	74.2	77.3	25.23	0.02
	I	7	11.29	1.350	12.90	8.52	0.38	67.2	86.7	25.39	0.03
	J	10	12.26	1.437	16.15	7.15	0.36	62.0	94.6	25.44	0.04
X	K	15	12.89	1.747	18.10	4.94	0.29	59.6	100.0	25.72	0.05
	Integrated age ± 2σ		n=11			90.9	0.62	K2O=2.18%		25.37	0.03
	Plateau ± 2σ	**steps A-J**	**n=10**	**MSWD=9.90**		**86.004**	**0.883±0.879**		**94.6**	**25.32**	**0.06**
	Isochron±2σ	steps A-K	n=11	MSWD=14.32			$^{40}Ar/^{36}Ar$= 298±3			25.25	0.15

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)

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 interfering reaction or J uncertainties.
Integrated age calculated by summing isotopic measurements of all steps.
Integrated age error calculated by quadratically combining 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.
Plateau error is weighted error of Taylor (1982).
Decay constants and isotopic abundances after Min et al. (2000).
X symbol preceding sample ID denotes analyses excluded from plateau age calculations.
Weight percent K_2O calculated from ^{39}Ar signal, sample weight, and instrument sensitivity.
Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 28.201 Ma
Decay Constant (LambdaK (total) = 5.463e-10/a
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.000653 ± 0
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.0002633 ± 0
$(^{38}Ar/^{39}Ar)_K$ = 0.01077
$(^{40}Ar/^{39}Ar)_K$ = 0.007529 ± 0.000237