DR1. $^{40}Ar/^{39}Ar$ geochronology:

For:

A Conceptual Model for the Rapid Weathering of Tropical Ocean Islands: A Synthesis of Geochemistry and Geophysics, Kohala Peninsula, Hawaii, USA

Kimberly Sowards[2], Stephen Nelson[1], John McBride[2], Barry Bickmore[2], Matt Heizler[3], David Tingey[2], Kevin Rey[2], and John Yaede[2],

[2]Dept. of Geological Sciences, S-389 ESC, Brigham Young University, Provo Utah, 84602
[3]New Mexico Bureau of Geology & Mineral Resources, New Mexico Tech, 801 Leroy Place, Socorro NM 87801-4796

$^{40}Ar/^{39}Ar$ geochronology was conducted the Basal Flow sample (Table 1, 2). A pilot aliquot of sample (10 mg) along with a 2nd aliquot weighing approximately 100 mg were step-heated (data not shown, see below[1]) and yielded complex age spectra with variable apparent ages. These two initial analyses suggested that the sample could be heterogeneous with respect to age and therefore, ~10-15 mg individual aliquots were step-heated with low-resolution (2-step) age spectrum analysis (Figure 1; Table 1, 2). The individual age spectra overall yield concordant steps based on MSWD values that are acceptable for n-1 degrees of freedom (cf. Mahon, 1996). These data indicate that the sample is homogeneous at the 10-15 mg level and therefore all steps of the 11 aliquots are combined on the probability distribution diagram where 21 of the 22 steps yield a normal distribution with a weighted mean age of 0.303±0.015 Ma (Figure 2). This age is interpreted as the eruption age of the Basal Flow.

[1]The cause of the spurious age data from the pilot aliquots was later found to be a software error that incorrectly positioned the mass spectrometer magnet thus yielding inaccurate isotopic measurements and consequently inaccurate age determinations.

References cited.

Kuiper, K. F., Deino A., Hilgen, F. J., Krijgsman, W., Renne, P. R., and Wijbrans, J. R., 2008, Synchronizing the rock clocks of Earth history: Science 320, 500–504.

Mahon, K.I., 1996, The New "York" regression: Application of an improved statistical method to geochemistry: International Geology Review, 38, 293-303.

Min, K., Mundil, R., Renne, P. R. 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: Geochim. Cosmochim. Acta, 64, 73–98.

Steiger, R.H., and Jäger, E., 1977, Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology: Earth and Planet. Sci. Lett., 36, 359-362.

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

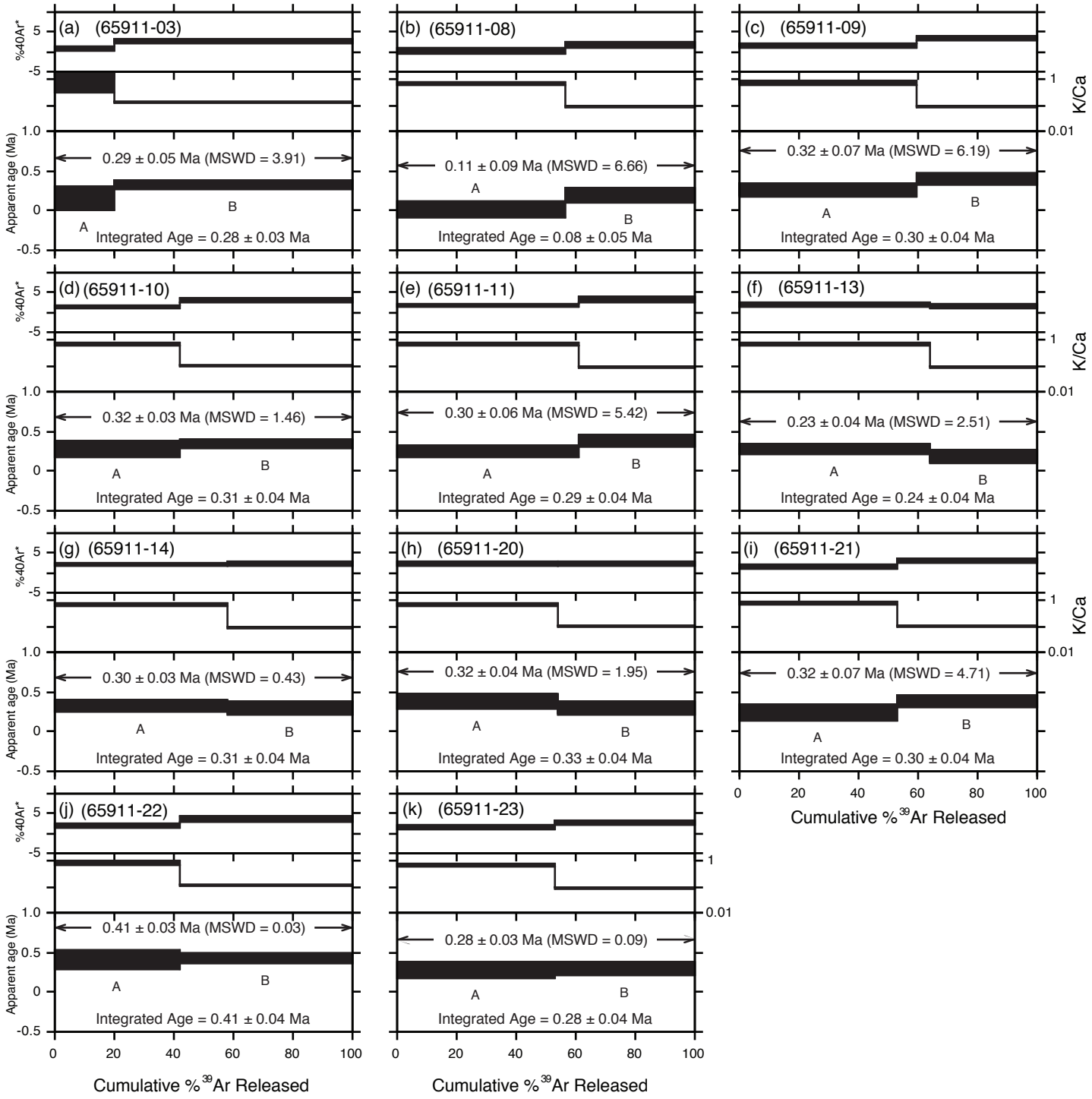

Figure 1. Two-step age spectra, K/Ca and radiogenic yield diagrams for 11 replicate splits of Basal Flow groundmass. Each aliquot yielded concordant increments with "plateau" ages ranging from 0.11±0.09 to 0.41±0.03 Ma with a dominate grouping at ~0.3 Ma. Combining all heating steps less the 'A' step of run 65911-08 yields a weighted mean age of 0.303±0.015 Ma.

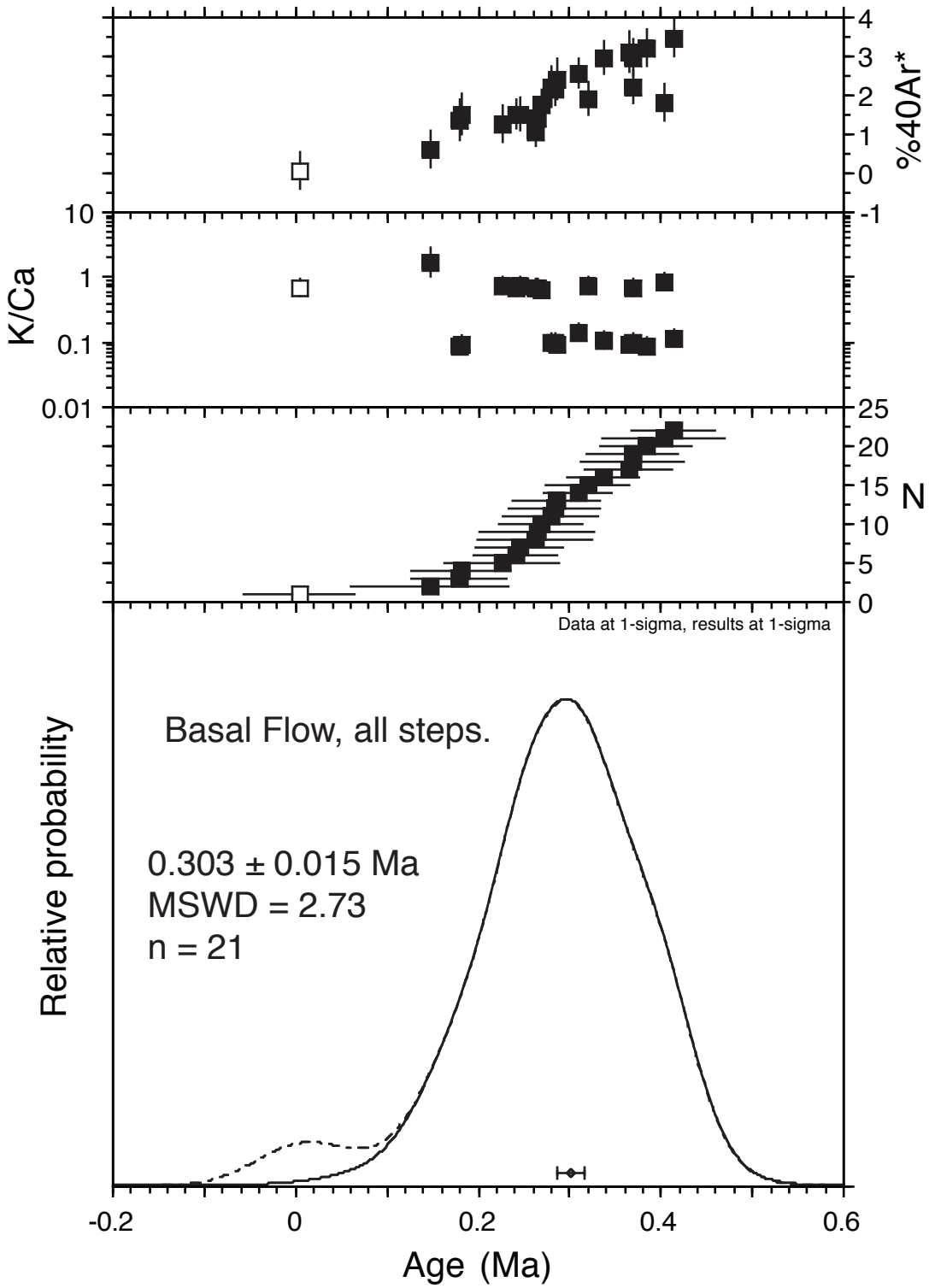

Figure 2. Age probability, K/Ca and radiogenic yield diagrams for Basal Flow groundmass 40Ar/39Ar data. These data are the individual heating steps of 11 aliquots that were each step-heated with two increments. All two-step spectra are concordant and 21 of 22 heating increments yield a normal distribution of ages with a weighted mean age of 303±0.15 Ma.

Table 1. Summary of ages and analytical methods.

Summary

Basal Flow Groundmass ages for individual replicate splits.

L#	Age	±	MSWD	%^{39}Ar	n
65911-03	0.278	0.052	3.9	100.0	2 of 2
65911-08	0.083	0.088	6.7	100.0	2 of 2
65911-09	0.303	0.070	6.2	100.0	2 of 2
65911-10	0.307	0.032	1.5	100.0	2 of 2
65911-11	0.291	0.062	5.4	100.0	2 of 2
65911-13	0.238	0.044	2.5	100.0	2 of 2
65911-14	0.306	0.027	0.43	100.0	2 of 2
65911-20	0.330	0.043	2.0	100.0	2 of 2
65911-21	0.295	0.069	4.7	100.0	2 of 2
65911-22	0.411	0.030	0.03	100.0	2 of 2
65911-23	0.276	0.031	0.09	100.0	2 of 2

Weighted mean age of combined steps = 0.303±0.015 Ma

L# = Lab number
n = number of steps for plateau
%^{39}Ar = percentage of total ^{39}Ar comprising the plateau steps.
All errors at 1σ

Analytical Methods and Instrumentation

Sample preparation and irradiation:
Groundmass prepared by crushing and hand-picking fragments devoid of phenocrysts.
Samples were loaded into machined Al discs and irradiated for 20 minutes, USGS TRIGA Reactor, Denver, CO
Neutron flux monitor Fish Canyon Tuff sanidine (FC-2). Assigned age = 28.201 Ma (Kuiper et al., 2008)

Instrumentation:
Thermo-Fisher Scientific Helix MC-Plus mass spectrometer on line with automated all-metal extraction system.
System = Felix
Multi-collector configuration: 40Ar-H2, 39Ar-H1, 38Ar-Ax, 37Ar-L1, 36Ar-L2
Amplification: H2, H1, L1 all 1E12 Ohm Faraday, AX 1e14 Ohm Faraday, L2 - CDD ion counter, deadtime 20 nS.
Laser Step-heating:
Samples step-heated (40 sec) with 75W Photon-Machines 810 nm diode laser
Reactive gases removed by 1 min reaction with 1 SAES GP-50 getter at 450°C.
Gas also exposed to cold finger operated at -140°C.

Analytical parameters:
Mass spectrometer sensitivity = 3E-16 mol/fA
Total system blank and background: 10±8%, 0.2±150%, 0.1±60%, 0.1±100%, 0.05±7%, x 10^{-17} moles for masses 40, 39, 38, 37, 36, respectively.
J factor determined to a precision of ~± 0.05% by CO_2 laser-fusion of 6 single crystals from each of 8 radial positions around the irradiation tray.
Correction factors for interfering nuclear reactions were determined using K-glass and CaF_2 and are as follows:
$(^{40}Ar/^{39}Ar)_K$ = 0.0088±0.0004; $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.0002755±0.000001; and $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007115±0.000009.

Table 2. Argon isotopic results.

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)
Basal Flow, Groundmass, J=0.0000826±0.05%, IC=1.031661±0.0012149, NM-292F, Lab#=65911-03, Argus VI										
A	1.0	169.4	0.3285	569.9	0.4	1.6	0.58	20.3	0.149	0.077
B	12.0	81.95	3.714	271.4	1.4	0.14	2.51	100.0	0.311	0.028
Integrated age ± 1σ			n=2		1.8	0.17			0.278	0.027
Plateau ± 1σ		steps A-B	n=2	MSWD=3.91	1.807	0.425±1.001		100.0	0.278	0.052
Basal Flow, Groundmass, 11.28 mg, J=0.0000826±0.05%, IC=1.052596±0.0019645, NM-292F, Lab#=65911-08, Argus VI										
A	1.5	113.9	0.7997	385.5	0.8	0.64	0.04	56.6	0.007	0.051
B	12.0	82.61	5.867	277.1	0.6	0.087	1.46	100.0	0.183	0.045
Integrated age ± 1σ			n=2		1.5	0.17	K2O=0.61%		0.083	0.035
Plateau ± 1σ		steps A-B	n=2	MSWD=6.66	1.484	0.399±0.390		100.0	0.083	0.088
Basal Flow, Groundmass, 10.22 mg, J=0.0000826±0.05%, IC=1.030422±0.0008115, NM-292F, Lab#=65911-09, Argus VI										
A	1.5	111.3	0.7401	371.2	0.8	0.69	1.47	59.8	0.247	0.040
B	12.0	80.62	6.330	265.9	0.5	0.081	3.15	100.0	0.386	0.039
Integrated age ± 1σ			n=2		1.3	0.17	K2O=0.60%		0.303	0.029
Plateau ± 1σ		steps A-B	n=2	MSWD=6.19	1.322	0.445±0.430		100.0	0.303	0.070
Basal Flow, Groundmass, 12.63 mg, J=0.0000826±0.05%, IC=1.030422±0.0008115, NM-292F, Lab#=65911-10, Argus VI										
A	1.5	169.0	0.7702	566.1	0.7	0.66	1.04	42.1	0.265	0.052
B	12.0	76.54	4.891	252.8	0.9	0.10	2.91	100.0	0.338	0.031
Integrated age ± 1σ			n=2		1.6	0.16	K2O=0.58%		0.307	0.028
Plateau ± 1σ		steps A-B	n=2	MSWD=1.46	1.565	0.339±0.395		100.0	0.307	0.032
Basal Flow, Groundmass, 10.59 mg, J=0.0000826±0.05%, IC=1.030422±0.0008115, NM-292F, Lab#=65911-11, Argus VI										
A	1.5	109.2	0.7898	364.4	0.9	0.65	1.47	61.1	0.243	0.037
B	12.0	78.20	5.817	258.1	0.5	0.088	3.08	100.0	0.366	0.038
Integrated age ± 1σ			n=2		1.4	0.19	K2O=0.62%		0.291	0.027
Plateau ± 1σ		steps A-B	n=2	MSWD=5.42	1.406	0.429±0.395		100.0	0.291	0.062
Basal Flow, Groundmass, 10.55 mg, J=0.0000826±0.05%, IC=1.02755±0.0008834, NM-292F, Lab#=65911-13, Argus VI										
A	1.5	104.3	0.8195	347.0	0.9	0.62	1.72	64.1	0.271	0.036
B	12.0	88.48	6.227	297.1	0.5	0.082	1.34	100.0	0.180	0.044
Integrated age ± 1σ			n=2		1.4	0.18	K2O=0.62%		0.238	0.028
Plateau ± 1σ		steps A-B	n=2	MSWD=2.51	1.399	0.428±0.382		100.0	0.238	0.044
Basal Flow, Groundmass, 10.84 mg, J=0.0000826±0.05%, IC=1.02755±0.0008834, NM-292F, Lab#=65911-14, Argus VI										
A	1.5	112.6	0.7456	374.2	0.9	0.68	1.88	58.2	0.321	0.037
B	12.0	89.37	5.590	297.6	0.6	0.091	2.10	100.0	0.285	0.040
Integrated age ± 1σ			n=2		1.5	0.18	K2O=0.63%		0.306	0.027
Plateau ± 1σ		steps A-B	n=2	MSWD=0.43	1.473	0.436±0.419		100.0	0.306	0.027
Basal Flow, Groundmass, 12.68 mg, J=0.0000826±0.05%, IC=1.028254±0.0020496, NM-292F, Lab#=65911-20, Argus VI										
A	1.5	113.2	0.7705	375.0	0.9	0.66	2.16	54.3	0.370	0.048
B	12.0	85.15	5.363	283.3	0.8	0.095	2.18	100.0	0.282	0.041
Integrated age ± 1σ			n=2		1.7	0.18	K2O=0.62%		0.330	0.032
Plateau ± 1σ		steps A-B	n=2	MSWD=1.95	1.695	0.403±0.401		100.0	0.330	0.043

Table 2. Argon isotopic results.

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)
Basal Flow, Groundmass, 13.04 mg, J=0.0000826±0.05%, IC=1.028254±0.0020496, NM-292F, Lab#=65911-21, Argus VI										
A	1.5	122.8	0.7168	410.6	0.9	0.71	1.23	53.0	0.228	0.052
B	12.0	83.83	5.506	276.9	0.8	0.093	2.91	100.0	0.371	0.040
Integrated age ± 1σ			n=2		1.7	0.17	K2O=0.62%		0.295	0.033
Plateau ± 1σ		steps A-B	n=2	MSWD=4.71	1.732	0.421±0.438		100.0	0.295	0.069
Basal Flow, Groundmass, 18.78 mg, J=0.0000826±0.05%, IC=1.028254±0.0020496, NM-292F, Lab#=65911-22, Argus VI										
A	1.5	148.8	0.6456	494.6	1.0	0.79	1.79	42.3	0.404	0.058
B	12.0	79.72	4.580	261.7	1.4	0.11	3.44	100.0	0.416	0.035
Integrated age ± 1σ			n=2		2.4	0.17	K2O=0.60%		0.411	0.032
Plateau ± 1σ		steps A-B	n=2	MSWD=0.03	2.414	0.399±0.480		100.0	0.411	0.030
Basal Flow, Groundmass, 14.36 mg, J=0.0000826±0.05%, IC=1.028254±0.0020496, NM-292F, Lab#=65911-23, Argus VI										
A	1.5	126.6	0.7598	422.7	1.0	0.67	1.39	53.2	0.267	0.052
B	12.0	78.75	5.715	261.7	0.9	0.089	2.40	100.0	0.287	0.038
Integrated age ± 1σ			n=2		1.8	0.17	K2O=0.59%		0.276	0.033
Plateau ± 1σ		steps A-B	n=2	MSWD=0.09	1.826	0.399±0.412		100.0	0.276	0.031

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 calculated by recombining isotopic measurements 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).
Isotopic abundances after Steiger and Jäger (1977).
# symbol preceding sample ID denotes analyses excluded from plateau age calculations.
IC = detector intercalibration: Measured 40Ar/36Ar divided by 295.5
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 (Kuiper et al., 2008)
Decay Constant (LambdaK (total)) = 5.463e-10/a (Min et al., 2000)
Lab#=65911-08A omitted from calculation of preferred eruption age.
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.0007115 ± 0.000009
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.0002755 ± 0.0000010
$(^{40}Ar/^{39}Ar)_K$ = 0.0088 ± 0.0004