$^{40}Ar/^{39}Ar$ Geochronology Results for the North Willow Canyon Quadrangle, Utah

by

Utah Geological Survey and

Nevada Isotope Geochronology 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 investigations funded or partially supported by the Utah Geological Survey (UGS). Table 1 provides sample numbers and locations for the age data. The references listed in table 1 generally provide additional information such as sample location, geologic setting, and significance or interpretation of the samples in the context of the area where they were collected. This report was prepared by the Nevada Isotope Geochronology Laboratory (NIGL) 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	Latitude (N) WGS84	Longitude (W) WGS84	Reference
T24	North Willow Canyon	40.55543	-112.59221	Clark and others, in prep.
T30	North Willow Canyon	40.54427	-112.57715	Clark and others, in prep.

ACKNOWLEDGMENTS

Geologic mapping of the Tooele 30′ x 60′ quadrangle was funded by the UGS and U.S. Geological Survey, National Cooperative Geologic Mapping Program through USGS STATEMAP award numbers G13AC00169, G14AC00214, G15AC00249, and G16AC00191.

REFERENCES

Clark, D.L., Oviatt, C.G., and Dinter, D.A., in preparation, Interim geologic map of the Tooele 30′ x 60′ quadrangle, Tooele, Salt Lake, and Davis Counties, Utah, year 4: Utah Geological Survey Open-File Report, GIS data, scale 1:62,500.

The Nevada Isotope Geochronology Laboratory

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June 25, 2015
Project No. 400

Nevada Isotope Geochronology Laboratory - Description and Procedures

Samples analyzed by the $^{40}Ar/^{39}Ar$ method at the University of Nevada Las Vegas were wrapped in Al foil and stacked in 6 mm inside diameter sealed fused silica tubes. Individual packets averaged 3 mm thick and neutron fluence monitors (FC-2, Fish Canyon Tuff sanidine) were placed every 5-10 mm along the tube. Synthetic K-glass and optical grade CaF_2 were included in the irradiation packages to monitor neutron induced argon interferences from K and Ca. Loaded tubes were packed in an Al container for irradiation. Samples irradiated at the U. S. Geological Survey TRIGA Reactor, Denver, CO were in-core for 7 hours in the In-Core Irradiation Tube (ICIT) of the 1 MW TRIGA type reactor. Correction factors for interfering neutron reactions on K and Ca were determined by repeated analysis of K-glass and CaF_2 fragments. Measured $(^{40}Ar/^{39}Ar)_K$ values were 3.32 (± 12.05%) x 10^{-2}. Ca correction factors were $(^{36}Ar/^{37}Ar)_{Ca}$ = 2.45 (± 8.75%) x 10^{-4} and $(^{39}Ar/^{37}Ar)_{Ca}$ = 7.20 (± 3.27%) x 10^{-4}. J factors were determined by fusion of 4-8 individual crystals of neutron fluence monitors which gave reproducibility's of 0.64% to 0.75% at each standard position. Variation in neutron fluence along the 100 mm length of the irradiation tubes was <4%. Matlab curve fit was used to determine J and uncertainty in J at each standard position. No significant neutron fluence gradients were present within individual packets of crystals as indicated by the excellent reproducibility of the single crystal fluence monitor fusions.

Irradiated FC-2 sanidine standards together with CaF_2 and K-glass fragments were placed in a Cu sample tray in a high vacuum extraction line and were fused using a 20 W CO_2 laser. Sample viewing during laser fusion was by a video camera system and positioning was via a motorized sample stage. Samples analyzed by the furnace step heating method utilized a double vacuum resistance furnace similar to the Staudacher et al. (1978) design. Reactive gases were removed by three GP-50 SAES getters prior to being admitted to a MAP 215-50 mass spectrometer by expansion. The relative volumes of the extraction line and mass spectrometer allow 80% of the gas to be admitted to the mass spectrometer for laser fusion analyses and 76% for furnace heating analyses. Peak intensities were measured using a Balzers electron multiplier by peak hopping through 7 cycles; initial peak heights were determined by linear regression to the time of gas admission. Mass spectrometer discrimination and sensitivity was monitored by repeated analysis of atmospheric argon aliquots from an on-line pipette system. Measured $^{40}Ar/^{36}Ar$ ratios were 282.64 ± 1.45 % during this work, thus a discrimination correction of 1.01457 (4 AMU) was applied to measured isotope ratios. The sensitivity of the mass spectrometer was ~6 x 10^{-17} mol mV^{-1} with the multiplier operated at a gain of 36 over the Faraday. Line blanks averaged 2.32 mV for mass 40 and 0.03 mV for mass 36 for laser fusion analyses and 3.90 mV for mass 40 and 0.02 mV for mass 36 for furnace heating analyses. Discrimination, sensitivity, and blanks were relatively constant over the period of data collection. Computer automated operation of the sample stage, laser, extraction line and mass spectrometer as well as final data reduction and age calculations were done using LabSPEC software written by B. Idleman (Lehigh University). An age of 28.02 Ma (Renne et al., 1998) was used for the Fish Canyon Tuff sanidine fluence monitor in calculating ages for samples.

For $^{40}Ar/^{39}Ar$ analyses a plateau segment consists of 3 or more contiguous gas fractions having analytically indistinguishable ages (i.e. all plateau steps overlap in age at $\pm 2\sigma$ analytical error) and comprising a significant portion of the total gas released (typically >50%). Total gas (integrated) ages are calculated by weighting by the amount of ^{39}Ar released, whereas plateau ages are weighted by the inverse of the variance. For each sample inverse isochron diagrams are examined to check for the effects of excess argon. Reliable isochrons are based on the MSWD criteria of Wendt and Carl (1991) and, as for plateaus, must comprise contiguous steps and a significant fraction of the total gas released. All analytical data are reported at the confidence level of 1σ (standard deviation).

Renne, P.R., Swisher, C.C, Deino, A.L., Karner, D.B., Owens, T.L., DePaolo, D.J., 1998, Intercalibration of standards, absolute ages and uncertainties in $^{40}Ar/^{39}Ar$ dating, *Chemical Geology*, v. 145, p. 117-152.

Staudacher, T.H., Jessberger, E.K., Dorflinger, D., and Kiko, J., A refined ultrahigh-vacuum furnace for rare gas analysis, *J. Phys. E: Sci. Instrum*., *11*, 781-784, 1978.

Wendt, I., and Carl, C., 1991, The statistical distribution of the mean squared weighted deviation, *Chemical Geology*, v. 86, p. 275-285.

Note: Check your samples data sheets for the discrimination, and fluence monitor values used for each sample.

Nevada Isotope Geochronology Laboratory - Sample Descriptions – Clark UT DNR

General Comments: Your samples were run as conventional furnace step heating analyses on bulk basalt groundmass or amphibole mineral separates, as well as single crystal laser fusion analyses on sanidine. All data are reported at the 1σ uncertainty level, unless noted otherwise.

Furnace step heating analyses produce what is referred to as an apparent age spectrum. The "apparent" derives from the fact that ages on an age spectrum plot are calculated assuming that the non-radiogenic argon (often referred to as trapped, or initial argon) is atmospheric in isotopic composition ($^{40}Ar/^{36}Ar = 295.5$). If there is excess argon in the sample ($^{40}Ar/^{36}Ar > 295.5$) then these apparent ages will be older than the actual age of the sample. U-shaped age spectra are commonly associated with excess argon (the first few and final few steps often have lower radiogenic yields, thus apparent ages calculated for these steps are effected more by any excess argon present). Excess argon can also produce generally discordant age spectra. This is often verified by isochron analysis, which utilizes the analytical data generated during the step heating run, but makes no assumption regarding the composition of the non-radiogenic argon. Thus, isochrons can verify (or rule out) excess argon, and isochron ages are usually preferred if a statistically valid regression is obtained (as evidenced by the MSWD, mean square of weighted deviates, a measure of the coherence of the population). If such a sample yields no reliable isochron, the best estimate of the age is that the minimum on the age spectrum is a maximum age for the sample (it could be affected by excess argon, the extent depending on the radiogenic yield). $^{40}Ar/^{39}Ar$ total gas ages are equivalent to K/Ar ages. Plateau ages are sometimes found, these are simply a segment of the age spectrum which consists of 3 or more steps, comprising >50% of the total gas released, which overlap in age at the ±2σ analytical error level (not including the J-factor error, which is common to all steps). However, in general an isochron age is the best estimate of the age of a sample, even if a plateau age is obtained.

T24 Biotite

This sample produced a nearly ideal flat and concordant step heating age spectrum. The total gas age (equivalent to a conventional K/Ar age) for this sample is 39.58 ± 0.44 Ma. Steps 3-13 (98% of the ^{39}Ar released) define an indistinguishable plateau age of 39.68 ± 0.50 Ma. There is no isochron defined by these data. Ca/K ratios are low and consistent with analysis of a homogeneous biotite mineral separate, and radiogenic yields are high and thus do not indicate recent alteration. The plateau age should be considered the most reliable.

T30 Biotite

Aside from lower ages in the initial and final steps, this sample produced a generally concordant step heating age spectrum, although not as ideal as T24 described above. The total gas age is 40.20 ± 0.47 Ma. Steps 2-9 (84% of the ^{39}Ar released) define a statistically indistinguishable plateau age of 41.30 ± 0.60 Ma. There is no isochron defined by these data. Ca/K ratios are low and consistent with analysis of a homogeneous biotite mineral separate, and radiogenic yields are high and thus do not indicate recent alteration. The plateau age should be considered the most reliable.

The interpretations given above are based simply on inspection of the laboratory data. Geologic relationships, which are unknown to us, are not considered. Please feel free to call or email (best way to contact me terry.spell@unlv.edu) if you have questions.

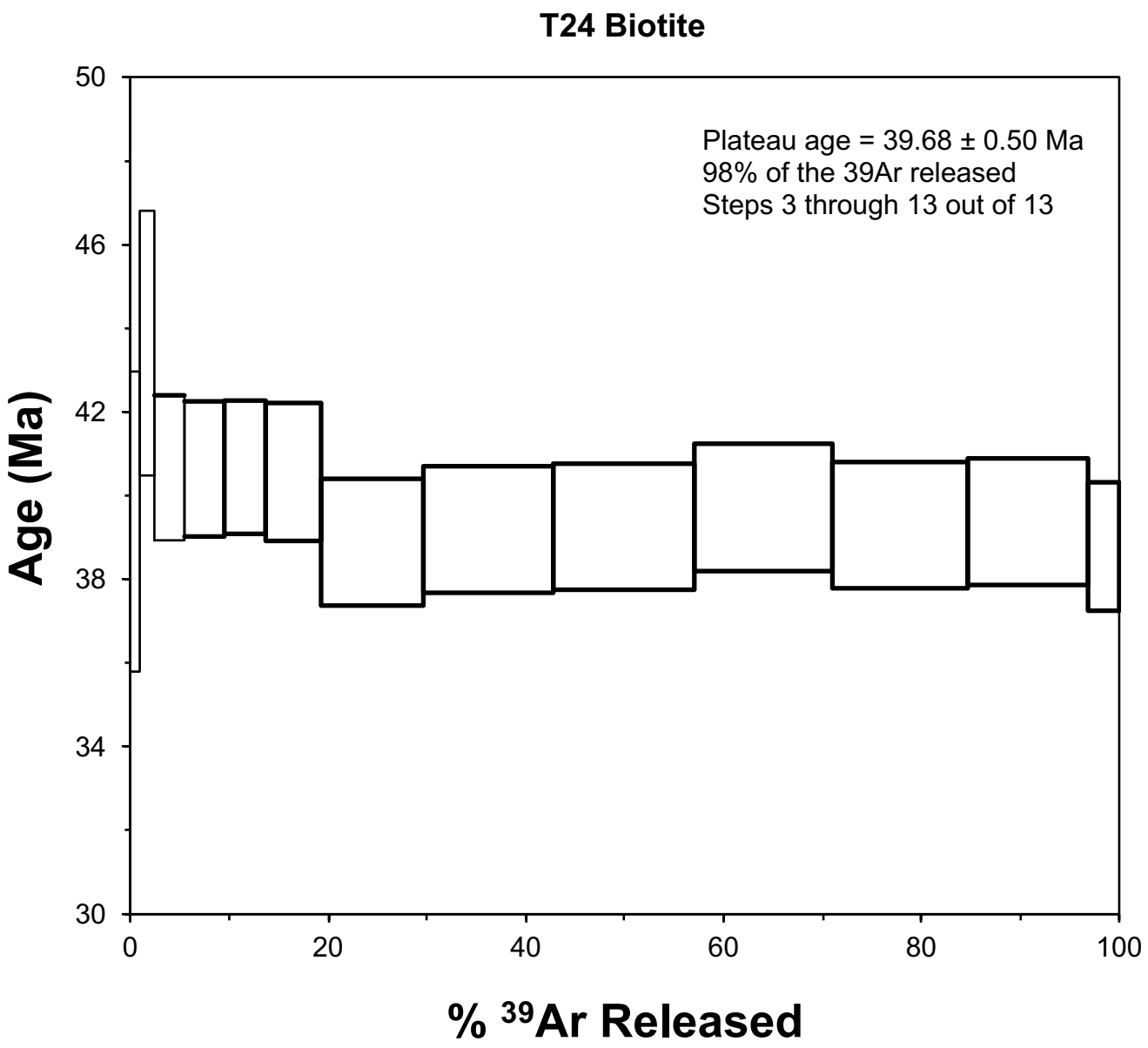
APPENDIX

Analytical data for samples T24 biotite and T30 biotite

Clark-UT DNR, T24, Biotite, 17.67 mg, J = 0.001702 ± 0.58%

4 amu discrimination = 1.0457 ± 1.45%, 40/39K = 0.0332 ± 12.05%, 36/37Ca = 0.000245 ± 8.75%, 39/37Ca = 0.000720 ± 3.27%

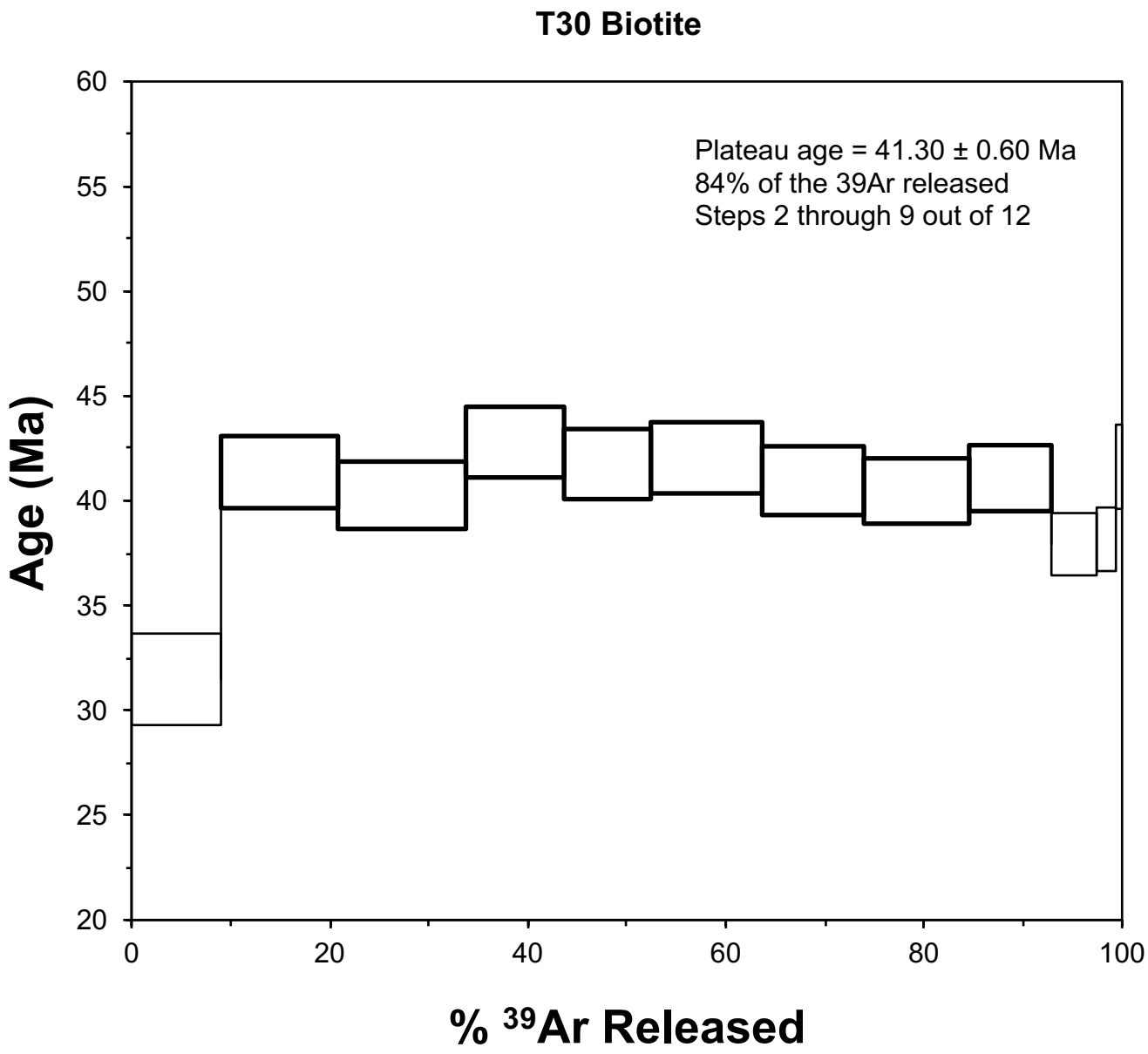
step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	650	12	1.001	0.870	0.424	10.986	422.001	33.6	1.0	0.617019314	12.966108	39.38	1.79
2	725	12	1.019	0.739	0.585	16.834	533.265	45.5	1.5	0.342010023	14.386779	43.64	1.58
3	790	12	0.347	0.425	1.114	34.599	555.721	83.0	3.0	0.095691556	13.393655	40.66	0.87
4	850	12	0.173	0.358	1.614	45.895	656.251	93.1	4.0	0.060766068	13.384662	40.64	0.81
5	905	12	0.151	0.366	1.711	47.563	672.829	94.2	4.2	0.059945311	13.398319	40.68	0.80
6	960	12	0.130	0.419	2.263	63.717	879.187	96.2	5.6	0.051227232	13.360680	40.57	0.82
7	1015	12	0.243	0.605	4.142	117.676	1561.16	95.7	10.3	0.040050519	12.802029	38.89	0.76
8	1055	12	0.210	0.622	5.327	149.404	1969.69	97.0	13.1	0.032431556	12.902867	39.19	0.76
9	1095	12	0.229	0.811	5.798	162.335	2144.11	97.0	14.3	0.038917883	12.925167	39.26	0.75
10	1125	12	0.236	0.950	5.729	158.826	2125.14	96.9	14.0	0.046595456	13.078626	39.72	0.76
11	1155	12	0.243	1.669	5.841	155.673	2065.14	96.7	13.7	0.083519833	12.937482	39.29	0.75
12	1210	12	0.234	3.911	5.914	138.367	1843.68	96.5	12.2	0.22020159	12.965109	39.38	0.76
13	1400	12	0.151	0.724	1.462	35.896	496.145	92.1	3.2	0.157126376	12.767754	38.78	0.77
							Cumulative %39Ar rlsd =		100.0		Total gas age =	39.58	0.44
note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma											Plateau age =	39.68	0.50
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)											(steps 3-13)		
											No isochron		


T24 Biotite
Plateau age = 39.68 ± 0.50 Ma
98% of the 39Ar released
Steps 3 through 13 out of 13
Age (Ma)
50
46
42
38
34
30
0
20
40
60
80
100
% 39Ar Released

Clark-UT DNR, T30, Biotite, 14.20 mg, J = 0.001671 ± 0.48%

4 amu discrimination = 1.0457 ± 1.45%, 40/39K = 0.0332 ± 12.05%, 36/37Ca = 0.000245 ± 8.75%, 39/37Ca = 0.000720 ± 3.27%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	700	12	3.542	0.619	3.090	77.183	1805.73	44.6	9.0	0.063756308	10.534445	31.48	1.09
2	790	12	0.910	0.487	3.264	100.871	1643.80	84.5	11.8	0.038380741	13.880352	41.37	0.86
3	850	12	0.572	0.442	3.520	110.456	1639.35	90.2	12.9	0.0318114	13.505756	40.26	0.80
4	905	12	0.337	0.302	2.618	84.702	1311.39	92.1	9.9	0.028344097	14.366242	42.80	0.84
5	960	12	0.455	0.329	2.344	74.852	1166.72	89.2	8.8	0.034941596	14.010360	41.75	0.84
6	1015	12	0.664	0.470	3.128	96.087	1530.47	87.9	11.2	0.038885171	14.111874	42.05	0.85
7	1055	12	0.445	0.598	2.951	87.773	1320.05	90.6	10.3	0.054161802	13.741888	40.96	0.82
8	1095	12	0.291	1.281	3.129	90.828	1302.95	93.9	10.6	0.112121815	13.574279	40.46	0.78
9	1125	12	0.175	1.182	2.374	70.975	1017.49	95.5	8.3	0.132396216	13.782270	41.08	0.79
10	1155	12	0.095	0.730	1.385	39.062	528.348	95.5	4.6	0.148571012	12.713889	37.93	0.74
11	1210	12	0.075	1.054	0.761	16.591	230.482	92.6	1.9	0.505105633	12.793843	38.16	0.76
12	1400	12	0.115	0.581	0.273	5.318	104.250	73.4	0.6	0.868743145	13.966908	41.62	1.01
							Cumulative %39Ar rlsd =		100.0		Total gas age =	40.20	0.47
note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma											Plateau age =	41.30	0.60
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)											(steps 2-9)		
											No isochron		


T30 Biotite
Plateau age = 41.30 ± 0.60 Ma
84% of the 39Ar released
Steps 2 through 9 out of 12
Age (Ma)
60
55
50
45
40
35
30
25
20
0
20
40
60
80
100
% 39Ar Released