$^{40}Ar/^{39}Ar$ Geochronology Results for the Furner Ridge and Tintic Mountain Quadrangles, Utah

by
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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 the sample numbers and locations. Table 2 provides the rock names and map units from which the samples were collected; see the map references for additional information such as 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)	Longitude (W)
TM111907-1	Tintic Mountain	39° 48' 52.7"	112° 05' 55.3"
TM111907-2	Tintic Mountain	39° 48' 56.0"	112° 05' 34.1"
TM111907-3	Tintic Mountain	39° 49' 07.8"	112° 04' 26.8"
TM111907-4	Tintic Mountain	39° 49' 00.1"	112° 04' 52.8"
TM112007-1	Tintic Mountain	39° 47' 37.7"	112° 04' 54.6"
TM112007-3	Tintic Mountain	39° 47' 26.3"	112° 05' 11.3"
TM112007-4	Tintic Mountain	39° 47' 38.7"	112° 06' 56.9"
FR112007-1	Furner Ridge	39° 39' 31.0"	112° 04' 13.8"

Location data based on NAD27.

Table 2. Rocks names and map units.

Sample #	Rock Name	Map Unit	Map Unit Reference
TM111907-1	Latite	Flows of Rattlesnake Peak	Keith and others, 2009
TM111907-2	Rhyolite	Intrusions of Keystone Springs	Keith and others, 2009
TM111907-3	Latite	Latite of Rock Canyon	Keith and others, 2009
TM111907-4	Shoshonite	Shoshonite of Buckhorn Mountain	Keith and others, 2009
TM112007-1	Latite	Plagioclase-rich lava flows	Keith and others, 2009
TM112007-3	Shoshonite	Latite of Dry Herd Canyon	Keith and others, 2009
TM112007-4	Shoshonite-K Trachybasalt	Flows of Rattlesnake Peak	Keith and others, 2009
FR112007-1	Rhyolite	Fernow Quartz Latite	Morris, 1977

Rock names based on total alkali-silica classification diagram of Le Bas and others (1986).
Clark (2009) presents geochemical data for these samples.

DISCLAIMER

This open-file release is intended as a data repository for information gathered in support of various UGS projects. The data are presented as received from the NIGL and do not necessarily conform to UGS technical, editorial, or policy standards; this should be considered by an individual or group planning to take action based on the contents of this report. The Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding the suitability of this product for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

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LABORATORY DESCRIPTION AND PROCEDURES

Sample Irradiations

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 Oregon State University Radiation Center 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 5.09 (± 1.09%) x 10^{-2}. Ca correction factors were $(^{36}Ar/^{37}Ar)_{Ca}$ = 2.68 (± 0.03%) x 10^{-4} and $(^{39}Ar/^{37}Ar)_{Ca}$ = 6.66 (± 0.01%) x 10^{-4}. J factors were determined by fusion of 4-8 individual crystals of neutron fluence monitors which gave reproducibility's of 0.25% to 0.82% at each standard position. Variation in neutron flux along the 100 mm length of the irradiation tubes was <4%. An error in J was used in age calculations. No significant neutron flux gradients were present within individual packets of crystals as indicated by the excellent reproducibility of the single crystal flux monitor fusions.

Fluence Monitor

Note that the fluence monitor used is Fish Canyon Tuff sanidine, with an assumed age of 28.02 Ma. In order to compare this age to an analysis of the same sample using a different fluence monitor, or a different age for Fish Canyon sanidine, an adjustment must be made based on intercalibrations (different monitors) or age (different age for Fish Canyon sanidine).

Analytical Procedures

Irradiated crystals 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 274.85 ± 0.88% during this work, thus a discrimination correction of 1.0753 (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 1.7 mV for mass 40 and 0.09 mV for mass 36 for laser fusion analyses and 12.76 mV for mass 40 and 0.66 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., 1988) was used for the Fish Canyon Tuff sanidine flux 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 1 σ (standard deviation).

RESULTS

General Comments:

Most of the samples were run as conventional furnace step heating analyses. This type of sample run produces 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 ($^{40}Ar/^{36}Ar = 295.5$). An ideal age spectrum is flat, with concordant (identical within analytical uncertainty) ages throughout the gas release. If there is excess argon in the sample ($^{40}Ar/^{36}Ar > 295.5$) then these ages will be older than the actual age of the sample. U-shaped (or discordant in general) 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), and 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 value). 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). $^{40}Ar/^{39}Ar$ 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 $\pm 2\ \sigma$ analytical uncertainty level (not including the J-factor error, which is common to all steps). Such ages are preferred to total gas or maximum ages if obtained. However, in general an isochron age is the best estimate of the age of a sample, even if a plateau age is obtained. Plateau ages for samples with excess argon can still be anomalously old.

Samples analyzed by laser fusion of single crystals are treated statistically. Outliers which are beyond the 2σ level of the population are sequentially omitted until a coherent population is defined. MSWD criteria are used. These data are also plotted on an isochron plot, subject to statistical MSWD “goodness of fit” criteria as well.

TM111907-1 Groundmass

The age spectrum for this sample is discordant, with younger ages for the initial heating steps, rising to a plateau segment at ~34 Ma. A plateau age is defined by steps 3-10 (70% of the ^{39}Ar released) and yields an age of 34.3 ± 0.4 Ma. The total gas age is 32.7 ± 0.4 Ma, and is slightly younger than the plateau age due to the lower initial step ages. The plateau steps (3-10) define a statistically valid isochron, which yields an age of 33.5 ± 1.2 Ma, and indicates that within uncertainty this sample contains initial argon of atmospheric isotopic composition. Note that the isochron intercepts (age and initial argon) in this case is relatively poorly constrained due to the clustering of the data near the center of the diagram. The observation that the plateau and isochron ages overlap within uncertainty, and that no excess argon is indicated, suggest that the plateau age should be used for this sample. This sample should be considered reliable.

TM111907-2 Sanidine

This sample was analyzed by the single-crystal laser-fusion method. A total of 15 crystals were analyzed. These all defined a tightly coherent group, with a mean age of 35.6 ± 0.3 Ma. There are no statistical outliers in this population. A weighted mean defines an indistinguishable age of 35.6 ± 0.09 Ma. All 15 analyses define an isochron, which yields an identical age of 35.6 ± 0.2 Ma. The isochron suggests that initial argon is atmospheric within uncertainty. As for the biotite discussed above, the coherence of the population, and agreement between different age calculations indicates that this is a highly reliable sample. The isochron age should be used for this sample.

TM111907-3 Biotite

The age spectrum for this sample is very nearly perfectly flat and concordant. Initial steps (<10% of the ^{39}Ar released) are slightly older than the majority of the steps. A plateau age is defined by steps 6-16 (94% of the ^{39}Ar released) and yields an age of 34.6 ± 0.2 Ma. The total gas age is 34.7 ± 0.2 Ma, and is equivalent to a conventional K-Ar age. The plateau steps define a statistically valid isochron, which defines an age of 34.7 ± 0.3 Ma, and indicates that the initial argon composition is atmospheric. Thus, all 3 methods of calculating an age agree quite well. The isochron age should be used for this sample. Overall, this is a nearly ideal sample, and it should be considered highly reliable.

The initial, slightly higher age, steps are likely the result of ^{39}Ar recoil during irradiation. Minerals such as micas, with high surface/volume ratios, are expected to lose small amounts of ^{39}Ar produced during irradiation. This loss occurs in the surficial layer, which is the first to outgas during laboratory step heating. Thus, initial steps have anomalously high $^{40}Ar/^{39}Ar$ ratios and calculated ages. Note that these steps were not included in the plateau and isochron age calculations.

TM111907-4 Groundmass

This sample is also very similar to TM112007-3. The age spectrum is nearly ideally flat, with the exception of slightly higher initial step ages. A plateau age is defined by steps 4-15 (88% of the ^{39}Ar released) and yields an age of 34.3 ± 0.3 Ma. The total gas age is 35.2 ± 0.3 Ma, and is slightly older than the plateau age due to the higher initial step ages. All steps (1-15) define a statistically valid isochron, which yields an age of 33.8 ± 0.2 Ma, and indicates that this sample contains a small amount of excess argon (initial $^{40}Ar/^{36}Ar = 308 \pm 2$). The isochron age should be used for this sample. This sample should be considered highly reliable.

TM112007-1 Plagioclase

This sample is very similar to TM112007-3 plagioclase. The age spectrum is slightly more discordant, and the isochron does not indicate the presence of excess argon. A plateau age is defined by steps 7-11 (60% of the ^{39}Ar released) and yields an age of 35.2 ± 0.4 Ma. The total gas age is 36.8 ± 0.3 Ma, and is slightly older than the plateau age due to the higher initial step ages. Steps 7-10 define a statistically valid isochron, which yields an age of 35.1 ± 0.3 Ma, and indicates that this sample contains initial argon of atmospheric composition. The isochron age should be used for this sample. The concordance of the plateau and isochron ages indicates that this sample should be considered reliable.

TM112007-3 Plagioclase

This sample is very similar to TM111907-4 groundmass. The age spectrum for this sample is almost perfectly flat and concordant. A plateau age is defined by steps 5-12 (95% of the ^{39}Ar released) and yields an age of 35.4 ± 0.3

Ma. The total gas age is 35.6 ± 0.3 Ma, and is indistinguishable. Steps 2-11 define a statistically valid isochron, which yields an age of 35.1 ± 0.2 Ma, and indicates that this sample contains a small amount of excess argon (initial $^{40}Ar/^{36}Ar$ = 309 ± 2). Although all 3 methods of calculating an age agree within 2σ analytical uncertainty the isochron age should be used for this sample. Note that the isochron is very well defined, with a wide spread in data points, and is defined by a large portion of the steps (85% ^{39}Ar released). Overall, this is a nearly ideal sample, and it should be considered highly reliable.

TM112007-4 Groundmass

The age spectrum is discordant, with young ages in the initial heating steps (starting at ~12 Ma), rising to a ages of ~30 Ma for steps 8-13, and ending with the final 2 steps being slightly older. No plateau age is defined by these data. The total gas age is 26.6 ± 0.2 Ma. Steps 7-13 (74% of the ^{39}Ar released) define a statistically valid isochron, which yields an age of 34.3 ± 0.7 Ma and indicates that the initial $^{40}Ar/^{36}Ar$ ratio is 189. This is significantly below the atmospheric value of 295.5 and is clearly spurious. Note that the isochron, although statistically valid, is defined by data points that cluster very tightly together. Thus, the isochron is poorly defined and should be considered unreliable. The young initial ages (first ~40% gas released, steps 1-7) may be the result of argon loss. This can be caused by weathering and alteration, producing fine grained secondary minerals, which degas preferentially during the low temperature steps. Evaluation of a thin section may confirm this, if the alteration is visible using the petrographic microscope. Following this reasoning, the most reliable age for this sample is likely represented by the average age of steps 8-13, which define the generally concordant part of the age spectrum. This yields an age of 29.4 ± 0.5 Ma. This sample should be considered of relatively poor reliability.

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APPENDIX

Analytical data

Clark-UT Dept. Nat'l. Res., TM111907-1, groundmass, 26.80 mg, J = 0.0021 ± 0.46%

4 amu discrimination = 1.0753 ± 0.88%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	650	12	42.465	24.958	20.377	356.819	14004.461	16.7	13.1	0.5353421	6.657278	24.73	1.33
2	740	12	10.881	27.429	10.862	312.609	5500.81	45.8	11.4	0.671576	8.188563	30.37	0.64
3	800	12	8.095	30.395	8.189	309.297	4926.44	55.1	11.3	0.7521826	8.909433	33.02	0.59
4	850	12	6.320	28.937	6.538	299.817	4444.3	61.2	11.0	0.7387413	9.210993	34.12	0.56
5	900	12	5.388	25.979	5.566	273.282	3988.28	63.2	10.0	0.7276209	9.363342	34.68	0.55
6	950	12	4.591	20.622	4.270	203.332	3101.45	59.8	7.4	0.7762916	9.259500	34.30	0.57
7	1000	12	3.761	15.637	3.325	148.899	2373.04	57.1	5.5	0.8038314	9.235791	34.21	0.60
8	1050	12	6.187	18.257	4.686	186.086	3387.9	50.2	6.8	0.7509524	9.286208	34.40	0.66
9	1100	12	9.613	24.577	6.652	245.021	4924.29	46.6	9.0	0.767758	9.516556	35.24	0.72
10	1150	12	8.493	29.853	6.005	244.619	4611.37	49.6	9.0	0.9341519	9.502923	35.19	0.69
11	1200	12	2.877	20.633	2.320	98.745	1708.85	54.7	3.6	1.5997445	9.591817	35.52	0.64
12	1270	12	1.354	16.101	1.116	42.765	750.845	52.9	1.6	2.8835604	9.356528	34.66	0.64
13	1400	12	0.413	5.822	0.327	9.893	183.934	49.1	0.4	4.509341	8.792890	32.59	0.64
							Cumulative %39Ar rlsd =		100.0		Total gas age =	32.68	0.38

note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma	Plateau age =	34.33	0.44
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)	(steps 3-10)		
	Isochron age =	33.50	1.20
	(steps 3-10)		

Clark-UT Dept. Nat'l Res., TM111907-2, single crystal sanidine, J = 0.0021 ± 0.48%

4 amu discrimination = 1.0783 ± 0.60%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

Crystal	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	1600	6	0.247	0.668	1.940	149.389	1453.37	96.5	0.065384	9.547872	35.02	0.40
2	1600	6	0.519	0.545	1.479	110.485	1181.4	89.6	0.072129	9.735103	35.70	0.35
3	1600	6	0.297	0.557	1.377	105.118	1058.17	94.1	0.077481	9.630740	35.32	0.32
4	1600	6	0.179	0.455	1.193	94.061	925.202	96.9	0.070732	9.679477	35.50	0.32
5	1600	6	0.146	0.330	0.717	55.388	555.079	96.7	0.087120	9.837834	36.07	0.33
6	1600	6	0.442	0.606	1.853	144.440	1480.88	93.0	0.061348	9.693520	35.55	0.33
7	1600	6	0.358	0.438	1.135	86.886	904.518	91.4	0.073713	9.665984	35.45	0.33
8	1600	6	0.367	0.546	1.561	118.804	1212.73	93.2	0.067201	9.675071	35.48	0.33
9	1600	6	0.771	0.531	1.634	119.352	1347.99	85.7	0.065055	9.839487	36.08	0.35
10	1600	6	0.277	0.473	1.265	99.002	1007.86	94.4	0.069861	9.767600	35.82	0.33
11	1600	6	0.191	0.344	0.807	60.004	612.261	95.0	0.083829	9.837834	36.07	0.33
12	1600	6	0.193	0.449	1.174	92.539	912.977	96.4	0.070948	9.662955	35.44	0.32
13	1600	6	0.467	0.524	1.438	106.288	1129.1	90.4	0.072088	9.757134	35.78	0.34
14	1600	6	0.312	0.585	1.500	117.8	1191.94	94.4	0.072613	9.708390	35.60	0.33
15	1600	6	0.585	0.462	1.252	92.334	1021.92	86.3	0.073164	9.700955	35.58	0.35
note: isotope beams in mV rlsd = released, error in age includes J error, all errors 1 sigma										Mean ± s.d. =	35.63	0.29
(36Ar through 40Ar are measured beam intensities, corrected for decay in age calculations)										Wtd mean age =	35.64	0.09
										(15 crystals)		
										Isochron age =	35.59	0.19
										(15 crystals)		

Clark-UT Dept. Nat'l. Res., TM111907-3, biotite, 16.90 mg, J = 0.0020 ± 0.47%

4 amu discrimination = 1.072 ± 0.63%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	750	12	3.932	0.335	0.952	6.113	1151.79	6.5	0.2	0.760196	12.410175	44.25	4.24
2	850	12	2.260	1.195	0.777	18.688	818.989	25.0	0.6	0.8870665	11.015337	39.33	1.20
3	900	12	0.826	0.727	0.706	29.294	524.41	58.6	0.9	0.344222	10.494383	37.49	0.48
4	940	12	0.626	0.780	1.226	54.024	704.747	76.9	1.7	0.20025	10.073425	36.00	0.38
5	970	12	0.451	0.662	1.740	79.148	898.184	87.2	2.4	0.1160038	9.962378	35.61	0.35
6	990	12	0.366	0.580	2.262	104.863	1111.93	91.7	3.2	0.0767105	9.805313	35.05	0.34
7	1010	12	0.335	0.504	2.321	107.7	1121.35	92.5	3.3	0.0649027	9.714656	34.73	0.33
8	1030	12	0.384	0.489	2.642	120.346	1251.44	92.1	3.7	0.0563539	9.673145	34.59	0.33
9	1050	12	0.453	0.552	3.113	143.036	1481.94	92.0	4.4	0.0535229	9.633615	34.45	0.33
10	1070	12	0.565	0.744	3.515	160.922	1686.3	91.1	4.9	0.0641217	9.653380	34.52	0.33
11	1090	12	0.656	0.922	3.694	162.694	1727.56	89.8	5.0	0.0785975	9.649427	34.50	0.33
12	1110	12	0.707	1.240	3.643	156.161	1691.34	88.8	4.8	0.1101292	9.729058	34.78	0.34
13	1130	12	0.860	1.736	3.772	156.592	1726.2	86.7	4.8	0.1537585	9.657615	34.53	0.34
14	1160	12	1.423	5.044	6.590	249.966	2788.56	86.1	7.6	0.2798781	9.726517	34.78	0.34
15	1200	12	2.326	12.14	13.400	507.422	5459.83	88.2	15.5	0.3318142	9.624862	34.42	0.34
16	1400	12	3.080	5.019	26.314	1212.68	12434.94	92.8	37.1	0.0574006	9.667216	34.57	0.33
									100.0		Total gas age =	34.70	0.23
note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma											Plateau age =	34.63	0.24
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)											(steps 6-16)		
											Isochron age =	34.69	0.28
											(steps 6-16)		

Clark-UT Dept. Nat'l. Res., TM111907-4, groundmass, 42.20 mg, J = 0.00196 ± 0.46%

4 amu discrimination = 1.0753 ± 0.88%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	600	12	64.860	23.975	23.833	206.591	20197.87	11.8	5.1	0.9063183	11.762539	41.20	3.09
2	650	12	20.816	15.463	9.474	116	7134.46	20.1	2.9	1.0410851	12.579764	44.03	1.94
3	700	12	19.336	19.300	9.354	159.341	6997.07	24.3	4.0	0.9459502	10.871064	38.11	1.40
4	750	12	9.872	24.456	7.179	209.99	4820.62	44.0	5.2	0.9095378	10.260609	35.99	0.77
5	800	12	7.071	26.897	7.244	289.378	4782.69	59.6	7.2	0.7258538	10.007591	35.12	0.59
6	850	12	6.792	32.194	8.553	402.058	5755.71	67.7	10.0	0.6252942	9.848186	34.56	0.53

7	900	12	6.376	36.075	9.105	465.581	6253.42	72.1	11.6	0.6050716	9.837254	34.52	0.50
8	950	12	6.006	37.624	9.069	477.763	6236.08	73.6	11.9	0.6149635	9.768215	34.28	0.49
9	1000	12	3.633	25.538	5.645	298.099	3849.82	74.4	7.4	0.6690061	9.757285	34.25	0.49
10	1050	12	3.594	36.055	5.992	324.112	4087.17	76.2	8.0	0.8687587	9.748656	34.22	0.48
11	1100	12	5.148	51.878	7.861	398.513	5189.97	73.0	9.9	1.016689	9.662948	33.92	0.49
12	1150	12	4.810	81.021	8.581	445.327	5580.49	76.6	11.1	1.4210743	9.757285	34.25	0.48
13	1200	12	1.279	78.839	3.130	141.744	1671.81	80.9	3.5	4.3481286	9.673876	33.96	0.46
14	1270	12	0.773	140.91	1.730	60.804	737.347	78.4	1.5	18.189061	9.610035	33.73	0.47
15	1400	12	0.523	86.516	0.866	32.175	417.579	75.8	0.8	21.122497	9.833514	34.51	0.49
									100.0		Total gas age =	35.21	0.32
											Plateau age =	34.32	0.32
											(steps 4-15)		
											Isochron age =	33.81	0.15
											(steps 1-15)		

note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)

Clark-UT Dept. Nat'l. Res., TM112007-1, plagioclase, 14.60 mg, J = 0.00191 ± 0.51%
4 amu discrimination = 1.0783 ± 0.60%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	600	12	1.621	0.193	0.346	0.387	457.702	4.6	0.1	5.5556946	55.014531	180.08	22.69
2	660	12	2.875	0.312	0.619	0.992	798.875	2.3	0.4	3.5016845	18.723159	63.32	16.58
3	720	12	1.470	0.871	0.366	2.816	454.335	13.2	1.0	3.4435968	21.414668	72.25	3.66
4	780	12	0.834	5.236	0.314	11.678	337.489	35.6	4.2	4.9940475	10.288281	35.07	0.65
5	840	12	3.342	22.646	1.037	30.561	1260.53	28.6	10.9	8.2614351	11.966904	40.73	0.90
6	900	12	0.400	24.765	0.516	36.273	474.425	81.2	13.0	7.6103518	10.683283	36.40	0.37
7	960	12	0.281	28.679	0.488	34.039	404.845	86.5	12.2	9.3963916	10.278209	35.04	0.34
8	1025	12	0.341	26.935	0.507	33.325	414.58	82.6	11.9	9.013068	10.272582	35.02	0.35
9	1090	12	0.720	20.690	0.646	36.87	559.912	67.9	13.2	6.2526895	10.353749	35.29	0.39
10	1150	12	1.202	25.258	0.783	38.981	706.509	56.3	13.9	7.2218275	10.226375	34.86	0.45
11	1210	12	0.784	28.775	0.498	24.634	455.922	57.9	8.8	13.041005	10.654530	36.31	0.45
12	1270	12	0.700	25.559	0.369	13.948	323.897	47.2	5.0	20.501998	10.807801	36.82	0.53
13	1400	12	0.577	27.111	0.376	15.503	307.219	55.9	5.5	19.560337	10.879856	37.07	0.50
									100.0		Total gas age =	36.83	0.31
											Plateau age =	35.23	0.36
											(steps 7-11)		
											Isochron age =	35.13	0.25
											(steps 7-10)		

note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)

Clark-UT Dept. Nat'l. Res., TM112007-3, plagioclase, 24.10 mg, J = 0.00186 ± 0.71%
4 amu discrimination = 1.0783 ± 0.60%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	660	12	0.450	0.274	0.102	0.589	118.427	2.2	0.2	5.2628692	4.306975	14.36	4.02
2	720	12	0.428	0.793	0.126	1.421	127.447	14.9	0.5	6.3153662	12.896342	42.67	2.06
3	780	12	0.285	3.163	0.142	3.802	110.836	39.7	1.3	9.4231561	11.098413	36.78	0.91
4	840	12	0.678	7.983	0.256	8.742	275.875	37.2	2.9	10.346188	11.706530	38.78	0.74
5	900	12	0.646	19.614	0.426	21.881	397.88	60.0	7.3	10.155472	10.954564	36.31	0.49
6	960	12	0.371	34.447	0.561	37.776	477.977	83.8	12.7	10.331387	10.632259	35.25	0.39
7	1025	12	0.292	46.151	0.680	48.903	568.428	91.0	16.4	10.693359	10.636523	35.27	0.38
8	1090	12	0.419	40.637	0.742	47.658	595.876	85.2	16.0	9.6588336	10.709619	35.51	0.39
9	1150	12	0.612	37.274	0.798	48.227	656.543	78.7	16.2	8.7526785	10.725154	35.56	0.40
10	1210	12	0.255	24.424	0.411	24.579	309.272	85.5	8.2	11.261399	10.542425	34.96	0.39
11	1270	12	0.168	12.519	0.216	11.485	153.885	83.7	3.8	12.357075	10.522938	34.90	0.43
12	1400	12	0.316	45.763	0.680	43.471	526.59	91.0	14.6	11.9327	10.832078	35.91	0.38
									100.0		Total gas age =	35.60	0.33
											Plateau age =	35.42	0.33
											(steps 5-12)		
											Isochron age =	35.06	0.21
											(steps 2-11)		

note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)

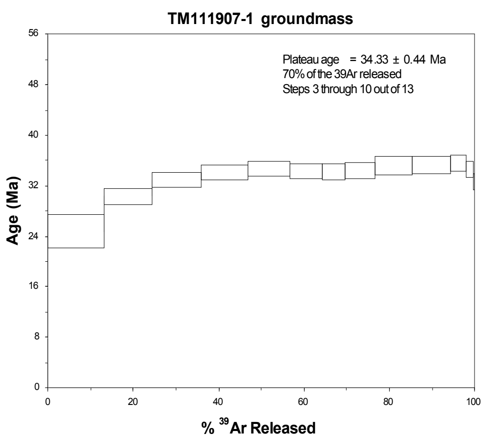
Clark-UT Dept. Nat'l. Res., TM112007-4, groundmass, 26.50 mg, J = 0.00211 ± 0.31%

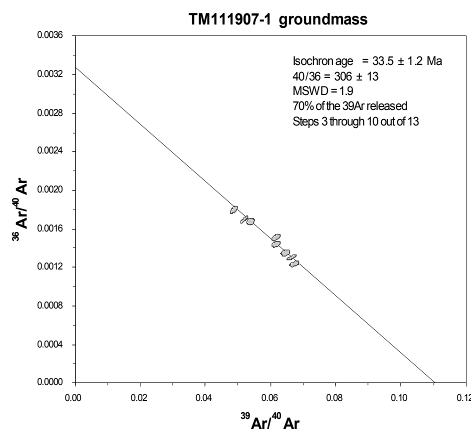
4 amu discrimination = 1.0783 ± 0.60%, 40/39K = 0.051 ± 1.09%, 36/37Ca = 0.000268 ± 0.03%, 39/37Ca = 0.000666 ± 0.01%

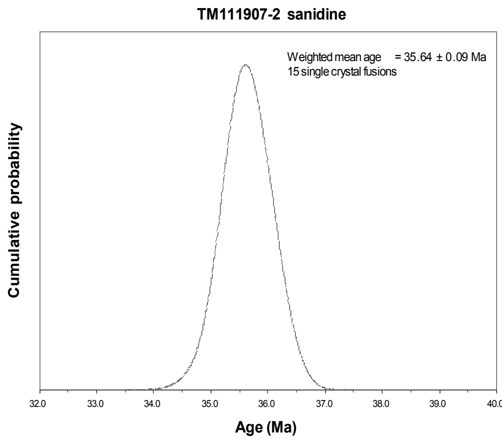
step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	600	12	5.873	6.680	5.564	121.904	1983.52	19.1	7.2	0.6229849	3.151818	11.96	0.38
2	650	12	2.883	4.742	2.689	62.21	1024.96	23.6	3.7	0.8666645	3.939466	14.93	0.39
3	700	12	0.223	0.254	0.167	3.331	64.751	18.5	0.2	0.8669794	3.328502	12.63	0.43
4	750	12	0.495	0.882	0.528	12.382	177.337	28.7	0.7	0.8098793	4.026886	15.26	0.47
5	800	12	3.474	5.906	2.602	61.838	1277.69	26.1	3.7	1.0859635	5.469236	20.70	0.49
6	850	12	4.647	12.255	4.311	129.031	2080.49	39.2	7.6	1.0799302	6.411121	24.24	0.40
7	900	12	3.658	22.496	5.500	224.512	2634.34	62.3	13.3	1.1393303	7.421822	28.03	0.31
8	950	12	3.342	29.476	5.758	261.267	2925.2	69.0	15.5	1.2828798	7.845712	29.62	0.31
9	1000	12	2.659	27.281	4.551	202.349	2290.31	68.7	12.0	1.5331782	7.888709	29.78	0.31
10	1050	12	2.215	21.659	3.570	150.021	1734.49	65.7	8.9	1.6418498	7.697521	29.07	0.31
11	1100	12	2.458	23.330	3.836	153.685	1810.66	63.5	9.1	1.7263982	7.580337	28.63	0.31
12	1150	12	2.751	37.999	4.867	194.469	2207.81	66.7	11.5	2.2225003	7.671359	28.97	0.30
13	1200	12	0.833	44.336	1.716	65.314	718.062	72.3	3.9	7.7332524	7.961091	30.05	0.30
14	1270	12	0.534	85.308	0.880	30.4	354.345	71.8	1.8	32.194836	8.297773	31.31	0.32
15	1400	12	0.422	64.236	0.471	18.219	245.712	70.7	1.1	40.547426	9.019490	34.01	0.35
									100.0		Total gas age =	26.62	0.19
											No plateau		
											Isochron age = (steps 7-13)	34.30	0.70

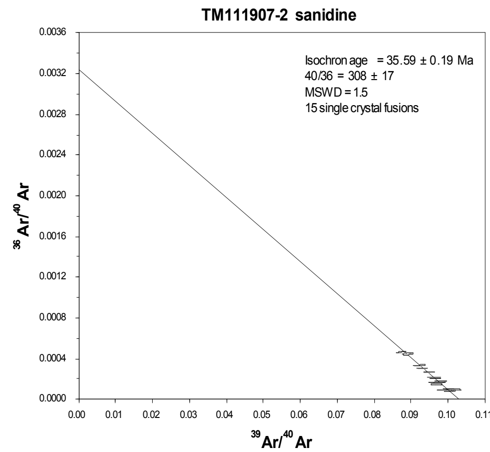
note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma
(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)

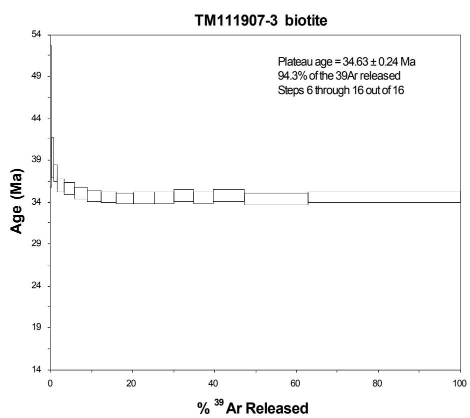
Age Spectra, Isochrons and Probability Plots

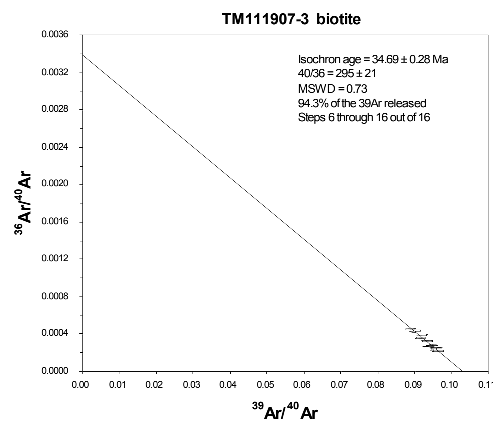


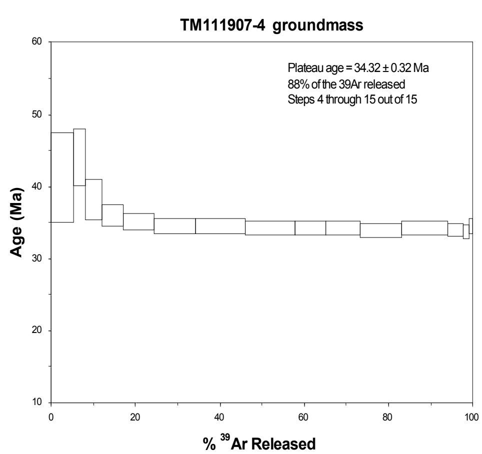


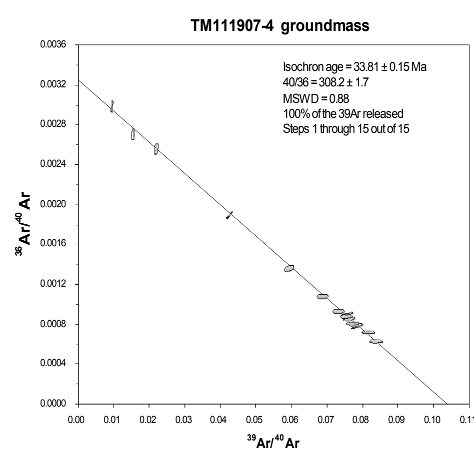

TM111907-2 sanidine
Weighted mean age = 35.64 ± 0.09 Ma
15 single crystal fusions
Cumulative probability
Age (Ma)

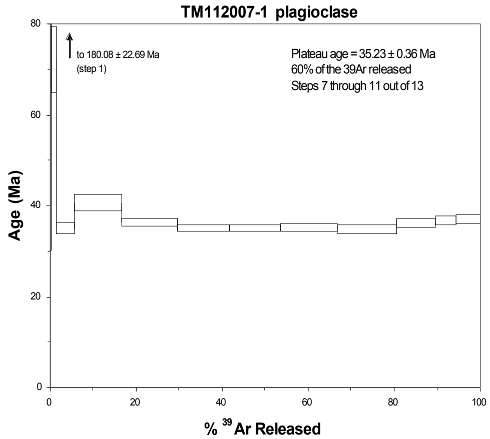

TM111907-2 sanidine
Isochron age = 35.59 ± 0.19 Ma
40/36 = 308 ± 17
MSWD = 1.5
15 single crystal fusions
36Ar/40Ar
39Ar/40Ar

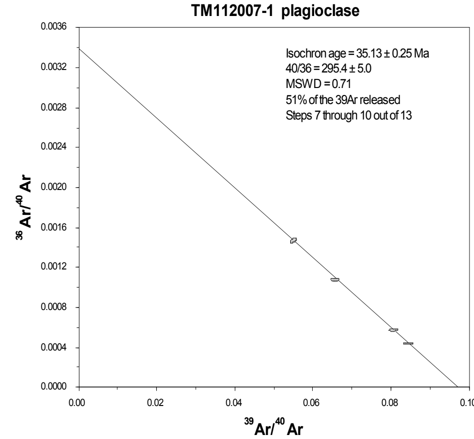

TM111907-3 biotite
Plateau age = 34.63 ± 0.24 Ma
94.3% of the 39Ar released
Steps 6 through 16 out of 16
Age (Ma)
% 39Ar Released

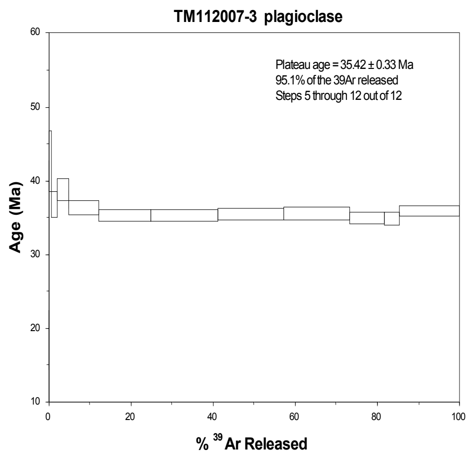

TM111907-3 biotite
Isochron age = 34.69 ± 0.28 Ma
40/36 = 295 ± 21
MSWD = 0.73
94.3% of the 39Ar released
Steps 6 through 16 out of 16
36Ar/40Ar
39Ar/40Ar

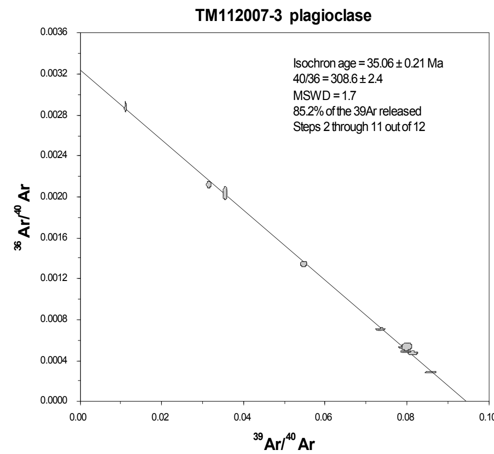

TM111907-4 groundmass
Plateau age = 34.32 ± 0.32 Ma
88% of the 39Ar released
Steps 4 through 15 out of 15
Age (Ma)
% 39Ar Released

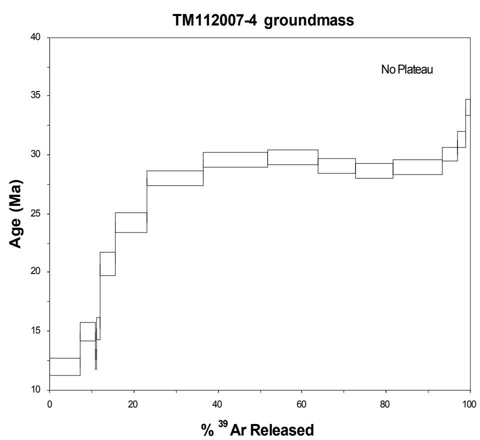

TM111907-4 groundmass
Isochron age = 33.81 ± 0.15 Ma
40/36 = 308.2 ± 1.7
MSWD = 0.88
100% of the 39Ar released
Steps 1 through 15 out of 15
36Ar/40Ar
39Ar/40Ar

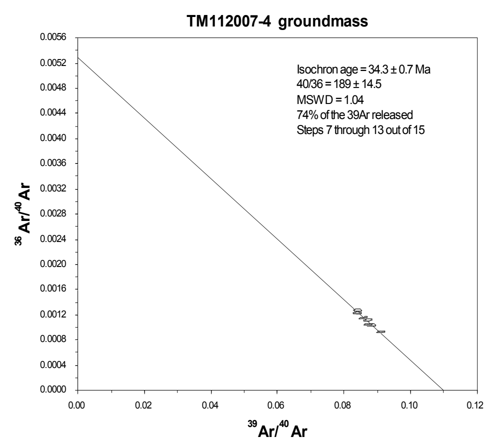

TM112007-1 plagioclase
to 180.08 ± 22.69 Ma
(step 1)
Plateau age = 35.23 ± 0.36 Ma
60% of the 39Ar released
Steps 7 through 11 out of 13
Age (Ma)
% 39 Ar Released


TM112007-1 plagioclase
Isochron age = 35.13 ± 0.25 Ma
40/36 = 295.4 ± 5.0
MSWD = 0.71
51% of the 39Ar released
Steps 7 through 10 out of 13
36Ar/40Ar
39Ar/40Ar


TM112007-3 plagioclase
Plateau age = 35.42 ± 0.33 Ma
95.1% of the 39Ar released
Steps 5 through 12 out of 12
Age (Ma)
% 39 Ar Released


TM112007-3 plagioclase
Isochron age = 35.06 ± 0.21 Ma
40/36 = 308.6 ± 2.4
MSWD = 1.7
85.2% of the 39Ar released
Steps 2 through 11 out of 12
36Ar/40Ar
39Ar/40Ar


TM112007-4 groundmass
No Plateau
Age (Ma)
% 39 Ar Released


TM112007-4 groundmass
Isochron age = 34.3 ± 0.7 Ma
40/36 = 189 ± 14.5
MSWD = 1.04
74% of the 39Ar released
Steps 7 through 13 out of 15
36Ar/40Ar
39Ar/40Ar

The Nevada Isotope Geochronology Laboratory

University of Nevada, Las Vegas
Department of Geoscience

Report prepared by Terry Spell (Lab Director)
and Kathleen Zanetti (Lab Manager)
for the Utah Geological Survey
May 26, 2009
Project No. 265

LABORATORY DESCRIPTION AND PROCEDURES

FR112007-1 Irradiation

Sample FR112007-1 was analyzed by the $^{40}Ar/^{39}Ar$ method at the University of Nevada Las Vegas was wrapped in Al foil and stacked in 6 mm inside diameter sealed fused silica tube. 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. The loaded tube was packed in an Al container for irradiation. The minerals were irradiated at the Oregon State University Radiation Center 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 1.72 (± 55.0%) x 10^{-2}. Ca correction factors were $(^{36}Ar/^{37}Ar)_{Ca}$ = 2.61 (± 7.33%) x 10^{-4} and ($^{39}Ar/^{37}Ar)_{Ca}$ = 6.89 (± 1.32%) x 10^{-4}. J factors were determined by fusion of 4-8 individual crystals of neutron fluence monitors which gave reproducibility's of 0.13% to 0.41% at each standard position. Variation in neutron flux along the 100 mm length of the irradiation tubes was <4%. An error in J of 0.38% was used in age calculations. No significant neutron flux gradients were present within individual packets of crystals as indicated by the excellent reproducibility of the single crystal fluence monitor fusions.

Analytical Procedures

Irradiated crystals 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. 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. 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 283.47 ± 0.73% during this work, thus a discrimination correction of 1.0425 (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 45 over the Faraday. Line blanks averaged 1.0 mV for mass 40 and 0.01 mV for mass 36 for laser fusion 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 27.9 Ma (Steven et al., 1967; Cebula et al., 1986) was used for the Fish Canyon Tuff sanidine flux monitor in calculating ages for samples.

For this 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). All analytical data are reported at the confidence level of 1σ (standard deviation).

RESULTS

FR112007-1 Sanidine

This sample was analyzed by single crystal laser fusion using a 20W CO_2 laser. A total of 18 crystals were analyzed, 17 of which defined a single, coherent group with a mean age of 34.90 ± 0.78 Ma. The weighted mean age of these 17 crystals is 35.08 ± 0.09 Ma and the MSWD is 0.55, indicating that the variability among all these ages can be accounted for by analytical uncertainties alone, i.e., there are no statistical outliers. One crystal was a distinct outlier with a significantly younger age of 31.83 ± 0.34 Ma (crystal #3). All analyses have high radiogenic yields (%^{40}Ar*) of ~98% and low, constant Ca/K ratios, indicating a single population of pure, unaltered sanidine. Because of the high and consistent radiogenic yields no isochron is defined by these data. The weighted mean age 35.08 ± 0.09 Ma is the preferred age for the sample. There was no evidence for xenocrystic contamination as no older outliers were identified. Crystal #3 does not show evidence for alteration (low %^{40}Ar*) or anomalous composition (plagioclase, or sanidine with plagioclase inclusions/intergrowths, or a plagioclase/sanidine composite grain), so it is not clear why this analysis was of significantly younger age. Regardless, it is easily identified and excluded statistically based on MSWD criteria. Overall this is a well behaved sample that is easily interpretable and should provide a very reliable age.

Note that the fluence monitor used is Fish Canyon Tuff sanidine, with an assumed age of 27.9 Ma. In order to compare this age to an analysis of the same sample using a different fluence monitor, or a different age for Fish Canyon sanidine, an adjustment must be made based on intercalibrations (different monitors) or age (different age for Fish Canyon sanidine).

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Cebula, G.T., M.J. Kunk, H.H. Mehnert, C.W. Naeser, J.D. Obradovich, and J.F. Sutter, The Fish Canyon Tuff, a potential standard for the ^{40}Ar-^{39}Ar and fission-track dating methods (abstract), *Terra Cognita (6th Int. Conf. on Geochronology, Cosmochronology and Isotope Geology), 6*, 139, 1986.

Steven, T.A., H.H. Mehnert, and J.D. Obradovich, Age of volcanic activity in the San Juan Mountains, Colorado, *U.S. Geol. Surv. Prof. Pap., 575-D*, 47-55, 1967.

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

APPENDIX

Analytical data for sample FR112007-1 Sanidine.

Clark-UT Geological Survey, FR112007-1, single crystal sanidine, J = 0.001824 ± 0.38%

4 amu discrimination = 1.04249 ± 0.73%, 40/39K = 0.01718 ± 55.2%, 36/37Ca = 0.0002613 ± 7.33%, 39/37Ca = 0.0006893 ± 1.32%

Crystal	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	Ca/K	40Ar*/39ArK	Age (Ma)	1s.d.
1	1600	6	0.131	0.476	2.275	181.805	1962.92	98.1	0.020721	10.6908	34.84	0.35
2	1600	6	0.123	0.518	2.788	225.058	2445.84	98.5	0.018216	10.8098	35.23	0.35
3	1600	6	0.059	0.303	1.149	83.633	824.167	98.1	0.028673	9.7575	31.83	0.34
4	1600	6	0.085	0.371	1.870	152.817	1633.72	98.5	0.019214	10.6329	34.65	0.35
5	1600	6	0.073	0.361	1.791	142.618	1548.7	98.7	0.020033	10.8166	35.25	0.35
6	1600	6	0.115	0.440	1.902	153.166	1657.97	98.1	0.022735	10.7125	34.91	0.35
7	1600	6	0.153	0.420	1.869	150.144	1648.77	97.4	0.022139	10.7940	35.17	0.35
8	1600	6	0.150	0.419	1.973	158.423	1731.05	97.6	0.020932	10.7599	35.06	0.35
9	1600	6	0.189	0.380	1.578	125.938	1398.05	96.2	0.023880	10.7807	35.13	0.36
10	1600	6	0.154	0.512	2.777	222.061	2437.48	98.2	0.018248	10.8789	35.45	0.35
11	1600	6	0.115	0.469	1.555	126.105	1368.93	97.7	0.029434	10.7014	34.88	0.35
12	1600	6	0.077	0.404	1.962	156.498	1705.24	98.7	0.020431	10.8594	35.39	0.35
13	1600	6	0.100	0.487	2.577	204.711	2224.12	98.7	0.018828	10.8253	35.28	0.35
14	1600	6	0.084	0.353	1.607	127.333	1378.71	98.3	0.021941	10.7450	35.02	0.35
15	1600	6	0.119	0.406	1.923	156.248	1711.2	98.0	0.020565	10.8383	35.32	0.35
16	1600	6	0.079	0.293	1.229	97.633	1071.3	98.0	0.023751	10.8538	35.37	0.35
17	1600	6	0.171	0.596	2.934	236.669	2538.21	98.0	0.019930	10.6155	34.60	0.35
18	1600	6	0.165	1.312	3.009	245.115	2642.56	98.2	0.042362	10.6871	34.83	0.35
										Mean ± s.d. =	34.90	0.78
										Wtd mean age = (17 crystals)	35.08	0.09

note: isotope beams in mV rlsd = released, error in age includes J error, all errors 1 sigma
(36Ar through 40Ar are measured beam intensities, corrected for decay in age calculations)