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$^{40}Ar/^{39}Ar$ Geochronology Results from a Cinder Cone from the Cutter Quadrangle and from Two Dikes from the Alivio Quadrangle, New Mexico

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Introduction

Three volcanic rocks from southern New Mexico were submitted for $^{40}Ar/^{39}Ar$ dating by Dr. William Seager. Groundmass concentrate was prepared from the WS-2 and WS-3 samples. No dateable material was found in sample WS-1.

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

The groundmass concentrate samples were analyzed by the furnace incremental heating age spectrum $^{40}Ar/^{39}Ar$ method. Abbreviated analytical methods for the furnace sample is given in Table 1. Details of the overall operation of the New Mexico Geochronology Research Laboratory are provided in the Appendix. Figures 1 and 2 show the age spectra and inverse isochrons yielded by the groundmass concentrates.

Groundmass concentrate WS-2 (Figure 1) yields a moderately discordant age spectrum. The initial six heating steps for WS-2 are concordant at approximately 2 Ma (step C has been excluded because the furnace failed to reach the desired temperature). Step H (1250°C) follows with almost 70%% of the total $^{39}Ar_K$ released and an apparently anomalously old age of 7.15 Ma. Step I (the fusion step) has only a minor amount of the total potassium and is older still at 15.70 Ma. Radiogenic yields for WS-2 are very low for the majority of the age spectrum (<6%), but increase to 9% and 16% for the final two heating steps. The K/Ca ratios are variable, ranging from less than 0.05 to 1.5. A plateau assigned to steps D through G yields a weighted mean age of 2.04±0.36 Ma (29.3% of the $^{39}Ar_K$ released). The inverse isochron results for WS-2 are analytically indistinguishable from the spectrum weighted mean age and atmosphere.

The age spectrum for the WS-3 groundmass concentrate (Figure 2) is highly discordant with ages ranging from 18.2 Ma to 27.1 Ma. The lower temperature heating steps for WS-3 yield the youngest ages while the highest temperature steps yield the oldest ages. The intermediate temperature steps (steps C through F) present a gradient from the youngest ages to the oldest ages. The radiogenic yields are consistent throughout much of the age spectrum at about 50-55%. The K/Ca ratios are high (4.1) for the earliest gas released, but then steadily decrease through the rest of the heating steps to less than 0.1. A weighted mean for the five highest temperature heating steps yields an age of 26.80±0.68 Ma (52.6% of the $^{39}Ar_K$ released). The inverse isochron results for WS-3 are analytically indistinguishable from the spectrum weighted mean age and atmosphere.

Discussion

For the WS-2 groundmass concentrate sample, the spectrum weighted mean age (2.04±0.36 Ma) is inferred to be the best estimate of the age of the lava emplacement. However, the final two, anomalously old, heating steps of the WS-2 age spectrum indicate that excess argon or contamination may be a problem with this sample. The excess argon may be contained within a relatively high temperature (>1100°C), low potassium (K/Ca<0.5) mineral phase, such as pyroxene or olivine. An additional problem with this sample is the very low radiogenic yields (<6%) that combine with the young age and low potassium content of the sample to yield a relatively imprecise age. Also, because of the low potassium content and the low radiogenic yields, the weighted mean age may be more susceptible to the influence of excess argon. Therefore, the weighted mean age of 2.04±0.36 Ma should be considered a maximum age.

The age spectrum for the WS-3 groundmass concentrate sample is more difficult to interpret. While the overall shape of the spectrum is indicative of a ~26 Ma sample that has undergone $^{40}Ar^*$ loss because of alteration/hydration, the radiogenic yields are higher and more consistent than would be expected. The alternative to the $^{40}Ar^*$ loss scenario is an ~18 Ma sample that has been contaminated by excess argon or xenocrysts. However, the inverse isochron contains no evidence of an excess argon component. Because the shape of the age spectrum is more similar to other samples known to have alteration and/or hydration products, it is our estimate that the weighted mean from steps E to 1 (26.80±0.68 Ma) yields the best estimate of the eruption age of WS-3. However, argon loss may have influenced some or all of the heating steps included in the weighted mean age so that it should be considered a minimum age. This hypothesis is strengthen by the apparent field relationship between the WS-3 dike and the Vicks Peak Tuff. According to the field description provided by Dr. Seager, the WS-3 dike crosscuts several units below the Vicks Peak Tuff, but does not intersect the Vicks Peak Tuff itself. The WS-3 dike may also merge into a basaltic andesite flow immediately below the Vicks Peak Tuff. If this last statement is true, then the stratigraphically lower WS-3 sample must be older than the Vicks Peak Tuff (28.56±0.08 Ma; McIntosh et al., 1990). This indicates that the WS-3 groundmass concentrate has lost enough $^{40}Ar^*$ through alteration/hydration to decrease its $^{40}Ar/^{39}Ar$ apparent age by *at least* 2 million years.

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.

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

McDougall, I., and Harrison, T.M., 1988, Geochronology and thermochronology by the $^{40}Ar/^{39}Ar$ method: New York Oxford [Oxfordshire], Oxford University Press ; Clarendon Press, xi, 212 p.

McIntosh, W.C., Sutter, J.F., and Chapin, C.E., 1990, High-Precision $^{40}Ar/^{39}Ar$ sanidine geochronology of ignimbrites in the Mogollon-Datil volcanic field, southwestern New Mexico: Bulletin of Volcanology, v. 52, p. 584-601.

Samson, S.D., and, Alexander, E.C., Jr., 1987. Calibration of the interlaboratory $^{40}Ar/^{39}Ar$ dating standard, Mmhb-1, Chem. Geol., 66, 27-34.

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.

York, D., 1969. Least squares fitting of a straight line with correlated errors, Earth and Planet. Sci. Lett., 5, 320-324.

Table 1. 40Ar/39Ar analytical methods used for the groundmass concentrate samples.

Sample preparation and irradiation:

Geological samples provided by Dr. William Seager.

Groundmass concentrates were prepared using standard separation techniques (crushing, sieving, franzing and hand-picking).

Samples were packaged and irradiated in machined Al discs 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.

Samples step-heated in Mo double-vacuum resistance furnace. Heating duration 7 minutes.

Reactive gases removed by reaction with 3 SAES GP-50 getters, 2 operated at ~450°C and 1 at 20°C, together with a W filiment operated at ~2000°C.

Analytical parameters:

Electron multiplier sensitivity averaged 2.82×10^{-16} moles/pA.

Total system blank and background for the furnace averaged 4400, 57.0, 1.7, 6.8, 14.1 x 10^{-18} moles at masses 40, 39, 38, 37, and 36, respectively for temperatures <1300°C.

J-factors determined to a precision of ± 0.1% by CO_2 laser-fusion of 4 single crystals from each of 6 radial positions around the irradiation tray.

Correction factors for interfering nuclear reactions were determined using K-glass and CaF_2 and are as follows:

$(^{40}Ar/^{39}Ar)_K = 0.0002 \pm 0.0003$; $(^{36}Ar/^{37}Ar)_{Ca} = 0.00028 \pm 0.000005$; and $(^{39}Ar/^{37}Ar)_{Ca} = 0.0007 \pm 0.00002$.

Age calculations:

Weighted mean age calculated by weighting each age analysis by the inverse of the variance.

Weighted mean error calculated using the method of (Taylor, 1982).

Total gas ages and errors calculated by weighting individual steps by the fraction of ^{39}Ar released.

Isochron ages, $^{40}Ar/^{36}Ar_i$ and MSWD values calculated from regression results obtained by the methods of York (1969).

Decay constants and isotopic abundances after Steiger and Jäger (1977).

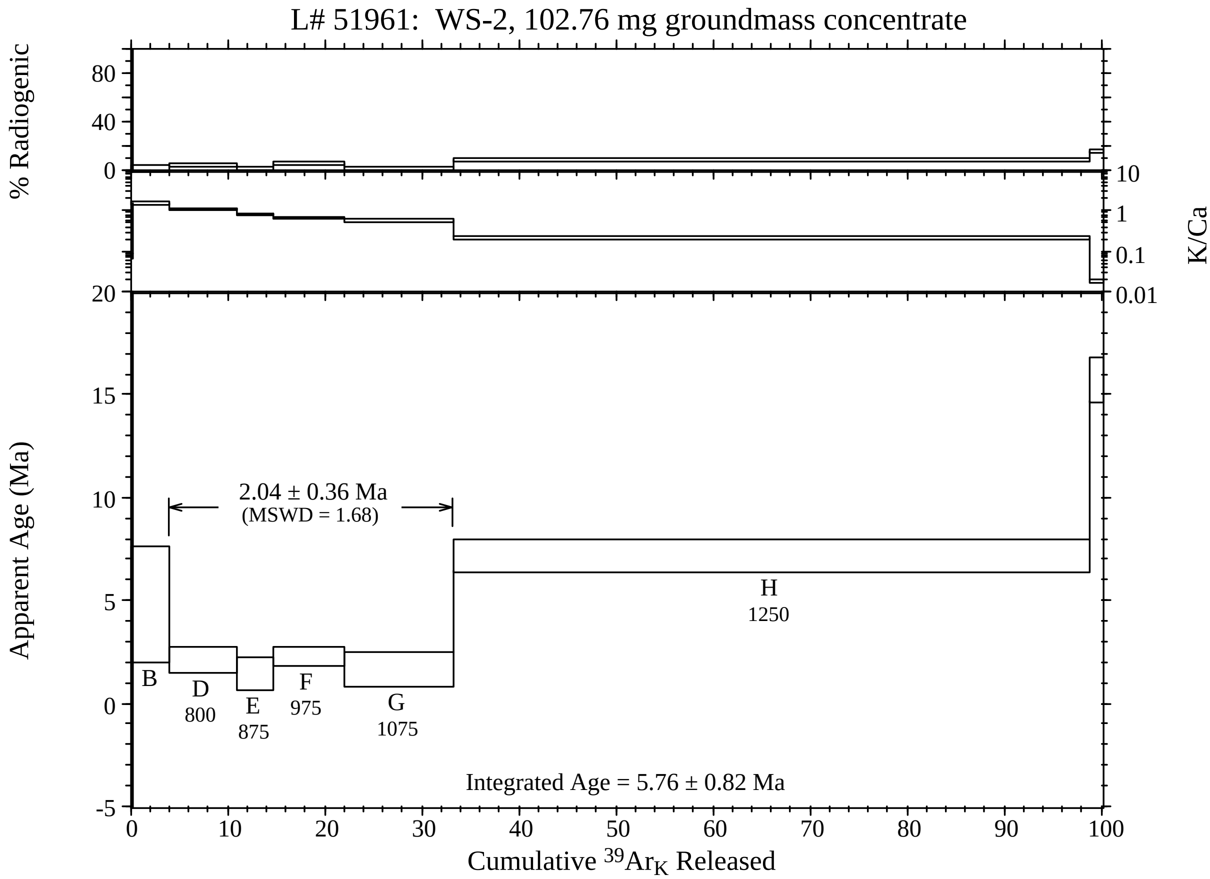
All final errors reported at ±2□, unless otherwise noted.

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)
	WS-2, 102.76 mg groundmass concentrate, J=0.000702±0.11%, NM-133, Lab#=51961-01										
#	A	575	39874	6.529	134012.6	0.030	0.078	0.7	0.0	319	210
#	B	650	236.8	0.3365	788.6	3.17	1.5	1.6	3.8	4.8	1.4
#	C	700	88.61	12.62	299.5	0.026	0.040	1.3	3.9	1.5	4.8
	D	750	42.63	0.4542	138.8	5.87	1.1	3.9	10.9	2.10	0.28
	E	825	55.07	0.6295	182.8	3.14	0.81	2.0	14.7	1.41	0.38
	F	925	30.74	0.7553	98.19	6.04	0.68	5.8	21.9	2.27	0.20
	G	1025	67.92	0.8848	225.6	9.37	0.58	1.9	33.1	1.68	0.39
#	H	1200	62.15	2.388	191.9	54.7	0.21	9.1	98.7	7.15	0.37
#	I	1600	76.09	28.37	224.4	1.05	0.018	16.0	100.0	15.70	0.52
	Integrated age ± 2σ			n=9		83.4	K2O=0.44 %			5.76	0.82
	Plateau ± 2σ		steps D-G	n=4	MSWD=1.68	24.4	0.76		29.3	2.04	0.36
	Isochron±2σ			n=6	MSWD=2.3		$^{40}Ar/^{36}Ar$=297±2			1.82	0.43
	WS-3, 14.09 mg groundmass concentrate, J=0.0007019±0.11%, NM-133, Lab#=51962-01										
#	A	575	1739.3	0.1244	5813.4	0.116	4.1	1.2	1.4	27	10
#	B	650	26.36	0.2445	40.31	2.07	2.1	54.9	26.2	18.23	0.15
#	C	700	31.93	0.4006	45.22	0.649	1.3	58.3	34.0	23.42	0.27
#	D	750	37.10	0.7190	57.57	1.11	0.71	54.3	47.4	25.34	0.22
	E	825	40.00	0.9025	63.17	1.26	0.57	53.5	62.6	26.92	0.22
	F	925	41.87	1.022	68.18	1.24	0.50	52.1	77.5	27.43	0.24
	G	1025	44.38	1.435	82.20	0.717	0.36	45.5	86.2	25.44	0.37
	H	1200	50.97	7.282	105.2	0.610	0.070	40.2	93.5	25.92	0.42
	I	1600	67.11	7.792	156.8	0.540	0.065	31.9	100.0	27.12	0.49
	Integrated age ± 2σ			n=9		8.31	K2O=0.32 %			24.17	0.53
	Plateau ± 2σ		steps E-I	n=5	MSWD=6.32	4.37	0.38		52.6	26.80	0.68
	Isochron±2σ			n=7	MSWD=11		$^{40}Ar/^{36}Ar$=296±3			26.32	1.01

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interferring 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 interferring 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 root MSWD where MSWD>1.
Plateau and integrated ages incorporate uncertainties in interferring reaction corrections and J factors.
Decay constants and isotopic abundances after Steiger and Jaeger (1977).
# symbol preceding sample ID denotes analyses excluded from plateau age calculations.
Discrimination = 1.0069 ± 0.001
Correction factors:
$(^{39}Ar/^{37}Ar)_{Ca}$ = 0.00089 ± 3e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028 ± 1.1e-05
$(^{38}Ar/^{39}Ar)_K$ = 0.01077
$(^{40}Ar/^{39}Ar)_K$ = 0.0002 ± 0.0003



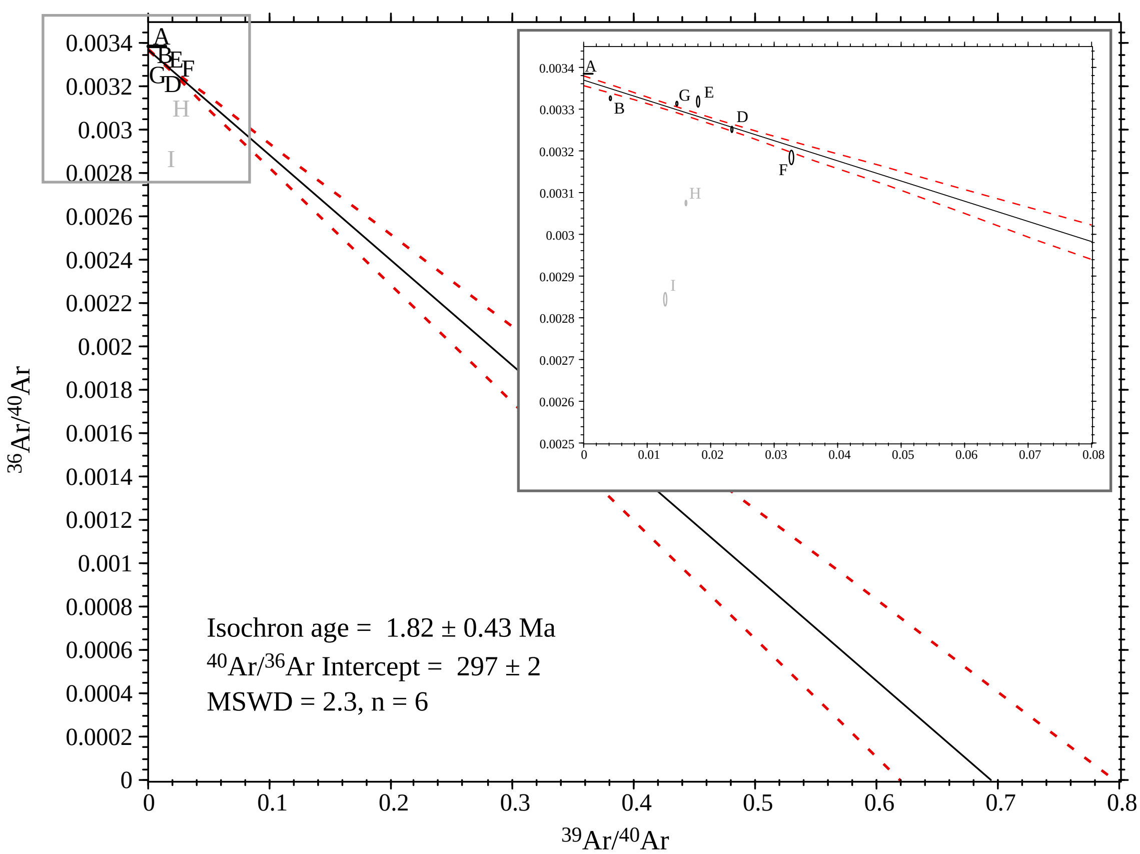
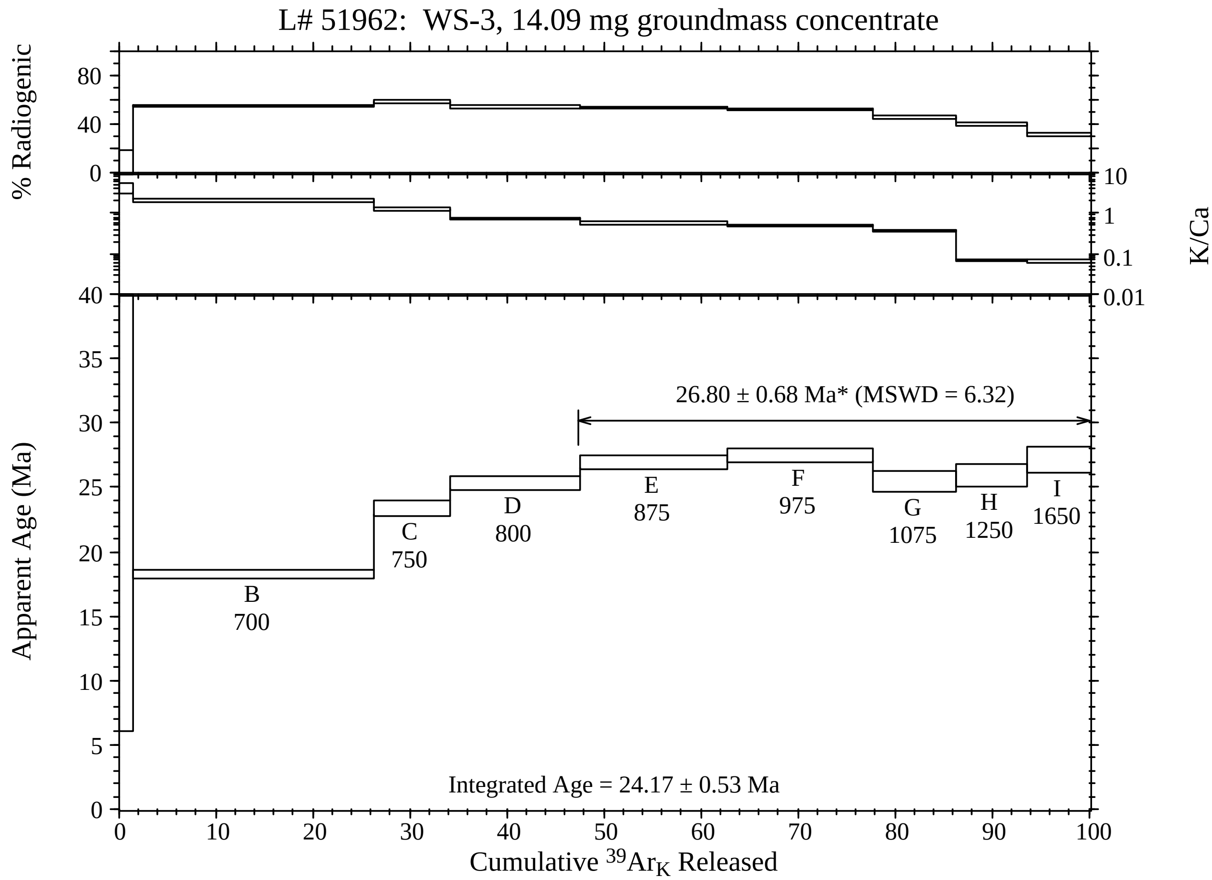


Figure 1. $^{40}Ar/^{39}Ar$ age spectrum and inverse isochron for the WS-2 groundmass concentrate. The weighted mean of steps D through G (2.04 ± 0.36 Ma) is the preferred age of this sample. All errors are two-sigma.



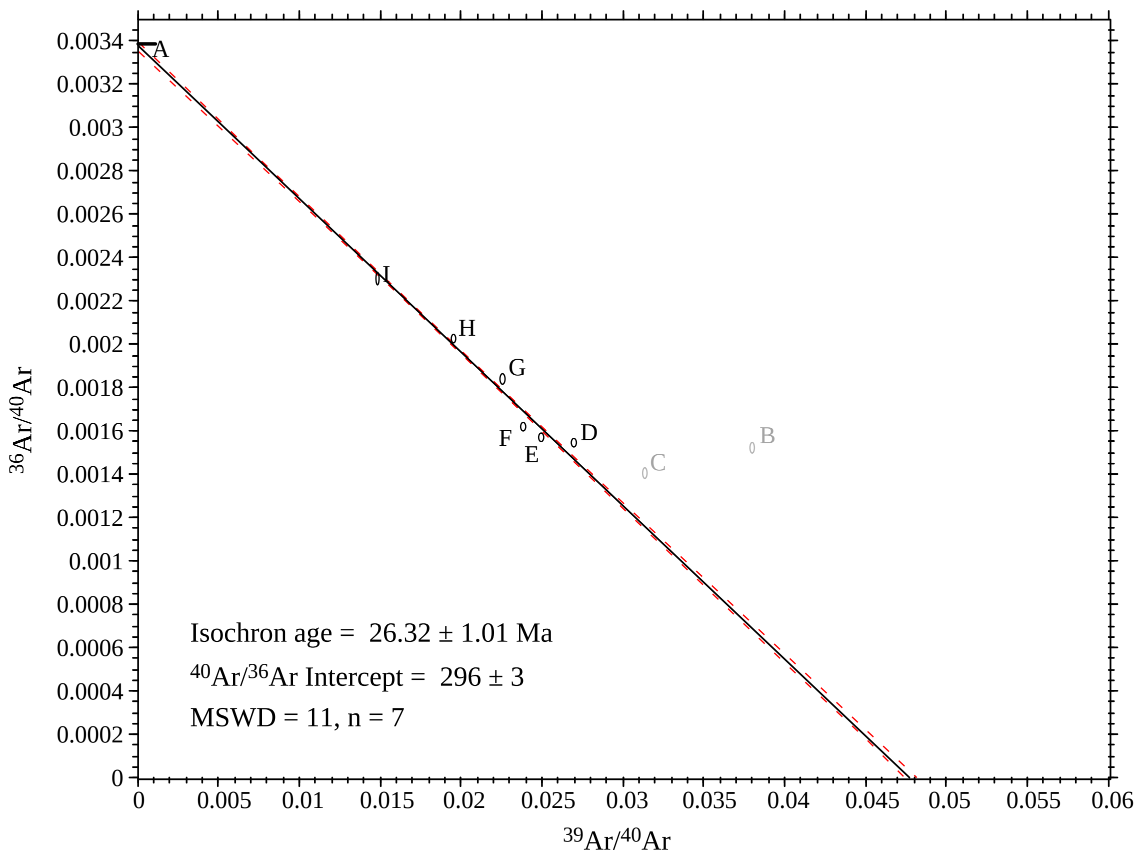


Figure 2. $^{40}Ar/^{39}Ar$ age spectrum and inverse isochron for the WS-3 groundmass concentrate. The weighted mean of steps E through I (26.80 ± 0.68 Ma) is the preferred age of this sample. All errors are two-sigma.