GSA Data Repository Item 2015236

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$^{40}Ar/^{39}Ar$ geochronology analytical methods

$^{40}AR/^{39}AR$ SAMPLE PREPARATION

After mechanical mineral separation from the host rock to achieve 99% purity, white mica with grain size between 106 and 250 µm was picked and washed with dilute HCl. Individual mineral separates were loaded into 2–3 mm-deep aluminum foil packets, which were subsequently stacked vertically into 35-mm long foil tubes and placed into the tubular holes of an aluminum cylinder. Several flux monitor grains of Fish Canyon tuff sanidine (FCT-SAN) (28.02 ± 0.16 1σ Ma; Renne et al., 1998, ^{40}K decay = 5.543e-10/a, Steiger and Jäger, 1977) were loaded into each sample packet. The vessel was irradiated for 160 MWH in medium flux position 8A at the research nuclear reactor of McMaster University (MNR) in Hamilton, Canada. Neutron fluence was ~1.08×10^{13} neutrons/cm^2 operating at a 2.5 MW power level. Correction factors for typical interference species produced by thermal neutrons during irradiation are 0.058 ($^{40}Ar/^{39}Ar_K$), 0.000743 ($^{39}Ar/^{37}Ar_{Ca}$) and 0.000258 ($^{36}Ar/^{37}Ar_{Ca}$).

$^{40}AR/^{39}AR$ ANALYSES

Analytical conditions follow the protocol of Kellett and Joyce (2014). Small aliquots (3–4 grains) and monitors were loaded into separate 1.5 mm diameter pits in a copper planchet and placed under vacuum. Individual grains were progressively heated and analyzed using a Photon Machines Ltd. Fusion 10.6 55W CO_2 laser coupled to the all-metal extraction line and a Nu Instruments Noblesse multicollector mass spectrometer operated at the Geological Survey of Canada, Ottawa, Canada. Laser heating was homogenized over a beam radius of 2 mm for a total of 40 s, after which the released gas was exposed to SAES™ NP-10 (~400 °C) and HY-STOR® 201 (25 °C) getters in the extraction line for three minutes. Following gettering, sample gas was expanded into the mass spectrometer. The Nu Noblesse is a single-focusing, Nier-source, magnetic sector multicollector noble gas spectrometer equipped with two quadrupole lens arrays. Argon ions were measured with a fixed array of three ETP® discrete dynode ion-counting multipliers (IC0, IC1, IC2). Data collection occurred in two multicollection cycles: cycle 1 = $^{40}Ar_{IC0}$, $^{38}Ar_{IC1}$ and cycle 2 = $^{39}Ar_{IC0}$, $^{37}Ar_{IC1}$, $^{36}Ar_{IC2}$. Blanks were run every 5 analyses, in an identical manner to unknowns. Air shots were analyzed every 10 analyses to monitor efficiency and mass fractionation. Relative collector efficiency and mass bias corrections were made for IC1 and IC2 collectors relative to IC0 using $^{40}Ar_{IC0}/^{36}Ar_{IC1}$ and $^{40}Ar_{IC0}/^{36}Ar_{IC2}$ measurements of air. Mass bias in IC0 was not corrected as it would be equally applied to the $^{40}Ar/^{39}Ar$ ratio in unknowns and J-factors determined from monitors in the age calculation, thereby cancelling out (e.g., Brumm et al., 2010). Error in J-factor values are conservatively estimated at ± 0.6% (2σ). Sensitivity of the Nu Noblesse at the time of analyses was 7.1–7.5 Amps/mol. Data collection,

reduction, error propagation, age calculation and plotting were performed using the software MassSpec (version 7.93; Deino, 2001).

Analytical results are presented in Table S1; Figure 4 presents the data as spectra where the width of each bar (thermal increment) represents the proportion of evolved gas, and the height represents the uncertainty associated with the apparent age. The integrated (or total gas: Tg) age is an average age for the sample calculated by summing the isotopic measurements of all steps with an uncertainty calculated by quadratically combining errors of isotopic measurements of all steps. Plateau ages are conventionally defined as the portion of an age spectrum composed of contiguous increments representing >70% of gas released which result in concordant ages (Mahon, 1996). A preferred age (Tp), on the other hand, is calculated as the weighted mean of a selection of mostly contiguous increments which represent >50% of ^{39}Ar gas released and result in concordant ages. The calculated age uncertainties are relatively small because analytical precision in the age of each heating step is high. In our samples, both Tg and Tp are relatively similar in age, and both host rock marble and shear zone are within error of each other, suggesting the ages are robust.

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Table DR1. $^{40}Ar/^{39}Ar$ isotopic data for white mica, Syros, Greece

	Watts	^{40}Ar	±1σ	^{39}Ar	±1σ	^{38}Ar	±1σ	^{37}Ar	±1σ	^{36}Ar	±1σ	^{39}Ar Mol†	$^{36}Ar/^{39}Ar$††	±1σ	%(^{36}Ar)Ca	$^{37}Ar/^{39}Ar$
SYB4 marble (J: 1.971x10-3 ± 0.010)																
A	0.25	101561.60	4885.79	7742.78	15.13	131.16	3.36	51.06	4.57	84.23	3.46	0.03	1086.95	44.76	0.2	0.0590
B	0.27	263828.40	4966.60	25648.26	51.62	339.20	4.92	54.73	4.24	37.82	2.22	0.09	147.33	8.66	0.4	0.0191
C*	0.30	484492.10	5051.84	39306.62	56.65	531.51	5.96	71.96	4.41	85.99	3.15	0.14	218.60	8.00	0.2	0.0164
D	0.45	167124.50	5787.72	11623.60	21.42	147.55	3.47	10.17	3.79	25.37	3.05	0.04	218.11	26.19	0.1	0.0078
E*	0.55	321279.70	3882.19	25387.08	28.97	2391.49	15.25	421.29	6.91	88.00	3.21	0.09	346.39	12.66	1.0	0.1290
F*	0.85	475754.50	3895.03	38974.44	27.72	507.64	6.35	137.77	4.55	52.13	3.84	0.14	133.66	9.85	0.6	0.0275
G	1.00	22097.65	3998.68	1952.79	7.76	39.40	3.51	13.43	4.33	7.00	2.97	0.01	358.45	151.84	0.4	0.0535
H*	6.00	142761.50	3936.54	11823.26	17.66	243.36	4.96	40.01	3.92	15.54	3.08	0.04	131.37	26.02	0.6	0.0263
SYB2/1 mylonite (J: 1.967x10-3 ± 0.010)																
A*	0.25	112386.70	3790.64	9239.68	18.91	142.46	3.75	0.46	4.07	39.57	3.76	0.03	427.96	40.69	0.0	0.0004
B*	0.27	1925233	13491.39	165615.5	146.94	2177.45	25.50	47.92	17.14	97.11	11.85	0.58	58.59	7.15	0.1	0.0022
C*	0.30	163292.90	4025.69	14767.66	16.40	199.12	4.33	5.97	3.87	25.03	2.55	0.05	169.37	17.24	0.1	0.0031
D*	0.55	3321160	20972.84	258546.2	281.62	3696.59	32.02	79.09	22.00	986.40	20.97	0.91	381.24	8.11	0.0	0.0024
E*	0.85	89935.93	2973.16	7292.94	15.14	104.86	3.85	0.00	5.24	11.04	3.20	0.03	151.30	43.79	0.0	0.0000
F	1.00	235736.80	3940.48	19993.99	23.93	279.41	4.98	7.35	4.00	31.55	3.22	0.07	157.67	16.11	0.1	0.0029
G	6.00	66520.77	4200.40	5339.17	11.99	74.56	3.83	3.39	4.50	17.70	2.55	0.02	331.36	47.80	0.0	0.0050

* steps used to calculate Tp

† $x10^{-14}$, †† $x10^{-5}$

Table 1. continued

±1σ	Ca/K	±1σ	$^{38}Ar/^{39}Ar$	±1σ	$^{40}Ar/^{39}Ar$	±1σ	$^{40}Ar^*/^{39}Ar$	±1σ	$\%^{40}Ar^*$	^{39}Ar %	Age (Ma)	±1σ
0.0053	0.115569	0.010346	0.0169	0.00044	12.5641	0.0267	9.2994	0.135153	74.2	4.6	32.77	0.47
0.0015	0.037403	0.002902	0.0132	0.00019	9.8204	0.0205	9.3573	0.032567	95.5	15.2	32.98	0.11
0.0010	0.032103	0.001969	0.0135	0.00015	11.7972	0.0188	11.1212	0.029981	94.5	23.3	39.13	0.10
0.0029	0.015362	0.005729	0.0127	0.00030	10.5597	0.0203	9.8843	0.080562	93.8	6.9	34.82	0.28
0.0021	0.252875	0.004160	0.0941	0.00061	12.5376	0.0157	11.4954	0.04073	91.9	16.2	40.43	0.14
0.0009	0.053874	0.001780	0.0130	0.00016	12.1299	0.0099	11.7085	0.031076	96.7	24.9	41.17	0.11
0.0173	0.104821	0.033812	0.0202	0.00180	11.2616	0.0507	10.1718	0.455799	90.5	1.2	35.82	1.59
0.0026	0.051597	0.005052	0.0206	0.00042	11.8982	0.0191	11.4840	0.079932	96.7	7.6	40.39	0.28
0.0034	0.000755	0.006702	0.0154	0.00041	11.9504	0.0260	10.6480	0.123767	89.3	2.4	37.40	0.43
0.0008	0.004400	0.001573	0.0131	0.00015	10.6650	0.0110	10.4654	0.024072	98.4	43.7	36.76	0.08
0.0020	0.006161	0.003989	0.0135	0.00029	10.8725	0.0143	10.3423	0.053366	95.3	3.9	36.33	0.19
0.0007	0.004668	0.001298	0.0143	0.00012	12.1478	0.0151	10.9850	0.028097	90.6	44.4	38.57	0.10
0.0056	0.000000	0.010964	0.0144	0.00053	10.7682	0.0242	10.2911	0.132833	95.8	1.3	36.16	0.46
0.0016	0.005618	0.003057	0.0140	0.00025	11.7463	0.0163	11.2509	0.050699	96.0	3.4	39.49	0.18
0.0066	0.009720	0.012891	0.0140	0.00072	12.5459	0.0313	11.5322	0.145688	92.1	0.9	40.47	0.51

TABLE DR2. WHITE MICA ANALYSES

	Host rock			Shear zone		
	Measured		Generated	Measured		Generated
	Analysis #27	Avg. ± Std N=44	Avg. ± Std N=50	Analysis #62	Avg. ± Std N=48	Avg. ± Std N=50
SiO_2	52.936	52.781 ± 0.580	52.783 ± 0.497	52.697	52.857 ± 0.404	52.948 ± 0.553
TiO_2	0.071	0.094 ± 0.019	0.089 ± 0.049	0.140	0.112 ± 0.026	0.112 ± 0.048
Al_2O_3	25.202	25.517 ± 0.765	25.512 ± 0.226	25.737	25.495 ± 0.635	25.483 ± 0.238
Cr_2O_3	0.091	0.162 ± 0.132	0.157 ± 0.051	0.024	0.055 ± 0.067	0.056 ± 0.049
FeO	0.013	0.039 ± 0.030	0.044 ± 0.044	0.173	0.158 ± 0.034	0.168 ± 0.053
MgO	5.657	0.006 ± 0.007	5.433 ± 0.112	0.001	0.007 ± 0.010	5.342 ± 0.095
MnO	0.174	5.430 ± 0.314	0.022 ± 0.030	5.275	5.342 ± 0.209	0.026 ± 0.033
CaO	0.000	0.244 ± 0.071	0.236 ± 0.051	0.117	0.221 ± 0.087	0.211 ± 0.056
Na_2O	0.294	0.260 ± 0.093	0.273 ± 0.056	0.261	0.257 ± 0.093	0.254 ± 0.056
K_2O	11.095	10.956 ± 0.193	10.946 ± 0.200	10.886	10.836 ± 0.223	10.815 ± 0.259
Total	95.533	95.489 ± 0.290	95.495 ± 0.6128	95.311	95.339 ± 0.295	95.415 ± 0.610
Structural formula based on 11 oxygens and end-member calculation after Schliestedt (1986)						
Si	3.494	3.484 ± 0.034	3.484 ± 0.015	3.482	3.492 ± 0.027	3.494 ± 0.017
Al	0.506	0.516 ± 0.034	0.516 ± 0.015	0.518	0.508 ± 0.027	0.506 ± 0.017
Sites IV	4.000	4.000 ± 0.000	4.000 ± 0.000	4.000	4.000 ± 0.000	4.000 ± 0.000
Al	1.455	1.469 ± 0.029	1.469 ± 0.010	1.487	1.477 ± 0.023	1.477 ± 0.020
Ti	0.004	0.005 ± 0.001	0.004 ± 0.002	0.007	0.006 ± 0.001	0.005 ± 0.002
Cr	0.005	0.008 ± 0.007	0.008 ± 0.003	0.001	0.003 ± 0.004	0.003 ± 0.003
Mg	0.536	0.518 ± 0.030	0.518 ± 0.008	0.505	0.515 ± 0.022	0.514 ± 0.009
$Fe^{2+\S}$	0.000	0.000 ± 0.000	0.000 ± 0.001	0.000	0.000 ± 0.000	0.001 ± 0.002
Mn	0.000	0.000 ± 0.000	0.000 ± 0.000	0.000	0.000 ± 0.000	0.001 ± 0.000
Sites M2	2.000	2.000 ± 0.000	2.000 ± 0.000	2.000	2.000 ± 0.000	2.000 ± 0.000
Mg	0.020	0.017 ± 0.007	0.016 ± 0.008	0.015	0.011 ± 0.007	0.011 ± 0.009
$Fe^{2+\S}$	0.001	0.002 ± 0.002	0.002 ± 0.002	0.010	0.009 ± 0.002	0.008 ± 0.004
Mn	0.000	0.000 ± 0.001	0.001 ± 0.002	0.000	0.000 ± 0.001	0.001 ± 0.002
Site M1	0.021	0.019 ± 0.007	0.020 ± 0.008	0.024	0.020 ± 0.007	0.021 ± 0.010
Ca	0.012	0.017 ± 0.005	0.017 ± 0.004	0.008	0.016 ± 0.006	0.015 ± 0.004
Na	0.038	0.033 ± 0.012	0.035 ± 0.007	0.033	0.033 ± 0.012	0.033 ± 0.007
K	0.934	0.923 ± 0.016	0.922 ± 0.019	0.918	0.913 ± 0.019	0.911 ± 0.022
Site A	0.984	0.973 ± 0.013	0.973 ± 0.020	0.959	0.962 ± 0.014	0.958 ± 0.024
XMg	0.999	0.996 ± 0.003	0.996 ± 0.004	0.982	0.984 ± 0.003	0.983 ± 0.006
Tri	0.024	0.023 ± 0.007	0.023 ± 0.078	0.027	0.024 ± 0.007	0.025 ± 0.020
Prl	0.014	0.024 ± 0.013	0.024 ± 0.020	0.039	0.036 ± 0.014	0.040 ± 0.024
Mu	0.424	0.432 ± 0.022	0.430 ± 0.013	0.443	0.427 ± 0.016	0.425 ± 0.017
Cel	0.486	0.468 ± 0.033	0.469 ± 0.019	0.448	0.462 ± 0.030	0.461 ± 0.025
Pg	0.038	0.033 ± 0.012	0.035 ± 0.007	0.033	0.033 ± 0.012	0.033 ± 0.007
Mar	0.012	0.017 ± 0.005	0.017 ± 0.004	0.008	0.016 ± 0.006	0.015 ± 0.004
Total	0.998	0.997 ± 0.001	0.997 ± 0.001	0.998	0.998 ± 0.001	0.998 ± 0.001