Data Repository Item DR 2006094
Supplementary Geochronologic and Thermochronologic Data

GEOCHRONOLOGIC METHODS

Summary of analytical methods for U-Pb analysis (University of Arizona)

Zircons and titanite were separated from 1-2 kg samples of fresh rock using standard crushing and separation techniques, including a water table, magnetic separator and heavy liquids. Individual zircon crystals and titanite fragments were than hand-picked under a binocular microscope to select large, inclusion free grains. Approximately 50 grains were than mounted in epoxy and polished to approximately 2/3 of the crystal thickness. The grains were ablated with a New Wave DUV193 Excimer laser, operating at a wavelength of 193 nm and using a spot diameter of 25, 35, or 50 microns, depending on the size of the crystal. The ablated material is then carried in argon gas into the plasma source of a Micromass Isoprobe multicollector ICP-MS and ionized. The Micromass Isoprobe is equipped with a flight tube of sufficient width that U, Th, and Pb isotopes are measured simultaneously using nine Faraday collectors, an axial Daly detector and four ion-counting channels. All measurements were made in static mode, using Faraday detectors for ^{238}U, ^{232}Th, and $^{208-206}$Pb and an ion-counting channel for ^{204}Pb. ^{235}U is determined from the ^{238}U measurement assuming ^{238}U/^{235}U = 137.88. Ion yields are ~1 mV per ppm. Each analysis consists of one background run with 20-second integration on peaks and the laser off, 20 1-second integrations with the laser firing, and a 30-second delay to purge for the next analysis. The laser ablates at ~1 micron/second, resulting in an ablation pit ~20 microns in depth. A common lead correction was performed by using the measured ^{204}Pb and assuming an initial Pb composition from Stacey and Kramers (1975) (with uncertainties of 1.0, 0.3, and 2.0 for ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb, respectively). Measurement of ^{204}Pb is unaffected by the presence of ^{204}Hg because backgrounds are measured on peaks (thereby subtracting any background ^{204}Hg and ^{204}Pb) and because very little Hg is present in the argon gas.

The errors in determining ^{206}Pb/^{238}U and ^{206}Pb/^{204}Pb result in a measurement uncertainty of several percent (at 2-σ level) in the ^{206}Pb*/^{238}U age. The low concentrations of ^{207}Pb in younger samples (approximately < 1000 Ma), due to the low concentration of ^{235}U relative to ^{238}U, result in a substantially larger measurement uncertainty for ^{206}Pb/^{207}Pb. The ^{207}Pb*/^{235}U and ^{206}Pb*/^{207}Pb* ages for younger grains accordingly have larger uncertainties. Inter-element fractionation of Pb/U is generally <20%, whereas isotopic fractionation of Pb is generally <5%. These fractionations were corrected by analysis of a standard, with a known, concordant ID-TIMS age, between every three unknown analyses. The zircon standards are fragments of a large zircon crystal from a Sri Lankan pegmatite (e.g. Dickinson and Gehrels, 2003) with an age of 564 ± 4 Ma (2σ), while the titanite standards are fragments of a large titanite crystal from the Bear Lake region, Canada, with an age of 1050 ± 2 Ma (2σ) (Mark Schmitz and John Aleinikoff, written communication, 2003). The uncertainty resulting from the calibration correction is generally

~3% (2σ) for both $^{207}Pb/^{206}Pb$ and $^{206}Pb/^{238}U$ ages. U and Th concentrations were determined by analyzing a piece of NIST 610 glass with ~500 ppm U and Th and using the resulting measured intensities to calibrate the sample measured U and Th intensities.

The crystallization ages reported in this paper (Table 1; Fig. 3a; Fig. DR1) are weighted averages of individual, concordant spot analyses using the $^{206}Pb^*/^{238}U$ ages, since the $^{207}Pb^*/^{235}U$ and $^{207}Pb/^{206}Pb^*$ ages are less precise for these younger granitoids. The stated uncertainties (2σ) on the assigned crystallization ages are absolute values and include contributions from all known random and systematic errors. Random errors are included in the data tables. Systematic errors (2σ) are as follows: PK97-6-4-3A, 2.06%; JG062004-4, 1.00%; JG062204-1, 1.00%; JG061504-7, 0.81%; AP061504-B, 1.02%; AP061604-B, 1.00%; AP060604-A, 1.06%; AP052904-A, 1.06%; AP062104-A, 0.96%; PK97-6-4-1A Titanite, 2.16%.

All U-Pb plots and weighted average calculations were made using Isoplot 3.00 (Ludwig, 2003).

Summary of analytical methods for mica $^{40}Ar/^{39}Ar$ analyses (University of California, Los Angeles).

High-purity mica mineral separates for $^{40}Ar/^{39}Ar$ analysis were obtained using standard mineral separation techniques. They were irradiated for 45 hours at the Ford Reactor, University of Michigan, along with Fish Canyon sanidine (27.8 ± 0.3 Ma; Renne et al., 1994) or Taylor Creek sanidine (28.1 ± 0.3 Ma) flux monitors to calculate J-factors and K_2SO_4 and CaF_2 salts to calculate correction factors for interfering neutron reactions. Samples were step-heated in a Ta crucible within a double-vacuum furnace, and $^{40}Ar/^{39}Ar$ isotopic measurements were conducted on a VG 1200S or VG 3600 mass spectrometer at UCLA. Apparent ages were calculated using conventional decay constants and isotopic abundances. The uncertainties for apparent ages listed in Table A1 are at the one sigma level and do not include uncertainties in the J factor or decay constants.

Summary of analytical methods for hornblende and feldspar $^{40}Ar/^{39}Ar$ analyses (New Mexico Geochronological Research Laboratory).

Feldspar and hornblende separates were obtained by standard heavy liquid and magnetic separation methods. The separates were loaded into machined Al discs and irradiated for 75 mW hours in 5-c position at the McMaster reactor, Hamilton, Ontario along with the Fish Canyon Tuff sanidine (FC-2) as a neutron flux monitor. The FC-2 standard has an assigned age = 27.84 Ma (Deino and Potts, 1990) relative to Mmhb-1 at 520.4 Ma (Samson and Alexander, 1987).

The hornblendes and K-feldspars were step heated in a Mo resistance furnace, the former for 10 minutes while the latter ranged from 15 to 180 minutes. Isotopes were measured on a Mass Analyzer Products 215-50 mass spectrometer on line with automated all-metal extraction system. Reactive gases were removed during heating with an SAES GP-50 getter operated at ~450°C. Additional cleanup (5 minutes hornblendes; 2 minutes K-feldspar) following the step heating with two SAES GP-50 getters, one operated at ~450°C and one at 20°C. The gas was also exposed to a W filament operated at ~2000°C.

The electron multiplier sensitivity averaged 2.87×10^{-16} moles/pA. The total system blank and background for hornblendes was 70, 1.0, 0.4, 0.4, 0.5 x 10^{-17} moles for masses 40, 39, 38, 37, 36, respectively. The total system blank and background for K-feldspars was 45, 1.2, 0.3, 0.4, 0.3 x 10^{-17} moles for masses 40, 39, 38, 37, 36, respectively. The J-factors were determined to a precision of ± 0.1% by CO_2 laser-fusion of 6 single crystals from each of 4 radial positions around the irradiation tray. The Correction factors for interfering nuclear reactions were determined using K-glass and CaF_2 and are as follows: NM-173: $(^{40}Ar/^{39}Ar)_K = 0.02895 \pm 0.00059$; $(^{36}Ar/^{37}Ar)_{Ca} = 0.000284 \pm 0.000006$; $(^{39}Ar/^{37}Ar)_{Ca} = 0.00074 \pm 0.00002$; $(^{38}Ar/^{39}Ar)_K = 0.0129$.

K-Feldspar multi-domain diffusion modeling methods

Thermal histories are calculated from the feldspar data using the multi-domain diffusion (MDD) model (Figs. DR6d, DR7d, DR8d). The diffusion domain distribution for each feldspar is obtained by modeling the release of ^{39}Ar relative to the laboratory heating schedule. In all cases, the activation energy (E) is assumed to be constant for all diffusion domains of a given sample and seven diffusion domains were imposed on each model (Table DR4). The model Arrhenius and log(r/ro) plots show that the measured data can be well approximated by seven diffusion domains of varying proportions (Figs DR6b,c; DR7b,c; DR8b,c). For each sample, two thermal histories are shown: first the measured age data that have only been corrected for an assumed atmospheric $^{40}Ar/^{36}Ar$ initial value are modeled and secondly, apparent ages corrected for implied trapped components from isochron analysis are modeled (Figs. DR6a,d; DR7a,d; DR8a,d). Because the feldspar age spectra climb above the hornblende apparent ages we can be reasonably certain that the final heating steps for each feldspar are contaminated with excess ^{40}Ar. However, it is not obvious that the initial age gradients, which appear to climb in a steady fashion and are younger than coexisting hornblendes, are contaminated by excess ^{40}Ar. These age gradients are well fit by model age spectra that are created by cooling the samples from about 300°C at 150 Ma to about 100°C by 120 Ma (Figs. DR6a,d; DR7a,d; DR8a,d).

The accuracy of these models depends critically upon the assumption that the apparent ages are not influenced by excess ^{40}Ar, however the isochron data appear to challenge this assumption (Fig. DR5). Admittedly the isochron data define poor linear trends as revealed by high MSWD values; however we still assign overall meaning to their indication of excess argon (Fig. DR5). The probable cause for the scatter on the isochron arrays is incomplete separation of multiple trapped components (i.e. Heizler and Harrison, 1988) and potential true $^{40}Ar^*$ gradients related to complex thermal histories. We recognize problems with rigorous quantitative use of the isochron data, but feel that it is more appropriate to model age spectra that have been corrected with corresponding isochron trapped components rather then choose models that only correct of an atmospheric trapped initial $^{40}Ar/^{36}Ar$ value. Therefore, each apparent age is calculated using the inferred isochron trapped values (Fig. DR5) and recast as "isochron corrected" age spectra in Figures DR6a, DR7a, and DR8a. These spectra are much flatter than the atmosphere corrected spectra and thus produce model thermal histories that require cooling at a younger time and faster rate (Figs. DR6d, DR7d, DR8d). The "flattening" of the age spectra is most pronounced in samples PK-97-6-4-1A and PK-97-6-4-3A, whereas sample PK-97-6-4-2 is less sensitive to choice of the initial trapped $^{40}Ar/^{36}Ar$ component. This is mainly because the apparent radiogenic yields for samples PK-97-6-4-1A and 3A are significantly lower than that for PK-97-6-4-2 (Table DR2). As expected from the high MSWD values calculated from the isochron arrays, the corrected age spectra show significant scatter, but are overall much flatter than the original spectra and we assert that these isochron corrected spectra yield more accurate thermal histories.

The thermal histories determined from the isochron corrected age spectra indicate two periods of rapid cooling. Samples PK-97-6-4-1A and 3A suggest cooling from about 300°C to 100°C occurred between 125 and 120 Ma; whereas PK-97-6-4-2 suggests this same cooling range took place at about 140 Ma (Figs. DR6d, DR7d, DR8d). We have the least amount of confidence in sample PK-97-6-4-2 feldspar as both versions of the age spectra reveal a significant intermediate age hump that is suggested to be caused by post-argon closure modification of the diffusion domains (Lovera et al., 2002). For instance, Lovera et al. (2002) showed that complex age spectra with intermediate age humps could result from relatively low-temperature recrystallization and cautioned against assigning significance to model thermal histories in some instances.

References Cited

Deino, A., and Potts, R., 1990, Single-Crystal $^{40}Ar/^{39}Ar$ dating of the Olorgesailie Formation, Southern Kenya Rift: Journal of Geophysical Research, v. 95, p. 8,453-8,470.

Dickinson, W.R., and Gehrels, G.E., 2003, U-Pb ages of detrital zircons from Permian and Jurassic eolian sandstones of the Colorado Plateau, USA: paleogeographic implications: Sedimentary Geology, v. 163, p. 29-66.

Heizler, M.T., and Harrison, T.M., 1988, Multiple trapped argon isotope components revealed by $^{40}Ar/^{39}Ar$ analysis. Geochimica Cosmochima Acta, v. 52, p. 1,295-1,303.

Lovera, O. M., Grove, M., Harrison, T. M., 2002, Systematic analysis of K-feldspar $^{40}Ar/^{39}Ar$ step heating results; II, Relevance of laboratory argon diffusion properties to nature: Geochimica Cosmochimica Acta, v. 66, p. 1,237-1,255.

Ludgwig, K.R., 2003, Isoplot 3.00: Berkeley Geochronology Center Special Publication No. 4, 70 p.

Renne, P.R., Deino, A.L., Walter, R.C., Turrin, B.D., Swisher, C.C., Becker, T.A., Curtis, G.H., Sharp, W.D., and Jaouni, A.R., 1994, Intercalibration of astronomical and radioisotopic time: Geology, v. 22, p. 783-786.

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

Stacey, J.S., and Kramers, J.D., 1975, Approximation of Terrestrial Lead Isotope Evolution by a 2-Stage Model: Earth and Planetary Science Letters, v. 26, p. 207-221.

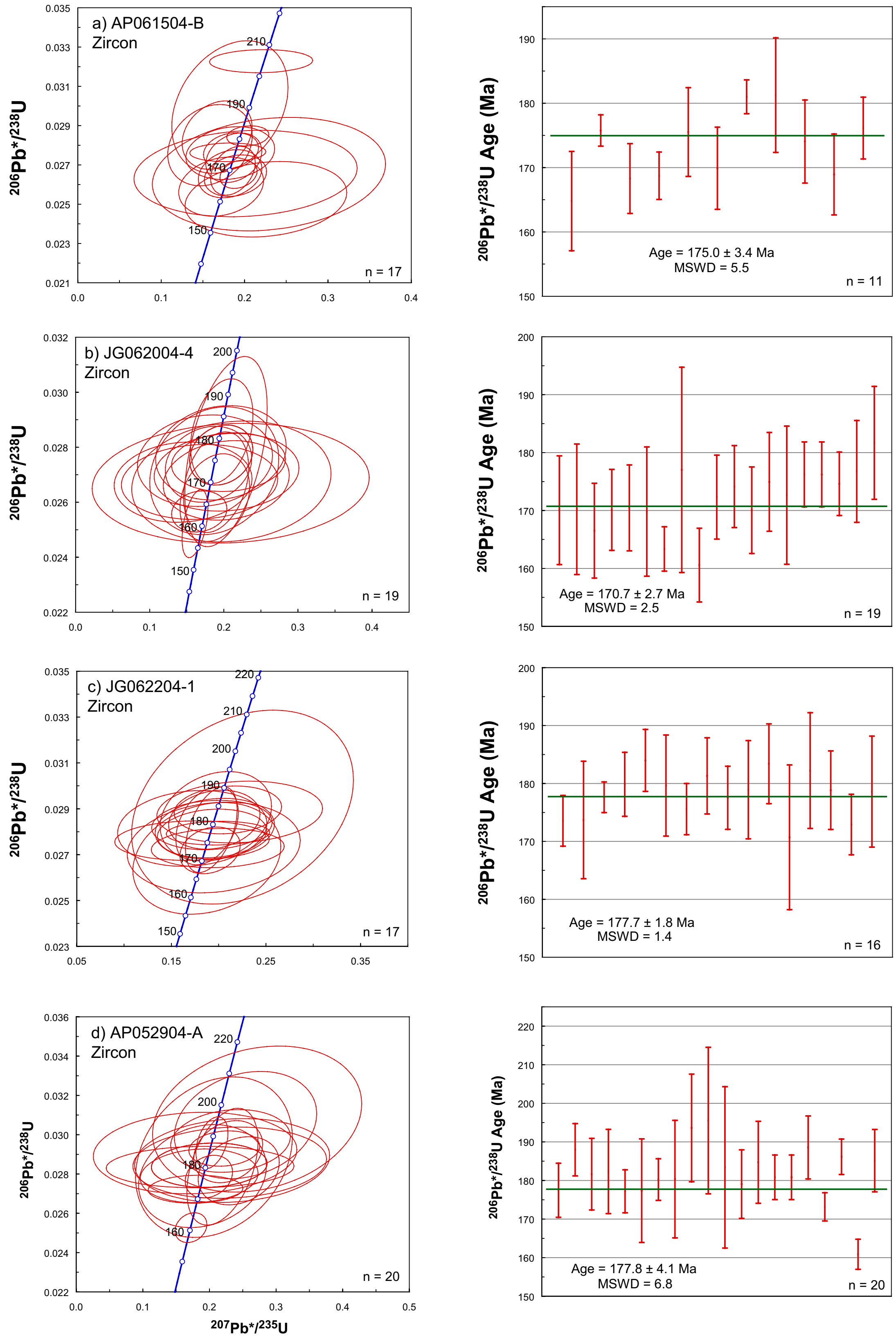

Figure DR1. U-Pb concordia plots and weighted averages for Jurassic granitoids a) AP061504-B, b) JG062004-4, c) JG062204-1, and d) AP052904-A. Error ellipses and error bars in this and all subsequent plots are at the 2-σ level. Note that mean age only includes random errors; see Table 1 for random & systematic errors.

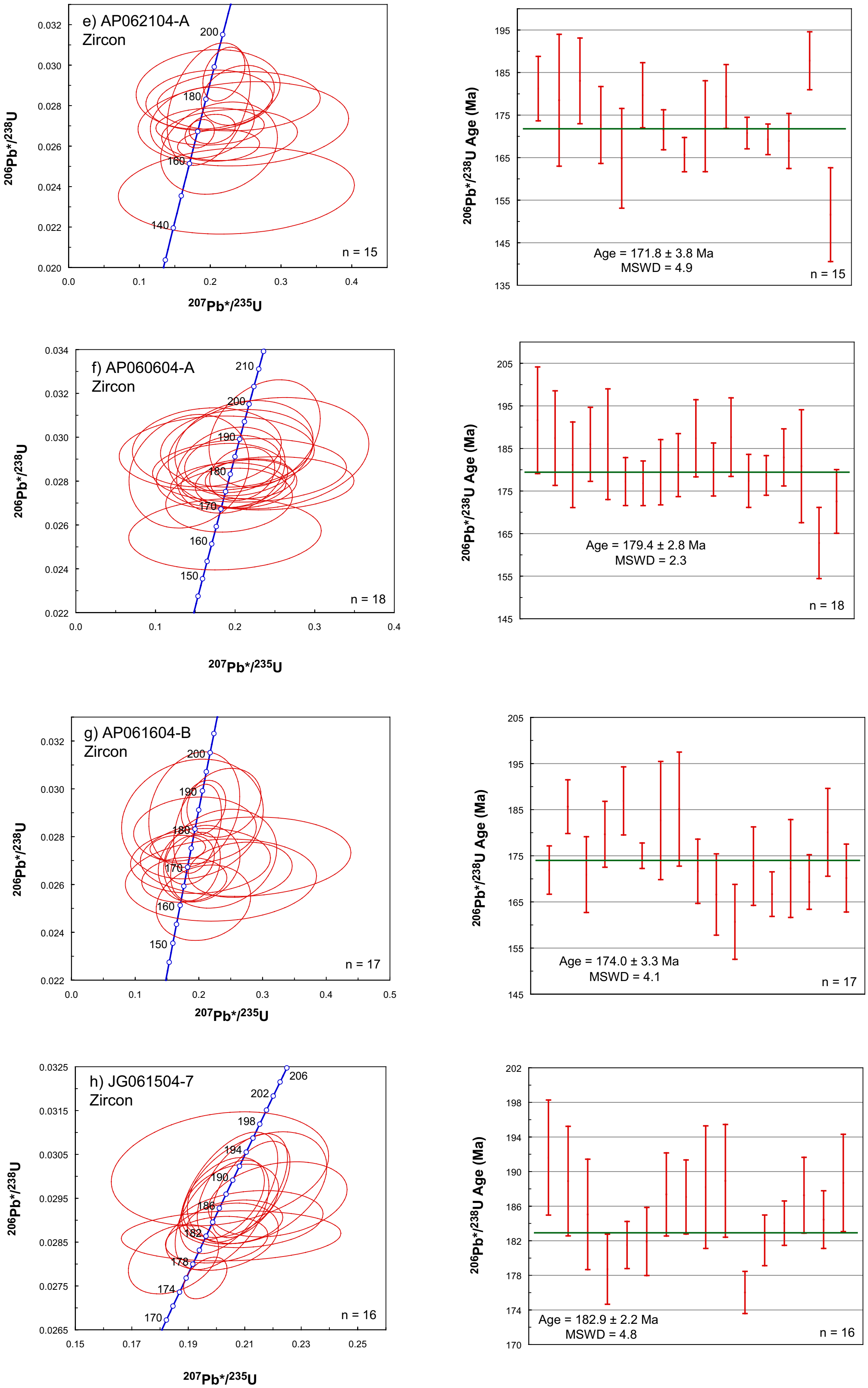

Figure DR1 continued. U-Pb concordia plots and weighted averages for Jurassic granitoids e) AP062104-A, f) AP060604-A, g) AP061604-B, and h) JG061504-7

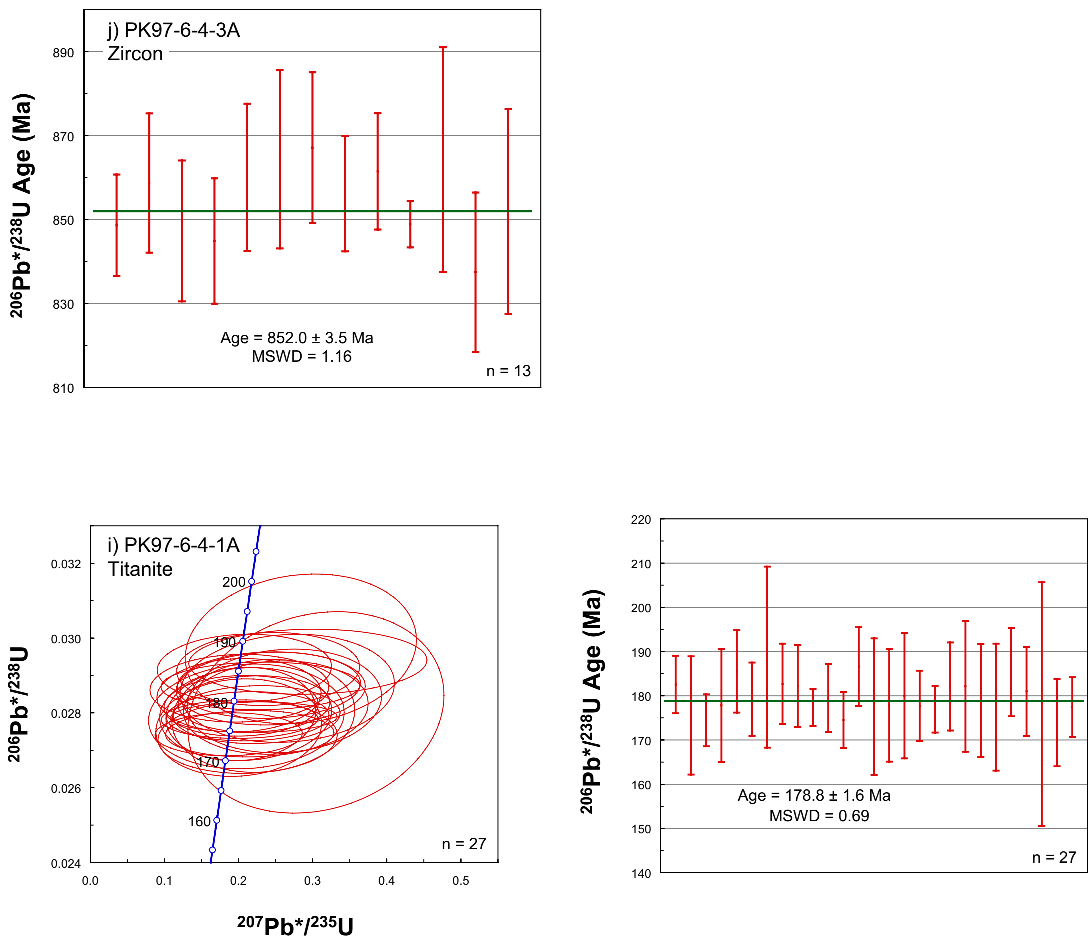

Figure DR1 continued. i) Weighted average of selected, concordant zircons from orthogneiss PK97-6-4-3A to define a crystallization age and j) U-Pb concordia plot and weighted average for Titanite from orthogneiss PK97-6-4-1A.

Table DR1. U-Pb data

Sample spot numbers in bold were used to calculate the weighted averages

				Isotopic ratios					Apparent ages (Ma)					
Sample spot	U (ppm)	$^{206}Pb/^{204}Pb$	U/Th	$^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	error corr	$^{206}Pb^*/^{238}U$	± (Ma)	$^{207}Pb^*/^{235}U$	± (Ma)	$^{206}Pb^*/^{207}Pb^*$	± (Ma)
PK97-6-4-3A Zircon														
1	74	23236	3.8	1.04585	2.28	0.11275	2.01	0.88	689	14.6	727	23.9	846	11
2	49	82186	3.9	1.35389	1.50	0.14203	0.75	0.50	856	6.9	869	20.3	903	13
3	42	64844	3.8	1.31590	2.37	0.14004	0.83	0.35	845	7.5	853	31.2	873	23
6	26	28827	4.1	1.36611	3.82	0.14298	0.75	0.20	861	6.9	874	51.6	908	39
9	29	31145	32.5	0.48372	9.15	0.05947	5.00	0.55	372	19.1	401	44.0	567	83
10t	66	197058	10.9	0.83463	3.53	0.09433	3.09	0.88	581	18.8	616	29.4	747	18
11	34	119041	3.8	1.33345	2.38	0.14349	1.15	0.48	864	10.6	860	31.7	850	22
12	67	58200	31.5	0.24671	6.32	0.03185	1.21	0.19	202	2.5	224	15.7	459	69
16	103	63471	4.2	0.85294	1.53	0.08796	1.16	0.76	543	6.6	626	13.2	938	10
17	23	133570	5.1	1.31926	2.51	0.14272	0.95	0.38	860	8.8	854	33.1	839	24
17t	52	49148	31.9	0.28783	8.27	0.03364	1.35	0.16	213	2.9	257	23.9	676	87
18	24	134179	4.2	1.24968	3.61	0.13489	1.09	0.30	816	9.5	823	44.9	844	36
19	20	81693	3.8	1.37145	3.22	0.14348	1.45	0.45	864	13.4	877	43.9	908	30
20	35	180701	3.1	1.22229	2.19	0.12916	0.80	0.36	783	6.6	811	26.8	888	21
22t	50	68318	6.6	0.71205	3.77	0.07248	1.99	0.53	451	9.3	546	26.9	965	33
25t	65	629740	5.5	0.99926	2.79	0.10830	2.16	0.77	663	15.1	703	27.9	835	18
27t	41	95493	12.0	0.37717	6.80	0.04607	2.14	0.32	290	6.4	325	25.7	581	70
29	26	381676	4.3	1.23819	2.40	0.13362	0.86	0.36	808	7.4	818	29.7	844	23
31	18	64114	12.0	0.82039	7.25	0.09058	3.88	0.54	559	22.6	608	58.7	797	64
32	76	852773	6.4	1.02338	1.45	0.11115	0.53	0.37	679	3.8	716	15.0	831	14
35	24	169750	4.0	1.24817	3.68	0.13182	0.82	0.22	798	6.9	823	45.6	889	37
2-1tr	24	57085	4.8	1.09325	4.86	0.11497	1.44	0.30	702	10.7	750	52.5	898	48
2-2c	14	8430	3.4	1.30092	3.46	0.14046	0.93	0.27	847	8.4	846	44.7	843	35
2-2tl	26	17008	3.7	0.92843	2.70	0.10475	1.44	0.53	642	9.7	667	25.2	751	24
2-2tr	19	6676	3.2	0.84426	5.01	0.09903	1.11	0.22	609	7.1	621	42.1	668	52
2-3c	14	33488	4.9	1.39342	4.73	0.14128	1.34	0.28	852	12.2	886	64.8	973	46
2-4c	35	20342	2.3	1.28120	2.89	0.14070	0.67	0.23	849	6.0	837	36.9	808	29
2-4tl	52	5798	10.2	0.50719	3.30	0.06164	2.15	0.65	386	8.5	417	16.9	592	27
2-5c	27	15189	2.4	1.29755	4.10	0.14248	0.90	0.22	859	8.3	845	52.6	808	42
2-5cr	25	68770	4.0	1.03891	3.37	0.10743	1.20	0.36	658	8.3	723	34.9	932	32
2-5tr	39	2117	10.9	0.50971	6.73	0.06138	2.51	0.37	384	9.9	418	34.2	612	67
2-6c	35	16064	2.5	1.34398	1.86	0.14398	0.97	0.52	867	9.0	865	25.0	859	16
2-7c	24	42070	4.3	1.04769	4.48	0.11452	3.71	0.83	699	27.4	728	46.6	818	26
2-10c	13	27809	2.6	1.37472	4.98	0.13872	1.06	0.21	837	9.5	878	67.2	982	50
2-10tr	19	6864	4.3	0.64831	6.30	0.07839	2.11	0.33	486	10.6	507	40.7	603	64
2-11c	24	29165	1.8	1.29767	4.60	0.13613	1.43	0.31	823	12.5	845	58.8	903	45
2-11tr2	25	8302	6.4	0.76238	6.10	0.08854	5.03	0.82	547	28.6	575	46.2	689	37
2-13c	26	3544	3.3	1.36904	2.60	0.14074	0.30	0.12	849	2.8	876	35.5	944	26
2-13tl	43	4932	7.5	0.71289	5.21	0.07458	4.37	0.84	464	21.0	546	37.0	909	29
2-14c	41	166873	3.4	1.24897	4.40	0.13447	2.08	0.47	813	18.0	823	54.3	849	40
2-17tl	17	6702	5.3	0.78529	6.08	0.09252	1.54	0.25	570	9.2	588	47.4	659	63
2-17tr	25	3192	11.9	0.50105	5.95	0.05328	2.71	0.46	335	9.3	412	29.8	875	55

Table DR1. U-Pb data

				Isotopic ratios					Apparent ages (Ma)					
Sample spot	U (ppm)	$^{206}Pb/^{204}Pb$	U/Th	$^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	error corr	$^{206}Pb^*/^{238}U$	± (Ma)	$^{207}Pb^*/^{235}U$	± (Ma)	$^{206}Pb^*/^{207}Pb^*$	± (Ma)
AP061504-B Zircon														
1R	554	6834	1.4	0.21990	11.49	0.03228	0.74	0.06	205	1.5	202	21.0	167	269
1C	718	4756	0.7	0.17190	12.09	0.02589	2.37	0.20	165	3.9	161	18.0	107	281
2T	998	5831	1.8	0.17999	10.35	0.02764	0.70	0.07	176	1.2	168	16.0	61	247
2C	340	2575	1.7	0.18240	15.62	0.02995	4.60	0.29	190	8.6	170	24.5	-101	368
3R	1168	2968	2.2	0.18909	8.06	0.02645	1.63	0.20	168	2.7	176	13.0	279	181
3C	835	352	1.0	0.22565	17.56	0.02525	3.11	0.18	161	4.9	207	32.8	768	367
4C	465	1621	1.2	0.22924	24.92	0.02653	4.45	0.18	169	7.4	210	47.2	697	530
5	304	3547	1.2	0.20124	27.17	0.02656	3.38	0.12	169	5.6	186	46.3	410	613
6	1219	6951	2.0	0.19277	4.72	0.02652	1.10	0.23	169	1.8	179	7.7	317	104
7	301	2102	1.1	0.18288	11.89	0.02760	1.99	0.17	176	3.4	171	18.7	102	278
8	1641	1138	2.1	0.18608	5.88	0.02671	1.90	0.32	170	3.2	173	9.4	220	129
9	1082	3471	2.2	0.20390	5.05	0.02848	0.74	0.15	181	1.3	188	8.7	282	114
10	294	1879	1.1	0.15854	13.06	0.02801	3.02	0.23	178	5.3	149	18.1	-284	325
12	363	2641	1.3	0.16708	10.25	0.02852	2.49	0.24	181	4.5	157	14.9	-197	250
13	1368	1446	2.5	0.18713	7.34	0.02737	1.88	0.26	174	3.2	174	11.7	176	166
16	587	4443	1.9	0.18269	8.52	0.02655	1.88	0.22	169	3.1	170	13.4	190	194
18	1031	6906	2.3	0.18375	7.34	0.02770	1.38	0.19	176	2.4	171	11.6	105	170
JG062004-4 Zircon														
1R	390	2558	1.4	0.18947	9.49	0.02673	2.80	0.29	170	4.7	176	15.3	259	209
1C	340	2854	2.7	0.21016	26.14	0.02676	3.35	0.13	170	5.6	194	46.1	490	581
2R	241	2699	1.2	0.18777	10.21	0.02617	2.49	0.24	167	4.1	175	16.4	287	227
2C	208	1458	1.7	0.16727	25.77	0.02674	2.08	0.08	170	3.5	157	37.5	-36	632
3T	107	872	0.6	0.41713	12.09	0.02939	4.01	0.33	187	7.4	354	36.2	1677	211
3C	226	2345	0.9	0.20325	17.08	0.02679	2.20	0.13	170	3.7	188	29.3	413	381
4	147	937	0.5	0.20923	36.50	0.02669	3.33	0.09	170	5.6	193	64.2	486	828
5	886	711	1.1	0.16684	9.13	0.02567	1.19	0.13	163	1.9	157	13.3	57	216
6	661	2961	1.2	0.20293	11.19	0.02784	5.07	0.45	177	8.9	188	19.2	323	227
7	1514	1884	1.0	0.16104	4.41	0.02522	2.01	0.45	161	3.2	152	6.2	14	95
8	320	932	2.0	0.20361	19.60	0.02709	2.13	0.11	172	3.6	188	33.7	392	441
10	361	2375	1.3	0.17926	13.29	0.02738	2.06	0.16	174	3.5	167	20.5	74	313
11	258	2021	0.3	0.14503	26.19	0.02673	2.23	0.09	170	3.7	138	33.7	-393	689
12	262	1711	1.7	0.17450	21.34	0.02751	2.47	0.12	175	4.3	163	32.2	-2	516
13	693	506	0.3	0.18709	19.00	0.02714	3.50	0.18	173	6.0	174	30.4	194	437
14	788	8207	1.5	0.19645	8.87	0.02772	1.61	0.18	176	2.8	182	14.8	259	201
15	788	8207	1.5	0.19645	8.87	0.02772	1.61	0.18	176	2.8	182	14.8	259	201
18	1107	1243	1.2	0.20630	15.23	0.02746	1.59	0.10	175	2.7	190	26.5	391	342
19	206	2702	0.9	0.19609	18.35	0.02780	2.52	0.14	177	4.4	182	30.6	248	421
20	690	365	0.8	0.22546	6.16	0.02594	1.37	0.22	165	2.2	206	11.5	709	128
21	745	7149	1.2	0.19716	8.70	0.02858	2.72	0.31	182	4.9	183	14.5	196	192

Table DR1. U-Pb data

				Isotopic ratios					Apparent ages (Ma)					
Sample spot	U (ppm)	$\frac{^{206}Pb}{^{204}Pb}$	U/Th	$\frac{^{207}Pb^*}{^{235}U}$	± (%)	$\frac{^{206}Pb^*}{^{238}U}$	± (%)	error corr	$\frac{^{206}Pb^*}{^{238}U}$	± (Ma)	$\frac{^{207}Pb^*}{^{235}U}$	± (Ma)	$\frac{^{206}Pb^*}{^{207}Pb^*}$	± (Ma)
JG062204-1 Zircon														
1R	493	7111	1.2	0.19904	14.43	0.02729	1.28	0.09	174	2.2	184	24.3	324	328
1C	303	403	0.7	0.19484	19.18	0.02731	2.96	0.15	174	5.1	181	31.8	274	438
2R	458	2980	1.5	0.19928	11.21	0.02794	0.76	0.07	178	1.3	185	18.9	274	257
2C	607	2249	1.0	0.19292	13.48	0.02829	1.56	0.12	180	2.8	179	22.1	169	314
3	600	3654	1.0	0.20976	11.06	0.02895	1.47	0.13	184	2.7	193	19.5	309	250
4	704	3702	1.0	0.18778	7.18	0.02826	2.46	0.34	180	4.4	175	11.5	109	159
7	328	2151	1.4	0.17185	19.42	0.02761	1.28	0.07	176	2.2	161	28.9	-48	475
8	399	3155	1.2	0.19537	10.10	0.02852	1.84	0.18	181	3.3	181	16.8	180	232
9	442	2110	1.0	0.19302	12.23	0.02792	1.56	0.13	178	2.7	179	20.1	201	282
10	393	1527	0.9	0.22522	21.27	0.02907	5.94	0.28	185	10.8	206	39.7	460	457
11	390	3685	0.8	0.17208	18.75	0.02814	2.40	0.13	179	4.2	161	28.0	-92	459
12	207	2063	1.0	0.22227	16.10	0.02886	1.91	0.12	183	3.4	204	29.7	447	357
13	491	318	1.2	0.18751	17.04	0.02684	3.71	0.22	171	6.2	175	27.3	226	387
14	587	4731	1.1	0.19697	12.22	0.02867	2.78	0.23	182	5.0	183	20.4	187	278
17	596	8888	1.1	0.19587	13.15	0.02813	1.92	0.15	179	3.4	182	21.9	218	302
21	751	6720	1.0	0.19090	6.83	0.02719	1.53	0.22	173	2.6	177	11.1	238	154
24	585	9499	0.9	0.19223	5.80	0.02809	2.72	0.47	179	4.8	179	9.5	178	120
AP052904-A Zircon														
1C	329	2497	0.8	0.23719	12.02	0.03017	3.32	0.28	192	6.3	216	23.4	492	256
4C	369	462	0.9	0.21124	16.79	0.02950	3.01	0.18	187	5.6	195	29.7	282	380
5C	337	4198	1.7	0.19466	14.29	0.02850	2.81	0.20	181	5.0	181	23.6	173	328
9C	540	303	0.5	0.17701	28.28	0.02927	2.37	0.08	186	4.4	165	43.2	-118	707
11C	160	314	1.8	0.24206	21.27	0.02927	3.54	0.17	186	6.5	220	42.1	603	459
12C	722	707	0.5	0.21378	12.21	0.02787	1.61	0.13	177	2.8	197	21.8	437	270
13C	416	2102	0.8	0.19161	15.45	0.02781	1.50	0.10	177	2.6	178	25.2	194	359
14C	331	4696	0.5	0.18376	18.33	0.02822	2.17	0.12	179	3.8	171	28.9	60	437
15C	168	2073	2.1	0.21815	22.80	0.02849	2.07	0.09	181	3.7	200	41.5	434	512
16C	251	2163	0.8	0.20212	19.37	0.02950	2.46	0.13	187	4.5	187	33.1	181	451
18C	513	10015	1.2	0.20896	7.99	0.02832	1.75	0.22	180	3.1	193	14.0	350	176
19C	249	490	2.2	0.16457	23.22	0.02954	2.50	0.11	188	4.6	155	33.3	-325	600
20C	262	2373	0.5	0.24066	18.45	0.02790	1.78	0.10	177	3.1	219	36.4	694	395
23T	283	1357	1.3	0.21861	10.47	0.02810	1.32	0.13	179	2.3	201	19.1	469	231
24T	2980	960	40.6	0.19708	12.52	0.02878	1.86	0.15	183	3.4	183	20.9	179	290
25T	334	248	1.2	0.14211	21.65	0.02845	3.72	0.17	181	6.6	135	27.4	-613	587
26T	394	361	0.3	0.18736	26.36	0.02557	2.60	0.10	163	4.2	174	42.3	335	604
27T	469	2352	1.0	0.19253	16.88	0.02713	2.20	0.13	173	3.7	179	27.7	262	387

Table DR1. U-Pb data

Sample spot	U (ppm)	$^{206}Pb/^{204}Pb$	U/Th	Isotopic ratios: $^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	error corr	Apparent ages (Ma): $^{206}Pb^*/^{238}U$	± (Ma)	$^{207}Pb^*/^{235}U$	± (Ma)	$^{206}Pb^*/^{207}Pb^*$	± (Ma)
AP062104-A														
2C	359	1381	1.3	0.23891	8.83	0.02851	2.12	0.24	181	3.8	218	17.3	631	185
3C	763	9004	2.1	0.19789	12.14	0.02808	4.40	0.36	178	7.7	183	20.4	246	261
4C	190	1971	1.2	0.19702	21.09	0.02880	2.79	0.13	183	5.0	183	35.3	177	492
5C	369	1501	1.0	0.18893	15.89	0.02715	2.65	0.17	173	4.5	176	25.7	217	365
9C	488	718	1.0	0.21249	15.85	0.02590	3.60	0.23	165	5.9	196	28.2	585	337
10C	210	3522	0.8	0.19871	18.41	0.02826	2.16	0.12	180	3.8	184	31.0	240	424
17C	638	1078	1.0	0.19988	15.65	0.02697	1.39	0.09	172	2.4	185	26.5	361	354
18C	472	5203	0.9	0.21183	11.19	0.02604	1.23	0.11	166	2.0	195	19.9	567	243
19C	416	353	1.1	0.24677	24.64	0.02710	3.14	0.13	172	5.3	224	49.6	808	519
21C	704	378	1.5	0.24037	19.56	0.02822	2.12	0.11	179	3.8	219	38.5	667	420
23C	1079	4470	1.6	0.20290	6.56	0.02685	1.10	0.17	171	1.9	188	11.2	405	145
24C	1076	4008	1.6	0.18512	4.58	0.02661	1.08	0.23	169	1.8	172	7.3	216	103
26T	888	286	0.6	0.22728	17.25	0.02655	1.94	0.11	169	3.2	208	32.4	677	369
27T	793	2819	2.0	0.21929	5.54	0.02956	1.84	0.33	188	3.4	201	10.1	363	118
30T	1340	221	2.1	0.23693	28.76	0.02379	3.68	0.13	152	5.5	216	56.0	992	592
AP060604-B														
1C	329	2497	0.8	0.23719	12.02	0.03017	3.32	0.28	192	6.3	216	23.4	492	256
4C	369	462	0.9	0.21124	16.79	0.02950	3.01	0.18	187	5.6	195	29.7	282	380
5C	337	4198	1.7	0.19466	14.29	0.02850	2.81	0.20	181	5.0	181	23.6	173	328
9C	540	303	0.5	0.17701	28.28	0.02927	2.37	0.08	186	4.4	165	43.2	-118	707
11C	160	314	1.8	0.24206	21.27	0.02927	3.54	0.17	186	6.5	220	42.1	603	459
12C	722	707	0.5	0.21378	12.21	0.02787	1.61	0.13	177	2.8	197	21.8	437	270
13C	416	2102	0.8	0.19161	15.45	0.02781	1.50	0.10	177	2.6	178	25.2	194	359
14C	331	4696	0.5	0.18376	18.33	0.02822	2.17	0.12	179	3.8	171	28.9	60	437
15C	168	2073	2.1	0.21815	22.80	0.02849	2.07	0.09	181	3.7	200	41.5	434	512
16C	251	2163	0.8	0.20212	19.37	0.02950	2.46	0.13	187	4.5	187	33.1	181	451
18C	513	10015	1.2	0.20896	7.99	0.02832	1.75	0.22	180	3.1	193	14.0	350	176
19C	249	490	2.2	0.16457	23.22	0.02954	2.50	0.11	188	4.6	155	33.3	-325	600
20C	262	2373	0.5	0.24066	18.45	0.02790	1.78	0.10	177	3.1	219	36.4	694	395
23T	283	1357	1.3	0.21861	10.47	0.02810	1.32	0.13	179	2.3	201	19.1	469	231
24T	2980	960	40.6	0.19708	12.52	0.02878	1.86	0.15	183	3.4	183	20.9	179	290
25T	334	248	1.2	0.14211	21.65	0.02845	3.72	0.17	181	6.6	135	27.4	-613	587
26T	394	361	0.3	0.18736	26.36	0.02557	2.60	0.10	163	4.2	174	42.3	335	604
27T	469	2352	1.0	0.19253	16.88	0.02713	2.20	0.13	173	3.7	179	27.7	262	387

Table DR1. U-Pb data

Sample spot	U (ppm)	$^{206}Pb/^{204}Pb$	U/Th	Isotopic ratios: $^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	error corr	Apparent ages (Ma): $^{206}Pb^*/^{238}U$	± (Ma)	$^{207}Pb^*/^{235}U$	± (Ma)	$^{206}Pb^*/^{207}Pb^*$	± (Ma)
AP061604-B														
1C	371	6026	0.9	0.18573	8.47	0.02702	1.54	0.18	172	2.6	173	13.5	188	194
3C	413	7975	6.1	0.20725	6.89	0.02922	1.59	0.23	186	2.9	191	12.0	261	154
4C	450	5536	1.3	0.20042	13.09	0.02687	2.44	0.19	171	4.1	185	22.2	375	290
5C	257	2739	1.2	0.19393	20.29	0.02826	2.02	0.10	180	3.6	180	33.5	184	474
7C	367	6755	2.1	0.23945	9.93	0.02942	2.00	0.20	187	3.7	218	19.5	568	212
10C	499	3301	2.6	0.16691	10.68	0.02752	0.80	0.08	175	1.4	157	15.5	-111	263
11C	238	2546	1.5	0.18991	23.93	0.02874	3.56	0.15	183	6.4	177	38.8	96	567
14C	310	1551	3.5	0.19278	15.13	0.02913	3.39	0.22	185	6.2	179	24.8	99	351
17C	234	1855	2.0	0.20254	22.16	0.02698	2.06	0.09	172	3.5	187	37.9	389	501
18C	674	710	3.7	0.23463	26.13	0.02618	2.68	0.10	167	4.4	214	50.5	774	556
19T	244	1378	1.1	0.20722	14.63	0.02524	2.56	0.17	161	4.1	191	25.5	587	314
21T	243	567	2.0	0.27346	24.69	0.02716	2.49	0.10	173	4.3	245	53.9	1014	505
22T	524	3534	3.2	0.17714	15.41	0.02619	1.47	0.10	167	2.4	166	23.6	150	361
23T	156	1485	0.7	0.23349	15.53	0.02708	3.12	0.20	172	5.3	213	29.9	692	326
25T	273	3786	1.3	0.26487	12.59	0.02661	1.77	0.14	169	3.0	239	26.8	991	255
26T	496	5920	6.4	0.19788	7.75	0.02833	2.68	0.35	180	4.8	183	13.0	225	168
27T	520	8114	2.2	0.19475	8.20	0.02675	2.19	0.27	170	3.7	181	13.6	320	180
JG061504-7														
2	347	5165	0.9	0.20123	7.81	0.03017	1.76	0.23	192	3.3	186	13.3	117	180
3	1167	18686	1.5	0.20916	3.12	0.02974	1.70	0.54	189	3.2	193	5.5	241	60
4	1256	25846	1.7	0.20197	3.36	0.02912	1.75	0.52	185	3.2	187	5.7	209	67
5	660	8527	1.1	0.18475	3.53	0.02811	1.15	0.33	179	2.0	172	5.6	83	79
7	1163	8317	1.1	0.20005	3.70	0.02856	0.76	0.21	182	1.4	185	6.3	232	84
9	1142	2014	1.8	0.20196	4.03	0.02862	1.10	0.27	182	2.0	187	6.9	249	89
11	1098	11644	1.5	0.20230	2.96	0.02949	1.30	0.44	187	2.4	187	5.1	183	62
14	1239	4097	1.7	0.20503	3.37	0.02944	1.16	0.34	187	2.1	189	5.8	218	73
15	1196	8106	1.7	0.20436	3.47	0.02962	1.91	0.55	188	3.5	189	6.0	196	67
17	1240	2456	1.9	0.21436	4.71	0.02974	1.75	0.37	189	3.3	197	8.4	297	100
18	1485	3635	1.6	0.19602	1.60	0.02768	0.70	0.44	176	1.2	182	2.7	257	33
19	1003	2857	1.3	0.20519	7.75	0.02864	0.82	0.11	182	1.5	190	13.4	283	176
20	1492	2653	1.6	0.20654	3.35	0.02896	0.71	0.21	184	1.3	191	5.8	273	75
22	467	1289	0.7	0.22168	4.53	0.02948	1.19	0.26	187	2.2	203	8.3	394	98
23	1466	2184	1.9	0.21214	4.93	0.02902	0.92	0.19	184	1.7	195	8.8	329	110
24	1505	3134	1.6	0.21210	2.68	0.02970	1.51	0.56	189	2.8	195	4.8	276	51

Table DR1. U-Pb data

Sample spot	U (ppm)	$^{206}Pb/^{204}Pb$	U/Th	Isotopic ratios: $^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	error corr	Apparent ages (Ma): $^{206}Pb^*/^{238}U$	± (Ma)	$^{207}Pb^*/^{235}U$	± (Ma)	$^{206}Pb^*/^{207}Pb^*$	± (Ma)
PK97-6-4-1A Titanite														
1	423	146	2.8	0.22957	47.78	0.02872	1.81	0.04	183	3.3	210	86.8	529	523
2	496	204	3.6	0.20024	45.61	0.02761	3.86	0.08	176	6.7	185	74.5	312	517
3	429	238	3.7	0.18681	43.48	0.02743	1.71	0.04	174	2.9	174	67.2	167	508
4	531	269	5.0	0.20325	40.66	0.02797	3.64	0.09	178	6.4	188	67.5	316	461
5	390	204	4.5	0.20796	46.18	0.02919	2.55	0.06	185	4.7	192	77.7	271	529
6	428	256	5.0	0.20349	41.81	0.02819	2.35	0.06	179	4.2	188	69.4	301	476
7	428	144	3.9	0.28401	44.86	0.02971	5.50	0.12	189	10.2	254	96.1	909	459
8	439	213	3.9	0.24096	41.98	0.02874	2.53	0.06	183	4.6	219	79.6	632	451
9	502	188	3.0	0.20119	49.01	0.02866	2.58	0.05	182	4.6	186	80.1	237	565
10	599	232	6.0	0.22083	41.61	0.02789	1.20	0.03	177	2.1	203	73.7	508	457
11	660	287	7.8	0.22097	37.87	0.02824	2.17	0.06	180	3.8	203	67.3	482	418
12	626	215	4.4	0.21520	43.11	0.02744	1.85	0.04	175	3.2	198	74.7	487	475
13	537	137	7.4	0.29358	44.73	0.02937	2.42	0.05	187	4.5	261	98.2	1000	454
14	468	194	5.1	0.23347	43.16	0.02792	4.41	0.10	178	7.7	213	79.7	627	463
15	522	206	3.4	0.20962	45.22	0.02797	3.63	0.08	178	6.4	193	76.6	386	506
16	473	203	6.9	0.26176	40.96	0.02832	4.00	0.10	180	7.1	236	82.8	839	424
17	443	237	3.9	0.22432	41.02	0.02795	2.26	0.06	178	4.0	205	73.6	537	448
18	551	251	3.7	0.20137	42.82	0.02783	1.51	0.04	177	2.6	186	70.4	306	487
19	459	206	4.3	0.24334	42.85	0.02865	2.78	0.06	182	5.0	221	81.8	660	458
20	425	153	7.3	0.26582	44.45	0.02866	4.12	0.09	182	7.4	239	90.6	846	460
21	424	209	4.3	0.25035	40.66	0.02814	3.62	0.09	179	6.4	227	79.5	759	427
22	551	154	4.4	0.21052	51.24	0.02791	4.10	0.08	177	7.2	194	86.7	401	572
23	423	209	3.1	0.23994	42.03	0.02917	2.74	0.07	185	5.0	218	79.4	591	455
24	376	221	3.7	0.20070	45.09	0.02847	2.81	0.06	181	5.0	186	73.8	246	518
25	422	121	4.2	0.30440	46.37	0.02801	7.85	0.17	178	13.8	270	104.3	1167	453
26	392	172	3.2	0.21224	46.53	0.02735	2.88	0.06	174	4.9	195	79.5	464	515
27	462	228	5.8	0.21243	42.17	0.02791	1.92	0.05	177	3.4	196	72.4	420	470

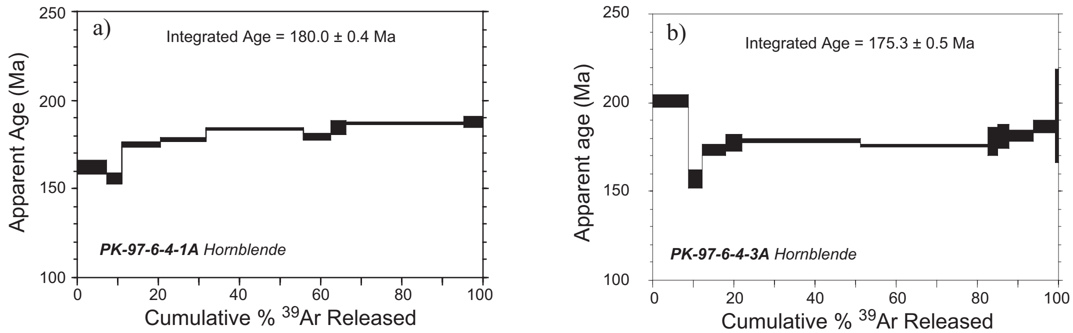

Figure DR2. Hornblende argon age and K/Ca spectra for (a) PK-97-6-4-1A and (b) PK-97-6-4-3A

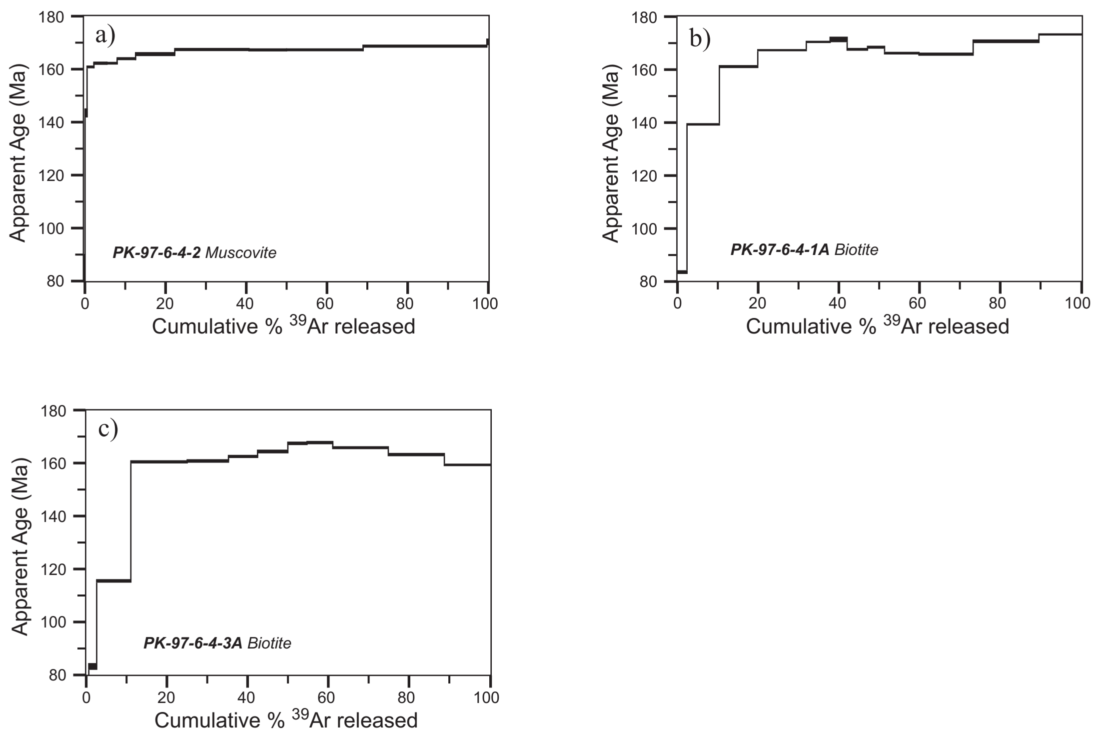

Figure DR3. $^{40}Ar/^{39}Ar$ apparent age spectra for mica from orthogneiss samples a) PK-97-6-4-2, b) PK-97-6-4-1A and c) PK-97-6-4-3A.

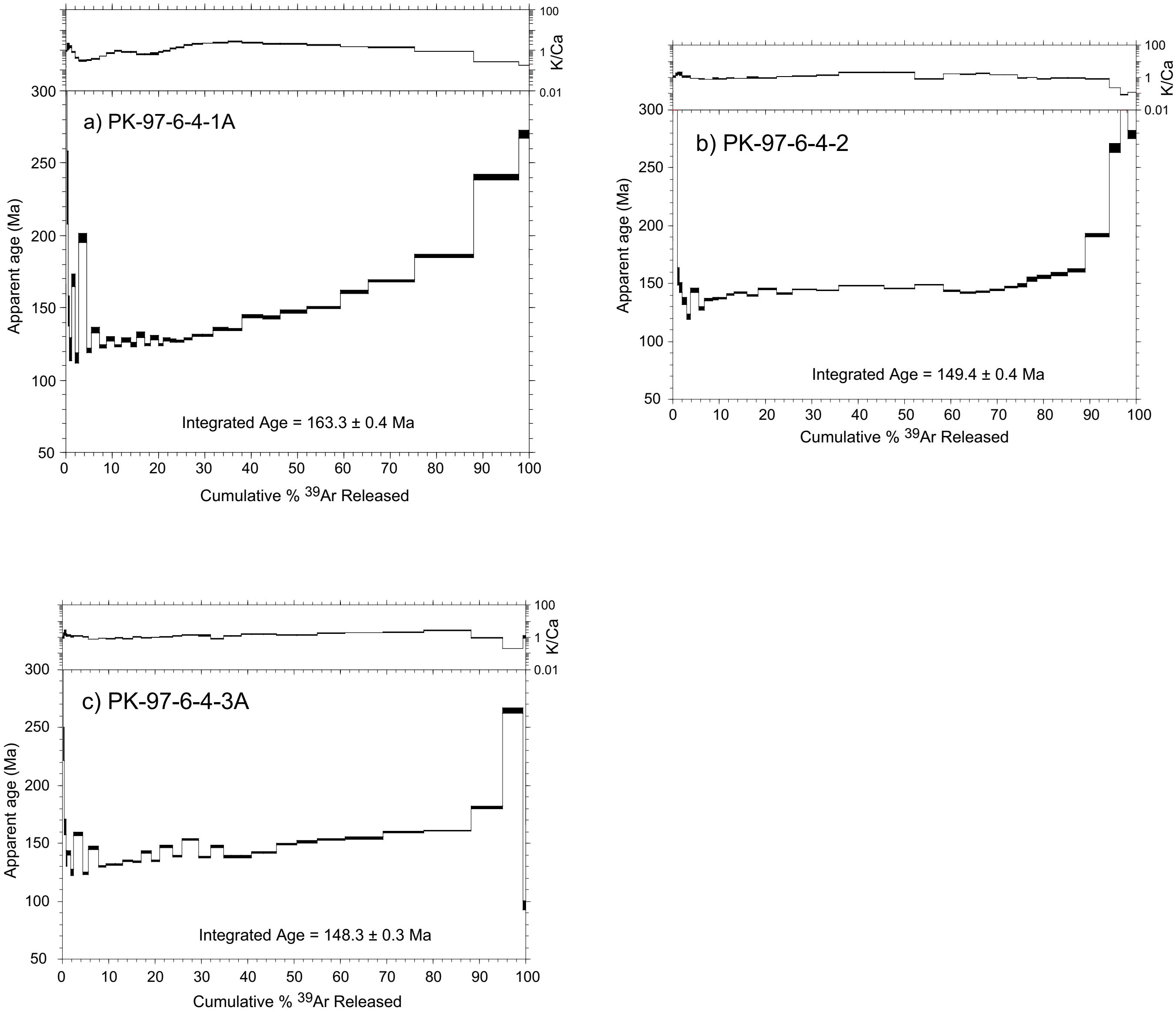

Figure DR4. Feldspar age and K/Ca spectra for a) PK-97-6-4-1A, b) PK-97-6-4-2 and c) PK-97-6-4-3A. All of the samples have relatively low K/Ca values and the ca. 1% bulk K_20 estimates indicate significant quartz and plagioclase contamination of the K-feldspar mineral separate (Table DR2). For the two samples that have coexisting hornblende pairs (PK-97-6-4-1A and 3A), the feldspars yield apparent ages significantly older then the hornblendes (Fig. DR2). This later observation strongly suggests excess argon contamination.

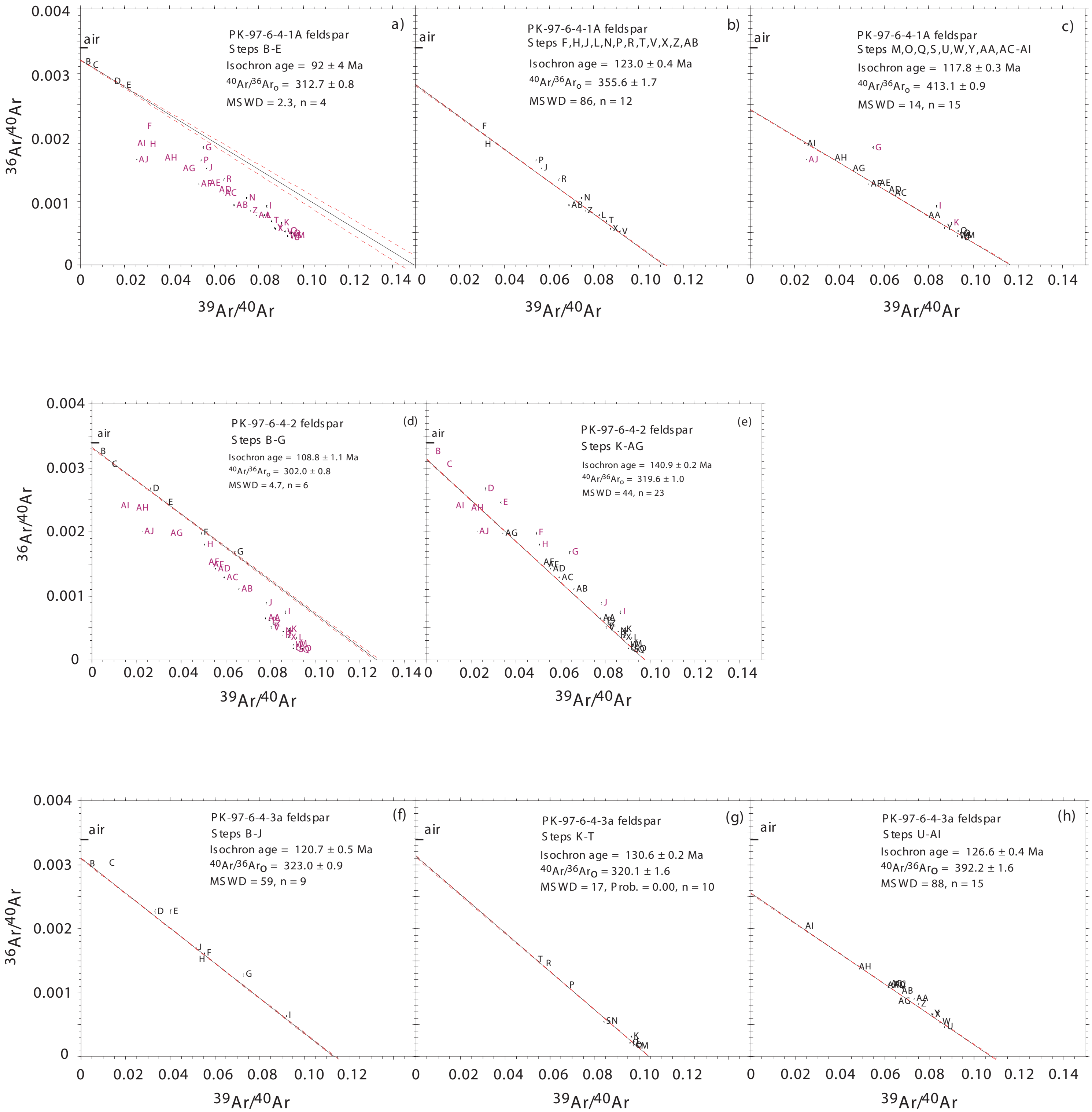

Figure DR5. Isotope correlation diagrams for selected steps from samples PK-97-6-4-1A (a-c), PK-97-6-4-2 (d,e) and PK-97-6-4-3A (f-h).

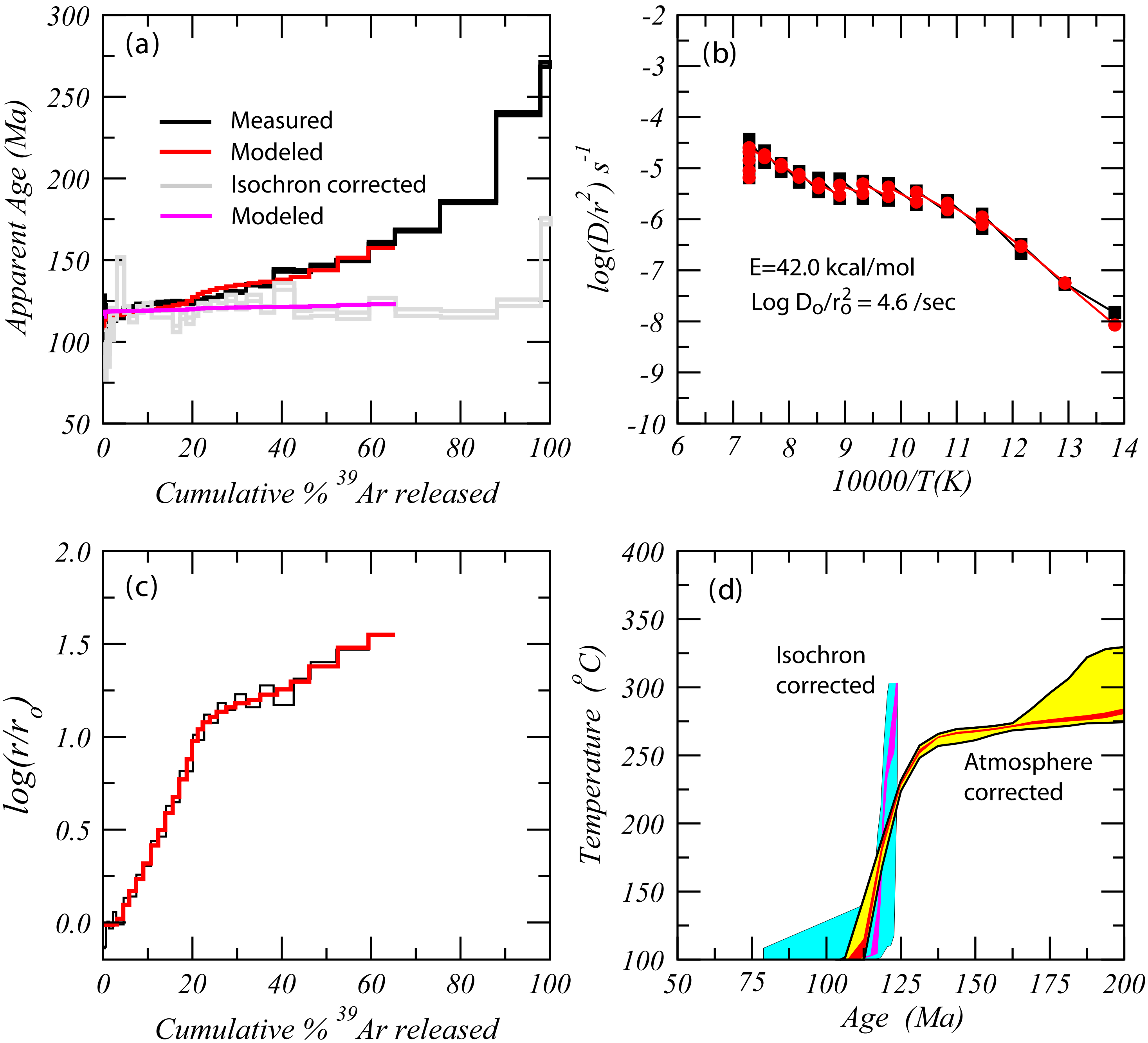

Figure DR6. Multiple diffusion domain modeling results for sample PK-97-6-4-1A feldspar.

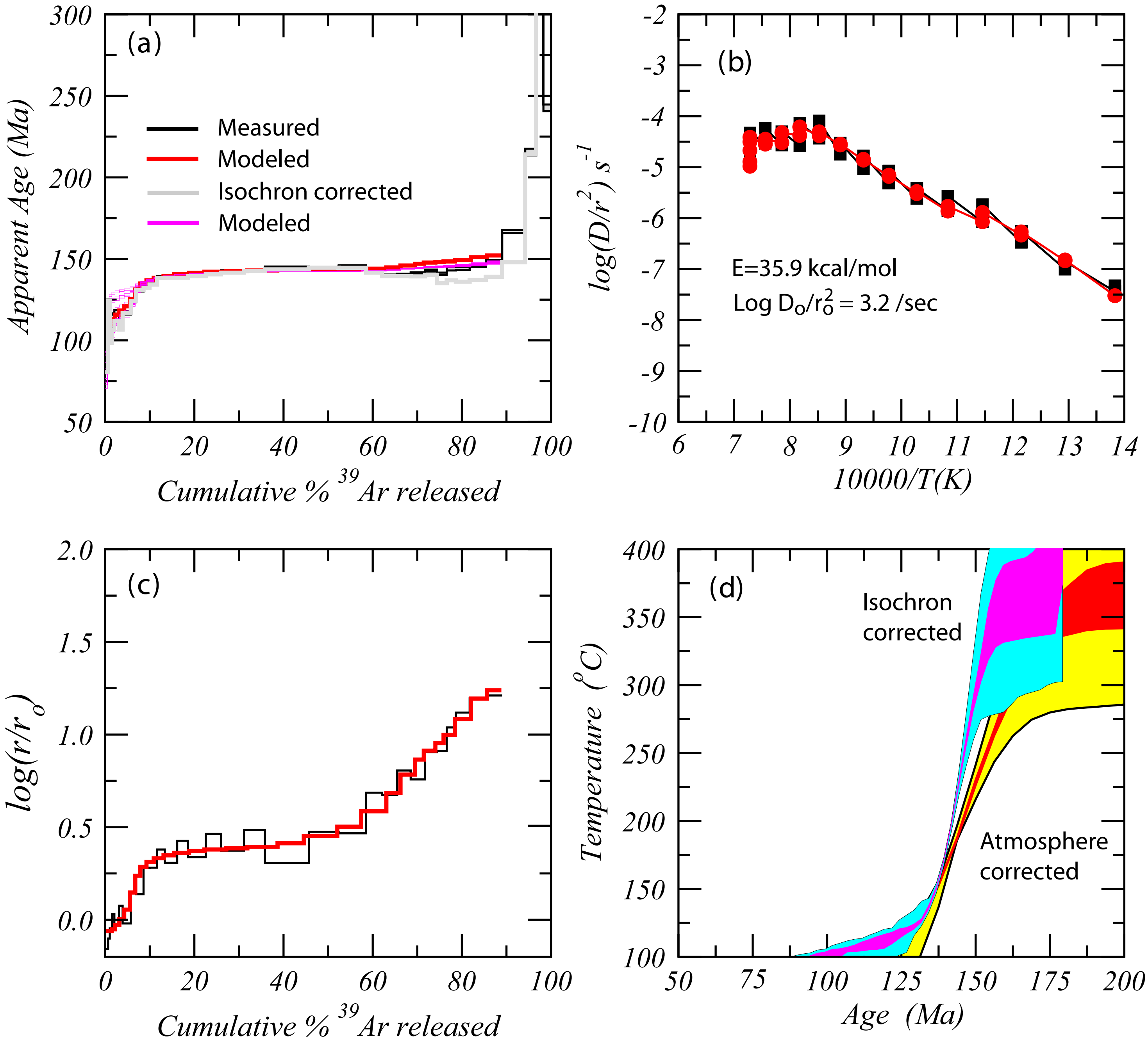

Figure DR7. Multiple diffusion domain modeling results for sample PK-97-6-4-2 feldspar.

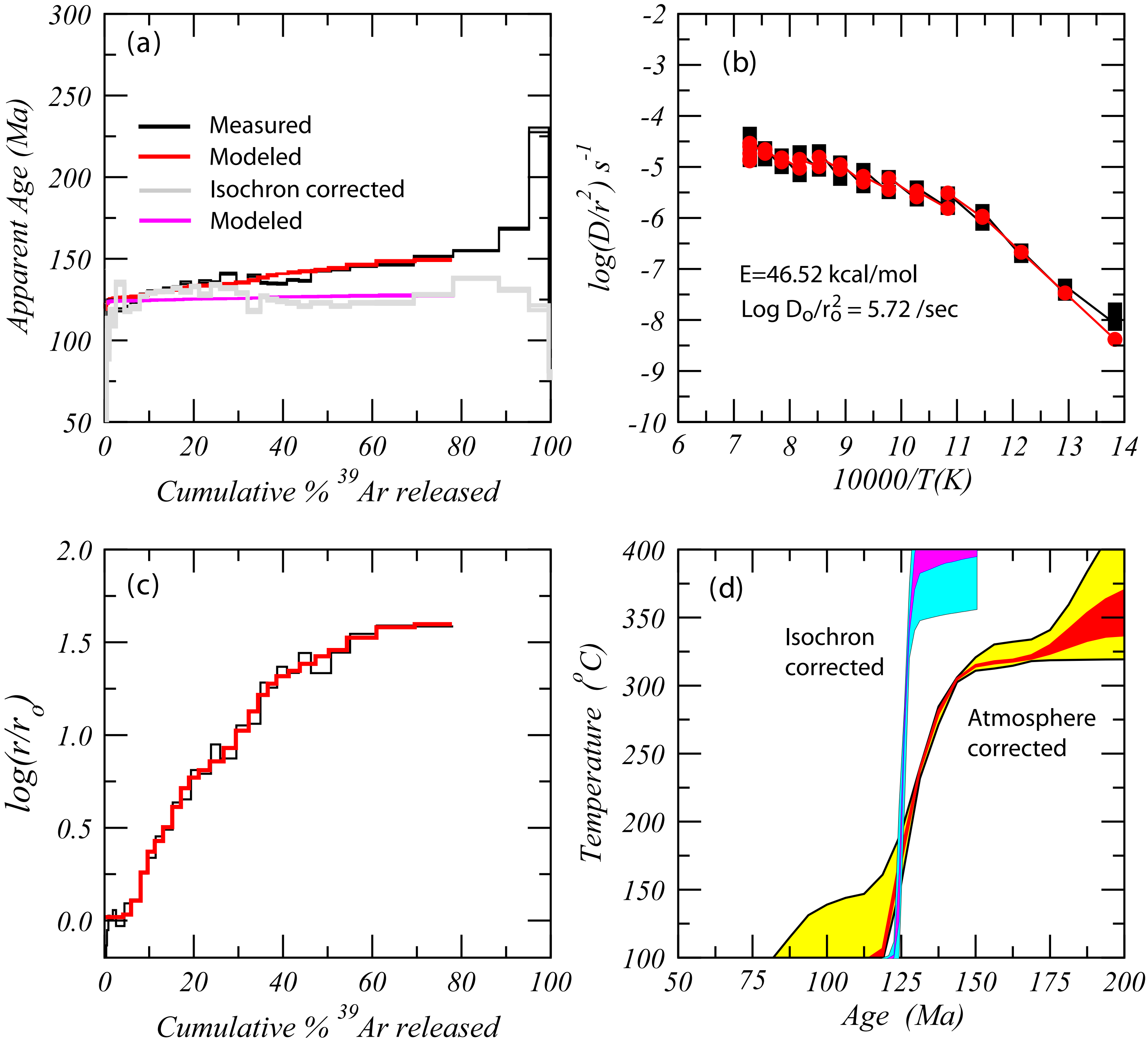

Figure DR8. Multiple diffusion domain modeling results for sample PK-97-6-4-3A feldspar.

Table DR2. NMGRL hornblende and feldspar argon isotopic data for Amdo orthogneiss samples.

ID	Temp (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)	Isochron Age (Ma)
PK-97-6-4-3A, Hornblende, 5.51 mg, J=0.007895±0.10%, D=1.004±0.001, NM-173D, Lab#=54529-01											
A	800	30.78	0.6795	60.56	4.25	0.75	42.0	8.9	175.4	2.1	
B	900	14.60	0.8884	12.14	1.61	0.57	75.9	12.2	151.1	2.9	
C	1000	15.76	6.768	13.63	2.85	0.075	78.1	18.2	167.8	1.8	
D	1030	14.74	7.546	8.709	1.87	0.068	86.9	22.1	174.4	2.6	
E	1060	13.87	6.648	4.818	14.0	0.077	93.9	51.3	176.99	0.54	
F	1090	13.28	6.217	3.246	15.0	0.082	96.8	82.7	174.80	0.50	
G	1120	15.05	7.545	9.700	1.15	0.068	85.2	85.1	174.6	4.3	
H	1170	14.30	9.200	6.625	1.36	0.055	91.8	87.9	178.8	3.6	
I	1200	14.11	6.595	4.857	2.90	0.077	93.9	93.9	179.8	1.7	
J	1250	14.46	6.936	4.752	2.59	0.074	94.4	99.3	185.2	2.0	
K	1300	18.67	8.930	19.68	0.313	0.057	72.9	100.0	185	15	
Integrated age ± 1σ		n=11			47.9	K2O=0.42 %			175.13	0.54	
PK-97-6-4-1A, Hornblende, 5.23 mg, J=0.007933±0.10%, D=1.004±0.001, NM-173D, Lab#=54530-01											
A	800	30.71	3.280	64.78	5.74	0.16	38.5	7.3	162.1	2.0	
B	900	13.29	0.8822	6.865	3.10	0.58	85.3	11.2	155.2	1.7	
C	1000	14.32	3.637	6.216	7.35	0.14	89.4	20.6	174.58	0.78	
D	1030	13.94	2.898	3.972	8.85	0.18	93.5	31.8	177.51	0.66	
E	1060	14.01	3.381	2.923	18.9	0.15	96.0	55.9	183.09	0.42	
F	1090	13.67	3.299	2.719	5.19	0.15	96.3	62.5	179.3	1.0	
G	1120	14.47	3.668	4.244	3.12	0.14	93.6	66.5	184.2	1.9	
H	1170	14.21	3.906	2.856	22.7	0.13	96.6	95.4	186.59	0.41	
I	1200	15.94	5.345	8.952	3.66	0.095	86.4	100.0	187.3	1.5	
Integrated age ± 1σ		n=9			78.6	K2O=0.73 %			179.78	0.42	
PK-97-6-4-3A, Feldspar, 11.53 mg, J=0.007844±0.10%, D=1.0035±0.0005, NM-173D, Lab#=54527-01											
B	450	344.3	0.5212	1036.0	1.80	0.98	11.1	0.4	473	11	133
C	450	86.62	0.4010	261.9	0.751	1.3	10.7	0.5	126.4	8.5	28
D	500	30.08	0.2849	68.25	1.54	1.8	33.0	0.9	135.1	3.8	110
E	500	24.87	0.3977	56.43	1.35	1.3	33.0	1.1	112.5	3.7	92
F	550	18.10	0.4053	29.31	3.44	1.3	52.3	1.9	128.9	1.3	118
G	550	13.78	0.4777	17.76	3.34	1.1	62.1	2.6	117.0	1.5	110
H	600	19.39	0.4653	29.36	9.02	1.1	55.4	4.5	145.75	0.91	135
I	600	10.89	0.5212	7.114	6.28	0.98	81.1	5.8	120.53	0.65	118
J	650	19.40	0.7211	33.16	10.1	0.71	49.7	7.9	131.50	0.92	120
K	650	10.38	0.6195	3.429	7.85	0.82	90.7	9.6	128.23	0.45	127
L	700	10.27	0.6549	2.567	8.90	0.78	93.1	11.5	130.19	0.48	129
M	700	10.05	0.5801	1.755	7.85	0.88	95.3	13.1	130.39	0.36	130
N	750	11.56	0.6557	6.491	10.3	0.78	83.8	15.3	131.94	0.47	130
O	750	10.29	0.5256	1.917	8.29	0.97	94.9	17.0	132.84	0.40	132
P	800	14.82	0.6021	16.63	11.2	0.85	67.1	19.4	135.32	0.75	130
Q	800	10.45	0.5525	2.361	8.63	0.92	93.7	21.2	133.24	0.44	133
R	850	17.52	0.5008	25.53	12.6	1.0	57.1	23.9	136.13	0.74	128
S	850	11.89	0.4431	6.593	9.8	1.2	83.9	25.9	135.61	0.53	134
T	900	18.73	0.3893	28.37	17.2	1.3	55.4	29.5	140.91	0.61	132
U	900	11.55	0.4197	5.436	12.1	1.2	86.4	32.1	135.68	0.49	129
V	950	15.22	0.6908	16.89	13.5	0.74	67.5	34.9	139.69	0.66	118
W	950	11.83	0.4481	6.472	7.53	1.1	84.1	36.5	135.27	0.59	127
X	1000	12.30	0.4347	8.177	10.3	1.2	80.6	38.7	134.89	0.61	125
Y	1000	12.36	0.3586	8.387	10.4	1.4	80.1	40.9	134.73	0.59	124
Z	1050	13.34	0.3548	11.10	12.6	1.4	75.6	43.5	137.04	0.57	123
AA	1050	13.70	0.3339	12.47	13.0	1.5	73.3	46.3	136.48	0.51	121
AB	1100	15.06	0.3854	15.49	21.4	1.3	69.8	50.8	142.69	0.47	123
AC	1100	15.86	0.3767	18.01	20.2	1.4	66.6	55.0	143.41	0.49	121
AD	1100	15.99	0.3047	17.89	28.5	1.7	67.0	61.0	145.47	0.47	123
AE	1100	16.23	0.2875	18.44	39.3	1.8	66.5	69.3	146.45	0.62	123
AF	1100	16.69	0.2636	18.68	42.0	1.9	67.0	78.1	151.45	0.37	128
AG	1200	15.40	0.2140	13.38	48.7	2.4	74.4	88.4	155.00	0.35	138
AH	1250	21.25	0.5813	29.78	32.0	0.88	58.8	95.1	168.45	0.62	131
AI	1350	43.17	2.669	88.52	21.1	0.19	39.9	99.6	228.9	1.5	120
AK	1700	9.641	0.5044	10.10	2.04	1.0	69.4	100.0	92.1	2.1	79
Integrated age ± 1σ		n=35			475.1	K2O=2.02 %			148.31	0.32	

Table DR2 continued. NMGRL hornblende and feldspar argon isotopic data for Amdo orthogneiss samples.

ID	Temp (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)	Isochron Age (Ma)
PK-97-6-4-1A, Feldspar, 11.95 mg, J=0.007871±0.10%, D=1.0035±0.0005, NM-173D, Lab#=54528-01											
B	450	711.7	0.5878	2254.1	1.77	0.87	6.4	0.4	554	18	95
C	450	218.7	0.3532	681.1	1.15	1.4	8.0	0.6	233	13	80
D	500	69.91	0.3420	200.0	1.55	1.5	15.5	1.0	147.5	5.2	102
E	500	51.20	0.3487	143.5	1.80	1.5	17.2	1.4	120.8	4.1	88
F	550	34.47	0.6782	74.62	3.99	0.75	36.1	2.2	168.7	2.2	110
G	550	18.17	1.254	33.58	3.32	0.41	45.9	2.9	114.6	1.8	
H	600	33.11	1.767	62.75	7.62	0.29	44.4	4.6	197.6	1.6	149
I	600	11.99	1.683	11.41	5.18	0.30	73.0	5.7	120.02	0.81	119
J	650	17.71	1.495	27.12	8.07	0.34	55.4	7.4	134.06	0.89	113
K	650	11.11	1.058	7.554	6.82	0.48	80.7	8.9	122.79	0.57	119
L	700	12.15	0.7320	9.588	8.33	0.70	77.1	10.7	128.16	0.64	121
M	700	10.43	0.5986	4.909	6.88	0.85	86.5	12.2	123.51	0.40	116
N	750	13.44	0.6450	14.23	8.54	0.79	69.1	14.1	127.05	0.74	116
O	750	10.60	0.6648	5.374	6.41	0.77	85.5	15.4	124.07	0.62	116
P	800	18.50	0.8440	30.36	7.88	0.60	51.8	17.1	131.1	1.1	107
Q	800	10.76	0.8776	5.938	6.19	0.58	84.3	18.5	124.17	0.53	115
R	850	15.57	0.8168	20.96	7.47	0.62	60.6	20.1	129.01	0.95	112
S	850	10.46	0.6635	4.892	4.99	0.77	86.7	21.2	124.03	0.55	117
T	900	11.68	0.5678	8.114	6.75	0.90	79.8	22.6	127.57	0.72	121
U	900	10.61	0.4347	4.665	5.98	1.2	87.3	23.9	126.64	0.54	120
V	950	10.93	0.3792	5.791	8.06	1.3	84.6	25.7	126.49	0.57	122
W	950	10.80	0.3163	4.909	8.15	1.6	86.8	27.4	128.10	0.44	121
X	1000	11.48	0.2540	6.515	9.9	2.0	83.4	29.6	130.70	0.51	126
Y	1000	11.51	0.2505	6.687	11.1	2.0	83.0	32.0	130.45	0.42	121
Z	1050	13.15	0.2249	11.10	14.7	2.3	75.2	35.1	134.91	0.41	126
AA	1050	12.73	0.2026	9.784	14.0	2.5	77.4	38.2	134.39	0.49	119
AB	1100	14.56	0.2281	13.59	20.8	2.2	72.5	42.7	143.73	0.76	133
AC	1100	15.68	0.2593	17.52	17.6	2.0	67.1	46.5	143.26	0.62	116
AD	1100	16.44	0.2661	19.17	26.6	1.9	65.6	52.2	146.77	0.54	117
AE	1100	17.63	0.3083	22.44	33.5	1.7	62.5	59.5	149.78	0.41	115
AF	1100	18.88	0.3660	23.89	27.1	1.4	62.7	65.3	160.51	0.69	124
AG	1200	22.31	0.3879	33.52	46.8	1.3	55.7	75.4	168.14	0.54	117
AH	1250	27.23	0.6375	45.70	58.3	0.80	50.6	88.0	185.53	0.61	116
AI	1350	40.88	2.106	77.88	45.6	0.24	44.1	97.9	239.65	0.97	123
AJ	1700	39.71	3.132	66.02	9.8	0.16	51.5	100.0	269.7	1.4	173
Integrated age ± 1σ			n=35		462.7	K2O=1.89 %			163.33	0.44	

Table DR2 continued. NMGRL hornblende and feldspar argon isotopic data for Amdo orthogneiss samples.

ID	Temp (°C)	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$^{40}Ar^*$ (%)	^{39}Ar (%)	Age (Ma)	±1σ (Ma)	Isochron Age (Ma)
PK-97-6-4-2, Feldspar, 11.67 mg, J=0.007937±0.10%, D=1.0035±0.0005, NM-173D, Lab#=54531-01											
B	450	349.1	0.4846	1134.3	2.42	1.1	4.0	0.6	190	12	92
C	450	123.8	0.3424	378.5	1.40	1.5	9.7	1.0	163.8	7.6	131
D	500	38.16	0.3123	102.0	2.00	1.6	21.0	1.5	111.4	4.3	102
E	500	30.16	0.3162	74.19	1.90	1.6	27.3	2.1	114.2	2.3	108
F	550	20.38	0.4961	40.51	3.89	1.0	41.4	3.1	116.9	1.9	113
G	550	15.66	0.4724	26.34	3.09	1.1	50.5	3.9	109.6	1.2	107
H	600	19.84	0.5960	35.84	6.87	0.86	46.8	5.7	128.2	1.1	117
I	600	11.55	0.6333	8.749	4.39	0.81	78.0	6.9	124.41	0.96	
J	650	12.84	0.7015	11.51	6.36	0.73	73.9	8.6	130.75	0.76	
K	650	11.33	0.6411	5.523	4.98	0.80	86.0	9.9	134.14	0.76	132
L	700	10.94	0.6672	3.947	6.52	0.76	89.8	11.7	135.21	0.54	134
M	700	10.90	0.5734	2.835	6.38	0.89	92.7	13.4	138.92	0.51	138
N	750	11.69	0.6272	5.358	10.4	0.81	86.9	16.1	139.65	0.45	138
O	750	10.64	0.5489	1.973	9.16	0.93	94.9	18.6	138.79	0.40	138
P	800	12.56	0.5869	7.857	15.0	0.87	81.9	22.6	141.34	0.41	139
Q	800	10.71	0.4889	1.795	12.7	1.0	95.4	26.0	140.38	0.33	140
R	850	11.71	0.4414	4.580	19.4	1.2	88.7	31.1	142.74	0.27	141
S	850	10.94	0.3741	1.897	17.7	1.4	95.2	35.8	142.84	0.24	142
T	900	12.50	0.2732	6.598	37.0	1.9	84.6	45.7	145.03	0.25	143
U	900	11.12	0.2623	2.086	25.0	1.9	94.6	52.4	144.36	0.22	144
V	950	12.45	0.6659	6.363	23.2	0.77	85.3	58.5	145.77	0.33	144
W	950	11.12	0.3256	2.677	13.4	1.6	93.1	62.1	142.21	0.32	141
X	1000	11.38	0.3446	4.121	12.7	1.5	89.5	65.5	140.01	0.41	139
Y	1000	11.59	0.3085	4.690	11.4	1.7	88.2	68.5	140.48	0.41	139
Z	1050	12.34	0.3775	7.048	12.1	1.4	83.3	71.8	141.24	0.55	139
AA	1050	12.89	0.3659	8.510	10.0	1.4	80.7	74.4	142.88	0.59	140
AB	1100	15.22	0.6169	16.97	8.15	0.83	67.3	76.6	140.86	0.73	135
AC	1100	16.90	0.5619	21.88	7.81	0.91	62.0	78.7	143.9	1.0	137
AD	1100	18.09	0.6334	25.89	11.5	0.81	57.9	81.7	144.04	0.85	136
AE	1100	18.85	0.5873	28.02	13.6	0.87	56.3	85.4	145.71	0.75	137
AF	1100	19.62	0.5717	29.91	13.8	0.89	55.1	89.0	148.40	0.90	139
AG	1200	29.39	0.6464	58.29	19.5	0.79	41.5	94.2	166.78	0.90	148
AH	1250	53.30	2.262	127.0	9.02	0.23	29.9	96.6	215.4	2.2	
AI	1350	83.01	6.169	201.3	6.22	0.083	29.0	98.3	316.4	3.2	
AJ	1700	44.36	4.325	90.11	6.49	0.12	40.8	100.0	242.7	2.0	
Integrated age ± 1σ			n=35		375.5	K2O=1.56 %			149.41	0.36	

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interfering reactions.
Ages calculated relative to FC-2 Fish Canyon Tuff sanidine interlaboratory standard at 27.84 Ma.
Errors quoted for individual analyses include analytical error only, without interfering reaction or J uncertainties.
Integrated age calculated by quadratically combining isotopic measurements of all steps.
Integrated age error calculated by quadratically combining 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 squareroot MSWD where MSWD>1.
Plateau and integrated ages incorporate uncertainties in interfering reaction corrections and J factors (0.1%).
Decay constants and isotopic abundances after Steiger and Jager (1977).
K_20 estimated from ^{39}Ar signal, sample weight and J-factor.
D = 1 AMU discrimination in favor of light isotopes.
Isochron age is age calculated using trapped initial $^{40}Ar/^{36}Ar$ determined from isochron analysis.
Correction factors: $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.00074 ± 2e-05
$(^{36}Ar/^{37}Ar)_{Ca}$ = 0.000284 ± 6e-06
$(^{40}Ar/^{39}Ar)_K$ = 0.02895 ± 0.00059

Table DR3. UCLA mica argon isotopic data for Amdo orthogneiss samples.

Step	T (°C)	$^{40}Ar/^{39}Ar$[a]	$^{38}Ar/^{39}Ar$[a]	$^{37}Ar/^{39}Ar$[a]	$^{36}Ar/^{39}Ar$[a]	$^{39}Ar_K$(mol)[b]	$\Sigma^{39}Ar_K$ (%)	$^{40}Ar^*$[c] (%)	$^{40}Ar^*/^{39}Ar_K$[d]	$\pm \sigma_{40/39}$	Age ± 1 (Ma)[e]
	97-6-4-2 Muscovite (J=0.007344, weight = 5.8 mg) Total gas age = 166.4 ± 0.4 Ma										
1	500	24.52636	0.72	0.08	0.06	0.00	0.4	26.7	6.57	0.40	85.1 ± 5.1
2	600	14.59611	0.02	0.07	0.01	0.00	0.9	76.7	11.27	0.12	143.4 ± 1.5
3	700	13.70792	0.01	0.03	0.00	0.00	2.5	92.4	12.68	0.02	160.7 ± 0.3
4	750	13.33618	0.01	0.02	0.00	0.00	5.8	95.9	12.80	0.03	162.1 ± 0.4
5	800	13.30572	0.01	0.01	0.00	0.00	8.3	96.1	12.80	0.02	162.1 ± 0.3
6	850	13.46846	0.01	0.01	0.00	0.00	12.8	96.0	12.94	0.03	163.8 ± 0.3
7	900	13.64588	0.01	0.01	0.00	0.00	22.5	95.8	13.08	0.04	165.5 ± 0.5
8	950	13.47412	0.01	0.00	0.00	0.00	40.8	98.0	13.23	0.03	167.2 ± 0.4
9	1000	13.48864	0.01	0.02	0.00	0.00	50.1	97.8	13.21	0.03	167.1 ± 0.3
10	1100	13.51966	0.01	0.01	0.00	0.00	68.9	97.7	13.22	0.03	167.1 ± 0.3
11	1200	13.50152	0.01	0.01	0.00	0.00	99.4	98.6	13.33	0.03	168.5 ± 0.4
12	1350	14.73287	0.01	0.51	0.00	0.00	100.0	90.9	13.46	0.09	170.1 ± 1.0
	Measured $^{40}Ar/^{36}Ar_{atm}$ = 175 ± 3.34 and $^{40}Ar/^{39}Ar_{atm}$ = 297.5 ± 0.5; Abundance sensitivity = 5 ppm; Date irradiated = 08-16-2000; Date analyzed = 9-29-2000										
	97-6-4-1A Biotite (J=0.007351, weight = 5.6 mg) Total gas age = 163.6 ± 0.3 Ma										
1	600	13.60089	0.42	0.15	0.02	0.00	2.5	47.3	6.45	0.04	83.5 ± 0.5
2	700	12.79718	0.03	0.07	0.01	0.00	10.5	85.1	10.91	0.02	139.1 ± 0.2
3	750	13.45496	0.02	0.02	0.00	0.00	19.9	94.2	12.69	0.03	160.9 ± 0.3
4	800	13.59582	0.02	0.01	0.00	0.00	31.9	97.0	13.20	0.01	167.1 ± 0.2
5	850	13.7659	0.03	0.01	0.00	0.00	37.8	97.6	13.46	0.02	170.2 ± 0.2
6	900	14.06217	0.03	0.02	0.00	0.00	42.0	96.1	13.53	0.07	171.1 ± 0.8
7	950	13.90634	0.03	0.04	0.00	0.00	47.0	95.0	13.23	0.03	167.4 ± 0.3
8	1000	13.95283	0.03	0.09	0.00	0.00	51.2	95.1	13.29	0.03	168.2 ± 0.3
9	1050	13.64354	0.03	0.13	0.00	0.00	59.7	96.0	13.11	0.02	166.0 ± 0.3
10	1100	13.47398	0.03	0.23	0.00	0.00	73.1	96.9	13.08	0.03	165.6 ± 0.3
11	1200	13.69293	0.04	0.29	0.00	0.00	89.3	98.3	13.48	0.04	170.4 ± 0.5
12	1350	13.87532	0.03	0.22	0.00	0.00	100.0	98.6	13.69	0.02	173.0 ± 0.2
	Measured $^{40}Ar/^{36}Ar_{atm}$ = -36.9 ± 0.65 and $^{40}Ar/^{39}Ar_{atm}$ = 297.5 ± 0.5; Abundance sensitivity = 5 ppm; Date irradiated = 08-16-2000; Date analyzed = 9-29-2000										
	97-6-4-3A Biotite (J=0.007364, weight = 7.6 mg) Total gas age = 156.5 ± 0.4 Ma										
1	500	25.96679	1.01	0.54	0.07	0.00	0.8	15.7	4.09	0.22	53.6 ± 2.8
2	600	9.390469	0.04	0.60	0.01	0.00	2.7	67.9	6.42	0.08	83.4 ± 1.0
3	700	10.49737	0.03	0.37	0.01	0.00	11.1	85.4	8.97	0.03	115.6 ± 0.4
4	780	13.13477	0.03	0.04	0.00	0.00	25.0	95.9	12.61	0.03	160.4 ± 0.4
5	850	13.14099	0.03	0.05	0.00	0.00	35.2	96.1	12.64	0.03	160.7 ± 0.4
6	900	13.35206	0.03	0.05	0.00	0.00	42.4	95.6	12.78	0.03	162.4 ± 0.3
7	950	13.48795	0.03	0.07	0.00	0.00	49.9	95.8	12.93	0.04	164.3 ± 0.5
8	1000	14.12381	0.03	0.29	0.00	0.00	54.6	93.2	13.19	0.03	167.4 ± 0.4
9	1050	14.23293	0.03	0.32	0.00	0.00	60.9	92.7	13.21	0.03	167.6 ± 0.4
10	1100	13.58004	0.04	0.51	0.00	0.00	74.6	96.0	13.05	0.03	165.7 ± 0.3
11	1200	13.21134	0.03	1.55	0.00	0.00	88.5	97.0	12.84	0.03	163.1 ± 0.4
12	1350	12.90057	0.03	0.53	0.00	0.00	100.0	96.9	12.52	0.02	159.3 ± 0.2
	Measured $^{40}Ar/^{36}Ar_{atm}$ = 1115 ± 1430 and $^{40}Ar/^{39}Ar_{atm}$ = 297.5 ± 0.5; Abundance sensitivity = 5 ppm; Date irradiated = 08-16-2000; Date analyzed = 9-28-2000										

Total gas age error is analytical only and 1σ

Table DR4. Arrhenius data for feldspar samples. Data shown in bold used for r_0 determination.

	PK-97-6-4-1A			**PK-97-6-4-2**			**PK-97-6-4-3A**	
Step	10000/T(K)	Log(D/r²)	Step	10000/T(K)	Log(D/r²)	Step	10000/T(K)	Log(D/r²)
B	13.83	-7.82	B	13.83	-7.33	B	13.83	-7.80
C	13.83	-7.84	C	13.83	-7.44	C	13.83	-8.07
D	**12.94**	**-7.25**	D	**12.94**	**-6.85**	D	**12.94**	**-7.33**
E	**12.94**	**-7.28**	E	**12.94**	**-7.00**	E	**12.94**	**-7.48**
F	**12.15**	**-6.49**	F	**12.15**	**-6.26**	F	**12.15**	**-6.64**
G	**12.15**	**-6.67**	G	**12.15**	**-6.48**	G	**12.15**	**-6.74**
H	**11.45**	**-5.90**	H	**11.45**	**-5.74**	H	**11.45**	**-5.87**
I	11.45	-6.18	I	11.45	-6.07	I	11.45	-6.11
J	10.83	-5.62	J	10.83	-5.57	J	10.83	-5.52
K	10.83	-5.86	K	10.83	-5.85	K	10.83	-5.80
L	10.28	-5.44	L	10.28	-5.42	L	10.28	-5.40
M	10.28	-5.71	M	10.28	-5.61	M	10.28	-5.64
M	9.78	-5.30	M	9.78	-5.07	M	9.78	-5.20
O	9.78	-5.63	O	9.78	-5.31	O	9.78	-5.49
P	9.32	-5.25	P	9.32	-4.78	P	9.32	-5.06
Q	9.32	-5.59	Q	9.32	-5.03	Q	9.32	-5.38
R	8.90	-5.20	R	8.90	-4.52	R	8.90	-4.91
S	8.90	-5.60	S	8.90	-4.75	S	8.90	-5.23
T	8.53	-5.19	T	8.53	-4.09	T	8.53	-4.69
U	8.53	-5.46	U	8.53	-4.43	U	8.53	-5.05
V	8.18	-5.06	V	8.18	-4.14	V	8.18	-4.71
W	8.18	-5.27	W	8.18	-4.58	W	8.18	-5.16
X	7.86	-4.90	X	7.86	-4.30	X	7.86	-4.78
Y	7.86	-5.07	Y	7.86	-4.56	Y	7.86	-5.00
Z	7.56	-4.66	Z	7.56	-4.24	Z	7.56	-4.63
AA	7.56	-4.89	AA	7.56	-4.53	AA	7.56	-4.85
AB	7.28	-4.43	AB	7.28	-4.33	AB	7.28	-4.35
AC	7.28	-4.71	AC	7.28	-4.58	AC	7.28	-4.57
AD	7.28	-4.89	AD	7.28	-4.74	AD	7.28	-4.78
AE	7.28	-5.03	AE	7.28	-4.90	AE	7.28	-4.86
AF	7.28	-5.19	AF	7.28	-4.93	AF	7.28	-4.86
AG	6.79	-3.53	AG	6.79	-3.26	AG	6.79	-3.26
AH	6.57	-3.18	AH	6.57	-3.31	AH	6.57	-3.10
AI	6.16	-2.82	AI	6.16	-3.23	AI	6.16	-2.67
AJ	5.07	-2.05	AJ	5.07	-2.06	AJ	5.07	-2.09

PK-97-6-4-1A	PK-97-6-4-2	PK-97-6-4-3A
E=42.0 kcal/mol	**E=35.9 kcal/mol**	**E=46.5 kcal/mol**
$Log(D_0/r_0^2)$ = 4.6 /sec	**$Log(D_0/r_0^2)$ = 3.2 /sec**	**$Log(D_0/r_0^2)$ = 5.72 /sec**

Domain	$Log(D_0/r^2)$	Volume fraction	Domain	$Log(D_0/r^2)$	Volume fraction	Domain	$Log(D_0/r^2)$	Volume fraction
1	7.225	0.0240	1	6.481	0.0051	1	7.830	0.0604
2	6.340	0.0359	2	5.640	0.0332	2	6.589	0.0613
3	5.668	0.0399	3	2.857	0.2462	3	5.286	0.0794
4	4.944	0.0616	4	2.800	0.1658	4	4.966	0.0738
5	2.843	0.2137	5	2.699	0.1155	5	3.685	0.1203
6	1.924	0.1939	6	1.871	0.1766	6	2.522	0.6047
7	1.200	0.4310	7	0.710	0.2576	7	2.320	0.0000