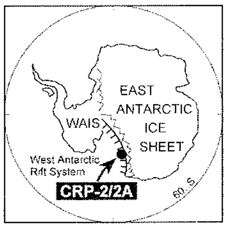
Terra Antartica
2000, 7(4), 621-630

$^{40}Ar/^{39}Ar$ Geochronology of Tephra and Volcanic Clasts in CRP-2A, Victoria Land Basin, Antarctica

W.C. McIntosh

New Mexico Institute of Mining and Technology, Socorro, NM, 87801 - USA (mcintosh@nmt.edu)

Received 22 September 1999; *accepted in revised form* 30 May 2000



Abstract - $^{40}Ar/^{39}Ar$ analyses of tephra and clasts of volcanic rock provide age constraints for upper parts of the CRP-2A core. Single-crystal laser-fusion analyses of anorthoclase phenocrysts from three tephra-bearing layers yielded the most precise age constraints for CRP-2A. The dated tephra layers are: 1) a 2.7-m-thick interval of pumice and ash layers between 111.5 and 114.2 meters below sea floor (mbsf) (weighted mean age = 21.44 ± 0.05 Ma, ± 2σ); 2) a concentration of pumice near 193.4 mbsf (23.98 ± 0.13 Ma); and 3) a concentration of pumice near 280 mbsf (24.22 ± 0.03 Ma) (all ages are calibrated relative to Fish Canyon Tuff sanidine at 27.84 Ma). The 111 to 114 mbsf tephra is almost entirely non-reworked, and the 193 mbsf and 280 mbsf tephra concentrations are interpreted as being reworked and redeposited soon after eruption. All three of the tephra ages are therefore considered to be equivalent to depositional ages. The variation in precision of these three age determinations is largely a function of phenocryst size and abundance. The accuracy of these ages is equal to the accuracy of the current calibration of the $^{40}Ar/^{39}Ar$ method (about ± 1%). $^{40}Ar/^{39}Ar$ results from volcanic clasts provide three additional maximum age constraints for the CRP-2A core. Single-crystal laser-fusion of sanidine phenocrysts from a rhyolitic clast from 294 mbsf yielded a precise maximum depositional age of 24.98 ± 0.08 Ma, and plateau ages of groundmass concentrates from basaltic clasts near 36.02 mbsf and 125.92 mbsf yielded maximum depositional ages of 19.18 ± 0.12 Ma, and 22.56 ± 0.14 Ma, respectively. The $^{40}Ar/^{39}Ar$ data, in association with biostratigraphic, paleomagnetic, and isotopic age constraints for CRP-2A, confirm interpretations of rapid sedimentation rates in the 36 to 280 mbsf interval, particularly in the 193 to 280 mbsf interval where they support interpretations for sedimentation cycles spanning 100 k.y. intervals. In addition to the 19 to 25 Ma ages measured from tephra layers and clasts, provenance-related ages ranging from 150 to 450 Ma were determined from clasts and individual detrital or xenocrystic crystals from CRP-2A.

INTRODUCTION

The CRP-2/2A core was drilled near Cape Roberts, Antarctica, as part of an international effort to sample marine sediments in McMurdo Sound, with the goal of reconstructing Cenozoic and possibly Cretaceous palaeoenvironment and palaeoclimate of Antarctica. CRP-2/2A penetrated to a depth of 624.15 meters below sea floor (mbsf) (Cape Roberts Science Team, 1999).

Interpretations of the palaeoenvironmental record sampled by the CRP-2/2A drillcore require an accurate chronology for the core. A large variety of biostratigraphic, magnetostratigraphic, and radioisotopic dating methods have been applied to the core, both during and after drilling (Cape Roberts Science Team, 1999; Wilson et al., this volume; Scherer et al, this volume; Watkins & Villa, this volume; Lavelle, this volume). This paper reports results of $^{40}Ar/^{39}Ar$ dating of volcanic materials encountered in the upper 294 m of the CRP-2A core, including prominent felsic pumice and tephra layers between 111.5 and 114.2 mbsf, concentrations of pumice fragments near 193.4 mbsf and 280 mbsf, and scattered reworked volcanic clasts between 36 and 294 mbsf in the CRP-2A core.

TEPHRA IN CRP-2A

Tephra in CRP-2A range from nearly pure layers of pumice lapilli and ash to diffuse intervals of dispersed pumice fragments and glass shards. The most concentrated tephra interval is between 111.5 and 114.2 mbsf and consists of a series of ash and pumice lapilli layers. Pumice lapilli within these layers are as large 8 mm in diameter and contain sparse but unaltered anorthoclase phenocrysts as large as 1 mm in diameter. The lack of detrital sand and silt in the tephra layers strongly suggests that they are not significantly reworked. The tephra layers are overlain by 3.4 m of sediments containing abundant pumice fragments, which probably reflect reworking of the top of the primary tephra interval. Detailed descriptions and considerations of possible sources for the tephra layers are presented elsewhere (Cape Roberts Science Team, 1999).

Less conspicuous concentrations of pumice clasts are present near 193.4 and 280.0 mbsf. Pumice clasts within these predominantly silt and sand intervals are as large as 7 mm, are generally well rounded, and contain anorthoclase phenocrysts as large as 1.5 mm in diameter. Although these pumice clasts have been reworked, their fragile nature and concentration in a restricted stratigraphic interval suggests that they were deposited soon after their eruption as pyroclastic ejecta, and therefore their eruption age is inferred to closely approximate the time of their deposition. Their rounding may reflect wind transport and abrasion after their deposition on either sea ice or the surface of the sea.

VOLCANIC CLASTS IN CRP-2A

Volcanic clasts observed in CRP-2A are similar to, but less common than, clasts described from the younger CRP-1 core (Smellie, this volume). They range in composition from basaltic to trachytic to rhyolitic, are commonly rounded, and tend to be between 1 and 10 mm in diameter. Most appear to have been eroded from variably vesicular lavas, although some may represent abraded scoriaceous to pumiceous pyroclasts. Because these clasts were eroded, transported, and deposited by sedimentary (dominantly glacial) processes, they only provide maximum ages for the time of deposition.

$^{40}Ar/^{39}Ar$ METHODS AND RESULTS

Samples from three tephra layers and nine clasts were analyzed by $^{40}Ar/^{39}Ar$ methods (Tab. 1, Figs. 1 and 2, Appendices 1 and 2). Potassium feldspar was separated from four subsamples of the 111 to 114 mbsf tephra layers, from single samples of pumice concentration zones near 193.4 mbsf and 280 mbsf, and from two clasts from 294.22 and 327.69 mbsf, respectively. Groundmass concentrates were also prepared from the clast from 327.69 mbsf and from seven other clasts which lacked K-feldspar phenocrysts (Tab. 1). Samples were irradiated with Fish Canyon Tuff sanidine as a flux monitor, using a monitor age of 27.84 Ma (Deino & Potts, 1990a), equivalent to an age of 520.4 Ma for the international $^{40}Ar/^{39}Ar$ standard Mmhb-1 (Samson & Alexander, 1987). The anorthoclase separates were analyzed by single-crystal CO_2 laser fusion. Groundmass concentrates from volcanic clasts were dated by the furnace incremental heating age spectrum method. All analyses were performed at New Mexico Geochronology Research Laboratory. Analytical methods and parameters are detailed in table 1 footnotes and in McIntosh & Chamberlin (1994).

Tab. 1 - Summary of $^{40}Ar/^{39}Ar$ results from CRP-2A.

Sample	ID number	Irrad	material	aliquot	analysis	n	$\%^{39}Ar$	K/Ca	Age (Ma)	$\pm 2\sigma$
Ash layers										
CRP2A-111/114	9595	NM-96	anorthoclase	single crystal	laser fusion	84		37.4	**21.44**	**0.05**
CRP2A-193	50513	NM-110	anorthoclase	single crystal	laser fusion	19		78.0	**23.98**	**0.13**
CRP2A-280	9954	NM-101	anorthoclase	single crystal	laser fusion	52		15.6	**24.22**	**0.03**
Cenozoic clasts										
CRP2A-36.02	50279-01	NM-105	groundmass	73.4 mg	plateau	6	72.4	0.7	**19.18**	**0.13**
CRP2A-125.92-2	50269-01	NM-105	groundmass	20.9 mg	plateau	8	90.6	0.4	21.48	0.62
CRP2A-125.92-3	50270-01	NM-105	groundmass	21.2 mg	plateau	7	74.0	1.6	**22.56**	**0.14**
CRP2A-182.44	50271-01	NM-105	groundmass	19.2 mg	total gas	11		0.8	25.52	0.16
CRP2A-294.22	50263	NM-105	sanidine	single crystal	laser fusion	5		110.5	**24.98**	**0.08**
pre-Cenozoic clasts										
CRP2A-453.58	50281-01	NM-105	groundmass	48.8 mg	plateau	6	69.8	0.2	178.4	0.8
CRP2A-347.86	50275-01	NM-105	groundmass	21.6 mg	total gas	12		0.5	182.0	1.1
CRP2A-108.64	50267-01	NM-105	groundmass	24.42 mg	total gas	11		0.3	401.3	4.5

Notes: n = number of crystals in weighted mean or heating steps in plateau. $\%^{39}Ar$ is the percent of ^{39}Ar released within the plateau age interval (not applicable to single-crystal laser-fusion analyses). K/Ca is the molar ratio calculated from reactor produced $^{39}Ar_K$ and $^{37}Ar_{Ca}$. Ages in bold are interpreted as accurate depositional ages.

Methods: *Sample preparation*: sanidine – crushing, LST heavy liquid, Franz, HF; groundmass concentrates – crushing, picking. *Irradiation*: six separate in vacuo 7- hr irradiations (NM-54, NM-58, NM-65, NM-69, NM-77, NM-86), D-3 position, Nuclear Science Center, College Station, TX. *Neutron flux monitor*: sample FC-1 of interlaboratory standard Fish Canyon Tuff sanidine with an assigned age of 27.84 Ma (Deino and Potts, 1990a), relative to Mmhb-1 at 520.4 Ma (Samson and Alexander, 1987); samples and monitors irradiated in alternating holes in machined Al discs. *Laboratory*: New Mexico Geochronology Research Laboratory, Socorro, NM. *Instrumentation*: Mass Analyzer Products 215-50 mass spectrometer on line with automated, all-metal extraction system. *Heating*: sanidine – single-crystal laser-fusion (SCLF), 10W continuous CO_2 laser; vitrophyric glass – 25 –45 mg aliquots in resistance furnace. *Reactive gas cleanup*: SAES GP-50 getters operated at 20°C and ~450°C; sanidine – 1 to 2 minutes, vitrophyric glass – 9 minutes. *Error calculation*: all errors reported at $\pm 2\sigma$, mean ages calculated using inverse variance weighting of Samson and Alexander (1987), *Plateau criteria*: Three or more consecutive analytically equivalent ($\pm 2\sigma$) steps totalling greater than 50% of released 39Ar. *Decay constant and isotopic abundances*: Steiger and Jaeger (1977). *Complete data set*: Appendices 1 and 2.
Analytical parameters: electron multiplier sensitivity = 1 to 3 x 10-17 moles/pA; typical system blanks were 300, 3 , 1 , 1, 2 x 10-18 moles (laser) and at 4800, 14 , 6 , 5, 18 (furnace) at masses 40, 39, 38, 37, 36 respectively; . J-factors determined to a precision of ± 0.2% using SCLF of 4 to 6 crystals from each of 4 to 6 radial positions around irradiation vessel. Correction factors for interfering nuclear reactions, determined using K-glass and CaF2 , (40Ar/39Ar) K = 0.00020±0.0003; (36Ar/37Ar) Ca = 0.00026±0.00002; and (39Ar/37Ar) Ca = 0.00070±0.00005.

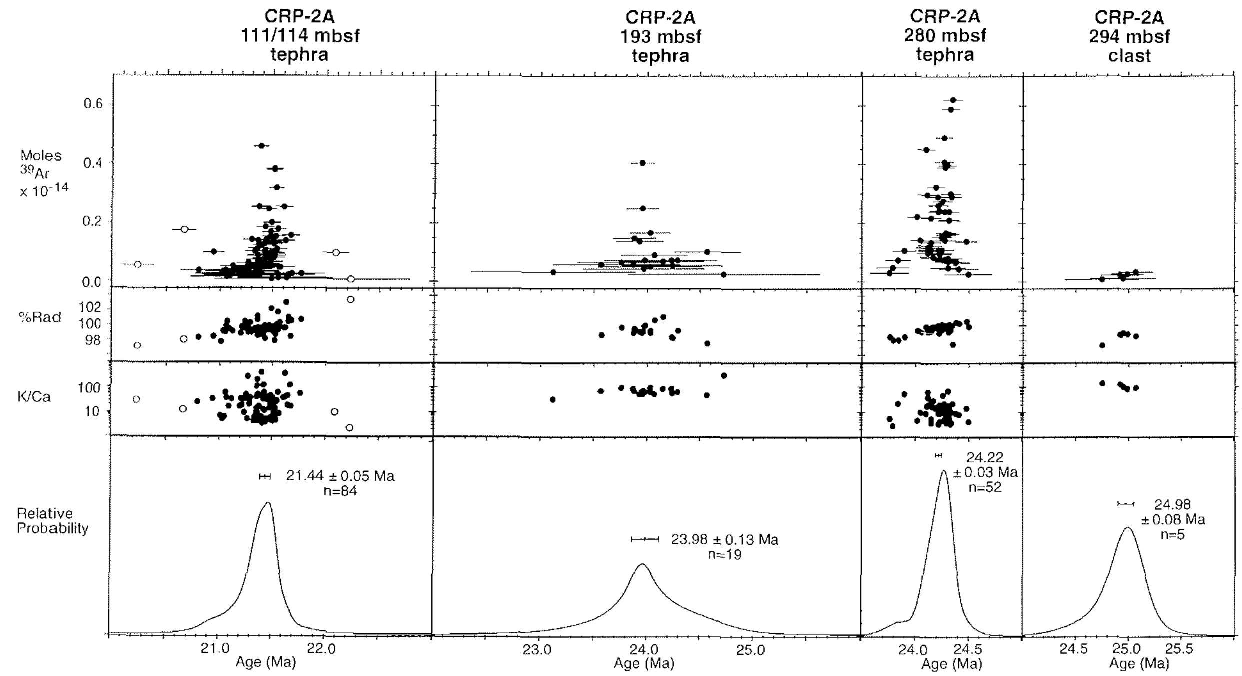


Fig. 1 - Probability distribution diagrams of $^{40}Ar/^{39}Ar$ single-crystal laser-fusion results (after Deino & Potts, 1990b). Bars in the uppermost panel show ± 1σ uncertainties. a) CRP-2A-111/114 mbsf tephra. The weighted-mean age of 21.44 ± 0.05 Ma is interpreted as a depositional age, open circles denote anomalous results not included in the calculation of the weighted-mean age. b) CRP-2A-193 mbsf tephra, which has a depositional age of 23.98 ± 0.13 Ma. The lower precision reflects smaller, scarcer crystals. c) CRP-2A-280 mbsf tephra, which has a depositional age of 24.22 ± 0.03 Ma. d) CRP-2A-294 mbsf clast, which has a maximum age of 24.98 ± 0.08 Ma.

$^{40}Ar/^{39}Ar$ analyses of all three of the tephra layers and three volcanic clasts yielded results that have direct bearing on the depositional age of CRP-2A sediments. Results from the remaining clasts are either too imprecise (two clasts) or too old (four clasts) to provide useful age constraints for CRP-2A, although the latter provide provenance information.

Results from laser fusion analyses are presented in figure 1 and table 1, and are summarized in figure 3. Analytical data are provided in appendix 1. Single-crystal laser-fusion results from the majority of crystals from each of the three tephra samples and from one of the clasts form tightly grouped, near Gaussian age distributions (Fig. 1). Results from the four subsamples of the 111 to 114 mbsf tephra layers were indistinguishable from each other and were therefore combined. The combined dataset (n=93 anorthoclase crystals) includes five anomalously old crystals that are believed to be xenocrystic or detrital in origin and four crystals with slightly anomalous ages (open circles in Fig. 1a) that probably reflect minor alteration or excessive adhering matrix glass. These nine anomalous analyses were not used in calculating the weighted-mean age for the 111 to 114 mbsf tephra layer. Weighted mean ages for the three tephra units and one clast dated by single-crystal laser-fusion range from 21.44 to 24.98 Ma, with ± 2σ ranging from ± 0.3 to ± 0.13 Ma (Figs. 1,2). These laser-fusion ages provide three precise depositional ages and one useful maximum age constraint for CRP-2A (Fig. 2). One crystal from a second clast analyzed by the single-crystal laser-fusion method yielded a Palaeozoic provenance age of 446.0 ± 1.6 Ma (Tab. 1). The remaining analyzed crystals from this sample gave low K/Ca values and imprecise ages characteristic of plagioclase (Appendix 1).

Results from incremental heating analyses of groundmass concentrates from eight CRP-2A clasts are presented in figure 2, table 1, and appendix 2. Four of the clasts yielded Cenozoic age spectra (Fig. 2). Three of these age spectra satisfy plateau criteria (Tab. 1), and two of the resultant plateau ages provide germane maximum ages for CRP-2A (19.18 ± 0.13 Ma for a clast at 36.02 mbsf, and 22.56 ± 0.14 Ma for a clast at 125.92 Ma). Data from the remaining two Cenozoic clasts (samples CRP-2A-125.92-2 and CRP-2A-182.44; Tab. 1, Fig. 2, Appendix 2) are not precise enough to provide useful age constraints for CRP-2A.

Incremental heating analyses of the remaining four clasts yielded Mesozoic or Palaeozoic ages (Tab. 1, Fig. 2, Appendix 2), which are interpreted as provenance ages for these clasts. The plateau age of the dated clast from 453.58 mbsf (178.4 ± 0.8 Ma) agrees closely with published ages from the Jurassic Ferrar Group Kirkpatrick Basalts (*e.g.* Foland et al., 1993). Clast CRP-2A-347.86 yielded a similar integrated age (182.0 ± 1.1 Ma), but failed to meet plateau criteria, which possibly reflects effects of ^{39}Ar recoil (Fig. 2). The final two clasts yielded Palaeozoic incremental heating ages. The plateau age of sample CRP-2A-327.69 (458.7 ± 4.6 Ma; Tab. 1) agrees relatively well with the age of the single K-feldspar dated by laser fusion (446.4 ± 0.8 Ma; Tab. 1), which supports a Palaeozoic provenance for this clast. All pre-Cenozoic ages obtained from clasts and individual K-feldspar crystals in this study are summarized in figure 4. The wide range of pre-Cenozoic K-feldspar single-crystal laser-fusion ages probably reflects partial resetting of Palaeozoic xenocrysts introduced to the magma chamber before or during the eruption of the 111 to 114 mbsf tephra.

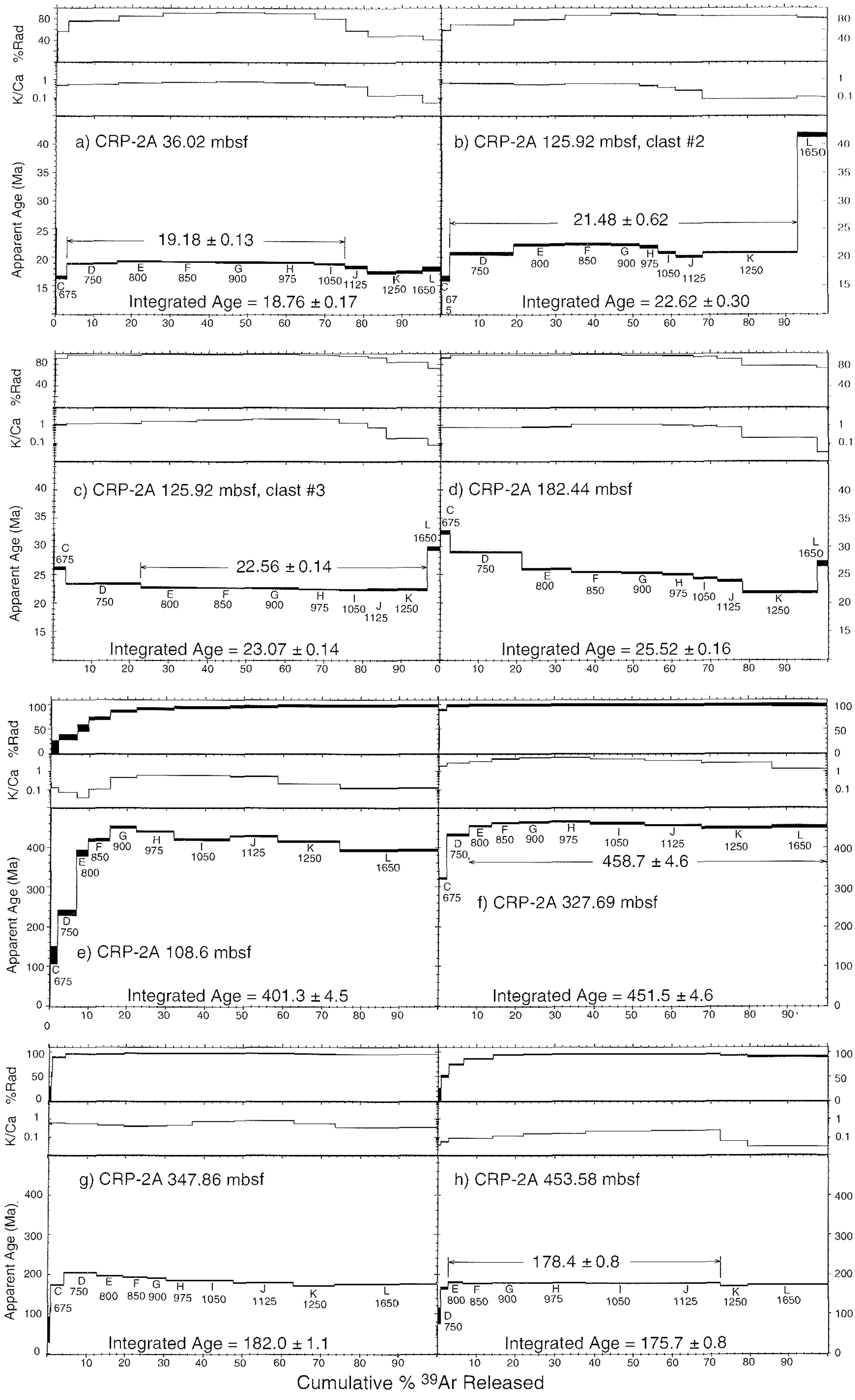


Fig. 2 - Age spectra for resistance-furnace incremental heating results for groundmass concentrates from clasts. Plateau ages are shown for spectra that satisfy the plateau criteria defined in the footnotes for table 1. The integrated age is the mean age of all steps, weighted by percent ^{39}Ar in each step. %Rad is percent radiogenic ^{40}Ar. K/Ca is a molar ratio calculated from K-derived ^{39}Ar and Ca-derived ^{37}Ar.

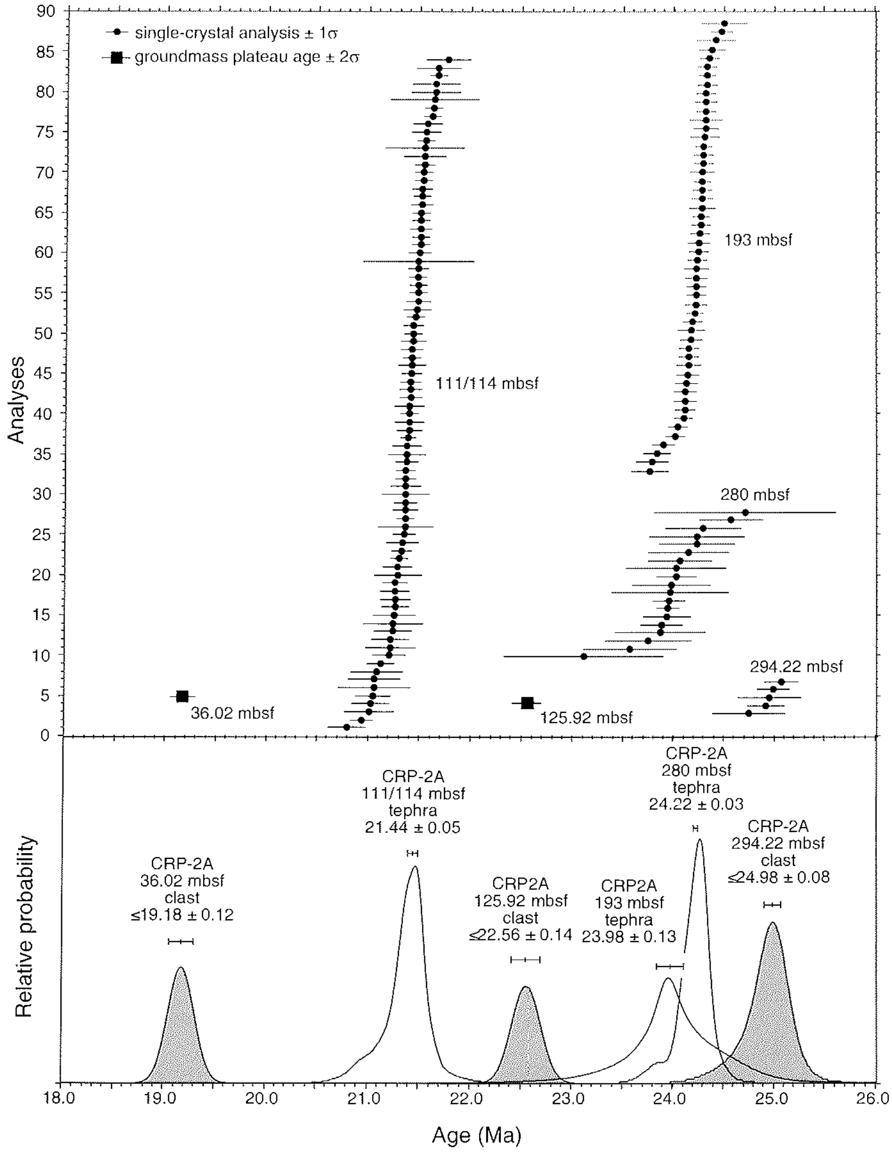


Fig. 3 - Summary of $^{40}Ar/^{39}Ar$ age constraints for CRP-2A, including single-crystal-laser fusion data, plateau ages, and age probability distribution curves. Unshaded age probability distribution curves denote depositional ages provided by tephra layers, and shaded age probability distribution curves denote maximum ages provided by clasts.

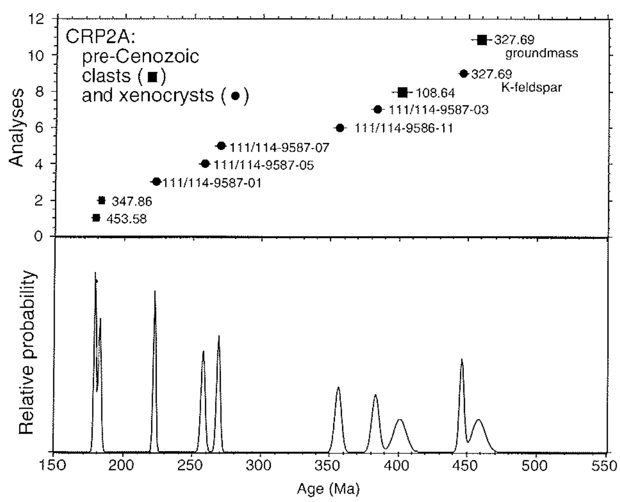


Fig. 4 - Age probability distribution of pre-Cenozoic ages determined from step-heated clast groundmass (squares) and single-crystal laser-fusion analyses of xenocrystic or detrital K-feldspar contaminant grains (circles).

DISCUSSION

The six $^{40}Ar/^{39}Ar$ age determinations that give precise age constraints for CRP-2A are summarized in figure 3. Laser-fusion ages of three tephra-bearing layers provide depositional ages for three stratigraphic levels: 21.44 ± 0.05 Ma for 111-114 mbsf, 23.98±0.13 Ma for 193.4 mbsf, and 24.22 ± 0.03 Ma for 280 mbsf. Laser-fusion and plateau ages for three volcanic clasts provide maximum ages for an additional three stratigraphic levels: ≤ 19.18 ± 0.13 Ma for 36.02 mbsf, ≤22.56±0.14 Ma for 125.92 mbsf, and ≤ 24.98 ± 0.08 Ma for 294.22 mbsf. These age constraints are generally in good agreement with age constraints based on biostratigraphy, palaeomagnetism, and other isotopic dating methods (Cape Roberts Science Team, 1999; Wilson et al., this volume; Scherer et al, this volume; Watkins & Villa, this volume; Lavelle, this volume). Implications of the $^{40}Ar/^{39}Ar$ ages and their integration with other geochronologic data and discussed in Wilson, Bohaty et al. (this volume).

ACKNOWLEDGEMENTS

This work was supported by NSF grant OPP95277329. The New Mexico Geochronology Research Laboratory is supported in part by the New Mexico Bureau of Mines and Mineral Research and by NSF Grants EAR-92064438 and EAR-9706062. The efforts of Philip Kyle, John Smellie, and Pietro Armienti in collecting dating samples from CRP-2A were essential to this study and are much appreciated. Nelia Dunbar characterized samples by electron microprobe. Lisa Peters and Richard Esser provided excellent laboratory assistance.

REFERENCES

Armienti P., Messiga B. & Vannucci R., 1999. Sand Provenance from Major and Trace Element Analyses of Bulk Rock and Sand Grains. *Terra Antartica*, **5**(3), 589-599.

Cape Roberts Science Team, 1999. Studies from the Cape Roberts Project, Ross Sea, Antarctica: Initial Report on CRP-2/2A. *Terra Antartica*, **6**(1/2), 1-173.

Deino A. & Potts R., 1990a. Single-Crystal $^{40}Ar/^{39}Ar$ dating of the Olorgesailie Formation, Southern Kenya Rift, *Journal of Geophysical Research*, **95**, 8453-8470.

Deino A. & Potts R., 1990b. Age probability spectra for examination of single-crystal $^{40}Ar/^{39}Ar$ dating results: examples from Olorgesailie Formation, Southern Kenya Rift. *Quaternary International*, **13/14**, 47-53.

Foland K. A., Fleming T.H., Heimann A. & Elliot D.H, 1993, Potassium-argon dating of fine-grained basalts with massive Ar loss; application of the $^{40}Ar/^{39}Ar$ technique to plagioclase and glass from the Kirkpatrick Basalt, Antarctica: *Chemical Geology*, **107**, 173-190.

McIntosh W.C. & Chamberlin R.M., 1994. $^{40}Ar/^{39}Ar$ geochronology of Middle to Late Cenozoic ignimbrites, mafic lavas, and volcaniclastic rocks in the Quemado Region, New Mexico. *New Mexico Geological Society Guidebook*, **45**, 165-185.

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

Smellie J. L., 1999. Sand Grain Detrital Modes in CRP-1: Provenance Variations and Influence of Miocene Eruptions on the Marine Record in the McMurdo Sound Region. *Terra Antartica*, **5**(3), 579-587.

Steiger R.H. & Jäger E., 1977. Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology. *Earth and Planetary Science Letters*, **36**, 359-362.

Appendix 1 - Analytical data for $^{40}Ar/^{39}Ar$ single-crystal laser-fusion analyses for samples from CRP-2A.

ID number		$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	%^{40}Ar*	Age (Ma)	±2σ (Ma)
CRP2A-111/114, ash, D=1.00292±0.00118, NM-96, all J-value uncertainties ±0.09%									
Sample number: Laboratory number/J-value:									
CRP2A-111.9: 9592/0.0003437, 9593/0.0003438, 9594/0.0003435,									
CRP2A-112.19: 9589/0.0003436, 9590/0.0003437,									
CRP2A-112.61: 9586/0.0003432, 9587/0.0003433, 9588/0.0003434,									
CRP2A-114.1: 9595/0.0003434, 9596/0.0003433									
9587-08	*	33.83	0.0180	3.251	0.572	28.3	97.2	20.24	0.12
9587-04	*	34.22	0.0436	2.296	1.74	11.7	98.0	20.66	0.08
9587-06		34.38	0.0226	2.013	0.361	22.6	98.3	20.80	0.14
9586-12		34.57	0.0162	1.879	0.978	31.4	98.4	20.94	0.07
9586-01		34.96	0.0773	2.797	0.252	6.6	97.7	21.01	0.21
9595-03		34.46	0.1061	1.093	0.339	4.8	99.1	21.03	0.14
9588-05		34.51	0.0896	1.139	0.364	5.7	99.0	21.05	0.13
9594-01		34.25	0.0088	0.2188	0.142	58.3	99.8	21.06	0.31
9589-07		34.04	0.0148	-0.4988	0.215	34.5	100.4	21.07	0.21
9588-03		34.43	0.0307	0.6842	0.213	16.6	99.4	21.09	0.21
9586-14		34.59	0.0168	0.9721	0.536	30.4	99.2	21.12	0.09
9593-07		34.81	0.0327	1.381	0.413	15.6	98.8	21.20	0.12
9589-06		34.54	0.0167	0.3645	0.221	30.5	99.7	21.21	0.21
9593-03		34.56	0.0280	0.4459	0.314	18.2	99.6	21.22	0.15
9592-04		34.50	0.0169	0.1779	0.316	30.1	99.8	21.24	0.15
9588-04		34.36	0.0554	-0.4089	0.181	9.2	100.4	21.24	0.25
9595-13		34.65	0.0143	0.5016	0.275	35.7	99.6	21.25	0.17
9596-02		34.74	0.0134	0.6985	0.519	38.2	99.4	21.26	0.10
9595-05		34.72	0.0110	0.6673	0.480	46.5	99.4	21.26	0.10
9593-08		34.63	0.0020	0.4542	0.457	254.0	99.6	21.27	0.11
9593-04		34.85	0.1084	1.183	0.645	4.7	99.0	21.27	0.08
9586-04		34.47	0.0187	-0.4060	0.259	27.3	100.4	21.29	0.19
9593-06		34.80	0.0255	0.8598	0.473	20.0	99.3	21.29	0.10
9587-02		34.96	0.0144	1.267	1.41	35.3	98.9	21.30	0.05
9586-03		34.86	0.1320	0.7171	1.02	3.9	99.4	21.33	0.06
9593-02		34.81	0.0835	0.6960	0.397	6.1	99.4	21.34	0.12
9595-11		35.15	0.0587	1.630	0.719	8.7	98.6	21.36	0.08
9592-06		34.27	0.0051	-1.2743	0.199	100.6	101.1	21.36	0.23
9596-04		34.89	0.0132	0.6725	1.38	38.8	99.4	21.36	0.05
9586-17		34.92	0.0399	0.7658	0.644	12.8	99.4	21.36	0.08
9593-05		34.82	0.0663	0.5769	0.867	7.7	99.5	21.36	0.07
9587-10		34.47	0.0028	-0.7548	0.233	182.0	100.6	21.36	0.20
9594-03		34.98	0.0929	1.088	0.475	5.5	99.1	21.36	0.11
9586-13		35.07	0.0550	1.218	1.12	9.3	99.0	21.36	0.06
9596-01		34.88	0.0809	0.6305	2.54	6.3	99.5	21.37	0.04

Appendix 1 - Continued.

ID number	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	%^{40}Ar*	Age (Ma)	±2σ (Ma)
9596-07	34.89	0.1227	0.6648	0.731	4.2	99.5	21.37	0.07
9594-02	35.02	0.0104	1.143	0.330	49.1	99.0	21.37	0.15
9595-06	34.84	0.0327	0.4524	0.453	15.6	99.6	21.38	0.11
9595-02	35.01	0.0839	1.013	4.59	6.1	99.2	21.38	0.04
9595-08	34.98	0.0124	0.7962	0.591	41.2	99.3	21.40	0.09
9589-04	35.19	0.0013	1.538	0.546	390.5	98.7	21.40	0.09
9596-05	35.04	0.0905	0.9603	1.25	5.6	99.2	21.40	0.05
9596-08	34.91	0.1512	0.5445	0.494	3.4	99.6	21.41	0.10
9595-04	34.93	0.0112	0.5482	0.748	45.7	99.5	21.42	0.07
9596-06	35.01	0.0046	0.7489	0.756	111.7	99.4	21.42	0.08
9586-07	34.90	0.0142	0.3563	1.02	35.8	99.7	21.42	0.06
9596-13	35.13	0.0420	1.167	1.27	12.1	99.0	21.42	0.05
9595-14	35.03	0.0154	0.8487	0.544	33.2	99.3	21.42	0.09
9586-02	35.46	0.0464	2.181	1.86	11.0	98.2	21.43	0.05
9590-05	34.84	0.0091	0.2523	1.04	56.1	99.8	21.43	0.06
9592-02	34.87	0.0168	0.3391	0.602	30.3	99.7	21.43	0.09
9586-09	34.99	0.1447	0.6029	1.40	3.5	99.5	21.44	0.05
9590-02	34.92	0.1044	0.4922	0.913	4.9	99.6	21.44	0.07
9589-05	35.06	0.0180	0.7803	2.48	28.4	99.3	21.46	0.04
9590-04	34.88	0.1144	0.1830	0.526	4.5	99.9	21.47	0.09
9592-03	34.98	0.0130	0.4693	0.669	39.1	99.6	21.48	0.08
9592-08	35.09	0.0164	0.8193	1.67	31.1	99.3	21.48	0.05
9596-10	35.02	0.0389	0.4319	1.54	13.1	99.6	21.48	0.05
9596-11	35.16	0.0973	0.9119	1.98	5.2	99.3	21.49	0.05
9592-05	34.98	0.0291	0.4168	1.01	17.5	99.7	21.49	0.06
9588-06	34.15	0.0119	-2.4967	0.087	43.0	102.2	21.49	0.51
9595-09	35.03	0.0355	0.4365	0.876	14.4	99.6	21.49	0.07
9595-10	35.13	0.0299	0.7376	1.36	17.1	99.4	21.50	0.05
9595-12	35.14	0.1303	0.8032	1.27	3.9	99.4	21.51	0.05
9586-16	35.02	0.0140	0.2667	0.819	36.5	99.8	21.51	0.07
9596-12	35.28	0.0361	1.164	3.84	14.1	99.0	21.51	0.05
9589-02	35.23	0.0158	1.090	3.79	32.3	99.1	21.51	0.04
9586-15	35.21	0.0629	0.8708	0.874	8.1	99.3	21.52	0.07
9596-14	35.22	0.0455	0.8776	1.30	11.2	99.3	21.52	0.05
9595-07	35.73	0.1085	2.672	0.970	4.7	97.8	21.52	0.06
9596-09	35.13	0.0406	0.5779	1.54	12.6	99.5	21.53	0.05
9589-03	35.37	0.0227	1.467	3.19	22.5	98.8	21.53	0.04
9586-08	35.18	0.0226	0.6309	1.11	22.6	99.5	21.54	0.06
9588-07	34.99	0.1162	0.0911	0.278	4.4	99.9	21.54	0.17
9586-05	34.40	0.0631	-2.0231	0.132	8.1	101.8	21.55	0.35
9595-01	35.24	0.0195	0.8227	1.80	26.2	99.3	21.55	0.04
9592-01	35.04	0.0094	0.2246	0.476	54.6	99.8	21.56	0.10
9590-01	34.90	0.0626	-0.2723	0.477	8.1	100.2	21.57	0.10
9589-01	35.21	0.0153	0.4553	2.53	33.4	99.6	21.61	0.05
9595-15	35.29	0.0016	0.5830	1.40	324.2	99.5	21.62	0.05
9588-08	34.11	0.0138	-3.4390	0.111	37.1	103.0	21.63	0.40
9592-07	34.80	0.0116	-1.1006	0.218	44.1	100.9	21.65	0.21
9586-18	35.06	0.0282	-0.4274	0.232	18.1	100.4	21.65	0.20
9586-10	35.79	0.0043	1.958	1.58	119.1	98.4	21.67	0.05
9586-06	35.02	0.0320	-0.6630	0.276	15.9	100.6	21.68	0.18
9588-02	35.08	0.0103	-0.8938	0.255	49.6	100.8	21.77	0.18
9593-01 *	54.07	0.0510	61.68	0.988	10.0	66.3	22.09	0.09
9586-19 *	34.90	0.2307	-4.0648	0.085	2.2	103.5	22.23	0.52
9587-09 *	335.7	4.285	227.1	0.073	0.12	80.1	159.75	3.46
9587-01 **	385.5	0.0125	9.889	1.86	40.9	99.2	222.61	0.91
9587-05 **	451.3	0.0104	12.64	1.27	49.2	99.2	257.84	1.47
9587-07 **	470.2	0.0088	6.445	1.97	58.2	99.6	268.96	1.27
9586-11 **	637.6	0.0134	6.161	1.49	38.0	99.7	356.05	2.29
9587-03 **	692.8	0.0203	10.16	3.19	25.1	99.6	383.42	2.61
weighted mean age			n=84		37.4 ±62.9		21.44	0.05
CRP2A-193.4, ash, J=0.0007968±0.10%, D=1.00531±0.00097, NM-110, Lab#=50512, 50513								
50512-20	17.34	0.0164	3.902	0.333	31.1	93.4	23.12	1.48
50513-09	16.73	0.0074	0.7666	0.584	69.3	98.6	23.57	0.83
50513-18	16.69	0.0056	0.1822	0.656	90.7	99.7	23.76	0.76
50513-05	16.88	0.0058	0.5612	0.587	88.7	99.0	23.87	0.82
50513-06	16.79	0.0074	0.2163	1.50	68.6	99.6	23.88	0.34
50512-08	16.90	0.0096	0.4896	1.38	53.2	99.1	23.93	0.39
50512-26	16.95	0.0084	0.6051	4.04	60.9	98.9	23.95	0.15
50512-07	16.92	0.0099	0.4672	2.49	51.4	99.2	23.96	0.23
50513-20	16.82	0.0075	0.0950	0.455	68.0	99.8	23.97	1.09
50513-24	16.80	0.0079	0.0037	0.721	64.6	100.0	23.98	0.71
50512-25	16.99	0.0082	0.5400	1.68	61.9	99.1	24.03	0.31
50513-10	16.96	0.0057	0.4223	0.524	89.7	99.3	24.03	0.92
50513-23	16.74	0.0095	-0.3909	0.930	53.6	100.7	24.07	0.55
50513-22	16.71	0.0062	-0.6765	0.696	82.3	101.2	24.15	0.72
50513-07	17.25	0.0062	0.9289	0.722	81.7	98.4	24.23	0.68
50513-02	17.27	0.0089	1.000	0.555	57.5	98.3	24.24	0.87
50513-16	17.15	0.0082	0.4476	0.726	62.1	99.2	24.29	0.68
50513-01	17.64	0.0107	1.461	1.03	47.8	97.6	24.57	0.56
50513-19	18.41	0.0017	3.720	0.286	298.3	94.0	24.72	1.73
weighted mean age			n=19		78.0 ±111.2		23.98	0.13

Appendix 1 - Continued.

ID number	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$\%^{40}Ar^*$	Age (Ma)	±2σ (Ma)
CRP2A-280.03, ash, J=0.0007679±0.10%, D=1.00361±0.00157, NM-101, Lab#=9954, 9955								
9954-29	17.54	0.0925	0.9326	0.319	5.5	98.5	23.76	0.15
9955-18	17.64	0.1878	1.226	0.497	2.7	98.0	23.79	0.12
9954-22	17.67	0.0243	1.171	0.736	21.0	98.1	23.84	0.09
9954-15	17.64	0.0096	0.9263	1.05	52.9	98.5	23.90	0.08
9955-10	17.57	0.1151	0.4335	2.20	4.4	99.3	24.02	0.06
9954-21	17.64	0.0527	0.5577	1.41	9.7	99.1	24.05	0.06
9955-20	17.55	0.0573	0.1352	4.50	8.9	99.8	24.10	0.05
9954-09	17.62	0.0304	0.3625	2.98	16.8	99.4	24.11	0.06
9955-29	17.68	0.0078	0.5117	1.15	65.3	99.1	24.12	0.08
9954-14	17.64	0.0132	0.3927	1.00	38.7	99.3	24.12	0.07
9954-20	17.60	0.0261	0.2347	1.06	19.6	99.6	24.13	0.07
9955-01	17.65	0.0281	0.3762	1.26	18.2	99.4	24.14	0.08
9954-08	17.60	0.0946	0.2117	1.09	5.4	99.7	24.15	0.08
9955-17	17.68	0.0214	0.4465	1.34	23.8	99.3	24.15	0.06
9955-06	17.63	0.1483	0.2871	2.19	3.4	99.6	24.15	0.06
9955-15	17.60	0.0327	0.1264	0.847	15.6	99.8	24.17	0.07
9954-25	17.60	0.0178	0.1203	0.852	28.7	99.8	24.17	0.09
9955-30	17.62	0.0341	0.1523	3.21	14.9	99.8	24.19	0.05
9955-11	17.59	0.0328	-0.0038	2.88	15.6	100.0	24.21	0.05
9955-28	17.66	0.0496	0.2148	1.11	10.3	99.7	24.22	0.07
9955-21	17.77	0.1590	0.6072	2.39	3.2	99.1	24.22	0.06
9955-27	17.67	0.0554	0.2477	2.61	9.2	99.6	24.22	0.06
9955-07	17.62	0.1330	0.0902	0.934	3.8	99.9	24.23	0.08
9954-30	17.67	0.0262	0.2342	0.985	19.4	99.6	24.23	0.08
9955-02	17.63	0.0583	0.0966	2.43	8.7	99.9	24.23	0.06
9954-24	17.71	0.0364	0.3220	1.52	14.0	99.5	24.25	0.06
9954-11	17.60	0.0530	-0.0605	1.08	9.6	100.1	24.25	0.08
9955-04	17.65	0.0105	0.0861	2.77	48.7	99.9	24.26	0.06
9954-02	17.63	0.0301	-0.0295	4.08	17.0	100.1	24.27	0.06
9954-28	17.69	0.0244	0.1712	4.93	20.9	99.7	24.27	0.05
9954-03	17.63	0.0990	-0.0035	0.762	5.2	100.0	24.28	0.09
9954-16	17.70	0.0455	0.1839	1.41	11.2	99.7	24.28	0.07
9955-23	17.65	0.1006	0.0475	3.91	5.1	100.0	24.28	0.05
9955-19	17.70	0.0524	0.1797	2.38	9.7	99.7	24.28	0.05
9954-12	17.65	0.0327	0.0210	0.753	15.6	100.0	24.29	0.09
9955-24	17.70	0.0644	0.1705	1.61	7.9	99.7	24.29	0.06
9954-07	17.67	0.1385	0.0830	1.65	3.7	99.9	24.29	0.06
9955-03	17.69	0.0323	0.1224	3.99	15.8	99.8	24.30	0.05
9954-27	17.76	0.0304	0.3212	0.799	16.8	99.5	24.31	0.10
9954-19	17.81	0.0430	0.5018	0.702	11.9	99.2	24.31	0.09
9954-05	17.67	0.0071	-0.0039	0.500	72.3	100.0	24.31	0.13
9955-12	17.66	0.0341	-0.0178	2.38	15.0	100.0	24.32	0.06
9955-26	17.65	0.0666	-0.0752	2.09	7.7	100.2	24.32	0.07
9954-17	17.68	0.0951	0.0518	1.63	5.4	100.0	24.32	0.06
9955-14	17.78	0.1591	0.3769	3.01	3.2	99.4	24.33	0.06
9955-08	17.77	0.0464	0.3147	5.88	11.0	99.5	24.33	0.05
9954-06	17.68	0.1414	0.0350	2.89	3.6	100.0	24.34	0.06
9955-16	18.16	0.0248	1.555	6.19	20.6	97.5	24.35	0.06
9954-04	17.64	0.0594	-0.2449	0.657	8.6	100.4	24.38	0.10
9954-26	17.68	0.0628	-0.1881	0.442	8.1	100.3	24.41	0.15
9954-01	17.70	0.0362	-0.2958	1.37	14.1	100.5	24.48	0.07
9954-23	17.82	0.1227	0.0899	0.271	4.2	99.9	24.50	0.19
weighted mean age			n=52		15.6 ±15.0		24.22	0.03
CRP2A-294.22, clast, J=0.0007782±0.10%, D=1.00361±0.00157, NM-105, Lab#=50263								
50263-12	18.24	0.0036	1.665	0.081	142.9	97.3	24.75	0.32
50263-03	18.10	0.0042	0.7646	0.243	122.3	98.8	24.92	0.15
50263-04	18.07	0.0049	0.5838	0.139	103.3	99.0	24.95	0.28
50263-10	18.13	0.0057	0.7233	0.286	88.8	98.8	24.99	0.12
50263-05	18.24	0.0053	0.8781	0.337	95.4	98.6	25.07	0.13
weighted mean age			n=5		110.5 ±22.0		24.98	0.08
CRP2A-327.69, clast, J=0.000778676±0.10%, D=1.00361±0.00157, NM-105, Lab#=50264								
50264-07 ***	262.7	1.520	42.27	0.192	0.34	95.3	321.7	2.1
50264-10 ***	285.7	1.921	113.8	0.159	0.27	88.3	324.0	2.7
50264-05 ***	320.6	2.763	34.34	0.160	0.18	96.9	391.8	3.0
50264-09 ***	352.4	2.501	123.1	0.245	0.20	89.7	397.9	3.3
50264-06 ***	355.0	2.652	67.17	0.285	0.19	94.5	419.5	2.2
50264-03 ***	353.8	2.981	45.49	0.234	0.17	96.3	425.4	2.6
50264-02 ***	371.8	3.052	83.25	0.295	0.17	93.5	433.0	2.3
50264-04 ***	365.0	1.503	41.82	0.517	0.34	96.6	438.4	2.2
50264-08	362.5	0.0135	6.358	0.941	37.9	99.5	446.4	1.6
50264-01 ***	380.5	3.232	63.01	0.409	0.16	95.2	449.3	2.2
weighted mean age			n=1		37.9	94.6	446.4	1.6

Isotopic ratios are corrected for blank, radioactive decay, and mass discrimination, but are not corrected for interferring reactions. Individual analyses show analytical error only; mean age errors also include error in J and irradiation parameters. Analyses with ID numbers followed by one or more stars are excluded from calculations of weighted mean age.

*denotes analyses with slightly anomalous ages attributed to alteration of adhering glass. **denotes analyses with anomalous ages attributed to xenocrystic origin. ***denotes analyses of plagioclase.

Correction factors: $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.00070±0.00005 (CRP2A-112/114 and CRP2A-280); $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.00089±0.00003 (CRP2A-193 and CRP2A-294); $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00026±0.00002 (CRP2A-112/114 and CRP2A-280); $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.00028±0.00001 (CRP2A-193 and CRP2A-294); $(^{38}Ar/^{39}Ar)_K$ = 0.0119; $(^{40}Ar/^{39}Ar)_K$ = 0.0002±0.0003

Appendix 2 - Analytical data for resistance-furnace step-heating analyses of clasts.

ID number		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)	±2σ (Ma)
__Cenozoic clasts__											
CRP2A-36.02, 73.4 mg groundmass, J=0.000788631±0.10%, D=1.00361±0.00157, NM-105, Lab#=50279-01											
50279-01A	†	550	244,3	1,028	788,7	0,081	0,50	4,6	0,1	16,1	9,2
50279-01B	†	600	49,02	0,9950	126,7	0,071	0,51	23,8	0,2	16,5	2,9
50279-01C	†	675	20,51	1,005	30,21	2,03	0,51	56,9	2,9	16,53	0,26
50279-01D		750	17,53	0,8940	14,28	9,90	0,57	76,3	16,2	18,96	0,16
50279-01E		800	15,92	0,7385	7,910	8,65	0,69	85,7	27,9	19,32	0,12
50279-01F		850	14,95	0,6597	4,734	10,2	0,77	91,0	41,6	19,27	0,10
50279-01G		900	14,57	0,6243	3,554	9,18	0,82	93,1	53,9	19,216	0,092
50279-01H		975	14,74	0,6464	4,139	9,96	0,79	92,1	67,3	19,21	0,11
50279-01I		1050	16,38	0,8470	10,39	5,98	0,60	81,7	75,4	18,95	0,12
50279-01J	†	1125	21,93	1,120	30,57	4,33	0,46	59,2	81,2	18,41	0,21
50279-01K	†	1250	25,15	3,676	44,48	10,6	0,14	49,0	95,5	17,49	0,28
50279-01L	†	1650	30,72	9,140	63,69	3,36	0,056	41,2	100,0	18,06	0,39
plateau age				n=6	steps D-I	53,9	0,71	86,7	72,4	19,18	0,12
CRP2A-125.92-2, 20.9 mg groundmass, J=0.000778947±0.10%, D=1.00361±0.00157, NM-105, Lab#=50269-01											
50269-01A	†	550	370,4	0,5321	1253,6	0,018	0,96	0,0	0,1	0,1	69,1
50269-01B	†	600	23,02	0,7315	36,72	0,009	0,70	53,1	0,2	17,1	10,3
50269-01C	†	675	19,67	0,7164	27,31	0,343	0,71	59,3	2,5	16,32	0,45
50269-01D		750	21,21	0,7765	21,81	2,48	0,66	69,9	19,2	20,73	0,22
50269-01E		800	20,08	0,9168	14,29	1,97	0,56	79,4	32,4	22,27	0,22
50269-01F		850	18,35	0,8210	8,102	1,78	0,62	87,3	44,3	22,39	0,17
50269-01G		900	17,59	0,8331	5,747	1,13	0,61	90,7	51,9	22,31	0,18
50269-01H		975	17,57	1,034	6,568	0,714	0,49	89,4	56,7	21,96	0,25
50269-01I		1050	16,99	1,365	7,282	0,693	0,37	88,0	61,3	20,91	0,24
50269-01J		1125	16,51	1,895	7,431	1,03	0,27	87,6	68,3	20,25	0,21
50269-01K		1250	17,32	5,873	10,05	3,70	0,087	85,7	93,1	20,83	0,13
50269-01L	†	1650	36,34	4,204	23,07	1,02	0,12	82,2	100,0	41,65	0,39
plateau age				n=8	steps D-K	13,5	0,42	84,8	90,6	21,5	0,6
CRP2A-125.92-3, 21.2 mg groundmass, J=0.000778548±0.10%, D=1.00361±0.00157, NM-105, Lab#=50270-01											
50270-01A	†	550	63,75	0,4512	153,8	0,046	1,1	28,8	0,1	25,6	5,1
50270-01B	†	600	23,95	0,4889	16,19	0,019	1,0	80,2	0,2	26,8	5,6
50270-01C	†	675	20,52	0,4718	6,129	0,929	1,1	91,4	3,2	26,15	0,22
50270-01D	†	750	17,19	0,4212	1,595	6,01	1,2	97,5	22,8	23,38	0,12
50270-01E		800	16,56	0,3091	1,002	4,42	1,7	98,4	37,1	22,74	0,11
50270-01F		850	16,52	0,2540	0,9359	4,41	2,0	98,5	51,4	22,70	0,11
50270-01G		900	16,47	0,2183	0,8976	3,72	2,3	98,5	63,5	22,65	0,11
50270-01H		975	16,49	0,2196	1,482	3,22	2,3	97,5	74,0	22,44	0,11
50270-01I		1050	16,68	0,3737	2,471	2,29	1,4	95,8	81,4	22,32	0,13
50270-01J		1125	17,39	0,6725	4,696	1,43	0,76	92,3	86,1	22,42	0,18
50270-01K		1250	19,06	2,716	11,09	3,30	0,19	84,0	96,8	22,40	0,15
50270-01L	†	1650	29,11	6,447	28,69	0,994	0,079	72,7	100,0	29,65	0,34
plateau age				n=7	steps E-K	22,8	1,6	95,0	74,0	22,56	0,14
CRP2A-182.44, 19.2 mg groundmass, J=0.000777852±0.10%, D=1.00361±0.00157, NM-105, Lab#=50271-01											
50271-01B		600	51,15	0,8176	102,6	0,014	0,62	40,8	0,1	29,1	7,7
50271-01C		675	25,35	0,6809	7,110	0,617	0,75	91,9	2,7	32,43	0,32
50271-01D		750	21,58	0,6734	2,691	4,36	0,76	96,6	21,3	29,02	0,14
50271-01E		800	19,18	0,6359	1,821	2,98	0,80	97,5	34,1	26,06	0,13
50271-01F		850	18,63	0,4586	1,372	3,00	1,1	98,0	46,9	25,45	0,13
50271-01G		900	18,68	0,4435	1,692	2,50	1,2	97,5	57,6	25,39	0,14
50271-01H		975	18,69	0,4836	2,403	1,90	1,1	96,4	65,7	25,12	0,14
50271-01I		1050	18,69	0,5642	4,127	1,47	0,90	93,7	72,0	24,42	0,15
50271-01J		1125	19,13	0,6815	7,007	1,49	0,75	89,5	78,3	23,87	0,17
50271-01K		1250	20,12	2,669	15,91	4,54	0,19	77,7	97,7	21,86	0,16
50271-01L		1650	26,09	16,23	28,49	0,527	0,031	72,9	100,0	26,86	0,45
total gas age				n=11		23,4	0,76	86,6		25,52	0,16
__Pre-Cenozoic clasts__											
CRP2A-327.69-2, 16.58 mg groundmass, J=0.000776784±0.10%, D=1.00361±0.00157, NM-105, Lab#=50274-01											
50274-01A	†	550	564,8	0,3717	1301,8	0,030	1,4	31,9	0,1	236,3	23,6
50274-01B	†	600	319,2	0,2636	313,8	0,021	1,9	71,0	0,2	292,4	13,5
50274-01C	†	675	280,2	0,2412	97,90	0,452	2,1	89,7	2,3	321,7	2,3
50274-01D	†	750	354,1	0,1639	22,05	1,27	3,1	98,2	8,1	431,3	2,2
50274-01E		800	369,7	0,1340	6,672	1,24	3,8	99,5	13,8	453,4	2,5
50274-01F		850	376,1	0,0978	3,913	1,54	5,2	99,7	20,9	461,2	2,1
50274-01G		900	377,6	0,0854	2,864	1,70	6,0	99,8	28,7	463,1	2,2
50274-01H		975	379,8	0,0837	2,347	2,25	6,1	99,8	39,0	465,6	2,2
50274-01I		1050	375,1	0,1032	3,431	3,12	4,9	99,7	53,2	460,2	2,3
50274-01J		1125	370,3	0,1271	4,571	3,17	4,0	99,6	67,7	454,7	2,1
50274-01K		1250	365,9	0,1692	9,212	4,03	3,0	99,3	86,2	448,4	2,6
50274-01L	†	1650	370,6	0,3620	16,12	3,01	1,4	98,7	100,0	451,4	3,5
plateau age				n=7	steps E-K	17,1	4,5	99,6	78,1	458,7	4,5

Appendix 2 - Continued.

ID number	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)	±2σ (Ma)
CRP2A-347.86, 21.6 mg groundmass, J=0.000776698±0.10%, D=1.00361±0.00157, NM-105, Lab#=50275-01										
50275-01A	550	743,8	0,8540	2368,0	0,101	0,60	5,9	0,5	60,9	31,6
50275-01B	600	147,6	0,9224	226,5	0,066	0,55	54,7	0,8	109,8	5,7
50275-01C	675	145,0	0,8175	49,36	0,660	0,62	90,0	4,1	174,3	1,0
50275-01D	750	160,5	0,8673	20,36	1,68	0,59	96,3	12,6	204,7	1,1
50275-01E	800	152,3	1,070	15,69	1,37	0,48	97,0	19,5	196,22	0,92
50275-01F	850	148,3	1,251	12,59	1,26	0,41	97,6	25,8	192,36	0,96
50275-01G	900	147,1	1,210	11,04	0,976	0,42	97,9	30,7	191,4	1,0
50275-01H	975	141,6	1,049	8,977	1,26	0,49	98,2	37,0	185,2	1,0
50275-01I	1050	141,1	0,6827	8,412	2,15	0,75	98,3	47,8	184,68	0,85
50275-01J	1125	136,9	0,5964	10,44	3,03	0,86	97,8	63,0	178,48	0,92
50275-01K	1250	133,6	0,8909	17,18	2,11	0,57	96,3	73,6	171,90	0,88
50275-01L	1650	137,0	1,512	20,14	5,27	0,34	95,7	100,0	175,26	0,83
total gas age			n=12		20,0	0,55	85,5		182,0	1,1
CRP2A-453.58, 48.8 mg groundmass, J=0.000783013±0.10%, D=1.00361±0.00157, NM-105, Lab#=50281-01										
50281-01C †	675	568,6	14,03	1695,1	0,101	0,036	12,1	0,8	95,8	19,6
50281-01D †	750	237,3	9,082	393,1	0,266	0,056	51,4	2,8	165,8	3,4
50281-01E	800	175,6	5,952	145,5	0,515	0,086	75,8	6,7	179,8	1,9
50281-01F	850	150,4	5,774	64,55	1,02	0,088	87,6	14,3	178,1	1,0
50281-01G	900	140,4	4,308	27,27	1,04	0,12	94,5	22,2	179,0	1,0
50281-01H	975	137,1	3,099	15,66	2,10	0,16	96,8	38,0	178,8	1,2
50281-01I	1050	136,4	2,307	15,43	2,25	0,22	96,8	54,9	177,8	1,2
50281-01J	1125	136,2	2,148	15,50	2,34	0,24	96,8	72,6	177,5	1,3
50281-01K †	1250	133,6	8,497	33,49	0,942	0,060	93,1	79,7	168,9	1,1
50281-01L †	1650	139,2	17,52	46,77	2,69	0,029	91,1	100,0	173,5	1,4
plateau age			n=6	steps E-J	9,3	0,18	91,4	69,8	178,4	0,8
CRP2A-108.64, 24.42 mg groundmass, J=0.000779382±0.10%, D=1.00361±0.00157, NM-105, Lab#=50267-01										
50267-01B	600	4126,7	2,385	13666,6	0,020	0,21	2,1	0,2	120,4	595,9
50267-01C	675	947,7	3,918	2886,6	0,204	0,13	10,0	2,1	129,3	22,1
50267-01D	750	518,8	7,233	1157,8	0,501	0,071	34,2	6,7	234,9	6,9
50267-01E	800	578,7	14,11	941,7	0,334	0,036	52,1	9,8	385,2	8,2
50267-01F	850	460,3	4,693	429,5	0,611	0,11	72,5	15,5	418,7	4,0
50267-01G	900	418,2	1,126	183,6	0,730	0,45	87,0	22,3	451,0	3,0
50267-01H	975	382,8	0,8199	99,12	1,04	0,62	92,4	31,9	439,4	2,3
50267-01I	1050	354,5	0,8294	64,41	1,54	0,62	94,6	46,2	419,4	2,7
50267-01J	1125	353,3	0,9496	32,47	1,33	0,54	97,3	58,5	428,6	2,5
50267-01K	1250	338,5	2,364	26,66	1,75	0,22	97,7	74,7	414,6	2,6
50267-01L	1650	318,5	4,155	27,79	2,72	0,12	97,5	100,0	392,5	2,7
total gas age			n=11		10,8	0.32	67,0		401,3	4.5

Isotopic ratios are corrected for blank, radioactive decay, and mass discrimination, but are not corrected for interfering reactions. Individual analyses show analytical error only; mean age errors also include error in J and irradiation parameters. † denotes analyses excluded from plateau age calculations.

Correction factors:

$(^{39}Ar/^{37}Ar)_{Ca} = 0.00089 \pm 0.00003$

$(^{36}Ar/^{37}Ar)_{Ca} = 0.00028 \pm 0.00001$

$(^{38}Ar/^{39}Ar)_{K} = 0.0119$

$(^{40}Ar/^{39}Ar)_{K} = 0.0002 \pm 0.0003$