Preliminary $^{40}Ar/^{39}Ar$ results from the AND-1B core

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Summary Preliminary $^{40}Ar/^{39}Ar$ dating of 13 volcanic samples from four stratigraphic intervals within the AND-1B core provide key age constraints for the development of an accurate age-model. To date seven analyses have yielded statistically robust and stratigraphically meaningful ages (Table 1). The four different stratigraphic intervals represented by the seven successfully dated samples are: 1) 85.53-85.85 mbsf felsic tephra (1.014±0.004 Ma), 2) ~112-145 mbsf basaltic tephra (1.65±0.05 to 1.67±0.05 Ma), 3) 646.30-649.34 mbsf basaltic lava flow (6.48±0.13 Ma), and 4) ~1280 mbsf volcanic clasts (maximum depositional age 13.57±0.13 Ma)

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Introduction

The ANtarctic Geologic DRILLING Project is an international collaboration to recover stratigraphic intervals recording past ice sheet responses to climate forcing. To achieve this goal the ANDRILL MIS Project drilled a stratigraphic hole (AND-1B) from a platform on the McMurdo Ice Shelf, east of Hut Point Peninsula, Ross Island. The AND-1B core is composed of a variety of sediments, glacimarine, terrigenous, volcanic and biogenic, representing multiple geological processes. Core was recovered to a depth of 1284. 87 meters below sea floor (mbsf) making the AND-1B core the deepest recovery of Antarctic sediment to date.

$^{40}Ar/^{39}Ar$ dating of seven volcanic samples has yielded precise eruption ages for four stratigraphic intervals within the AND-1B core. These seven ages have been key in the development of an accurate age-model for the core, providing four constraining points for the Diatom biostratigraphy and magnetostratigraphy.

Methods

Sample Preparation

All samples were prepared at the New Mexico Geochronology Research Laboratory (NMGRL) in Socorro, New Mexico, with exception of the sample 85.53–85.85 mbsf, which was prepared at McMurdo Station. Sample preparation was tailored to each sample in order to optimize results. Sample 85.53–85.85 mbsf underwent ultrasonic cleaning followed by hand picking of K-feldspar grains at McMurdo Station. Four tephra samples (112.51-112.62 mbsf, 136.21-136.27 mbsf, 140.30-140.36 mbsf, and 145.12-145.16 mbsf) from the basaltic tephra interval were purified by extensive rinsing, sieving, acid treatment, magnetic separation and ultrasonic cleaning in an attempt to remove contaminants and hydration rims observed during electron microprobe sample characterization. The 648.37-648.43 mbsf lava sample was mechanically crushed and hand sieved. The 300-500 µm sieve fraction, used for $^{40}Ar/^{39}Ar$ analysis, was treated with 10% HCl for 10 minutes followed by ultrasonic cleaning in distilled water. K-feldspar phenocrysts from the three volcanic clasts (1277.91-1277.95 mbsf, 1278.84-1278.87 mbsf, and 1279.00-1279.04 mbsf) were easily removed by crushing and magnetic separation followed by hand picking of any contaminant grains. See Table 1 for more sample preparation information.

Irradiation

All samples were packaged with flux monitors of known age (Fish Canyon Tuff sanidine, 28.02 Ma; Renne et al., 1998), and irradiated for 7 hours, except for the 85.53–85.85 mbsf K-feldspar separate sample which was only irradiated for one hour, at the reactor facility at Texas A & M, College Park, TX.

Analysis

All $^{40}Ar/^{39}Ar$ analyses were preformed using either the CO_2 laser or resistance furnace systems at NMGRL. Further information on the instrumentation used at NMGRL, as well as details for analytical procedures, are located in the notes section of Table 1.

Results

85.53–85.85 mbsf Felsic Tephra (1.014 ± 0.004 Ma)

Euhedral sanidine phenocrysts separated from the 85.53–85.85 mbsf pumice rich layer were used for $^{40}Ar/^{39}Ar$ analysis. Following irradiation of the sample grains, single crystals and groups of two to three crystals were fused by a CO_2 laser, and then analyzed by the MAP-215-50 mass spectrometer. Data from 37 sanidine phenocrysts from the 85.53–85.85 mbsf tephra yielded a precise, robust isochron age of 1.014 ±0.004 Ma. The data form a unimodal normal distribution after rejecting two older crystals interpreted as xenocrysts (Figure 1a). On an isochron diagram (Figure 1b) the data form a well-aligned linear array indicating small but significant amounts of excess ^{40}Ar. The isochron age is interpreted as an accurate determination of the eruption age of the 85.53–85.85 mbsf tephra.

~112-145 mbsf Basaltic Tephra (1.65±0.05 to 1.67±0.05 Ma)

Two purified glass samples from the 112-145 mbsf basaltic tephra interval yielded precise ages that are concordant within uncertainty. The four purified glass samples (see Methods section) were incrementally heated in a resistance furnace. Two samples yielded precise isochron ages (112.51-112.62 mbsf, 1.65±0.05 Ma, Figure 1d; 136.21-136.27 mbsf, 1.67±0.05 Ma, Figure 1f) while the other two (140.30-140.36 mbsf and 145.12-145.16 mbsf) yielded spectra indicative of contamination by older material. Further sample purification work needs to be done to better date the bottom of this basaltic tephra section, thereby constraining the duration of the eruptive interval.

646.30-649.34 mbsf Basaltic Lava Flow (6.48±0.13 Ma)

A whole rock sample (648.37-648.43 mbsf) from the basaltic lava flow located near the middle of the core was incrementally heated in the resistance furnace yielding a moderately robust plateau age of 6.48±0.13 Ma (Figure 1g). This lava flow was identified in McMurdo as an attractive dating target. Electron microprobe sample characterization indicates that the lava consists of a glassy groundmass containing abundant calcic plagioclase microphenocrysts with K-bearing rims. The isochron plot for this sample yielded an isochron age within 2σ uncertainty of the plateau age. In addition, the isochron produced an initial $^{40}Ar/^{36}Ar$ value within 2σ uncertainty of the atmospheric value $((^{40}Ar/^{36}Ar)_{atm} = 295.5)$. The age spectrum results for this sample, in conjunction with the results of an isochron plot, yield what we believe to be an accurate eruption age of 6.48±0.13 Ma.

~1280 mbsf Volcanic Clasts (maximum depositional age 13.57±0.13 Ma)

After failing to find fresh K-feldspar phenocrysts in altered pumice from the bottom of the core we dated three volcanic clasts from near 1280 m in an attempt to determine a maximum depositional age. In contrast to the altered tephra, these volcanic clasts contain large fresh sanidine crystals. Fifteen sanidine phenocrysts separated from each of these clasts were individually fused using a CO_2 laser. Sanidine from each of these three clasts yield tightly grouped normal age distributions. Weighted mean ages for the three clasts are: 1277.91-1277.95 mbsf, 13.82±0.09 Ma; 1278.84-1278.87 mbsf, 13.85±0.18 Ma and 1279.00-1279.04 mbsf, 13.57±0.13 Ma (Figure 1h). Although these clasts do not directly date the depositional age of the bottom of the core, they do provide a precise and accurate maximum depositional age of 13.57±0.13 Ma for the sediment at 1279.00 mbsf.

Summary

The preliminary $^{40}Ar/^{39}Ar$ results provide key age information for four stratigraphic intervals within the AND-1B core, thereby adding significant age constraints to the age-model. A highly precise age for the upper core at 85.53-85.85 mbsf was obtained by analysis of single crystal and groups of two to three K-feldspar grains. Analyses of glass from the basaltic tephra interval spanning from approximately 112-145 mbsf, while not as precise as the K-feldspar age, provide two other age-constraining points for the core. The whole rock lava sample is the least precise of all the analyses but does yield a statistically acceptable eruption age. Two of the three volcanic clasts, 1277.91-1277.95 and 1278.84-1278.87 mbsf, yielded ages within 2σ uncertainty of each other. The third volcanic clast (1279.00-1279.04 mbsf) yielded a mean age younger than the two other clasts providing a maximum depositional age for sediment at 1279.00 mbsf.

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Table 1. Summary of $^{40}Ar/^{39}Ar$ results

Sample	Location (mbsf)	L#	Irrad	Material	Preferred Age analysis	n	MSWD	K/Ca ± 2s	Age(Ma) ± 2s
AN85-1	85.53-85.87	56529	NM-198M	K-spar	Isochron	37	1.2	19.5 ± 18.3	1.014 ± 0.004
An112_51	112.51-112.62	56873-01	NM-203P	Glass	Isochron	9	2	0.2 ± 0.0	1.65 ± 0.05
An136_21	136.21-136.27	56867-01	NM-203O	Glass	Isochron	11	1	0.3 ± 0.1	1.67 ± 0.05
648-GM-HCl	648.37-648.43	56788-01	NM-203C	WR	Plateau	6	1.7	0.4 ± 0.3	6.48 ± 0.13
1277-91	1277.91-1277.95	56793	NM-203D	K-spar	Mean	15	0.3	31.0 ± 30.4	13.82 ± 0.09
1278-84	1278.84-1278.97	56794	NM-203D	K-spar	Mean	14	0.5	1854.7 ± 11014.7	13.85 ± 0.18
1279-00	1279.00-1279.04	56792	NM-203D	K-spar	Mean	15	0.5	8.7 ± 5.8	13.57 ± 0.13

L# = Lab number, Irrad = Irradiation number and tray letter, n = number of analyses use to compute age, MSWD = Mean Square Weighted Deviation

Notes:

Sample preparation and irradiation:

Samples were mechanically crushed and hand sieved at NMGRL

Sieve fractions 106-125 µm were used for sample An112_51 and 136_21, and 300-500 µm for 648-GM-HCl

K-feldspar phenocrysts from samples AN85-1, 1277-91, 1278-84, 1279-00 were hand picked under a stereo microscope

Samples treated with acid were immersed in 10% HCl within an ultrasonic bath, followed by ultrasonic rinsing with distilled water to remove the residual acid.

All samples and neutron flux monitors were loaded into machine Al discs in a known geometry

Neutron flux monitor Fish Canyon Tuff sanidine (FC-1). Assigned age = 28.02 Ma (Renne et al, 1998)

Instrumentation:

Mass Analyzer Products 215-50 mass spectrometer on line with automated all-metal extraction system.

Separate was step-heated using a Mo double-vacuum resistance furnace. Heating duration in the furnace was 10 minutes

Reactive gases removed during furnace analysis by reaction with 3 SAES GP-50 getters, 2 operated at ~450°C and 1 at 20°C. Gas also exposed to a W filament operated at ~2000°C.

Analytical parameters:

Averaged furnace sensitivity 1.24×10^{-16} moles/pA. Averaged laser sensitivity 7.12×10^{-17} moles/pA

Total system blank and background for the furnace averaged 5017, 5.6, 6.5, 29.1, 7.8, 21.7 x 10^{-18} moles.

Total system blank and background for the laser averaged 376, 5.3, 1.9, 5.6, 7.8, 29.7 x 10^{-18} moles.

J-factors determined to a precision of ± 0.1% by CO_2 laser-fusion of 4 to 6 single crystals from each of the 6 or 10 radial positions around the irradiation tray (6 for a 12 hole disc, 10 for a 20 hole disc).

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

$(^{40}Ar/^{39}Ar)_K = 0 \pm 0.0004$; $(^{36}Ar/^{37}Ar)_{Ca} = 0.000289 \pm 0.000005$; and $(^{39}Ar/^{37}Ar)_{Ca} = 0.00068 \pm 0.00002$

Age calculations:

Plateau age or preferred age calculated for the indicated steps by weighting each step by the inverse of the variance.

Plateau age error is inverse-variance-weighted mean error (Taylor, 1982) times root MSWD where MSWD>1.

MSWD values are calculated for n-1 degrees of freedom for plateau age.

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

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

All errors reported at ±2s, unless otherwise noted.

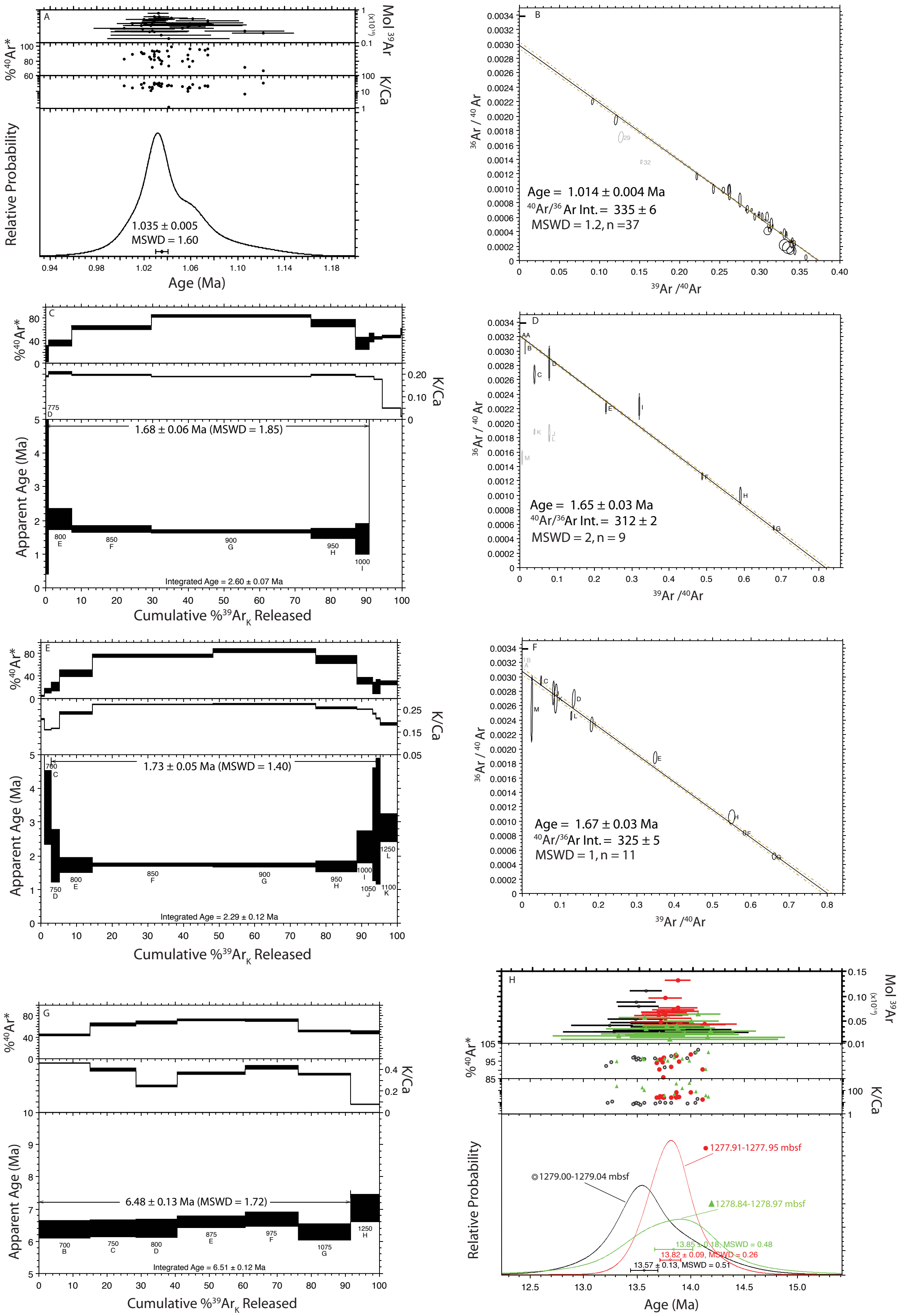

Figure 1. (a) Age probability plot and (b) "inverse" isochron for 85.35-85.85 mbsf K-feldspars; (c) age spectrum and (d) "inverse" isochron for 112.51-112.62 msbf glass; (e) age spectrum and (f) "inverse" isochron for 136.21-136.27 mbsf glass; (g) age spectrum for 648.37-648.43 mbsf whole rock and (h) age probability plot for ~1280 mbsf volcanic clasts.