16. $^{40}Ar/^{39}Ar$ AGE SPECTRA OF BASALTS, DEEP SEA DRILLING PROJECT SITE 516[1]

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INTRODUCTION

Submarine basalts are difficult to date accurately by the potassium-argon method. Dalrymple and Moore (1968) and Dymond (1970), for example, showed that, when the conventional K-Ar method is used, pillow lavas may contain excess ^{40}Ar. Use of the $^{40}Ar/^{39}Ar$ step-heating method has not overcome the problem, as had been hoped, and has produced some conflicting results. Ozima and Saito (1973) concluded that the excess ^{40}Ar is retained only in high temperature sites, but Seidemann (1978) found that it could be released at all temperatures. Furthermore, addition of potassium, from seawater, to the rock after it has solidified can result in low ages (Seidemann, 1977), the opposite effect to that of excess ^{40}Ar. Thus, apparent ages may be either greater or less than the age of extrusion. Because of this discouraging record, the present study was approached pragmatically, to investigate whether self-consistent results can be obtained by the $^{40}Ar/^{39}Ar$ step-heating method.

RESULTS

Four whole-rock samples from DSDP Cores 516F-126 and 516F-128 were analyzed as described in Mussett and others (1980). (For details of sample description and nomenclature, see Introduction and site chapters, this volume.) The quantity of water released on heating was much greater than in subaerial basalts and accounted for 10–15% of the weight of the samples. This defeated the clean-up system during analysis of the first sample, Sample 516F-126-3, 67–72 cm (piece 3b), resulting in the loss of heating Steps 2–6, which was particularly unfortunate because the remaining steps gave the best approximate age plateau of any of the four samples.

In all samples, the lowest temperature step gave the highest apparent age, but thereafter the age spectra (Table 1) of the four samples showed little similarity. This lack of similarity is perhaps not surprising because the samples came from two flows, and even the samples from the same flow were separated by at least 40 cm, over which distance the core varied noticeably (see site chapter, Site 516, this volume, and Thompson et al., this volume). Because significant quantities of argon were released in the lowest temperature steps, it is possible that nonatmospheric argon was lost either during irradiation, as reported by Seidemann (1978), or during the bake-out to 200°C after loading into the argon extraction line. However, because the apparent ages of the lowest-temperature-recorded steps are evidently far in excess of the extrusion age of the lavas, probably only a little dating information of significance was lost.

Only two of the four samples yielded what even superficially could be regarded as age plateaus (Table 1, Fig. 1). Lanphere and Dalrymple (1978) suggest the following criteria for a geologically meaningful age:

1) A well-defined high temperature plateau for more than 50% of the ^{39}Ar released;

2) A well-defined 'isochron' (correlation of $^{40}Ar/^{39}Ar$ with $^{39}Ar/^{36}Ar$) for the plateau steps;

3) Concordant plateau and isochron ages;

4) $^{40}Ar/^{39}Ar$ isochron intercept not significantly different from the atmospheric ratio of 295.5.

Sample 516F-128-2, 62–67 cm (Piece 2d) meets these criteria (Table 2) but probably only because of its high errors. Moreover, the exclusion of the two highest temperature steps from the plateau is somewhat arbitrary. For these reasons, the apparent plateau age of about 100 Ma for this sample is rejected. Sample 516F-126-3, 67–72 cm (Piece 3b) also meets the criteria, except that an unknown amount of ^{39}Ar was lost with Steps 2–6, though the plateau makes up 58% of the measured ^{39}Ar. The high age of Step 10 + 11, the amalgamation of two small steps, is attributed to diffusive effects sometimes found in small steps (Dalrymple and Lanphere, 1974) and so discounted. Thus it is tentatively concluded that the age of Section 516F-126-3, 67–72 cm (Piece 3b) is 86.0 ± 4 Ma. Unfortunately, this, the first analysis, was not confirmed by any of the three subsequent analyses.

AGE OF THE SEAFLOOR

The chemistry of the basalts from Cores 516F-126 and 516F-128 resembles that of basalts from the Reykjanes Ridge and Iceland, and suggests that they were erupted at or very close to the crest of the Mid-Atlantic Ridge (Barker et al., 1981; Thomson et al., this volume; Weaver et al., this volume). Thus, to estimate a basement age, we may use rates and poles of South Atlantic opening (0.69°/Ma, about 41.3°N, 43.8°W, Rabino-

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[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

Table 1. Apparent ages from $^{40}Ar/^{39}Ar$ heating steps for Hole 516F basalts.

Core-section (interval in cm) (piece number) irradiation number	Heating step	Temperature (°C)	Radiogenic argon (%)	^{39}Ar released (%)	Interfering isotopes correction	$^{40}Ar/^{36}Ar$	$^{39}Ar/^{36}Ar$	$^{37}Ar/^{36}Ar$	Apparent age (Ma ± 1 SD)
126-3, 67–72 (Piece 3b) R1396	1	500	14.5	41.7	1.9	346	0.264	1.78	313 ± 30
	2 to 6	750							
	7	880	76.4	20.4	3.4	1149	17.8	357	87.2 ± 1.8
	8	900	83.1	6.9	3.4	1528	27.3	556	82.3 ± 1.8
	9	950	86.9	12.7	3.6	1890	33.5	703	86.6 ± 1.8
	10 + 11	1030	102.6[a]	1.6	4.0	—[a]	—[a]	—[a]	107.3 ± 2.4
	12	1200	20.9	7.0	4.1	371	1.48	35.1	92.6 ± 3.9
	13	fusion	53.0	9.7	3.6	609	6.59	138	86.6 ± 1.9
128-2, 62–67 (Piece 2d) R1397	1	400	22.5	11.6	0.2	382	0.679	0.718	212 ± 17
	2	500	51.1	16.0	0.6	603	4.05	13.6	131 ± 3.5
	3	820	60.2	30.1	1.2	734	7.68	53.4	99.8 ± 2.7
	4	870	55.8	16.2	1.4	662	6.27	47.9	102 ± 4.1
	5	900	45.9	5.4	1.7	542	4.60	44.9	94.4 ± 4.8
	6	920	51.9	5.9	1.8	607	5.53	56.1	99.0 ± 4.3
	7	950	50.3	4.5	1.9	588	5.34	57.1	96.5 ± 2.4
	8	975	53.7	3.3	2.3	626	6.71	90.2	87.7 ± 5.4
	9	1000	51.9	6.8	3.0	599	6.22	109	87.6 ± 2.9
126-2, 3–9 (Piece 1a) R1427	2	400	8.0	3.1	1.4	322	0.432	1.24	296 ± 32
	3	450	6.5	7.7	2.3	316	1.03	5.66	105 ± 21
	4	500	13.8	10.7	3.5	342	2.09	17.4	118 ± 8
	5	550	28.3	13.8	4.7	408	4.62	51.5	130 ± 3.8
	6	600	51.3	18.3	7.3	584	9.96	169	157 ± 3.0
	7	650	62.4	21.8	11.0	739	11.1	268	214 ± 3.2
	8	750	51.0	8.1	7.0	577	12.1	201	127 ± 2.3
	9	850	68.6	12.9	13.2	826	17.8	538	166 ± 2.5
	10	900	−1.7	3.7	4.7	291	0.446	6.09	−61 ± 73
128-2, 15–21 (Piece 2a) R1428	1	500	4.8	2.4	0.4	311	0.244	0.204	303 ± 93
	2	600	9.6	12.4	0.5	327	3.57	4.21	46.9 ± 6.8
	3	700	7.9	10.2	0.6	321	3.74	5.56	36.1 ± 6.9
	4	750	15.5	7.0	1.1	349	4.55	12.3	63.5 ± 5.3
	5	850	43.1	2.1	1.8	514	11.7	50.5	99.9 ± 3.3
	6	940	47.9	3.5	1.9	560	13.0	61.0	108.4 ± 2.5
	7	980	48.5	3.9	2.8	562	14.6	98.9	98.8 ± 2.1
	8	1000	51.4	5.8	3.0	593	16.0	115	100.8 ± 1.9
	9	1020	56.3	5.4	3.2	653	20.2	155	96.2 ± 2.1
	10	1040	56.4	5.7	3.3	653	20.6	165	94.5 ± 1.6
	11	1150	51.0	6.5	4.3	577	18.6	195	84.2 ± 1.7
	12	1200	50.6	6.8	4.5	571	18.3	202	83.8 ± 1.9
	13	fusion	33.2	28.4	20.8	395	9.2	472	77.9 ± 2.9

Note: Blanks indicate "not measured" (see text for explanation). Decay constants, etc., used are those recommended by Steiger and Jager (1977). ^{39}Ar released = percentage of total released over steps measured. $^{40}Ar/^{36}Ar$, $^{39}Ar/^{36}Ar$, and $^{37}Ar/^{36}Ar$ ratios corrected for mass discrimination and interfering isotopes.

[a] A zero measured ^{36}Ar caused these results.

witz and LaBrecque, 1979) to extrapolate westward from nearby identifications of Anomalies 33 and 34 (Cande and Rabinowitz, 1979), assuming that no major ridge jump intervenes. Using the magnetic reversal time scale of LaBrecque and others (1977), this gives a basement age at Site 516 of 84.5 ± 0.5 Ma. The quoted uncertainty stems from: (1) an offset between the identified magnetic anomalies, implying oblique spreading or an undetected fracture zone close to Site 516 and (2) a possible subaerial ridge crest (Milliman, this volume; Barker et al., this volume), permitting lavas to flow as far as 10 km from the spreading center. A third source of error, the uncertainty in this part of the magnetic reversal time scale (e.g., Ness et al., 1980; Lowrie and Alvarez, 1981), is difficult to quantify, but is probably much more important than the other two.

The evidence from overlying sediments is compatible with the marine magnetic data (although the biostratigraphic age estimate is less precise), and therefore supports the assumption that no significant ridge jump intervened. A Santonian-Coniacian (*Marthasterites furcatus* Zone) age has been obtained from nannoflora in Core 516F-124 (site chapter, Site 516, this volume). The shallow marine basal sediments indicate a rapid subsidence (Milliman, this volume) but there is no sign, in them or in the vein filling of the underlying basalts, of a preceding subaerial episode of any great length. The magnetic field reversal corresponding to Anomaly 34 (79.65 Ma, LaBrecque et al., 1977) is seen in Core 516F-119, and the underlying sediments and basalts are all normally magnetized (Hamilton, this volume).

Thus, the radiometric, biostratigraphic, and magnetostratigraphic estimates for the age of basaltic basement at Site 516 are compatible, within their respective error ranges, which argues against the occurrence of a major ridge jump between the time of eruption and Anomaly 34 time. Such a jump of the ridge crest is still required at some time *before* the eruption of Site 516 basalts to explain the anomalously great distance to the South American margin (Barker et al., 1981).

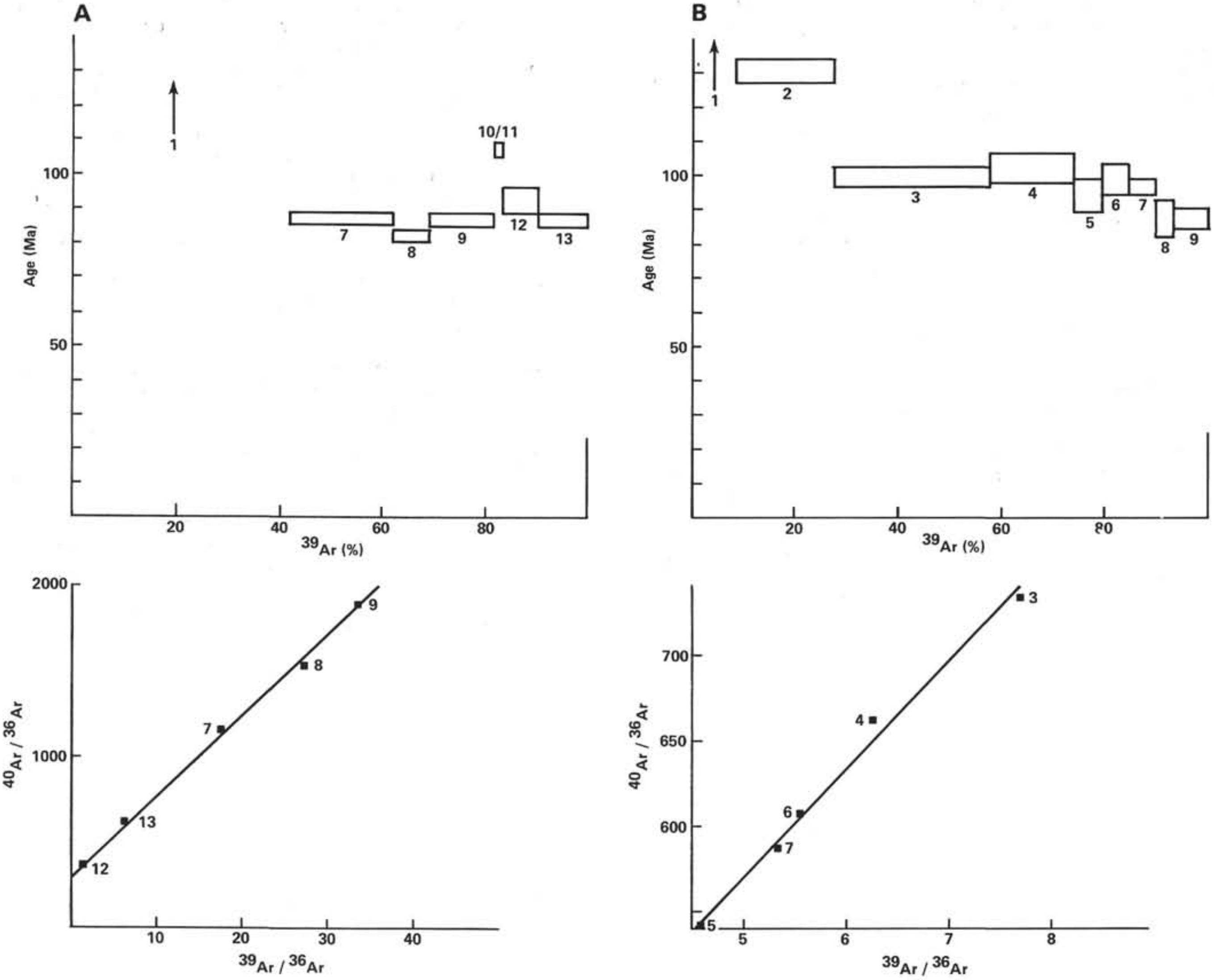

Figure 1. Age spectra (top) and correlation diagrams (bottom). The ordinates of the age spectra give the cumulative percentage of ^{39}Ar released. The points on the correlation diagrams correspond to the steps of the age spectra, numbered as in Table 1. A: Sample 516F-126-3, 67–72 cm (Piece 3b); Steps 10 and 11 have been omitted in calculating the best line shown. B: Sample 516F-128-2, 62–67 cm (Piece 2d).

Table 2. Summary of age determinations.

Core-section (interval in cm) (piece number)	Total fusion age[a] (Ma)	Heating steps[b]	Plateau	Isochron slope age (Ma)	Intercept	MSWD
126-3, 67–72 (Piece 3b)	184	7 to 13	88.6 ± 7.3			
		7 to 9, 12, 13	86.0 ± 2.4	85.9 ± 4.2	302 ± 7	0.09
128-2, 62–67 (Piece 2d)	116	3 to 7	98.3 ± 2.3	109.3 ± 14.4	257 ± 48	0.27
126-2, 3–9 (Piece 1a)	152	—	—			
128-2, 15–21 (Piece 2a)	80	—	—			

Note: Dashes indicate not applicable; blanks indicate no completion. MSWD = mean standard weighted deviate.

[a] From stepwise degassing measurements, *not* a separate "total fusion" measurement.

[b] Steps used for calculating plateau and isochron results, see Table 1.

CONCLUSION

Although none of the four samples analyzed yielded a completely satisfactory plateau, the results are less discouraging than most described in the literature. Step ages are not scattered so apparently haphazardly, nor with such large errors, as in some reported age spectra. One of the four samples, although it contained excess argon, met criteria for a meaningful plateau age, except that gas of several low-temperature steps, containing an unknown amount of argon, was lost because of the large amount of water released. This was the first sample to be analyzed, and unfortunately none of the succeeding three samples behaved as favorably. It does suggest, however, that the $^{40}Ar/^{39}Ar$ step-heating method may occasionally yield a true plateau age for oceanic basalts.

The best estimate of the age of basalt at the base of Hole 516F is 86.0 ± 4 Ma, which agrees with estimates from a seafloor spreading model of 84.5 ± 0.5 Ma.

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