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47. K-Ar DATING OF BASALTS FROM SITE 647, ODP LEG 105[1]

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ABSTRACT

Alteration of basalt samples in the basement rocks of Site 647 produced a range of K-Ar ages from 35 to 71 Ma. Microprobe data indicate that an alteration phase contributes nearly 50% of the potassium in the samples. Thus, a component with uncertain argon-retention characteristics is considered responsible for the range of ages. While the older ages are consistent with the expected magnetic anomaly age and the fossil evidence, the presence of the alteration makes these ages unreliable for defining the age of the basaltic crust.

INTRODUCTION

The chronology of Labrador Sea evolution is not known precisely because of the difficulty of correlating the magnetic anomalies in the region to the defined anomaly pattern in the rest of the North Atlantic (Srivastava, Arthur, et al., 1987). Direct radiometric dating of basement could resolve much of the uncertainties. A previous drilling project on a basement high was unsuccessful in collecting basement basalt suitable for dating (Laughton et al., 1972), while in much of the Labrador Sea the basement is inaccessible because of a large thickness of sediment. Ocean Drilling Program (ODP) Site 647, on the southern edge of the Labrador Sea, penetrated a thick basalt sequence that appeared to be potentially suitable for K-Ar dating.

K-Ar dating was done on seven samples of basaltic rocks at Site 647 in the Labrador Sea. Basalt was recovered from 699 to 736 meters below the sea floor (mbsf), and the dated samples are from 705 to 736 mbsf. The basalts of the section are generally massive, fine- to medium-grained rocks having stockwork veins near the top of the section and minor serpentinite veins farther downsection. The section may be a single, thick flow. Samples were selected from the massive zones remote from any veins. Petrographically, the samples are composed of pyroxene, plagioclase, and oxides, with minor alteration associated with the oxides and pyroxene grains. While often fractured, the plagioclase is fresh and contains very minor sericite developed along the fractures. Minor interstitial quartz is a late crystallizing phase. Because Site 647 is located over marine magnetic anomaly 24, the expected age of the basalt is about 55 to 56 Ma, according to Berggren et al. (1985). The oldest sediments above the basalt are of early Eocene age (nanofossil zone NP11) and thus provide a minimum age of 55–56 Ma for the basalt (Srivastava, Arthur, et al., 1987).

METHODS

Whole-rock samples free of vein material were crushed and sized to between 0.5 and 0.35 mm.; 0.5 to 1.0 g was taken for argon extraction. Samples were fused with an RF induction heater in a high vacuum line. The argon was then purified and analyzed by isotope-dilution mass spectrometry. Sample aliquots were taken and ground to less than 0.10 mm for potassium determination by atomic absorption spectrometry. Further details of the analytical procedures are given in Roddick and Souther (1987), but we did not employ acid washing of the crushed and sized samples.

Electron microprobe analyses of major mineral phases in two of the samples were obtained on a CAMEBAX wavelength dispersive microprobe, at 15 kV accelerating voltage, and 30 nA regulated beam current. Calibration was against natural and synthetic mineral and pure metal standards, with a PAP matrix correction. Low potassium concentrations were analyzed with a trace element program using a fixed-spectrometer configuration with a low-potassium standard, calibrated against a potassium-free (quartz) background. The detection limit of this technique is about 0.009% potassium.

RESULTS

The K-Ar analytical data are given in Table 1. The determined ages range from 35 to 71 Ma and show no correlation with depth below the seafloor. Potassium contents are very low and range from 0.024% to 0.050%. These values are in the low range, but are typical of oceanic tholeiites (Hart, 1969; Melson et al., 1976). Potassium content increases with depth in the section, with samples below 719 m containing almost double the potassium of the samples higher in the section; however, there is no correlation with age of the samples.

DISCUSSION

The K-Ar ages are too variable and imprecise to define the age of the basaltic crust at this location. Clearly, from the fossil evidence, four of the ages are younger than the lower age limit of 55 Ma. The three remaining ages (61 to 71 Ma) are slightly older than the exþected age range of anomaly 24, when the error limits are taken into account. The low potassium content of the samples makes them difficult to analyze but does not account for the range of ages nor the poor precision. A lack of correlation of younger ages with higher potassium contents rules out the addition of potassium as a single process responsible for the young ages. It appears that some samples have lost radiogenic argon.

The great uncertainty of the ages mostly results from high atmospheric argon in the analyses. This argon, which was corrected for extraction system blank, is from the samples themselves and is not an artifact of the analytical procedures. Extraction-line blanks are less than 10% of the measured atmospheric argon, except for the sample at 709 m (30%). High atmospheric contamination of basalts is often an indication of secondary alteration associated with interaction with seawater (Dymond and Hogan, 1973; Roddick, 1978). In this case, basalt samples lower in the section have the higher atmospheric contamination. They also have higher contents of potassium—another index of alteration of fresh basaltic rocks (Hart, 1969). Similar degrees of minor alteration were seen in thin sections of all the samples. The deeper samples do not appear to have greater alteration. However, the alteration is patchy and minor, and the thin sections may not be totally representative of the bulk samples analyzed.

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Table 1. K-Ar data for whole-rock basalts at Site 647.

Core-section (cm from top)	Depth (mbsf)	Lab no.	K (wt%) (± 1σ%)	Rad ^{40}Ar (cm/g·10^{-7})	Atmospheric ^{40}Ar (%)	Age ± 2σ (Ma)
105-647-72R-1, 9-11	704	3778	0.0294 ± 2.2	0.5242	94.2	45.3 ± 4.3
72R-3, 9-10	707	3779	0.0325 ± 2.0	0.9109	95.2	70.7 ± 11
72R-4, 10-11	709	3781	0.0321 ± 1.5	0.4366	92.8	34.7 ± 12
73R-4, 99-101	719	3777	0.0236 ± 3.0	0.6259	97.8	67.0 ± 13
74R-2, 25-32	725	3776	0.0499 ± 1.8	0.7580	95.0	38.7 ± 4.1
74R-2, 32-35	725	3780	0.0488 ± 1.5	1.1770	98.0	61.0 ± 12
75R-4, 49-52	736	3775	0.0503 ± 2.9	0.9222	96.5	46.6 ± 6.7

To characterize the main phases contributing to the K-Ar ages, electron microprobe analyses were conducted on two samples (704 and 719 m depth). The analyses (Table 2) show that the determined potassium contents of the major igneous phases (clinopyroxene and plagioclase) are not enough to produce the bulk potassium values determined in the whole rocks without considering the potassium in the alteration phase (Table 1). For the two samples (704 and 719), the average plagioclase (0.029% and 0.025% potassium) and clinopyroxene (0.015% and 0.012% potassium) concentrations are similar to or lower than the whole-rock values of 0.029% (704) and 0.024% (719) potassium. In contrast, the alteration, which perhaps was originally glass and is now an iron-magnesium alumino-silicate, has 10 times the potassium (0.25% and 0.29%) of the whole rocks. The samples typically are composed of about 40% clinopyroxene, 30% plagioclase, 25% oxides, and minor orange-brown alteration. Using the measured potassium concentrations of the phases (Table 2) and whole rocks (Table 1), mass-balance calculations indicate that about 3% to 5% alteration occurred and that this alteration contributes about 45% of the potassium in both whole-rock samples. This alteration has poor radiogenic argon-retention characteristics and is also likely to be the major source of atmospheric argon in the samples. Thus, the ages and the poor precision of Table 1 can be attributed to this alteration phase.

Most K/Ar and $^{40}Ar/^{39}Ar$ studies of altered submarine basalts have had similar problems of a wide scatter in ages (see Walker and McDougall, 1982, for references). In contrast, Macintyre and Hamilton (1984) apparently were able to resolve the scattered data for altered oceanic basalts and extract an age consistent with the magnetic anomaly time scale. In that case, the samples were altered extensively and Macintyre and Hamilton suggested that the alteration was associated with a hydrothermal event during burial, just after extrusion of the basalts. The alteration may have been extensive enough to produce mineral assemblages more retentive of argon. However, several samples had anomalously old ages, which were attributed to the incorporation of extraneous argon during the hydrothermal event. Here, the basalts are much less altered, and several samples have ages that are too young, which indicates that they have lost argon, rather than gained any extraneous argon.

CONCLUSIONS

Minor alteration of basalt samples in the basement rocks of Site 647 produced secondary minerals with poor argon retention characteristics. This alteration contributes proportionately large quantities of potassium to the total potassium in the basalt. This results in samples with a range of K-Ar ages from 35 to 71 Ma. While the older ages are consistent with the expected magnetic anomaly age of about 56 Ma, the ages are not reliable enough to constrain the tectonic evolution of the region. Plagioclase in these rocks is essentially unaltered, and it may be possible to determine a precise age by $^{40}Ar/^{39}Ar$ analysis of this mineral.

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Table 2. Electron-probe analyses of some phases of two basalts for Site 647.

	Lab no. 3778			Lab no. 3777		
Mineral	Plag.	Cpx.	Alt.	Plag.	Cpx.	Alt.
SiO_2	52.59	51.35	41.14	52.93	52.38	42.29
TiO_2	0.06	0.50	0.15	0.05	0.33	0.26
Al_2O_3	28.31	2.39	6.02	28.08	1.57	5.26
[1]Fe_2O_3+	1.26	11.77	27.32	1.23	10.74	22.37
MnO	0.00	0.25	0.15	0.01	0.27	0.05
MgO	0.16	16.34	13.55	0.15	17.71	13.93
CaO	12.31	17.34	1.81	12.11	16.95	2.14
Na_2O	4.25	0.25	0.28	4.42	0.17	0.29
K_2O	0.04	0.05	0.28	0.04	0.01	0.41
Total	98.98	100.24	90.70	99.02	100.13	87.00
[2]K	0.029	0.015	0.246	0.025	0.012	0.294

[1] Total iron calculated as ferric oxide.
[2] Potassium average of five analyses as a trace element. Plag. = Plagioclase, the average of three analyses; Cpx. = Clinopyroxene, average of two analyses; Alt. = Alteration, average of three analyses.