Reports

Potassium-Argon Ages and Spreading Rates on the Mid-Atlantic Ridge at 45° North

Abstract. *Potassium-argon dates obtained from extrusives collected on a traverse across the Mid-Atlantic Ridge at 45°N are consistent with the hypothesis of ocean-floor spreading. The dates suggest a spreading rate in the range of 2.6 to 3.2 centimeters per year near the axis of the ridge; the rate agrees with that computed from fission-track dating of basalt glasses. Additional data for a basalt collected 62 kilometers west of the axis gives a spreading rate of 0.8 centimeter per year, which is similar to the rate inferred from magnetic anomaly patterns in the area. Reasons for the difference in calculated spreading rates are discussed.*

With detailed bathymetric and bottom photographic coverage, a series of closely spaced samples of rock were collected by dredging along a traverse from the center of the Median Rift Valley to the adjacent western crest mountains of the Mid-Atlantic Ridge (*1*). These basalts which exhibited good development of fresh glass, and which were expected to be very young, were dated by the fission-track method (*2*). The preceding paper (*3*) demonstrates the efficacy of using fission tracks for dating very young extrusive lavas which are low in potassium. Unfortunately, the glass of basalts collected farther away from the axis of the ridge system is often strongly weathered and highly palagonitized, making fission-track dating impossible. However, since the age of extrusives may increase as the distance from the axis increases, potassium-argon dating is feasible when fission-track dating is no longer efficient.

Three additional specimens of basalt (samples 33, 47, and 48) from the western crest mountains at 45°N were selected for dating by the K-Ar method. The locations of specimens 47 and 48 are plotted (Fig. 1 in *3*); specimen 33 is form a north–south elongated seamount (Bald Mountain) at 45°13′N, 28°54′W (*4*), approximately 62 km west of the axis of the ridge. Specimen 48 is an alkali basalt with coarse plagioclase needles and interstitial clinopyroxene set in a dark devitrified residuum. Partially analcitized plagioclase xenocrysts scattered throughout the residuum make up 15 percent of the rock. There is a further development of zeolite in the vesicles. Weathering has effected only the outer 1 to 2 mm; the weathered portion was not used. Specimen 47 is a fresh tholeiitic basalt with a composition transitional to an alkali basalt. It has a dark glassy groundmass with fine acicular plagioclase which gives it a subvariolitic texture. Some 30 percent by volume of the rock is composed of large plagioclase xenocrysts of An_{86-88} composition showing evidence of resorption. The rock does not show signs of secondary alteration, but weathering has penetrated 2 mm into the specimen. The material selected for K-Ar dating was taken from the center of the specimen, more than 10 cm from the nearest outer surface. Specimen 33 is a fine-grained alkali basalt free from phenocrysts or xenocrysts and with a pilotaxitic arrangement of microlites. The specimen is very fresh.

The samples were dated by the Geochronology Section of the Geological Survey of Canada with a mass spectrometer (*5*) operated under static conditions. A high-frequency generator was used to fuse the sample material in a vacuum, and the radiogenic argon content was determined by isotope-dilution techniques. Table 1 gives the data on K-Ar content and age. Specimen 33 was analyzed three times, each time with a fresh piece of basalt. Specimen 48, with the highest K content and youngest expected age, was analyzed twice, but no radiogenic Ar was detected. For the third extraction, zeolites infilling the many vesicles of the specimen and the altered plagioclase xenocrysts were removed, resulting in an increase in the K content from 1.58 to 1.98 percent. Specimen 47 was analyzed once.

The K-Ar ages determined for specimens 47 and 48 (0.74 million years and 0.31 million years, respectively) indicate rates of ocean-floor spreading ranging from 2.6 to 3.2 cm/yr, essentially in agreement with the rate based on fission-track dating of basalts 9 and 56 (*3*). Specimen 33, by contrast, gives a mean age of 8 million years and a calculated spreading rate of only 0.8 cm/yr.

The apparent agreement between the fission-track and K-Ar spreading rates near the axis and the discrepancy between this rate and that computed for the more distant basalt on Bald Mountain may be in part due to the type of sample available for K-Ar measurement. By dredging rocks from the slopes of seamounts, material from the outer shell of the seamount, consisting of the last lavas extruded, can usually be retrieved. The dates from these basalts will therefore be younger than the events which initiated the formation of the

Table 1. Potassium-argon age data based on rock samples collected from the Mid-Atlantic Ridge (M.A.R.).

Sample No. (19–66–)	K* (%)	Ar^{40}-K^{40}	Radiogenic Ar^{40} (%)	Age † (10^6 yr)	Distance from axis of M.A.R. (km)	Spreading rate: Mean (cm/yr)	Spreading rate: Range (cm/yr)
			Iron-rich alkali basalt (4)				
33 (–10)	0.98	0.00052	68	9 ± 2			
33 (–10)	.98	.00040	37	7 ± 2	62	0.8	0.6 to 1.2
33 (–10)	.98	.00040	35	7 ± 2			
			Tholeiite (9)				
47 (B–1)	.33	.000043	2	0.74 ± 0.37	19	2.6	1.9 to 4.8
			Alkali basalt (9)				
48 (–1)	1.58						
48 (–1)	1.58				10		
48 (–1)	1.98	0.000018	2	0.31 ± 0.07		3.2	2.6 to 4.1

* Potassium determined by x-ray fluorescence analyses. † Decay constants used in K-Ar age calculations: electron capture half-life, 0.585×10^{-10} yr^{-1}; half-life total, 5.30×10^{-10} yr^{-1}; K^{40} atomic abundance, 1.19×10^{-4}.

volcanoes. The bulk of the extrusives beneath stations 9, 47, and 48 which are responsible for the observed magnetic anomalies may therefore be an order of magnitude older than the dated surface specimens. Age determinations on the inaccessible buried rocks would reduce the calculated rates of spreading. Specimen 33, by way of distinction, was collected from an upthrusted and considerably eroded seamount (*4*), so that a more deep-seated layer may have been sampled, giving a closer approximation to the age of formation of the seamount. In addition, due to the greater ages and distances involved, time lapses between the first and last eruptions on Bald Mountain would not significantly alter the calculated rate of spreading. As noted above, the age of 0.31 million years for sample 48 was obtained after the deuteric zeolitic material had been removed. The K-Ar ages reported for the altered plagioclase component of submarine lavas are markedly lower than for associated biotite and whole rock samples (*7*). Since the beneficiation process probably did not remove all of the altered plagioclase from sample 48, the resulting age is considered to represent a minimum value. Specimen 47 has a high content of large, resorbed, but unaltered plagioclase. However, since the argon retentivity of plagioclase is open to question this result may also be lower than the true age. Conversely, specimen 33 is an extremely fine-grained, very fresh, phenocryst-free basalt, and hence the age obtained should closely approximate the time of extrusion. If the ages determined for samples 47 and 48 are in fact too low, the true rates of ocean-floor spreading will be less than stated in Table 1 and may approximate the rate based on the results for the Bald Mountain basalt.

A major change in the rate of spreading may possibly have taken place over the last 8 million years; the current rate appears to be two or three times greater than in early Pliocene times. Different rates of spreading may be responsible for the different morphological features found at 45°N. Plastic flow beneath the ridge (*8*) may be the result of the more rapid rate near the axis, whereas slower spreading rates may have resulted in brittle fracturing of the crust (*8*), and may have produced the block-faulted morphology of Bald Mountain (*3*). But Phillips (*9*) inferred a decrease in spreading rate in the last 9 million years based on magnetic anomalies at 27°N.

An alternative possibility is that, although the rate of spreading may have remained at a constant high value since the beginning of the Pliocene, there may have been one or more quiescent periods within the last 8 million years, thereby yielding a low overall rate. A discontinuity in the Miocene has been postulated (*10*) from evidence of abrupt changes in sedimentary thicknesses. The bathymetry at 45°N (*1, 4*) reveals a marked change in topography at 28°40′W. The rugged topography and orientation of features trending 19° east of north is replaced, west of 28°40′W, by a due-north orientation, with seamounts of low relief separated by large, smooth sedimentation ponds. Such a line of demarcation could represent the position at which sea-floor spreading, once active in an east–west direction, halted for some time. Renewed spreading at a later date may then have commenced parallel to the new orientation which we observed on the Median Rift Valley.

The rate of ocean-floor spreading at 45°N calculated from magnetic anomalies is 0.8 cm/yr (*6*), in agreement with the rate calculated for the basalt dated from Bald Mountain. This further suggests that the discrepancies in spreading rates are due mainly to sampling problems and only in part to the tendancy for K-Ar values to give lower limits, since fission-track dates are independent of the effects of argon loss. This rate is also in excellent agreement with the magnetic spreading rate of approximately 1 cm/yr across the Reykjanes ridge south of Iceland and the rate of 1.2 cm/yr based on new isotopic ages from Iceland, as reported by Moorbath *et al.* (*11*).

The progressive increase of the ages as determined by K-Ar and fission-track (*3*) methods with distance from the axis of the Mid-Atlantic Ridge, and the evidence that the extrusives are of similar or younger age than might be implied from the magnetic anomaly patterns, provide a positive although limited test for the hypotheses of ocean-floor spreading (*3*).

F. AUMENTO
R. K. WANLESS, R. D. STEVENS
Geological Survey of Canada,
Ottawa, Ontario, Canada

References and Notes

1. F. Aumento, *Can J. Earth Sci.* **5** (No. 1), 1 (1968).
2. Dated by R. L. Fleischer.
3. R. L. Fleischer, J. R. M. Viertl, P. B. Price, F. Aumento, *Science*, this issue.
4. F. Aumento and B. D. Loncarevic, in preparation.
5. Associated Electrical Industries, mass spectrometer type M.S. 10.
6. The average spreading rate computed from four negative and four positive magnetic anomaly strips which are clearly identifiable west of the axis of the Median Rift Valley at 45°N (B. D. Loncarevic, personal communication).
7. J. R. Dymond and H. L. Windom, *Trans. Amer. Geophys. Union* (abstr.) **48** (No. 1), 243 (1967).
8. T. H. van Andel and C. O. Bowin, *J. Geophys. Res.* **73**, 1279 (1968).
9. J. P. Phillips, *Science* **157**, 920 (1967).
10. J. Ewing and M. Ewing, *ibid.* **156**, 1590 (1967).
11. S. Moorbath, H. Sigurdsson, R. Goodwin, *Earth Planet. Sci. Lett.* **4**, 197 (1968).

22 April 1968; revised 12 July 1968

Mid-Atlantic Ridge: Age and Spreading Rates

Abstract. *Fission-track dating of basaltic glass from the Mid-Atlantic Ridge gives results which are consistent with the proposal of ocean-floor spreading. Solidification ages from ~10,000 years to ~300,000 years were measured. Correlation is also possible between the magnetic anomaly patterns over the Crest Mountains at 45°N and the geochronology of the outcropping basalts. Renewed volcanic activity well removed from the axis of the Mid-Atlantic Ridge has been demonstrated to have taken place in recent times.*

Two of the most striking features of the surface of the solid earth are the apparently matching borders of the continents on opposite sides of the Atlantic Ocean and the vast, seismically and volcanically active mountain ridge system bisecting the Atlantic. The matching coastlines have been taken as evidence of the drift of continents that followed the splitting of an originally larger land mass (*1*), and the ridge is similarly cited as the possible line from which the continents are moving (*2*). Additional findings—particularly the existence of a system of parallel magnetic anomalies that are symmetrical about the axis of the ridge system—have supported the earlier suggestion (*3*) that the ridge is the site of upwelling and subsequent lateral spreading of material from giant convection cells within the earth's mantle. These strips of alternating magnetic intensity (relative to the regional average) may be due to materi-