Ages of Pacific Deep-Sea Basalts, and Spreading of the Sea Floor

Abstract. *Potassium-argon determinations of age from whole-rock samples of tholeiitic basalts, dredged from the crest of the East Pacific Rise and from the flanks of three seamounts at varying distances from the crest, show that the crest is younger than 1 million years and that age does not correlate with distance from the crest. Our data, however, do not necessarily oppose the general concept of spreading of the ocean floor.*

Studies of magnetic anomalies on the sea floor (*1*), sediment thicknesses (*2*), and radiolarian distributions (*3*) in the region of the East Pacific Rise favor the hypothesis of spreading of the sea floor (*4, 5*). This concept is based essentially on the injection into the oceanic crust of mantle material as dikes along the crests of the oceanic rises. The crust, along with this mantle material, is subsequently carried laterally away from the crests and finally disappears downward, back into the mantle. Hess (*4*) has pointed out that in this model it is expected that most, though not necessarily all, seamounts originate on the crests of the rises and then drift with the sea floor to their present positions. Thus there should be direct correlation between the ages of seamounts and their distances from the rises. We have determined the K:Ar ages of basaltic rocks dredged from the crest of the East Pacific Rise and from points at several distances from the crest, attempting to detect such increase in age with increasing distance from the crest. We have observed large amounts of excess Ar^{40} in some rocks, leading to anomalously high ages (*6*), but this report is limited to data that we feel give valid K:Ar ages and that are therefore appropriate to discussion of spreading of the sea floor.

The whole-rock samples dated were of tholeiitic basalts gathered in March and April 1967 by R.V. *Pillsbury* (*7*) (Fig. 1). The rocks dredged from the crest of the East Pacific Rise (samples 27, 29, 32, 39, and 42) are part of a basalt pavement that outcrops continuously along the axis of the ridge between 14° and 6°S in a band about 50 km wide (*8*); they were emplaced by fissure eruptions. Samples 20, 23, and 25 were dredged from flanks of seamounts. Our dating techniques have often been described. The K determinations were made by atomic-absorption spectroscopy on splits of the same rock used for the Ar measurements. Repeated measurements on different portions of the same rock usually agreed within 10 percent—always within 15 percent. The Ar was measured on a Reynolds-type mass spectrometer. Because of the low K contents and young ages of these samples, the atmospheric-argon correction is very great and the errors in our calculated ages (including fluctuations in standard air-argon ratios) are correspondingly high. The ages (Table 1) are sufficiently precise, however, to provide the meaningful answer sought.

Studies of thin sections of these samples and their H_2O^+ contents (Table 1), showed no evidence of alteration. Sample 23 alone showed signs of very mild alteration reflected in its higher H_2O^+ content. Many of the samples contained amounts of glass, but there is no evidence of devitrification, and therefore no reason to suspect loss of argon. We

Table 1. Potassium-argon ages of deep-sea basalts from the southeast Pacific.

Sample			Argon-40				
No., coordinates (S,W)	Nature	H_2O^+ (%)	Radiogenic ($\times 10^{-8}$ standard cm^3/g)	Terrestrial (%)	K (%)	Age ($\times 10^6$ yr)	Kilometers from rise crest
27, 12°46′,110°52′	Phenocrysts of bytownite, clinopyroxene, and minor olivine in a variolitic groundmass, with titanomagnetite and some glass	0.40		100	0.166	0 ± 1.5	0
29, 12°17′,110°44′	Phenocrysts of labradorite, olivine, and clinopyroxene, in a variolitic groundmass, with titanomagnetite and some glass	.27		100 100	.199	0 ± 1.7 0 ± 1.2	0
32, 10°01′,110°06′	Microcrystalline aggregate of labradorite and clinopyroxene, with traces of olivine and abundant titanomagnetite	.66		100 100	.26	0 ± 1 0 ± 0.1	0
39, 9°02′,109°19′	Few phenocrysts of bytownite and olivine in a groundmass of labradorite. olivine, and glass	1.25	0.795 1.23	97 94	.24	0.84 ± 0.6 $1.3 \pm .7$	0
42, 7°08′,107°30′	Microcrystalline aggregate of labradorite and clinopyroxene, with traces of olivine and abundant titanomagnetite	0.95	0.875	97 100	.307	$0.72 \pm .1$ $0 \pm .9$	0
20, 11°24′,94°33′	Sparse phenocrysts of labradorite in a groundmass of plagioclase baths, clinopyroxene, and glass	.40	2.98 2.25	80 65	.166	4.55 ± 1.0 3.45 ± 1.0	500
23, 14°08′,100°19′	Phenocrysts of bytownite in a groundmass of plagioclase baths, altered phemics, titanomagnetite, and some glass	2.40	1.5 2.4 4.1	95 90 62	.29	$1.3 {+9 \atop -1.3}$ 2.1 ± 2.1 3.6 ± 2.2	1200
25, 13°26′,106°26′	Sparse crystals of labradorite and olivine in a glassy groundmass	0.32	2.37	80	.19	$3.16 {+0.6 \atop -1.4}$	1600

point out that these samples have been maintained close to 0°C by the sea-water environment since effusion; thus enhancement by elevated temperatures of loss by diffusion is not a problem.

The other type of geochemical alteration likely to be encountered is attack by water. In one sample, K analyses made at depths of 0.87, 1.7, and 2.5 cm from the surface showed, respectively, 0.08, 0.08, and 0.08 percent. Since there is no petrographic evidence of water infiltration in this or any other sample, we believe that this possibility also may be ignored in our samples. We repeat that other samples still being investigated show evidence of excess Ar^{40}; the ages in Table 1 must therefore be regarded as maximum ages until the extent of possible excess Ar^{40} in these samples can be definitely established; the presence of any such excess would not affect our conclusions.

Previous evidence regarding the age of the basalts outcropping on the crest of the East Pacific Rise indicates a very young age, probably less than 1 million years (*8*), and our data (samples 27, 29, 32, 39, and 42) are in agreement.

Samples 25, 23, and 20 were dredged from the flanks of seamounts, approximately 500, 1200, and 1600 km from the crest of the rise. With a spreading rate of 4 cm/year (*2*) these seamounts would be 12, 30, and 40 million years old, respectively, if they had originated at the crest of the rise and drifted to their present locations (*4*). With a spreading rate of 8 cm/year (*3*), the ages would be about 6, 15, and 20 million years, respectively. If a period of quiescence preceded a spreading cycle beginning about 10 million years ago (*9*), the ages of at least samples 23 and 25 would be even greater; their measured ages (Table 1) contradict all these expectations.

One interpretation of these data is that these seamounts originated at or close to their present locations, far from the crest of the rise. Another possibility is that they did begin to form close to the crest, but, as they drifted away, later lava flows covered the early forms, giving them apparent low K:Ar ages. However, volcanic activities spanning a time period of 20 to 40 million years at the same eruptive center (as would be necessary in this latter explanation) are very unusual. We feel that these seamounts probably originated near their present locations, far from the crest of the rise.

Since this finding is true of all three seamounts investigated, it indicates that the extent of volcanic activity on the ocean floor far from the crests of oceanic ridges has been underestimated. Our data are not consistent with a model (*4*) in which seamounts are being formed nearly exclusively along the crest of the rise and subsequently drifting at rates of 4 to 8 cm/year to their present locations, without further changes, along with a spreading ocean floor. On the other hand, these data cannot be used for argument against the more general features of a model in which deep-seated material erupts slowly and continually through fissures along the ridge crests, so that rocks forming the sea floor increase in age with increasing distance from the crest. In fact, volcanism along the crest of the ridge appears to produce fissure flows rather than seamounts. During the spreading, these flows are buried beneath sediments and cannot be sampled by normal techniques, yet these are the rocks that must be dated for testing of the more general features of the spreading hypothesis.

We point out finally that the ages of all three seamounts are the same, within large limits of experimental error. Whether this finding indicates a related origin for the three or a period of intense volcanic activity on the ocean floor, or whether it is simply a coincidence perhaps due to the large errors, is not yet certain.

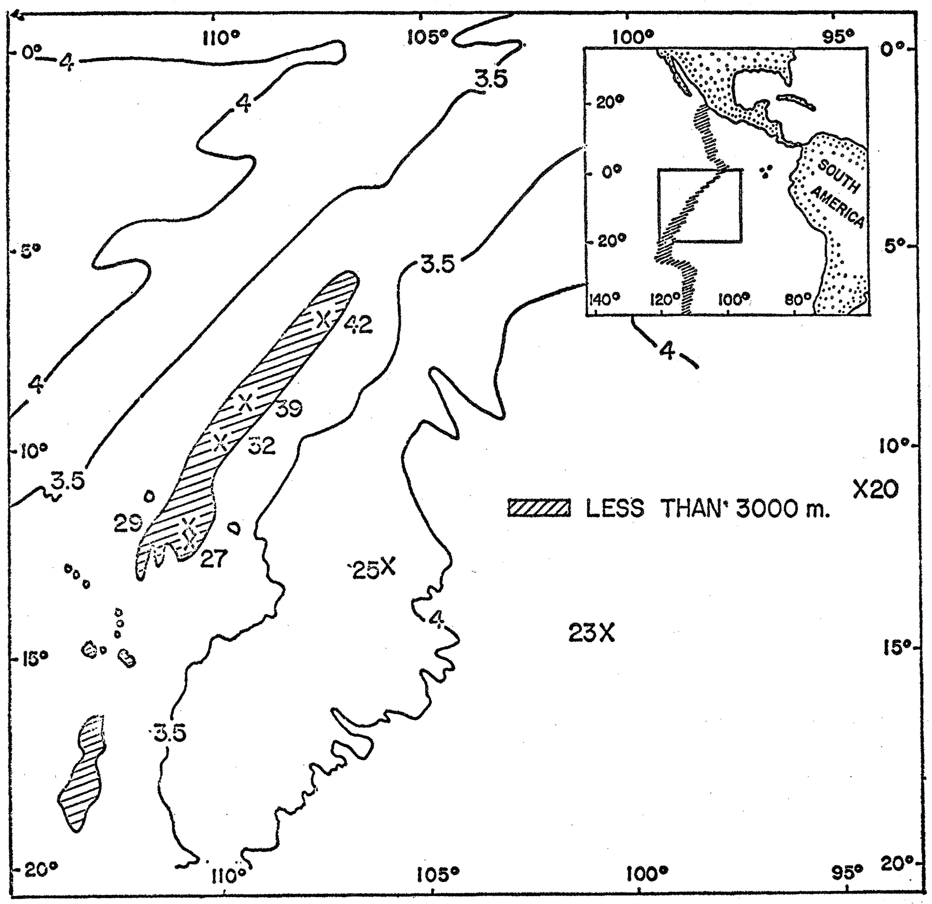

Fig. 1. Sources of samples studied.

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