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Fissure Basalts and Ocean-Floor Spreading on the East Pacific Rise

Abstract. *A basalt pavement outcrops almost continuously in a band along the crestal region of the East Pacific Rise from about 14°S to 6°S, that is, for more than 800 kilometers; the outcrop may well extend beyond the above limits along the axis of the rise. The basalt band is generally between 40 and 60 kilometers wide and is replaced laterally by sediment. The lavas are fresh, "oceanic tholeiites" which were emplaced less than 1 million years ago by fissure eruptions. These findings can be explained by the hypothesis of ocean-floor spreading; the basalts are the expression of material originating from the mantle and rising through fissures along the axis of the ridge. The absence of an axial rift valley on the East Pacific Rise may be explained by the fact that large volumes of lava are being outpoured along its crest.*

According to the hypothesis of ocean-floor spreading (*1*), formation of new crust due to injection of material from the mantle takes place along the axis of active oceanic ridges. In this connection it may be of interest to report some findings obtained on the East Pacific Rise by the R.V. *Pillsbury* of the University of Miami's Institute of Marine Sciences during cruise P6702 (March–April 1967).

The field work, which included bathymetric and magnetic surveys, deep-sea photography, sediment coring, and hard-rock dredging, was concentrated in the crestal region of the East Pacific Rise, between 14°S and 6°S. In the course of the surveys it was found that hard rock with no sediment cover invariably outcrops on the crest of the rise. The areal extension of such outcrops was determined with the aid of an echosounding system including a 12 kc precision depth recorder. The type of sound record obtained with this instrument depends on the nature of the material outcropping at the bottom (*2*); there was usually no difficulty in distinguishing reflections returned by soft pelagic sediments from those given back by hard, dense rocks (such as basalts), owing to the wide difference in acoustic impedance and scattering between the two materials. Information derived from the recorder was checked and complemented by direct sampling and photos of the sea floor.

It was thus established that the area where the hard rock outcrops is in the shape of a relatively narrow but apparently continuous band along the crestal zone of the rise (Fig. 1). The width of the band as measured in various transects across the crest of the rise is generally between 40 and 60 km; in one case it reached about 80 km. The bathymetry in some of the transects is shown in Fig. 2. The band appears to be continuous for at least 800 km along the ridge axis; it probably extends on the axis beyond the limits of the areas we surveyed.

The only hint that a break in the continuity of the band may exist was obtained at a latitude of about 9°S. Here the outcrop may be displaced laterally by about 30 km; alternatively, it is possible that two parallel bands are present at this latitude. More field work is needed to clarify this. The topography along the length of the lava band is remarkably constant in the portion of the rise we explored: gently rolling hills prevail at a depth varying between narrow limits (generally from 2600 to 3000 m below sea level).

The lateral contact between the hard rock and the sediment is not sharp: photographs show patches of sediment appearing more and more frequently toward the edges of the hard-rock band, until the sediment cover becomes continuous.

Samples of the rock were obtained by dredging at several sites along the outcrop (Fig. 1). They all consist of fragments and boulders of basalt which on visual observation appeared to be quite fresh. The original surface of the flows is marked by a crust of dark fresh glass; the thickness of such crust varies from a couple of millimeters to more than 1 cm. Below the glass crust, the rock is at least partially crystalline. The glassy crust of the flows must have been formed by the instant chilling of the melt upon effusion into seawater; as such, the crust acted as an insulator below which the basalt could be maintained warm and could flow on the ocean floor. This type of "quiet" deep-sea effusion contrasts with the volcanism which gives rise to seamounts, where evidence is commonly found of thermal shattering of the basalt due to extensive lava-water interaction during the eruption (*3*).

Some of the dredge hauls contain platy boulders which are limited by two parallel glass surfaces, which shows that the thickness of some of the individual flows can be as small as 5 cm. This, and the scarcity of first-generation phenocrysts, suggest that the lavas were very fluid when they were erupted. Deep-sea photos indicate that "pillow" structures are present occasionally (Fig. 3).

Microscopic examination indicates that the samples contain plagioclases ranging in composition from 65 percent An (labradorite) to 80 percent An (bytownite); clinopyroxenes, scarce olivine, titanomagnetite, and glass. First-generation phenocrysts are extremely scarce or absent. The basalts from the various stations have similar chemical composition. The results of a representative analysis of a moisture-free sample (P6702-39) are as follows (*4*): SiO_2, 49.57 percent; Al_2O_3, 15.44 percent; Fe_2O_3, 1.75 percent; FeO, 8.01 percent; CaO, 11.49 percent; MgO, 7.56 percent; MnO, 0.17 percent; Na_2O, 3.10 percent; K_2O, 0.28 percent; TiO_2, 1.80 percent; P_2O_5, 0.18 percent; H_2O^+, 1.02 percent; total: 100.37. The composition of these rocks is similar to that of low-potassium, "oceanic tholeiites" (*5*).

All evidence suggests that fissure eruptions were responsible for the emplacement of the basaltic pavement; the shape of the outcrop indicates that the fissures were probably parallel to the axis of the ridge. Thus, fissure volcanism, rather than the central, seamount-producing type, is prevalent on the crest of the rise.

The presence of flows of fissure basalt outcropping continuously along the crest of the East Pacific Rise can be best explained by the hypothesis of ocean-floor spreading (*1*). The ascending limbs of a convection cell in the mantle diverge below the axial zone of the oceanic ridge and carry the crustal layers away from the ridge axis. As a consequence, tensional fissures are likely to develop within the crestal region, through which deep material could reach the ocean floor. According to Green and Ringwood (*6*), oceanic tholeiites of the type reported here are produced by partial melting at relatively shallow depth (about 30 km) of rapidly ascending mantle material.

If the hypothesis is correct, the rocks from the crest of an active ridge must be very young. Many lines of evidence suggest that the basalt pavement on the rise was indeed emplaced very recently: sedimentation rates on the East Pacific Rise are relatively high, due to the fact that the rise is shallower than the carbonate-compensation depth, below which calcite is rapidly dissolved in seawater (*7*); in fact, sediments from the rise consist to a large extent of calcareous tests of foraminifera which accumulate on the bottom after the death of the organism. In view of concepts on sedimentation rates of red

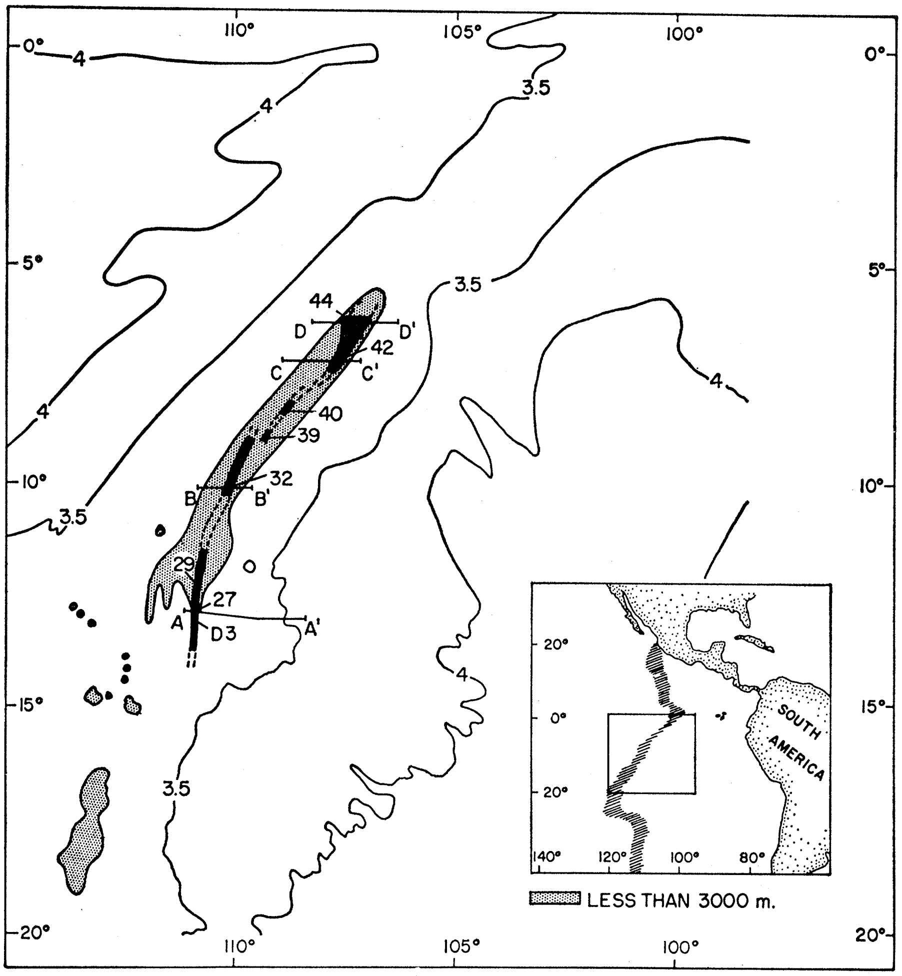

Fig. 1. Outcrop of fissure basalt along the axis of the East Pacific Rise. Black indicates the area where the band of basalt pavement was directly surveyed; dashed lines indicate areas along the crest which were not surveyed. Numbers indicate sites at which the outcrop was sampled. Letters indicate crossings shown in Fig. 2.

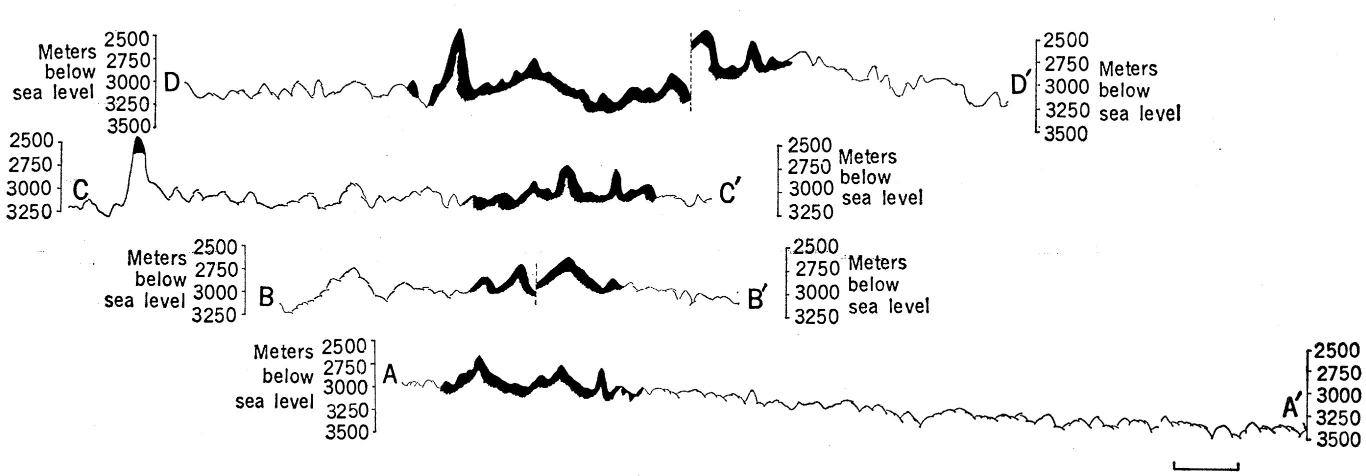

Fig. 2. Bathymetric transverses across the East Pacific Rise. Location of the crossings is indicated in Fig. 1. Heavy black indicates basalt outcropping. Dashed lines indicate discontinuities due to drifting of the vessel during stations. Vertical exaggeration is about × 24.

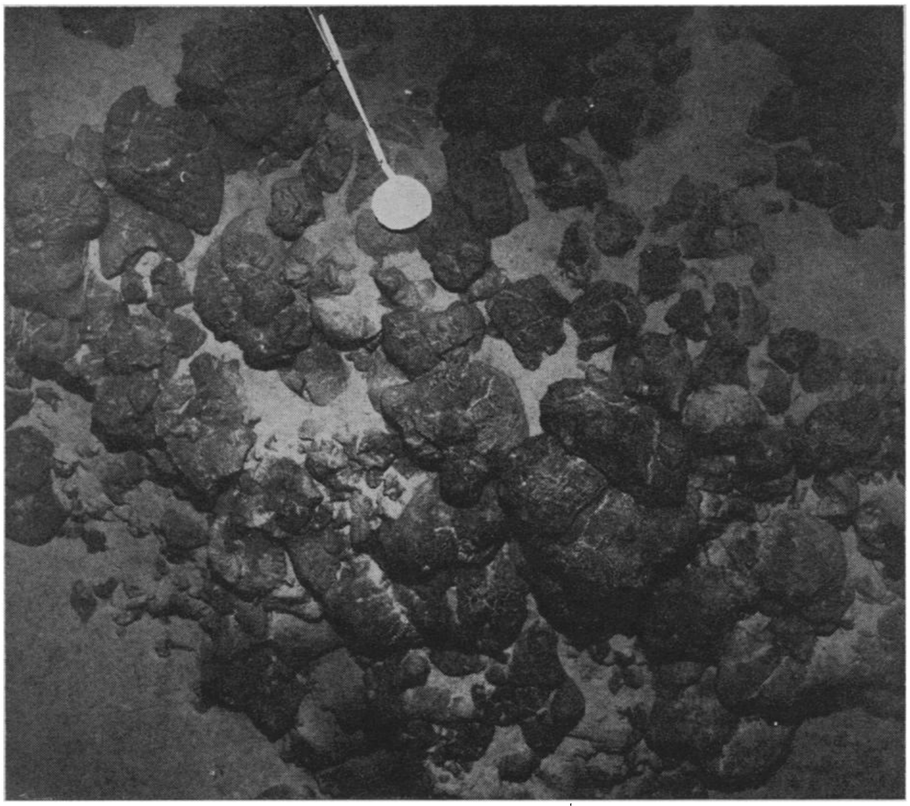

Fig. 3. Picture of the basaltic pavement showing pillow lavas. [Photo by E. Fisher]

clays and calcareous oozes in the Pacific, a rate of the order of at least 1 cm/10^3 years for the sediments accumulating on the rise seems reasonable. Under such circumstances, if the lava flows had been emplaced 10^6 or more years ago, they would by now have been covered by several meters of sediment. Lack of sediment cover suggests, therefore, that a reasonable upper limit for the age of the basalts in question is 10^6 years. This indirect estimate is substantiated by potassium-argon determinations of age on rocks from five locations along the outcrop which give ages of $< 10^6$ years (*8*). These concepts are in accordance with data which show thinning of sediment cover and increasingly younger age of the sediment as one moves toward the axis of the East Pacific Rise (*9*). The width of the axial band of basalt is similar to that of the axial positive magnetic anomaly observed in crossings of the rise at higher latitudes (*10*), which also suggests that the basalts were erupted since the last magnetic reversal, that is, since 0.8×10^6 years ago.

The fact that large volumes of fluid basalts are being outpoured from axial fissures along the rise may explain the absence of a central rift valley in the area we have surveyed: the rift valley is continuously kept filled by the lava flows. During periods of relative quiescence of the eruptive activity, tensional forces related to crustal spreading and subsidence of the thick basaltic pile at the ridge axis could result in the development of a rift valley such as is observed in the Mid-Atlantic Ridge.

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Solar Constant: First Direct Measurements

Abstract. *The solar constant was directly measured from an altitude of about 82 kilometers — apparently the first such determination. The total solar intensity was 136.1 milliwatts per square centimeter, or 1.952 calories per square centimeter, per minute—about 2.5 percent less than Johnson's derived value. Energy in the ultraviolet and visible regions (for λ less than 607 nanometers) was 7.0 percent less than that obtained by integration over Johnson's curve; for integral flux of λ greater than 607 nanometers there was almost perfect agreement. Seven supporting series of measurements from lower altitudes agreed extremely well with these results after correction for atmospheric extinction.*

The extraterrestrial flux of Sun's energetic radiation, integrated over all emission wavelengths and referred to one astronomical unit (defined as the mean Earth-Sun distance), is generally termed the solar constant of Earth. Earlier estimates of the total solar irradiance at the outer limit of Earth's atmosphere have been mainly derived, by extrapolation, from the classical pyrheliometric and spectral bolometric measurements made from high mountains. Additional information regarding the wavelength region unobservable from the ground, even from elevations ($\lambda < 295$ nm), was provided almost 20 years ago by use of rocket-borne spectrographs (*1*). The results, however, suffered from limitations of the then-experimental techniques in precision radiometry in the free atmosphere; the integrals ranged from 132 to 143 mw cm^{-2} (1.90 to 2.05 cal cm^{-2} min^{-1}) (*1*).

Recent attempts at precise measurement of the integral and spectral solar fluxes were made with large balloons, but the detectors remained in the ozonosphere (*2*); the results indicated (*3*) a value significantly lower than Johnson's (139.6 mw cm^{-2}) which has found most favor in the United States (*4*).

It has been pointed out (*5*) that knowledge of the extraterrestrial shortwave radiation flux, and of its spectral composition, is both important in astrogeophysical programs and a very necessary requirement for testing of spacecraft in space-simulation systems and for successful flight of vehicles. The basic object of a current program (*6*) is to make available a series of multichannel radiometers calibrated ulti-