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Sea Floor Spreading, Topography, and the Second Layer

Abstract. *Local sea floor topography and also the thickness of the second layer of the oceanic rise–ridge system appear related to the spreading rate in the region. Slow spreading, away from the ridge center at 1 to 2 centimeters per year, is associated with a thick second layer, a central rift, and adjacent rift mountains. Fast spreading, 3 to 4.5 centimeters per year, is associated with a thin second layer and subdued topography lacking any central rift. The volume of lava discharged in this layer per unit time and per unit length along the crest of the whole active system is relatively constant regardless of the spreading rate. Total second layer discharge of the system has been about 5 to 6 cubic kilometers per year during the last several million years.*

The sea floor spreading hypothesis of Hess (*1*) and the Vine-Matthews hypothesis (*2*) of the origin of a class of marine magnetic anomalies are strongly supported by recent evidence (*3, 4*). The magnetic anomalies parallel to mid-ocean ridges are bilaterally symmetrical to the crests of active ridges, and the distance between them is proportional to the time intervals between magnetic reversals dated on land. Moreover, the rate of spreading for periods of several million years in a given region is relatively constant although it differs by a factor of at least five in different regions. Regional variations in the thickness of the second crustal layer and in the vertical relief of the sea floor have been known for some time but have not been explained. This report examines the question of whether the topography and crustal structure of mid-ocean ridges are related to the rate of sea floor spreading.

Only a few spreading rates of magnetic anomaly patterns have been measured and other types of data are not always available at the same places. Nevertheless, Table 1 suggests that several phenomena associated with the oceanic rise–ridge system are related to the rate of sea floor spreading. Slow spreading, at 0.7 to 2.0 cm/yr half rate, appears to be associated with a thick second layer, a central rift, and adjacent rift mountains. Fast spreading, 2.9 to 4.5 cm/yr half rate, is associated with a thin second layer and subdued topography. The thickness of the second layer is notoriously difficult to measure because of its variability and relief. For this reason all measurements in a given region have been averaged. The thickness of the second layer can be assumed to be roughly equal to that of flow and intrusive volcanics produced by the central mechanism of the Hess model of sea floor spreading. The assumption contains two important uncertainties. One, probably less important, is that consolidated sediment is a relatively unimportant constituent of the second layer. Second, the oceanic layer is serpentinized peridotite with only minor basaltic intrusives. Accepting these limitations, the discharge of lava which forms the second layer at the crest of rises and ridges can be estimated by multiplying the spreading rate times the thickness times a unit length. The discharge on each flank is 25 to 45 $km^3/10^6$ yr per kilometer, which is a relatively constant figure compared to the considerably wider range in values of spreading rate and thickness. The total discharge of the whole system is 5 to 6 km^3/yr, depending on whether one takes only the oceanic parts or includes the probable extensions under the continents (*5*). This is far in excess of the 1.8 km^3/yr required to produce the volume of the continents during the age of the earth. Either part of this material is recaptured in the mantle or else it has not been produced as rapidly in the past.

Judging by Iceland, topography in an active rift system is produced both by vulcanism along rifts and by normal faulting. The mountainous topography of the Mid-Atlantic Ridge is crudely symmetrical and probably is produced at the central rift and then spreads to the flanks (*6*). A detailed comparison of magnetic anomalies and abyssal hills in the northeastern Pacific shows that they are remarkably parallel regardless of trend. This suggests that the hills, like the magnetic anomalies on the East Pacific Rise, are produced at the crest and spread to the flanks. Not all relief on the rise-ridge

Table 1. Spreading rates, topography, and second layer thickness of the central region of the mid-ocean ridge system. "Spreading half rate" refers to movement of each flank from crest.

Region	Spreading half rate (cm/yr)	Central rifts	Central flank relief	Average thickness of second layer (km)	Second layer Q (km^3 10^{-6} yr^{-1} km^{-1})
Iceland (*11*)	0.7	Yes	Mountains	3.5	25
Red Sea (*12, 3*)	1.0	Yes		3.3	33
Reykjanes Ridge (*13, 14*)	1.0	No	Mountains	3.3	33
Gorda Ridge, center	1.0	Yes	Mountains		
Carlsberg Ridge (*3, 4*)	1.5	Yes	Mountains		
South Atlantic (*15*)	1.5	Yes	Mountains		
North Atlantic, 30° to 40°N (*13, 16*)	1.0	Yes	Mountains	2.9	29
Juan de Fuca (*3, 17*)	2.9	No	Hills	1.5	44
Gorda Ridge, flank (*18*)	3.0		Hills	1.0	30
East Pacific Rise, 50°S (*4, 19*)	4.5	No	Hills	1.0	45
East Pacific Rise, 10° (*20*)		No	Hills	1.5	

system is produced at the crest, because active volcanoes exist on the flanks. However, it appears that very linear features, roughly parallel to the crest, generally are formed at the crest and preserved on the flanks. According to Table 1, the relief of the topography is proportional to the thickness of the second layer and inversely proportional to the spreading rate. Both relationships seem reasonable. The construction of a relatively thick second layer by lava flows and intrusions might be expected to produce a relatively high relief. The prolonged faulting of crustal blocks during slow spreading might produce more relief at the crest than the briefer faulting possible with fast spreading. In short, the relief can be correlated with the time of exposure to the relief-producing processes at the crest of a rise.

If the relationships and correlations above are correct they can be used to predict rates of spreading and the thickness of the second layer in regions where only the topography is known. One such prediction has been attempted and appears successful. The East Pacific Rise in the South Pacific typically has a relatively smooth crest, mountainous belts in the center of each flank, and smooth outer flanks (*7*). This information and Table 1 were sent to Heirtzler with the suggestion that the unpublished Lamont magnetic data in the region might provide a test (*8*). In this region, spreading at the crest is at a rate of about 4 cm/yr, on the midflanks it appears to be at about 1.5 cm/yr, and on the outer flanks at about 4 cm/yr (*9*). Although this is a relative time and spreading scale (*10*), it appears to confirm the relationships in Table 1. It should be obvious that the relationships apply only to the measured range of spreading rates and certainly not to zero spreading. The relationships cannot be extrapolated to the initiation or termination of motion, whether long continued or intermittent.

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Persistence of Chlorinated Hydrocarbon Insecticides in Soils

Abstract. *The percentages of technical aldrin, chlordane, endrin, heptachlor, Dilan, isodrin, BHC, and toxaphene remaining in Congaree sandy loam soil after 14, years were 40, 40, 41, 16, 23, 15, 10, and 45, respectively; those of purified aldrin and technical dieldrin after 15 years were 28 and 31, respectively; and the percentage of technical DDT in three soils after 17 years was 39. Treatments and maintenance of the soils were such that leaching, volatilization, photodecomposition, mechanical removal, and probably biological decomposition were at a minimum. These values may approach an upper limit of persistence of insecticides in soil.*

In 1949 and 1951 plots were established at the Plant Industry Station, Beltsville, Maryland, to study the long-term persistence and rates of disappearance of several chlorinated hydrocarbon insecticides in soil. These soils received from 0 to 448 kg of insecticide per hectare, mixed uniformly throughout their profile. We recently determined that 40, 40, 41, 16, 23, 15, 10, and 45 percent of the original applications of technical aldrin (determined as dieldrin degradation product), chlordane, endrin, heptachlor (plus heptachlor epoxide degradation product, 76 percent), Dilan (*1*), isodrin (plus endrin degradation product, 95 percent), BHC, and toxaphene, respectively, remained in soil after 14 years; that 28 and 31 percent of the original purified aldrin (determined as dieldrin) and technical dieldrin, respectively, remained after 15 years; and that 39 percent of the original technical DDT remained after 17 years (*2*).

Duplicate soil plots were established in 1951 on a Congaree sandy loam soil (*3*). Several technical chlorinated insecticides and purified aldrin, at rates of 0, 56 or 112, and 224 kg/ha [approximately 0, 25 or 50, and 100 parts per million (ppm)], were thoroughly mixed with the soil before it was placed in small plots to a depth of 38 cm. The plots were bounded by concrete block walls to a depth of 60 cm and provided with gravel and tile drainage.

In 1949 DDT was thoroughly mixed with Chester loam, Sassafras loam, and Evesboro loamy sand soils at rates of 0, 28, 112, and 448 kg/ha (approximately 0, 12.5, 50, and 200 ppm) before they were placed in plots similar to those for Congaree sandy loam (*3*). These soils were moved to a new location on the Plant Industry Station in June of 1962. Soil depth at the new location was 23 cm, whereas the original depth was 25 cm.

Soils were cropped at various times until 1962, in both plot series. Weeds were controlled by cutting, cultivation, or black plastic film. Since 1962, weeds were cut when necessary and allowed to decompose on the soil surface.

Samples of soil from the plots treated with DDT in 1949 were taken at the time of their establishment, and the concentration of DDT was determined. The first assay of soil plots treated in 1951 was made 1 year later. Soil samples of both series of plots were taken in the fall of 1952, 1953, 1954, 1955, 1958, 1962, and in June 1966. Several soil cores were taken; they were composited, thoroughly mixed, screened, and then subsampled for analysis. Through 1962, assay of insecticide was based on the total chlorine content of treated soil less the total