LETTERS TO NATURE

PHYSICAL SCIENCES

Geochemical Evidence for Ocean Floor Spreading in South Atlantic Ocean

THE basal sediment layer on the flanks of spreading ridges should be enriched in iron and relatively poor in aluminium if present concepts of ocean floor spreading are correct[1,2]. Recently published evidence from the third leg of the JOIDES expedition corroborates this hypothesis.

During this part of the expedition several stations were occupied at approximately 30° S and cores were taken at stations 14, 15, 16, 19, 20 and 21, between the Mid-Atlantic Ridge and South America. Rates of deposition, chemical compositions, water contents and densities were determined on the sediments from these cores[3].

The reported results[3] show that the ratio Al/(Al + Fe), which has been useful in the delineation of anomalous sediments on spreading ridges[1,2], shows a distinct decrease with depth (see Fig. 1). The most intensively studied cores came from station 19; the results[3] can be recalculated to show the accumulation rates for Al and Fe (see Fig. 2). The upper 100 m show normal pelagic accumulation rates, but in the lowest 40 m the accumulation rates for iron are anomalously high, resembling rates observed in recent sediments on the crest of the East Pacific Rise[4,5].

The evidence in Figs 1 and 2 strongly suggest that the formation of iron-rich crest sediments has taken place more or less uninterrupted since the middle Eocene, which is the age for the basal layer at station 19. The variations in thickness of the iron-rich basal layer may have resulted from the varying intensity in ocean floor spreading and volcanism or from intrusive basalt sills which would hide the true basement. Some of the undulations of the basement (see Fig. 1) are certainly also related to the fact that some stations (Nos. 20 and 21) are occupied on the Rio Grande Rise.

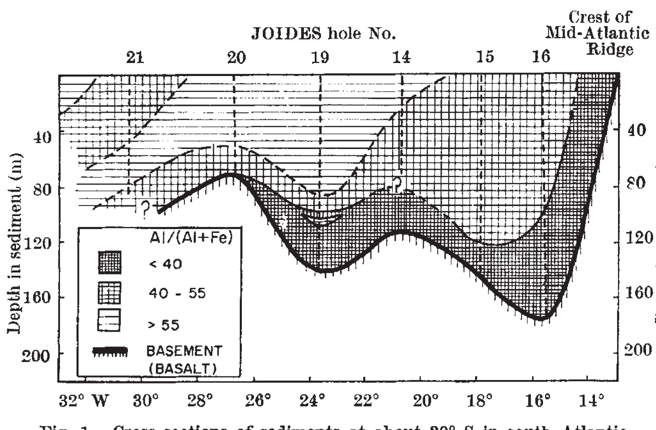

Fig. 1. Cross sections of sediments at about 30° S in south Atlantic Ocean. The number of the station is given above the figure and corresponding position (°W of Greenwich) below (for details see ref. 3). The ratio Al/(Al + Fe) = 0·40, is used to separate normal and iron-rich basal sediments. The lowermost part of the sediments locally have Al/(Al + Fe) values less than 0·20.

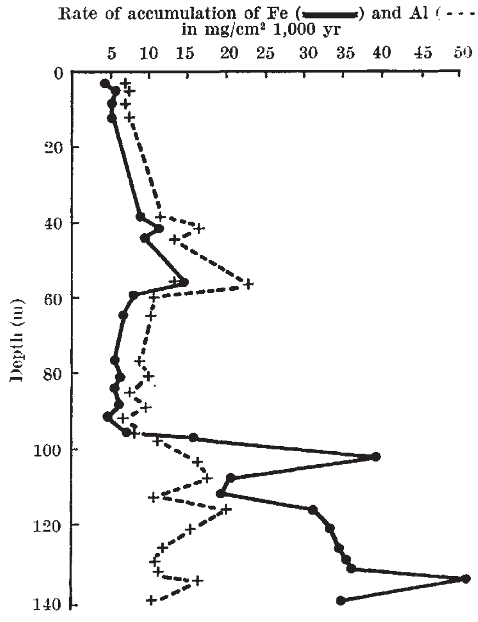

Fig. 2. Accumulation rates of iron and aluminium in sediments from station 19.

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Temperature Gradient above the Deep-Sea Floor

AT sufficient ocean depths (several km) there is an increase of temperature with depth corresponding to the adiabatic lapse rate $\Gamma \approx 10^{-6}$ °C/cm. Toward the bottom, the gradient becomes increasingly superadiabatic, because the water is heated from below by a geothermal heat flux H. Because H is small ($\sim 10^{-6}$ calories cm^{-2} s^{-1}), only a slight superadiabatic effect is expected: $|dT/dz| < 2\Gamma$ at elevation $z > 1$ m. Measurements of hyperadiabatic gradients ($|dT/dz| = 10$–$1{,}000\ \Gamma$) several metres, or even tens of metres, above the bottom have been reported[1-4], though it seems inconceivable that a strongly unstable layer several metres thick can persist. The experiment described here indicates that $|dT/dz| = 1{\cdot}3\ \Gamma$ at $z \sim 1$ m.

Critical Rayleigh number and Reynolds number considerations indicate that heat and momentum are transferred by molecular processes in a layer of thickness $h = 1$ to 4 cm just above the (smooth) sea floor[5]. Above this conductive layer there is convection. Townsend[6] describes three regimes which he terms "forced", "mixed", "natural" (Fig. 1). For various elevations and typical shear stresses in the deep sea, Table 1 shows the predicted convection type and temperature gradient relative to the adiabatic gradient $-\Gamma = -1{\cdot}2 \times 10^{-6}$ °C/cm. The predicted slightly