SEA FLOOR SPREADING

What Happens at Ridges?

from our Geomagnetism Correspondent

ALTHOUGH it is widely accepted that as part of the process of sea floor spreading mantle material rises into the Earth's crust beneath mid-oceanic ridges, details of this phenomenon remain obscure. Almost nothing is known about conditions at the Mohorovicic discontinuity; and this ignorance makes it quite impossible to decide between the various conceptual models which have been proposed or even to say whether any of them is valid at all. Weertman (*J. Geophys. Res.*, **76**, 1171; 1971) has now come up with an ingenious explanation of what might happen at or below mid-oceanic ridges based upon the dislocation theory which is probably more familiar to solid state physicists than geophysicists. It is interesting that this is not the first time that dislocation theory has been applied to a geophysical problem. Weertman himself, for example, used it to explain the behaviour of water-filled crevasses in glaciers; and it was this which apparently led him to develop a similar theory for lava-filled cracks in the Earth's crust.

The general problem that Weertman has tackled is thus that of a liquid-filled crack in a horizontal elastic plate. Needless to say, the analysis is highly idealized; it could hardly be otherwise without a detailed knowledge of the Earth's interior. The density and elastic constants of Weertman's plate are thus constant and do not vary with depth; the liquid that fills the crack is incompressible; and the crack itself is both vertical and two-dimensional. In addition, the upper and lower surfaces of the plate are assumed to remain planar. Because of these simplifications Weertman's problem is rather different from the real Earth problem. But his aim is not to describe the actual phenomenon in detail but rather to set up a model which is feasible in spite of its limitations. There will be time later to assess the consequences of over-simplification when parameters relating to the Earth's crust and mantle are known more accurately.

The starting point for Weertman's analysis is a concept familiar in solid state physics—that an open crack may be regarded as a set of infinitesimal edge dislocations in the solid. The analysis itself involves a complicated mathematical treatment; but the results of it can be stated quite simply. It is first necessary to suppose that a pool of liquid mantle material accumulates at the base of the crust beneath a ridge. The most obvious mechanism for this would be that mantle convection currents bring some mantle rock into a position where temperature and pressure are such as to liquefy it; but any mechanism would do as long as it produces the required liquid pool. It then turns out that as long as the crust is in a state of tension a bottom crack above the liquid pool will be "nucleated" into the crust—that is to say, there develops a crack into which liquid from the pools enters. Under the right conditions this bottom crack, filled with liquid, will grow in length until eventually it becomes sealed at the bottom and is thus cut off from the liquid pool. At this stage the crack is shaped like a tadpole with its tail pointing downwards. Because of its buoyancy the liquid-filled space will then rise until it reaches an equilibrium position near the surface of the crust, where the liquid solidifies.

In the meantime the remaining liquid pool will have produced another liquid-filled crack which again becomes sealed and which again rises. But this time the crack does not reach the surface of the crust but instead gets trapped by, and just below, the previous crack where it solidifies. The trapping process is then repeated at greater depths until the crust contains a solid "dyke" of ex-mantle material. By this time, of course, the "dyke" has forced the crust apart—the ocean floor has spread a little. The whole cycle will then repeat itself over and over again, producing more and more crustal spreading. At first sight it may seem unlikely that all the new cracks will form immediately below the previous ones. In practice the cracks probably form within a short horizontal distance from each other; but because a crack increases the tensile stress in the region below it, the new cracks are more likely to form below the old ones.

This is not, of course, the first time that the solidification of lava into dykes has been suggested in this context. It has been implicit in much of the thinking about sea floor spreading; and Bodvarson and Walker (*Geophys. J.*, **8**, 285; 1964) invoked it explicitly to explain the spreading of the mid-Atlantic Ridge where it crosses beneath Iceland. Weertman is at pains to point out, however, that the driving force for sea floor spreading is not the solidification of the lava as such but rather the tension which must exist in the crust before the process can take place.

"Synchro-Compton" Emission from the Crab?

THE discovery of the pulsar NP 0532 in the Crab Nebula provided a satisfying hint to astronomers of the origin of the energy driving this nebula outwards. With the almost universal acceptance of the oblique rotator model of pulsars, in which the pulsed radiation comes from a rapidly spinning neutron star surrounded by a strong magnetic field, it has now proved possible to explain in detail how the energy gets from the central pulsar to the wisps of matter in the nebula, and at the same time explain some of the observed polarization of the light from the Crab.

Next Monday, an article in *Nature Physical Science* by Dr Martin Rees of the Institute of Theoretical Astronomy shows that natural braking of the spin of the neutron star, occurring as a result of electromagnetic radiation at the pulsar frequency (30 Hz), ties in well with observations of the surrounding amorphous mass. The nature of this radiation should be the synchro-Compton emission which Rees presented recently as a possible source of the radiation seen in extragalactic radio sources. Although this can certainly provide the driving energy which keeps the nebula expanding, just as it can for larger, more distant sources (see, for example, *Nature* **229**, 368; 1971), the most immediate significance of this model is that it predicts exactly the polarization of the visible light from the source. Assuming a simple dipole field, an observer looking down on the pole of the pulsar will see circularly polarized light, while one viewing the source in its equatorial plane will see linearly polarized light. Not only is the optical radiation from the Crab pulsar linearly polarized, but the presence of the "interpulse" has already been interpreted as an effect caused by observation of the pulsar from its equatorial plane. Ordinary synchrotron radiation would be completely inadequate to account for the degree of linear polarization observed in the Crab at both optical and radio frequencies. At present, it looks as if a combination of the oblique rotator model with the synchro-Compton emission process is the best explanation of the pulsar phenomenon, and, possibly, radio galaxies. But one note of caution should be sounded—the Crab Nebula is so large that some parts of it should be radiating slightly circularly polarized light, according to this model, and it would seem that further observations to test for a few per cent circular polarization in the north-west and south-east parts of the nebula will very soon resolve the viability of the model one way or the other.

In this issue of *Nature* (p. 103), Landstreet and Angel report observations of the optical polarization of the light from the Crab Nebula which are of crucial importance in distinguishing the mechanisms active in the source. This work certainly must leave a question mark against the theory at present.