and Hecht[15] criticized various aspects of Ostrom's hypothesis, and they considered that he had misinterpreted the homologies of the limbs of *Archaeopteryx* and theropods. Thulborn and Hamley[8], reviewing all the criticisms, however, have concluded that they are without foundation (incorrect interpretations, inconclusive evidence, persistence of primitive characers), and that they do not "seriously weaken the hypothesis that *Archaeopteryx* is closely related to theropod dinosaurs".

The third current view of the relationships of *Archaeopteryx* has been given by Tarsitano and Hecht[12]. They revived an old idea that *Archaeopteryx* is a member of a distinct lineage that arose from the thecodontians and has no direct relationships with crocodiles or dinosaurs. Their evidence consists of a resemblance between the coracoid (a bone of the shoulder girdle) of *Archaeopteryx* and some thecodontians, as well as arguments against the 'crocodile' and 'theropod' hypotheses. Thulborn and Hamley[8] take the view that this hypothesis was selected merely by a process of elimination, but Hecht and Tarsitano have more recently reaffirmed their viewpoint[16].

There are thus three strongly held views on the relationships of *Archaeopteryx* — that it is related to crocodiles[9-11,13,14], that it is related to theropod dinosaurs[8,12] and that it is related to thecodontians[15,16]. It might seem to be an easy question to solve in view of the relatively well preserved specimens of *Archaeopteryx* and of thecodontians and early dinosaurs and crocodiles. But the arguments rest on interpretations of the anatomy of *Archaeopteryx* and related forms, and on modes of interpreting the data — whether by seeking general resemblances and ancestors, or in attempting a strict cladistic analysis of sister-group relationships. A rumoured sixth skeleton of *Archaeopteryx*[17] may offer new light on its anatomy. Interest in the 'early bird' or 'Urvogel' is so strong that a conference devoted to it is to be held in Eichstätt, West Germany, in September 1984. □

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Geophysics

Magnetic reversals from a submersible

from J.R. Cann

THE Vine–Matthews hypothesis[1] is 20 years old this year, and coincidentally a paper has just been published by Macdonald and co-workers[2] which represents a decisive step in the affirmation and development of the hypothesis. In case you need reminding, the hypothesis is that the lineations observed on magnetic anomaly maps of the ocean basins[3] can be explained as corresponding to strips of alternately normally and reversely magnetized sea floor. These strips were formed, it is argued, in a narrow zone along the crests of the mid-ocean ridges as the ocean floor spread apart continuously while the Earth's magnetic field periodically reversed. The ocean crust created, and especially the upper part of it, made up of submarine basalt lava flows, thus acted as a record of the field reversals.

A large amount of evidence has now accumulated that this hypothesis is a good model for the ocean floor, but the evidence has always been essentially indirect, and some scientists have contrived still to maintain their disbelief. The new paper does two things. It provides concrete support for the Vine–Matthews hypothesis through direct observation of a magnetic reversal on the ocean floor, and it also contributes important evidence about the creation of crust at mid-ocean ridges. The latter topic is especially important at present given the great interest in the black smoker springs and ore deposits of very young ocean crust[4].

Working from the US submersible *Alvin*, Macdonald and co-workers used a vertical magnetic gradiometer made from two vertical-component fluxgate magnetometers spaced 30 cm apart to find the polarity of magnetization of individual outcrops of basalt (usually single pillows) at nearly 300 places on several transects across a predicted reversal boundary on the sea floor. This boundary corresponds to the most recent major reversal of the Earth's field at 0.7 Myr (the Brunhes-Matuyama boundary). A previous survey with a near-bottom towed vehicle had enabled them to calculate where the reversal boundary was likely to occur. The submersible measurements found a sharp boundary as expected, on one side of which (the side nearer the mid-ocean ridge crust) the outcrops of basalt were all normally magnetized, and on the other all reversely magnetized. This is clearly the outcropping of a Vine–Matthews stripe edge. In places it was covered by a sediment pond, but in others it appeared as a flow front of normally magnetized lava overlying reversely magnetized lava (thus showing the normally magnetized lava to be younger, as indeed it ought to be). Near the boundary some of the outcrops are very weakly magnetized, and these may be of lava erupted while the magnetic field was in the course of reversing.

The experiment is a particularly elegant demonstration of the Vine–Matthews hypothesis because it is very direct and can be repeated in principle anywhere in the oceans where a reversal boundary is not covered by sediment.

But what about crustal formation? The important evidence here is that the reversal observed in the outcrops is systematically displaced 250–500 m away from that calculated from the near-bottom survey, in a direction opposite to that in which the mid-ocean ridge crest lies. This had been anticipated by some modellers[5], who considered from the evidence of ophiolite complexes (slices of ocean crust thrust above sea level during mountain building) that the zone of fissures from which lava is erupted must be about 50 m wide, much less than the distance that lavas flow away from the fissures (0.5–1 km)[4]. Macdonald and co-workers point out that the reversal from the near-bottom survey should correspond approximately to the position where the reversal is about half-way buried in the lava pile. This line in turn, if the fissure zone is indeed very narrow, should be displaced from the outcrop of the reversal by half of the lava flow length in the direction towards the mid-ocean ridge crest, which corresponds well with the observations.

Other modellers[6,7], whose experience had been conditioned by magnetic observations in deep-sea drilled holes on the Mid-Atlantic Ridge, had expected a much more irregular relationship. Such an irregular structure may be characteristic of the highly rifted (and generally slower spreading) ridges such as the Mid-Atlantic Ridge, while the narrow zone of fissuring may only be found on the less rifted ridges such as the East Pacific Rise where the experiment was performed. It is clearly necessary to resolve this question by repeating the experiment in the Atlantic. □

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