news and views

Assumed dipolar geomagnetic field

from Peter J. Smith

WHEN Johnson *et al.* (*Terr. Magn. atmos. Elect.*, **53**, 349; 1948) carried out their early palaeomagnetic work on recent Pacific sediments and the Holocene glacial clays of New England, they clearly saw their studies as just part of a much grander design. In respect of the wider aim their point was that "in order to determine the origin and nature of the Earth's magnetic field and to test the various hypotheses which have been advanced to explain the field, it is desirable to determine the history of this field throughout geologic time and to investigate more carefully its spatial variations, both inside and outside the Earth's surface".

As it turns out, it has been possible to make progress on the origin of the geomagnetic field largely without invoking the geological time dimension, and to this limited extent Johnson and his colleagues were mistaken. The self-exciting dynamo, the only viable field source known, may be regarded as an explanation of the present and recent fields without necessarily accepting that the details of any dynamo model applicable to today's field were valid throughout the Earth's history. Since the dynamo was discovered, detailed models have, of course, been extended to the geological time scale by the incorporation of field reversals and field intensity fluctuations, and for this and other reasons it is implicit in most modern models that the geomagnetic field has always been predominantly dipolar. But there is nothing in the dynamo principle as such that would preclude higher order fields in the past; and to the extent that more than the principle is applied to past ages, the dipolar nature of the field could be said to appear as an assumption.

It also appears as an assumption in most studies involving palaeomagnetic directions. Until the 1950s, palaeomagnetists generally felt that sufficient measurements would make it possible to define the morphology of the geomagnetic field throughout much of the Earth's life, subject only to the availability of enough rocks with sufficiently stable magnetisations. But ironically they were to be thwarted in this by their greatest achievement, the quantitative proof of continental drift. Once it became clear that continents had moved, it became equally evident that no simple test for dipolarity based on a stationary frame of reference could exist beyond very strict limits. It would be impossible to separate easily the effects of definitely moving rocks from those of possibly changing field shapes.

So the dipole assumption now appears in two different situations, making it just as desirable to determine the history of the geomagnetic field as it was in the time of Johnson *et al.* But how can the dipole hypothesis be put to the test? As far as very recent times are concerned there is no problem, for movement of the reference frame resulting from drifting continents has been small and changes in palaeomagnetic pole positions on that account have been within the errors of measurement. Thus more than a decade ago, Irving (*Paleomagnetism and Its Application to Geological and Geophysical Problems*, Wiley, New York, 1964) showed that the eleven then-available poles covering approximately the past 7,000 yr were grouped around the present geographic pole, and McElhinny (*Palaeomagnetism and Plate Tectonics*, Cambridge University Press, 1973) has shown that British archaeomagnetic poles taken at 100-yr intervals from AD 1900–1000 and AD 300–100 were distributed likewise. Both results suggest that during the past few thousand years at least the geomagnetic field has been dipolar and that on average the dipole lay along the rotational axis.

In practice, this test may also be successfully extended somewhat further back in time. According to McElhinny, for example, 67 poles covering the past 5 Myr are clearly grouped around the geographic pole with a mean pole at 88.8°N, 131.9°E. Opdyke and Henry (*Earth planet. Sci. Lett.*, **6**, 139; 1969) showed that palaeomagnetic inclinations from 52 deep sea sediment cores less than 3 Myr old were in close agreement with those to be expected from an axial geocentric dipole. And Tarling (*Principles and Applications of Palaeomagnetism*, Chapman and Hall, London, 1971) has even shown that poles from igneous rocks up to 20 Myr old are grouped around the geographic pole, albeit with a greater scatter than for shorter, more recent periods.

Wilson and Ade-Hall (in *Palaeogeophysics*, Academic, New York, 1970), on the other hand, found a tendency for Quaternary and Upper Tertiary poles from individual regions to lie on their respective far sides of the geographic pole. On the face of it, this would seem to call in question the average axial nature of the dipole, although Wilson (*Geophys. J.*, **19**, 417; 1970) attributed the phenomenon to deviations from geocentricity; the axial dipole is apparently shifted northward with respect to the Earth's centre. In any event, the effect is small enough to be regarded as a second approximation. In no case is the basic dipolarity of the field in question; on the contrary, the dipole assumption is strengthened.

Beyond the Upper Tertiary, however, interference from continental movements causes difficulty. Over the longer geological period, poles of similar age from different regions of a single rigid landmass seem to be consistent with an average axial dipole, the variation of the dispersion of palaeomagnetic directions with palaeolatitude is usually comparable with that to be expected from the present dipolar field, and palaeolatitudes calculated on the axial dipole hypothesis are broadly consistent with latitude-dependent palaeoclimatic indicators. But none of these can be regarded as a rigorous test of dipolarity; the best that can probably be said is that there is little evidence actually to refute the dipole. The new test for dipolarity and its application to the Phanerozoic, reported by Evans on page 676 of this issue of *Nature*, is thus very welcome, although other tests may still be required before the persistence of the dipole can be said to be scientifically certain. □