GEOMAGNETISM

Reversal ideas up-ended

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RECENT suggestions that virtual geomagnetic poles have a strong tendency to follow one of two paths during a geomagnetic reversal are called into question on page 400 of this issue[1], where Valet *et al.* suggest that the available data have been overinterpreted. In doing so, the authors upset an attractive hypothesis that links motions in the Earth's core with convection in the mantle and thereby with plate tectonics.

The polarity of the Earth's magnetic field remains constant for long intervals of time (ranging, in a random manner, from hundreds of thousands to millions of years) and then, for reasons we do not yet understand, will suddenly reverse. What happens in the 10,000 or so years it takes the field to reverse is both a puzzle and an important element in elucidating the reversal mechanism. The suggestion made last year[2–5] was that, at least for the last few geomagnetic reversals, the field retained a simple geometry during reversal and that the virtual geomagnetic poles simply swung from North to South, or vice versa, almost always along a path through North and South America or else (less frequently) through eastern Asia and Australia, 180° away.

However, the Earth's core (where the geomagnetic field is generated) cannot, by itself, 'know' its orientation in space, and so cannot have any memory from reversal to reversal of geographical location. In contrast, the time constants of mantle convection are orders of magnitude longer than those of the core, and the implication is that the mantle, probably through the temperature distribution at its base, is having an observable effect on the behaviour of the core. This has profound implications for a causal link between core motions and plate tectonics, and the suggestion was greeted with much excitement. The evidence presented was visually compelling, but Valet *et al.* now challenge the interpretation, claiming that the data are not inconsistent with a uniform random choice of transitional path.

Mapping

To map the configuration of the field at any time it is necessary to have synchronous observations from sites that are geographically well distributed. To map the changing configuration during a reversal one needs a sequence of such observations well distributed in time. As it happens, the remanent magnetization of rocks provides us with a record of the geomagnetic field. Unfortunately though, the palaeomagnetic recording process has been sporadic, often distorted, and susceptible to subsequent alteration. Thus the individual observations are difficult to read correctly, they are poorly distributed in space, it is difficult to find a record that captures a reversal transition, and there is currently no independent way to assign a timescale within a transition with sufficient precision and accuracy to align observations from different sites. Consequently, it is not possible to construct the maps we desire. The challenge then is to distil from the observations any systematics that may help us to understand the processes governing the behaviour of the core.

Given the direction of the magnetic field at some point on the Earth's surface it is a simple matter, assuming that the geomagnetic field is a dipole, to calculate the position of the north pole. The position of this hypothetical pole is then referred to as a virtual geomagnetic pole (VGP). If the geomagnetic field at the Earth's surface is largely dipolar (as it is now, and as it appears to have been throughout most of the past) then VGPs from different points on the Earth will coincide. Small variations in the position will represent noise due to the nondipolar content of the field. The VGP has therefore been a physically meaningful and powerful tool for tectonic palaeomagnetism. If the field retained a principally dipolar configuration during a reversal, then the VGPs from different sites would follow similar paths. But, without some external control, one would expect the path to differ from reversal to reversal.

If, however, the field has a complicated, nondipolar geometry, the VGP degenerates into a physically meaningless transformation and VGPs from different points will be widely dispersed. Transitional VGP paths from different sites will then disagree. Until last year, it was generally accepted that the transitional field was strongly non-dipolar[6] and so had a complicated geometry.

In the recent data, the individual VGP transition paths appear to be reasonably well confined to a longitudinal sector for much of each reversal. If, within a given reversal, there were a common preferred path for all sampling sites, then this would suggest a simple rotation of a largely dipolar field. However, the existence of a second preferred path, while still requiring a relatively simple geometry for the transitional field, rules out such dipole dominance[4]. There are in fact many relatively simple geometries that could produce antipodal paths, and Clement[4] has identified one with a dominant octupolar field.

The truly exciting suggestion, however, is that several reversals share the same preferred path, for this would indicate that the mantle has some direct control over the affairs of the core. Tric *et al.*[2], in a presentation that certainly suggests a preferred path, represented 48 transition records as a rose diagram, showing the number of reversal transition paths as a function of the mean longitudes of those paths. Laj *et al.*[3] plotted all the individual VGP positions (see the cover of *Nature*, 6 June 1991) in a presentation that almost compels one to accept the hypothesis of a preferred path. However, this latter presentation is naturally biased towards those paths with a large number of VGPs.

Standard tests

Valet *et al.*, elsewhere in this issue[1], use a representation similar to Tric *et al.*[2], in that a single weighted mean VGP longitude is assigned to each path to avoid the bias towards transitions with large numbers of VGPs. Using standard χ-square tests they conclude that different records of the same reversal do not have a common VGP transition path, and that there is no robust evidence for a preferred longitude sector for VGP paths from different reversals.

The major problem here is a paucity of data. Using clear selection criteria, Valet and colleagues have accepted only 39 individual records, 25 of these being from five reversals younger than 2 million years and the remaining 14 from reversals younger than 12 million years. However, their message is clear: the data do not at this stage demand a preferred longitude sector, for it is not implausible that the observed distribution of paths could have been obtained from a uniform random distribution. Clear resolution can come only with a substantial increase in the database, which is probably quite achievable, but will not be immediately forthcoming.

There is obvious attraction in the idea that the Earth's mantle exerts a direct control over the behaviour of the core during a reversal, but Valet *et al.* have shown that the hypothesis is not yet proven. □

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1. Valet, J.-P., Tucholka, P., Courtillot, V. & Meynadeir, L. *Nature* **356**, 400–407 (1992).
2. Tric, E. *et al. Phys. Earth planet. Inter.* **65**, 319–336 (1991).
3. Laj, C. *et al. Nature* **351**, 447 (1991).
4. Clement, B. M. *Earth planet. Sci. Lett.* **104**, 48–58 (1991).
5. Bogue, S. *Nature* **351**, 445–446 (1991).
6. Hillhouse, J. & Cox, A. *Earth planet. Sci. Lett.* **29**, 51–64 (1976).