Earth sciences

Statistical structure of geomagnetic reversals

from D. V. Kent

REVERSALS of the Earth's magnetic field have not occurred at a constant average rate over the past 170 Myr[1,2]. Shifts in the mean reversal rate at various times appear to be separated by periods of tens of millions of years in which the average rate of reversals remains nearly constant. Conclusions drawn from these and other statistical properties of reversal processes have been based on analyses of early versions of the geomagnetic polarity timescale (GPTS). More recent versions of the GPTS for the past 170 Myr incorporate a variety of new data from marine magnetic anomalies, magneto-biostrategraphic correlations and improved age calibrations, resulting in a new picture of the reversal behaviour of geomagnetic fields[3,4].

McFadden and Merrill[3] have analysed the mean rate of reversals using a sliding window with a fixed number of reversals. This reveals an approximately linear trend, increasing from less than one reversal per million years at about 86 Myr BP (just after the 30 Myr interval of constant normal polarity in the Cretaeceous) to over four per million years for the past few million years. Lowrie first arrived at a similar trend using a sliding window of fixed duration[4]. Then he and I documented such reversal behaviour in a different revised GPTS[5]. McFadden and Merrill suggest a change in the structure of the rate variations at about 10 Myr BP, although it has been suggested[4,6] that several maxima in reversal frequency associated with an apparent 15 to 20 Myr fluctuation are superposed on the long term linear trend.

The linear trend for the past 86 Myr is suggested by McFadden and Merrill to be part of a broader structure of the variable reversal process. The overall pattern seems to show a regular decline in reversal frequency from 165–119 Myr BP, when the process evidently ceased and the field remained in the same polarity state for ~30 Myr; then from about 86 Myr BP onward, field reversals again occurred at a gradually increasing rate. The observed long-term changes in mean reversal rate may represent secular changes in conditions in the Earth's core. McFadden and Merrill believe that variations in the mean temperature at the base of the mantle over long time periods are the most likely cause of the changes. Their interpretation requires at least intermittent convection deep within the mantle and it suggests that temperatures at the core–mantle boundary are highest during the long periods of constant polarity.

Despite the various refinements made to the GPTS, a number of important problems remain to be resolved before much confidence can be placed in our knowledge of the statistical structure of reversals. One long-standing but central issue concerns the presence or absence of short polarity intervals. It is clear that the distribution of observed polarity intervals is generally too deficient in short intervals for it to be fully compatible with either an exponential distribution or a Poisson reversal process in which the probability for the next reversal to occur is constant with time. Instead, it has been shown[2,7] that a gamma distribution provides a good fit to the observed polarity intervals, at least for the past 86 Myr.

In a companion paper to reference 3, McFadden argues that the observed distribution embodies a Poisson process combined with a filtering process that preferentially removes the record of short polarity intervals, giving rise to the observed gamma distribution[7]. Accordingly, McFadden and Merrill[3] calculate that the actual reversal frequency was 46 per cent higher than is observed, so that about half of the observed polarity intervals represent a concatenation of more than one interval of the actual reversal sequence; magnetostratigraphers, take note. The alternative is that short intervals seldomly occurred. This would imply a renewal process in which the probability per unit time of a reversal is not constant and that the occurrence of each reversal is not independent of earlier ones.

Difficult though it is to obtain firm evidence of short polarity intervals, because they are at or below the threshold of resolution of most palaeomagnetic studies, it will be important to do so because of their dramatic effect on the statistics of geomagnetic reversals according to our calculations[4,8]. Small-scale marine magnetic anomalies ('tiny wiggles') have been observed over high spreading-rate ridge systems and among other possibilities, may represent short (<40 kyr) polarity intervals; because of their uncertain nature, 'tiny wiggles' are usually not uniformly included in the GPTS[8]. If, however, tiny wiggles are all taken to represent ~30 kyr polarity intervals, they have a dramatic effect on the polarity-interval distribution, particularly over the past 40 Myr, in which 50 tiny wiggles have been identified. Taking them into account, the overall reversal frequency is increased by almost 80 per cent, and the sliding mean reversal rate becomes constant over this time span[4]. Although the distribution of all polarity interval lengths then approximates to an exponential, the normal and reverse polarity interval distributions develop an asymmetry in statistical properties, due to the unequal distribution of the added short intervals which are overwhelmingly of normal polarity.

If little less, this exercise with problematic tiny wiggles serves to re-emphasize how strongly the existence of short polarity intervals influences the statistical structure of geomagnetic polarity reversals. There is also the serious problem that spurious increases in reversal frequency may correspond to the most intensively studied time intervals. In my opinion a 'more' reliable description of the reversal process, whether it actually shows polarity asymmetry or even long-term linear trends in reversal frequency, must continue to await further improvements in resolution of the geomagnetic reversal timescale. □

1. Cox. A. *Rev. geophys. space Phys.* **13**, 35 (1975).
2. Phillips, J.D. *J. geophys. Res.* **82**, 835 (1977).
3. McFadden, P. & Merrill, R. *J. geophys. Res.* **89**, 3354 (1984).
4. Lowrie. W. & Kent, D. *Earth planet. Sci. Lett.* **62**, 305 (1983)
5. Lowrie, W. *Phil. Trans. R. Soc.* **A306**, 129 (1983).
6. Mazaud, A., Laj, C., de Seze, L., & Verosub, K.L. *Nature* **304**, 328 (1983).
7. McFadden, P.L. *J. geophys. Res.* **89**, 3363 (1984).
8. LaBrecque, J., Kent, D. & Cande, S. *Geology* **5**, 330 (1977).

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Molecular biology

Sigma factors in multitude

from Andrew Travers

SIXTEEN years ago, almost to the day, the discovery of a sigma initiation factor for the bacterium *Escherichia coli* was reported in *Nature*[1]. The factor is a polypeptide that binds to the enzyme RNA polymerase, conferring upon it the ability to initiate the transcription of certain genes. A conglomeration of recent papers illustrates the striking ramifications of that initial report, making it clear that sigma factors are widespread among bacteria, and that they are related to the polypeptide which mediates the response of bacteria to a sudden increase in temperature (heat shock). Moreover, it becomes possible to suggest how the different mechanisms that mediate the analogous responses to heat shock in bacterial and eukaryotic cells have evolved.

In *E. coli*, sigma factor binds to the 'core' RNA polymerase to form a holoenzyme that initiates transcription accurately from promoters that conform to the '-35' and '-10' consensus sequences of most *E. coli* promoters. It has long been