15-Myr periodicity in the frequency of geomagnetic reversals since 100 Myr

MAZAUD *et al.*[1] have recently analysed geomagnetic reversal time scales, covering the past 100 Myr, and they concluded that the geomagnetic reversal rate has a 15-Myr periodicity superimposed on a monotonic function, which they modelled with a lorentzian function. However, because of the analysis procedure they used, the origin (and hence interpretation) of this periodicity must be questioned. The reversal frequency as a function of time was determined using a fixed-length, rectangular, sliding window: the estimated reversal rate for each position of the window being the number of reversals appearing within the window divided by the window length. Fixed-length sliding window techniques such as this are notorious for producing spurious frequencies when used to analyse time-sequenced data generated by a process which embodies a random element. This occurs because the random component typically has a fairly broadband spectral representation and the fixed-length window acts as a filter which allows through only certain frequencies.

McFadden and Merrill[2] have also analysed geomagnetic reversal time scales and found no indication of a 15-Myr periodicity in the reversal rate. Instead, they concluded that the geomagnetic reversal process is essentially a Poisson process and that since the Cretaceous Normal Polarity Interval the reversal rate has increased approximately linearly with time. Using a maximum likelihood method they concluded that λ, the reversal rate, is given approximately by

$$\lambda = \alpha + \beta t \qquad (1)$$

where $\alpha = 4.41 \pm 0.85\ (\mathrm{Myr}^{-1})$ and $\beta = -0.051 \pm 0.014\ (\mathrm{Myr}^{-2})$ with $t = 0$ now and increasing backwards in time. A Poisson process produces randomly distributed interval lengths, τ, between events (reversals) with probability density, $\rho(\tau)$, given by

$$\rho(\tau) = \lambda \exp(-\lambda\tau) \qquad (2)$$

Using a random number generator, random sequences of interval lengths have been generated from the distribution of equation (2) with λ given by equation (1), using the point estimates of $\alpha(4.41)$ and $\beta(-0.051)$. Analysis of such sequences by the method of Mazaud *et al.*[1], using as they did a window of 4 Myr, results in estimated λ curves strikingly similar to theirs. Autocorrelation of these λ curves (after subtraction of a linear component) gives periodicities very similar to that of Mazaud *et al.*[1], yet λ contains no periodic component. Using a 2-Myr window, a similar periodicity is still apparent but buried by the (expected) increased noise. Using an 8-Myr window the amplitude of the periodicity is decreased by the increased smoothing of the longer filter.

Thus, the evidence for the observed 15-Myr periodicity being a real geodynamo phenomenon may not be as convincing as the claim of Mazaud *et al.*[1], and the possibility that λ has simply increased linearly with time and that the observed periodicity is merely a by-product of the analytical technique must be strongly considered.

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1. Mazaud, A., Laj, C., de Sèze, L. & Verosub, K. L. *Nature* **304**, 328–330 (1983).
2. McFadden, P. L. & Merrill, R. T. *J. geophys. Res.* **89**, 3354–3362 (1984).

MAZAUD *ET AL. REPLY*—McFadden suggests that our report of a 15-Myr periodicity in the frequency of geomagnetic reversals arises from our use of a fixed-length, rectangular window to determine the number of reversals per unit time. We are well aware that the use of such a window can introduce apparent periodicities (even for random data) because the fixed-length window acts as a filter, permitting only certain frequencies to be seen. However, when such a filter does introduce spurious periodicities, the period is directly related to the window width. In our work, we used windows ranging from 1 to 10 Myr. Although the amplitude of our periodicities and the signal-to-noise ratio varied somewhat, the period itself was confined to the narrow range of 13–17 Myr. If the period had merely been the result of using a rectangular window, we would expect a much larger variation in its value.

We now turn to the more important and more interesting point of McFadden's comment, namely, the periodicity in his computer-generated time series. Following McFadden's method we produced over 50 different synthetic time series, which were then analysed by the fixed-length, rectangular-window method. Our goal was to determine whether all of the time series resulted in periodic oscillations of the same period. In our study, the answer was clearly no: while some of the time series did give rise to a distinct periodicity, this was not the general case. In fact, we found an nearly continuous range between time series which had well-defined periodicities and those in which no clear periodicity could be discerned. This result provides additional evidence that the periodicity which we observed in the reversal frequency did not arise from our method of analysing the data. However, it also shows that a completely random phenomenon can sometimes give rise to a periodic one. With regard to the frequency of geomagnetic reversals, we certainly cannot exclude the possibility that in this particular situation, the periodicity results from a probabilistic process. In this respect, McFadden's criticism has contributed to a deeper insight of our own data.

Finally, note that we never expected that our work should serve as the final word on the nature of the reversal process. The fact that McFadden and Merrill have reached a different conclusion only demonstrates that this is a complex problem whose final resolution requires further work.

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