

The Spectrum of Geomagnetic Temporal Variations

Catherine G. Constable (Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0225; ph: (858) 534-3183; fax: (858) 534-8090; email; cconstable@ucsd.edu); **Catherine L. Johnson** (Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0225; ph: (858) 822-4077; fax: (858) 534-5332; email; cljohnson@ucsd.edu)

In the course of Neil Opdyke's career new uses for paleomagnetic data have evolved that make increasingly stringent demands on data quality and on temporal resolution in age constraints. Determinations of polarity and paleoinclination were sufficient for traditional magnetostratigraphic studies and for evaluation of the geocentric axial dipole (GAD) hypothesis. Today, paleomagnetic data are used to analyze geomagnetic field variations on time scales ranging from hundreds to billions of years. For example, researchers strive to make inter-hemispheric comparisons of marine sediment records with sub-millennial scale accuracy. Details of field behavior, such as deviations from GAD, run the risk of being interpreted in terms of specific temporal and spatial variations in core-mantle boundary conditions. Expectations are evolving that we may detect departures from GAD of the average magnetic field direction that are as small as 1 or 2 degrees. Yet there remains much that is poorly documented about geomagnetic field variations, including the nature of the geomagnetic spectrum. Still unanswered is the basic question of how long one needs to average the geomagnetic field in order to uncover a "stable time-averaged field", always assuming that such a thing exists. Knowledge of the spectrum could help resolve this issue.

We construct a power spectrum of geomagnetic paleointensity variations that spans the period range from 10 to 10 million years. The spectrum has the most power at long periods, reflecting the overwhelming influence of geomagnetic reversals, and in general the power decreases with increasing frequency (decreasing period). Empirical estimates of the spectrum are derived from the magnetostratigraphic time scale, from marine

1. MEETING: Chapman Conference on Timescales of the Geomagnetic Field 2. CONTRIBUTED 3a. Catherine G. Constable, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0225 3b. ph: (858) 534 3183 3c. fax: (858) 534-8090 3d. email; cconstable@ucsd.edu) 4. NOT a student*****

and lake sediment relative intensity records, and from historical observations. Existing spectral estimates do not indicate any distinctive behavior that allows separation of excursions and transitional field behavior from what might be called normal secular variation. However, there does appear to be a characteristic spectral signature associated with the recurrence time of cryptochrons during the Oligocene. A number of researchers have suggested the occasional presence of quasi-periodic field variations corresponding to changes in Earth's orbital parameters and by extension associated with long term climate modulation.

In the absence of reliable measurements of very long (greater than a few million years) period paleointensity variations, we use the magnetostratigraphic timescale and a simplistic statistical model which supposes that field intensity is constant except during finite intervals when the field is reversing. During a reversal, the intensity is diminished, but also constant. Under this model the time required to acquire a reliable average for the field intensity, and the average value itself, depend on the reversal rate and the typical reversal duration. For a fixed reversal rate the spectrum is essentially constant at low frequency. The spectrum falls off as approximately the inverse square of the frequency above a critical value determined by the characteristic reversal transition length. The actual geomagnetic spectrum differs from this predicted spectrum because of changes in reversal rate, fluctuations in paleointensity, and lack of uniformity in the time taken for individual reversals. We assess the limitations of the model and show how it can be extended to include more realistic field behavior based on empirical spectra derived from paleomagnetic records. The resulting spectrum is used to examine how long is needed to obtain a reliable estimate of paleosecular variation (PSV) and the time-averaged field (TAF).

Spectral estimates for intensity variations can pave the way to extend existing statistical models for PSV to include temporal covariance. Most recent statistical PSV models assume temporally independent or uncorrelated samples of the field except in the axial dipole. To include a general temporal covariance in our current PSV model, known as CJ98, we need to determine whether and how the characteristic time scales for

variations change with the spatial scale and/or non-zonal nature of the field. For example, there are indications in historical field models that small scale and/or non-zonal parts of the field may change more rapidly than others. In CJ98 the axial dipole has a special status, and because of this CJ98 predicts that at any single location temporal changes in the X and Z components of the geomagnetic field should be coherent for axial dipole field variations, with no coherence between X and Y or between Y and Z. By analyzing a relative intensity record with associated directional information it could be possible to identify the time scales characterizing variations in the axial dipole part of the field. This coherence between X and Z combined with a lack thereof among other components appears to exist at long periods for the record we have examined so far.

Such analyses indicate the importance of jointly estimating directional and intensity variations for the geomagnetic field. Unlike the usual estimates of coherence from separate cores, the single-core estimates described above are not afflicted by the relative uncertainties in dating. Standard techniques for identifying dipole variations from relative paleointensity records involve stacking records from multiple locations after using tie point and associated age estimates to put the records on a common time scale. The sampling process combined with correlating ages between cores with even slight variations in sedimentation rates can easily lead to incoherence at periods that are of considerable interest in the geomagnetic spectrum. We seek methods that will avoid such complications, or at least enable the evaluation of the resolution attainable with the available age information.