Forum

A nonmarine record of eccentricity forcing through the Upper Triassic of southwest England and its correlation with the Newark Basin astronomically calibrated geomagnetic polarity time scale from North America: COMMENT and REPLY

COMMENT: doi: 10.1130/G24805C.1

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Kemp and Coe (2007) employ spectral analyses of stratigraphic variations in rock color to detect regular alternations (cycles) suggestive of orbital forcing of Triassic lacustrine (Branscombe Mudstone Formation) sedimentation in southwest England. The analyses suggest "pervasive" 116 cm cycles in rock color layering. The periodicity assigned to these cycles is that which best accords with the assumed relative completeness of this section and its magnetostratigraphic counterpart in the Triassic of the Newark Basin, United States. This suggests that the cycles record the effects of 100 k.y. orbital eccentricity, and that the British section provides an ~75% complete record with respect to the correlative Newark Basin sequence.

There are three problems in this cyclostratigraphic approach: (1) Kemp and Coe's wavelet analysis fails to detect the pervasive 116 cm cycles in ~30% of the interval analyzed; (2) there are other cyclic components in the wavelet analysis, not discussed, that achieve the confidence levels of the 116 cm cycles (these do not conform to a Milankovitch model of layer cyclicity); and (3) the proposed relationship between the 116 cm cycles and the effects of 100 k.y. orbital eccentricity requires unchanging, ~1 cm/k.y., instantaneous rates of accumulation, despite hiatuses, for >3 m.y, including those intervals where no such cycles are detected.

Kemp and Coe's time calibrations and "robust" correlations rely on the spectral analyses of the Branscombe Mudstone color data series. Peaks in spectral power corresponding to the cycles are rated statistically significant, with an estimated 10% (or less) probability of occurring by chance in the analyses. It should be understood, however, that such estimates are useful only to the extent that they take account of the uncertainties in modeling the red noise power spectra that characterize such stratigraphic data (Vaughan, 2005; Weedon, 2003).

The layer thickness inventory (LTI) method (Bailey and Smith, 2005, 2008) offers an independent test for cyclicity in the Branscombe Mudstone data series. It provides objective evidence of the frequency of occurrence of all the layer thicknesses evidenced by this stratigraphic data series. Cyclicity is expressed in characteristically inflected bi-logarithmic plots of layer thickness versus frequency of occurrence. Modeling suggests that where cyclicity records periodic external forcing, such patterns will emerge where the record of forcing is intermittent, and despite hiatuses that result in "more gap than record." Inflected plots are, however, rare in the record, because strict stratigraphic cyclicity implies not only a linear sedimentary response to periodic forcing, but also unchanging instantaneous rates of accumulation.

We have applied the LTI test to the 4439 cm L* (lightness) rock color data series provided by Kemp and Coe (2007; GSA Data Repository item 2007245). In the scale-range of the 116 cm cycles, the LTI plots show a robust negative power law (Fig. 1). The plots not only fail to reveal the characteristic relative frequencies of occurrence (inflections) that cyclicity in layering should generate, but also show that the numbers of layers around 116 cm in thickness are too few for there to be pervasive cyclicity at this scale. Thus, there is no confirmation of the cycles detected by Kemp and Coe, which may be a chance outcome of the spectral analyses. By contrast, data series from the Newark Basin Triassic generate inflected plots consistent with the classically described cyclicity (Bailey and Smith, 2008).

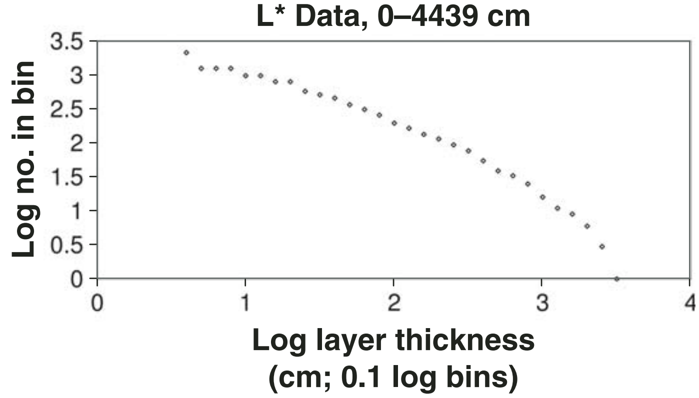

Figure 1. Bi-logarithmic layer thickness inventory (LTI) plot based on the 5 cm L* color sampling of the 4439 cm section of the Branscombe Mudstone (Kemp and Coe, 2007; GSA Data Repository item 2007245). Plot shows the log number of layers in each 0.1 logarithmic bin of layer thickness. The power law character of the relationship is also evident if the bi-logarithmic plots are made without binning, either cumulatively or noncumulatively.

The magnetostratigraphic correlation between the Branscombe Mudstone Formation and the Triassic of the Newark Basin is unaffected by the lack of confirmatory evidence for the presence of pervasive 116 cm cycles in the British section. The questionable evidence for these cycles must, however, undermine the case for periodic forcing of its deposition and the legitimacy of the resultant floating time scale.

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Bailey and Smith (2008) question the veracity of the 116 cm cycle we observed in the spectral analysis and wavelet analysis of our Branscombe Mudstone time series, and, using a technique of their own design, suggest instead that this cyclicity could be an artifact of the spectral analysis. The spectral analysis methodology we employed to identify this cycle is the established technique for studies of this type (e.g., Hinnov, 2000; Weedon, 2003), and this method has been used to derive an astronomical time scale for much of the Cenozoic (Gradstein et al., 2005). Bailey and Smith appear to have a fundamental distrust of spectral analysis per se as a technique for constructing astronomical time series, rather than presenting any specific criticism of our particular study. To reiterate our findings, our interpretation that the 116 cm cyclicity is a real feature was based on the fact that spectral analysis showed that this cyclicity is present in two data sets, in both halves of these data sets, and was also unambiguously identified using wavelet analysis. Wavelet analysis was employed specifically to look at the time-frequency evolution of the data, and, as Bailey and Smith point out, time-localized peaks in wavelet power do indeed occur. However, spectral analysis demonstrates that these very short-lived peaks do not contribute a significant amount of power against the overall variance of the data; hence, they are not interpreted as cyclic components generated by Milankovitch forcing.

Hiatuses and sedimentation rate changes can affect the spectral analysis where cycles are degraded to such a degree that cyclic peaks are no longer statistically resolvable against the red noise background. The 116 cm cyclicity, however, is pervasive (and of constant frequency) because it is a fully resolvable feature common to 70% of the analyzed record—it is highly unreasonable to expect a constant cyclicity to pervade through >30 m of strata out of pure chance. Over the intervals that the 116 cm cycles are not well resolved against the red noise background of the data is likely to be where the regularity of the cyclicity is compromised significantly by the hiatuses we discussed. However, this is strongly dependent on the nature (i.e., duration and distribution) of the hiatuses, which cannot be ascertained.

With regard to Bailey and Smith's layer thickness inventory (LTI) method, we can demonstrate that this technique is fundamentally flawed. We question the efficacy and utility of a technique that requires the subjective identification of an inflection in a logarithmic plot. The scaling of the layer-thickness distribution results from the strong red noise component of stratigraphic time series. Spectral analysis, when combined with the assignment of confidence intervals (e.g., Mann and Lees, 1996), can quantifiably and robustly take account of this red noise background, something that is lacking in the LTI method. We carried out our own experiment using the LTI method of Smith and Bailey by analyzing modeled time series constructed from sine waves with a wavelength of 116 cm (Fig. 1). The scaling pattern that results from the analysis of a simple 116-cm-wavelength sine wave reveals a highly ambiguous pattern of inflections, and an inflection at 116 cm cannot be unambiguously demonstrated (Fig. 1A). The addition to this sine wave of even small amounts of red noise (smaller in amplitude than the background noise level apparent in the Branscombe Mudstone time series) rapidly makes even these spurious inflections unresolvable (Figs. 1B–1C). Thus, without even incorporating artificial hiatuses into these modeled time series, the LTI test completely fails to reveal inflections corresponding to the 116 cm cyclicity. This is despite the fact that this cyclicity obviously exists and is revealed easily using spectral analysis (Fig. 1). We therefore stand by our original observations and interpretations.

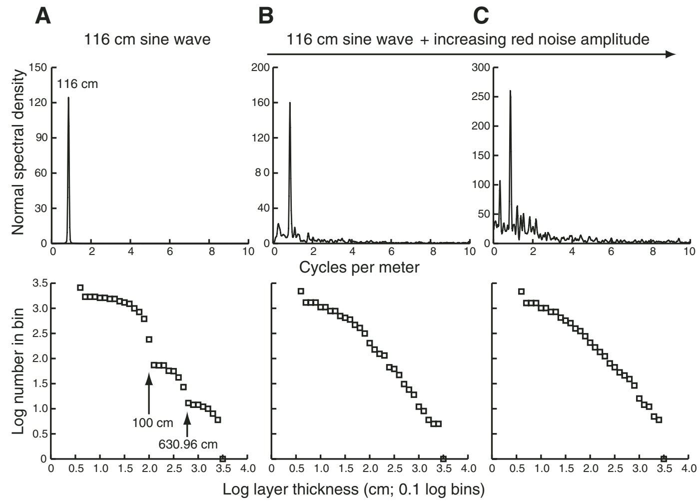

Figure 1. Results of spectral analysis and layer thickness inventory (LTI) analysis of modeled time series (889 samples at 5 cm intervals). A: Using a simple sine wave with a wavelength of 116 cm, the LTI method fails to unambiguously and accurately resolve this cyclicity. B and C: Sine waves with increasing red noise amplitude (red noise was modeled with the same autoregressive properties as the background spectra present in the Branscombe Mudstone time series data). LTI analyses of modeled time series in B and C fail to resolve even the spurious inflections present in the single sine wave analysis of A, even at noise levels unrealistically low for typical cyclostratigraphic time series data (i.e., B). In contrast, spectral analysis is able to accurately resolve the 116 cm cyclicity in all the time series. Note that the variance of the background noise of the Branscombe Mudstone time series analyzed by Kemp and Coe (2007) is higher than the modeled data analyzed in C.

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