Wavelet analysis of Paleoproterozoic tidal sediments distributed in the Singhbhum Craton, northeast India: Estimation of early Earth’s (2 Ga) rotation velocity

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The Paleoproterozoic Chaibasa Formation (c.a., 2.6 to 2.0 Ga) distributed in the Singhbhum Craton, northeast India, is known for the preservation of one of the oldest tidal sedimentary records (e.g., [1]). The tidal cycles recorded in the Chaibasa Formation have been utilized to reconstruct the astrophysics of Earth-Moon system during the Earth’s early history [1], [2]. In this study, we estimate the Earth’s rotation velocity at 2.0 Ga by extracting neap-spring lamina cycles based on wavelet analysis. The advantage of wavelet analysis is that it can distinguish continuous and sporadic spectra individually, meaning that the neap-spring spectrum can be isolated from any other irregular sedimentary events (e.g., storm).

The Chaibasa Formation consists of sand-dominated and mud-dominated facies. The sand-dominated facies are planer to trough cross-laminated and mud drapes are commonly intercalated in between the lamina. The mud-dominated facies consists of densely interlaminated sand and mud layers with occasional occurrences of flaser ripples and herringbone laminations. Since, the sand-dominated facies demonstrate deposition under unidirectional flows punctuated by mud drapes, this facies is interpreted as a record of the ebb-slack cycles (or flood-slack cycles). Meanwhile, the mud-dominated facies were deposited under the influence of bidirectional flows and can be interpreted as ebb-flow cycles.

Wavelet analysis of sand-dominated facies extracted spectral periodicities of 2.47, 4.11, 6.93, 14.0, 23.1 and 32.8 intervals. In addition, wavelet analysis revealed that the 32.8 spectrum was most stationary, while other spectra were sporadic in varying degrees. Therefore, we consider that the 32.8 interval change in lamina thickness likely represents the number of ebb-slack iterations in one neap-spring cycle. In other words, there was 32.8 lunar days per synodic month during 2.0 Ga, which is 27.32 in the present day. It follows that the number of solar days per synodic month would be 33.8 (cf. Table 1 of [5]), and the number of solar days per sidereal month is calculated as 31.4 (cf. [1]). Finally, these two values lead to calculations of the number of solar days per synodic year by applying the following equation [3]:

\[ \text{t} = \text{t} \times \left(1 + \frac{\text{t}}{\text{Y}_D}\right) \]

where \(t\), \(t\) and \(Y_D\) are number of solar days per sidereal month, synodic month and year, respectively. The result reveals that the number of solar days per year was 468 and the length of solar day was 18.7 hours during 2 Ga.

The rotation speed of 468 days/yr detected in the present study is comparable with estimates made from other Paleoproterozoic sites (e.g., 450 days/yr for 1.8 Ga [4] and 466 days/yr for 2.5 Ga [5]). These apparent uniform figures imply a slow deceleration of Earth’s rotation speed during most of the Paleoproterozoic. It follows that lunar recession speed in the Paleoproterozoic was slower than the Phanerozoic, as suggested by Williams [5]. However, the uncertainties are still large for Paleoproterozoic records and further investigations are required for the reasonable estimate.
References: