Simulations to the tides of ancient oceans and the evolution of the Earth-Moon-system

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Abstract

The angular momentum transfer in the Earth-Moon system is mainly determined by the ocean tides and closely interlinked with their resonance characteristics (e.g. Brosche and Sündermann, 1971; Thomas and Sündermann, 1999). The latter are considerably presupposed by the topography of the ocean basins which has changed significantly in the Earth’s history. For the current epoch astronomic and geodetic observations confirm a secular increase of the length of day of ca. 2 ms/century and a lunar recession rate of ca. 4 cm/year (Williams, J.D., et al., 2008), which equals a decrease of Earth’s rotational energy of ca. 4 \times 10^{-12} W.

The limited availability of geological proxy data has so far prevented a detailed quantification of the transfer of angular momentum in the Earth-Moon-system far back in the Earth’s history. Considering recent palaeontological data and advances in computing science the project GeoGEM, funded by the German Research Foundation (DFG), will strive to reduce these deficits. Firstly, self-consistent geological data on ocean tides, Earth’s rotational parameters and orbital elements of the Moon have been provided by the research of Williams (2000) on the sediment layers of South Australia for the Neoproterozoic ~620 Ma back. For this time slice we will reconstruct the spatial and temporal characteristics of the tides by means of simulations with the three-dimensional Max-Planck-Institute-Ocean circulation model MPI-OM forced by the complete tidal potential expressed by the ephemerides. The numerical results will be evaluated with the recent geological proxy data. Subsequently, the evolution of the ocean tides under the influence of the continental drift from the Neoproterozoic till today will be simulated. In this process a focus will be on the transfer of angular momentum between Earth and Moon in order to explain physically the geological proxy data.

Maps of the Neoproterozoic, Li et al. (2008)

- Synthesis on the formation (1300 Ma – 900 Ma) and break-up (<600 Ma) of the supercontinent Rodinia.
- 530 Ma formation of Gondwanaland completed.
- Based on palaeomagnetic constraints and on geological correlations.

Maps of the Phanerozoic

- Li and Powell (2001), Schettino and Scotese (2005), Müller et al. (2008) and the Paleomap Project of C. R. Scotese.

Palaeobathymetry

- The shelf and the ocean will be taken into consideration as well as possible (Williams, G.E., et al., 2008; Li and Powell, 2001).

Palaeocorotation parameters, Williams (2000)

-620 Ma
- Present

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar days per synodic month</td>
<td>29.5 ± 0.5</td>
</tr>
<tr>
<td>Solar days per synodic month</td>
<td>30.5 ± 0.5</td>
</tr>
<tr>
<td>Solar day per sidereal month</td>
<td>28.3 ± 0.5</td>
</tr>
<tr>
<td>Synodic months per year</td>
<td>13.1 ± 0.1</td>
</tr>
<tr>
<td>Sidereal months per year</td>
<td>14.1 ± 0.1</td>
</tr>
<tr>
<td>Lunar apsidis period [a]</td>
<td>9.7 ± 0.1</td>
</tr>
<tr>
<td>Lunar nodal period [a]</td>
<td>19.5 ± 0.1</td>
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<tr>
<td>Solar days per year</td>
<td>400 ± 7</td>
</tr>
<tr>
<td>Length of solar day [h]</td>
<td>21.9 ± 0.4</td>
</tr>
<tr>
<td>Lunar semimajor axis [R_E]</td>
<td>58.16 ± 0.30</td>
</tr>
</tbody>
</table>

- 4.2-year record of 1337 diurnal laminae from 110 neap-spring cycles

Palaeo-geographical maps of 720 Ma till present

Earth’s palaeocorotation

- Analysis of sedimentary rhythms from South Australia
- 60-year record of 1580 neap-spring cycles

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Simulations to the ephemerides

- Astronomical computation of the insolation quantities on Earth spanning from -250 Ma to 250 Ma (Laskar, 2004).
- This ephemerides model we would like to enhance with our result and the geological data (Laskar, pers. comm.).

Acknowledgement

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References

Heinemann, M., et al., 2009. 5, 785-802.