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

P. Nerge, University of Hamburg; T. Ludwig, University of Hamburg; M. Thomas, GFZ German Research Centre for Geosciences; J. Jungclaus, Max Planck Institute for Meteorology; J. Sündermann, University of Hamburg; P. Brosche, University of Bonn
Contact: petra.nerge@informatik.uni-hamburg.de

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 astronomical and geodetic observations confirm a secular increase of the length of day by 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. 4·10^-13 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 (Modellrechnungen zu den Gezeiten früherer Ozeane und zur Geschichte des Erde-Mond-Systems), funded by the 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 (MPIOM) 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.

Starting Point

Present M₂ ocean tide simulated by MPIOM
- Bi- or tripolar grid (here with the poles on North America, Asia, and Antarctica).
- The grid poles are freely selectable and the resolution around Antarctica can efficiently increased for evaluation of the results.
- MPIOM has been used for palaeoclimate studies e.g. for the warm Paleocene/Eocene (Heinemann et al., 2009).

Luni-solar ocean tides simulated by MPIOM

M₂ ocean tide for topographies of the Proterozoic
- Present and an important component of the evolution of the Earth-Moon system.

Maps of the Proterozoic

• Maps of the Neoproterozoic, Li et al. (2008)
  - Synthesis on the formation (~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 Palaeozoic

• 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).

Palaeorotation parameters, Williams (2000)
- Analysis of sedimentary rhythms from South Australia.
- 60-year record of 1580 neap-spring cycles.
- 4.2-year record of 1337 diurnal laminae from 110 neap-spring cycles.

Palaeorotation parameters
- ~620 Ma
  - Lunar days per synodical month 29.5 ± 0.5
  - Solar days per synodical month 29.5 ± 0.5
  - Solar day per sidereal month 28.3 ± 0.5
  - Synodic months per year 13.1 ± 0.1
  - Sidereal months per year 14.1 ± 0.1
  - Lunar apsides period [a] 9.7 ± 0.1
  - Lunar nodal period [a] 8.85
  - Solar days per year 365.24
  - Length of solar day [h] 24.00
  - Lunar semimajor axis [Re] 35.9 ± 0.2

Outlook

Earth’s system research
- One considerably denser reconstruction of the tidal dynamic from Neoproterozoic till present and an important component of the evolution of the Earth-Moon system.

References

Acknowledgement
We are grateful for the support from the German Research Foundation through the grant LU 1353/6-1, the German Academic Exchange Service through the grant 55934490 funded by the Federal Ministry of Education and Research, and the German Climate Computing Center.