TIDAL FRICTION, GEODYNAMICAL PROPERTIES AND ROTATION SPEED IN THE REMOTE GEOLOGICAL PAST

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1. Some remarks on the paleorotation of the Earth during Phanerozoic, Proterozoic and Archean.

The early formation of the Earth probably runs much faster as it was proposed earlier. Our planet was separating out a lighter continental crust 4.4 Ma BP (hundred million years after earth formation) (Kerr, 2000). Life begun very early in Earth's history, perhaps before 3800 million years ago (Marais, 2000). Eriksson and Simpson (2000) in the sedimentary rocks from South Africa detected tidal deformations dating 3.2 years ago. Their analysis implies that tides were not unusually strong than and that the Archean lunar orbit was similar to that seen today. Inspite of these facts it also can be concluded that our knowledge on the development of the Earth during its history is incomplete.

At present time the input of the tidal friction into Earth energetic balance is 10^{20} Nm/y (y=year). For a comparison the solar energy input is 10^{25} Nm/y, the heat flow loss, the tectonic activity and the energy released by earthquakes are 10^{22} Nm/y, 10^{20} Nm/y and 10^{18} Nm/y respectively. It can be therefore concluded that at present time the tidal despinning of Earth rotation is a significant component of the Earth's energetic household.
To estimate the role of tidal friction's input into development of the Earth and the Earth-Moon system it is necessary to determine the length of day in the early Katarchean, shortly after the Earth had been formed (4.5 Ga BP).

2. Estimate of LOD near to the time of Earth formation

With the use of fossils and tidal deposits Varga et al. (1998) infer the variations of the rotation speed during the last 3.10 Ga. It was found with the use of these data that the Earth's despinning rate was on the average about five time smaller in the Protorezoic =Ptz) than in Phanerozoic (Pz). The corresponding linear trends are:

$$LOD = 24.00 - 4.98\,t \qquad \text{for the Phanerozoic (Pz)}$$

$$LOD = 21.44 - 0.97\ t \qquad \text{for the Proterozoic (Ptz)}$$

(where t is the time before present (BP) expressed in Ga=10^9 year).
With the use of the second equation at the time of Earth formation (4.5 GaBP) the result will be 17.5 hours. This value should be an extreme short value and serves as a lower bound because the despinning of the Earth's axial rotation is due to oceanic tides first of all and the solid Earth tides has only a reduced despinning effect. It can be supposed however that the first oceans were formed significantly later than 4.5 GaBP. An another estimation became possible if the database described in Varga et al., (1998) is used in an unique robust estimation process. The database can be modelled in this case by an exponential expression which gives with the use of robust estimation procedure the numerical value:

$$LOD = 4.68.e^{-0.00166t} + 19.65$$

with the use of this model the length of day 4.5 GaBP was 19.6 hours.
From the mentioned above paper of Eriksson and Simpson (2000) we can conclude that the length of day 3.2 GaBP was closer to 15 hours than to 24 hours. In other words: LOD was less than 19.5 hours. This value derived from the study of the earliest known tidal deposit serves as an upper limit both for linear and exponential extrapolations. Consequently the value 19.6 hours for LOD 4.5 GaBP serves as on upper bound also.
For the interpretation of the original LOD value the equation for the characteristic time of the lunisolar despinning τ_T can also be of use (Hubbard, 1984)):

$$LOD = K\ c^6 / \tau_T$$

where

$$K = 2\ \Pi\ M_E / 3k_s\ GM^2_M\ R^3$$

Here δ is the tidal delay of the lunisolar bulge which was 6.8^o for Pz and 1.5^o for the Ptz (Varga, 1998). For the earlier parts of the Earth history we can suppose 1.0^o - 0.5^o if during the early history of our planet its surface not consists oceans. In above equation

- M_E and M_M are the masses of the Earth and the Moon
- k_S is the secular Lovenumber
- G is the gravitational constant
- c is the Earth-Moon distance
- R is the mean radius of the Earth.

For the use of the equation (1) given by Hubbard (1984) to estimate LOD 4.5 GaBP the value of c is needed in the remote past. Using the results obtained in Varga et al. (2002) for the Earth-Moon we get:

$33.844 \cdot 10^8$ m present epoch
$3.450 \cdot 10^8$ m 3·109 y BP
$3.200 \cdot 10^8$ m $4.5 \cdot 10^9$ y BP

For the characteristic time of tides τ_T – to a certain extent arbitrary – we suppose three values: 10^{10} y; $7.5 \cdot 10^9$ y; $5 \cdot 10^9$ y. Of course in the reality $\tau_T > 5 \cdot 10^9$ y and with high probability $\tau_T > 7.5 \cdot 10^9$ y.
In equation (1) to calculate K the following numerical values were in use:

$k_S = 0.96$
$G = 6.671 \cdot 10^{11}$ kg^{-1} m^3 s^{-2}
$R = 6.371 \cdot 10^6$ m
$M_E = 5.973 \cdot 10^{24}$ kg
$M_M = 7.347 \cdot 10^{22}$ kg

In the following table LOD values are estimated for $4.5 \cdot 10^9$ y BP for different phase delay values, for the c values valid for present epoch, $3 \cdot 10^9$ years BP and $4.5 \cdot 10^9$ years BP and for the three characteristic time of the lunisolar damping τ_T mentioned above:

δ=2^o

τ_{TID} (y) / C (m)	10^{10}	$7.5 \cdot 10^9$	$5 \cdot 10^9$
$3.844 \cdot 10^8$	11.39	15.19	22.78
$3.450 \cdot 10^8$	5.95	7.94	11.91
$3.200 \cdot 10^8$	3.79	5.05	7.58

δ = 1.5^o

$3.844 \cdot 10^8$	15.19	20.25	30.38
$3.450 \cdot 10^8$	7.94	10.59	15.88
$3.200 \cdot 10^8$	5.05	6.74	10.11

δ =1.0^o

$3.844 \cdot 10^8$	22.78	30.37	45.46
$3.450 \cdot 10^8$	11.91	15.88	23.82
$3.200 \cdot 10^8$	7.58	10.11	15.16

δ = 0.5^o

$3.844 \cdot 10^8$	45.57	60.75	91.12
$3.450 \cdot 10^8$	23.82	31.75	47.65
$3.200 \cdot 10^8$	15.15	20.22	30.30

In this table the values listed in lines for c = $3.844 \cdot 10^{18}$ (valid for present epoch) are unrealistic for LOD $4.5 \cdot 10^9$ y BP. Also the results in the last column can be excluded because $\tau_T > 5 \cdot 10^9$ year. According to result of Eriksson and Simpson LOD $3.2 \cdot 10^9$ y BP was already shorter than 19.5 hours. It is also probable that with the linear extrapolation of the paleorotational data we got the lowest bound for LOD 4.5 Ga BP (17.5 hours). So we remain with one possible conclusion: the realistic solution we got if $\delta = 0.5^o$, $c = 3.200 \cdot 10^8$ m and τ_T is between 10^{10} year and $7.5 \cdot 10^9$ year (see the values 15.15 and 20.22 in the last line of our table).

3. Conclusions

From the results of calculations demonstrated in previous section one can conclude that:

- at present we can accept that the values between 19.5 hours and 17.5 hours are giving realistic estimation for the rotation period in time of Earth formation. This means that during his lifetime our planet lost more than half of its rotational energy. What was the impact of this energy loss into the development of the Earth and of the Earth-Moon system? This question should be answered by future investigations.
- the phase shift of the tidal bulge was probably much lower at the time of very young Earth than during the Ptz and Pz when our planet had his oceans. This means: the early Earth has no oceans of continental scale distribution.
- the characteristic time of the lunisolar despinning rate τ_T is probably between 10^{10} year and $7.5 \cdot 10^9$ year.

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