Phantasmagoria of Earth's mantle convection and correct plates movements

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Introduction

In 1931 Arthur Holmes introduced the concept of mantle convection as a motive force to drive continental drift. Harry Hess (1962) adopted the idea of mantle convection as a critical component of seafloor spreading, which became an integral part of plate tectonics. This idea is absolutely incorrect, it contradicts to any observations and even worst, mantle convection should draw oceanic lithosphere deeply into mantle. This imagination persists till present. Present knowledge states that mantle is a solid body forming firm carapace round the Earth's core, as confirmed by the travel of seismic P and S waves. The Earth quickly rotates and its solid structure allows only negligible flattening 20 km. The axis Earth's rotation is firmly stable with regard of ecliptic by presence of Moon as proved Laskar et al. 1993.and also with regard of solid mantle, neglecting pole wobble variations and small irregular polar drift. Lithospheric plates really move, continental plates collide and moving oceanic lithosphere, created in mid-ocean ridges enigmatically disappears, dropping down in subduction zones. How oceanic lithosphere can pass through solid and brittle mantle, being only slightly dense then surrounding mantle, in which density increases with depth, remains an enigma solved in this paper. Driving forces of lithospheric plates are tides, what is confirmed by the most significant earthquakes in past 50 years. Imagination that whirling convection currants push apart lithospheric plates is phantasmagoria, which should draw plates on both sides into mantle.

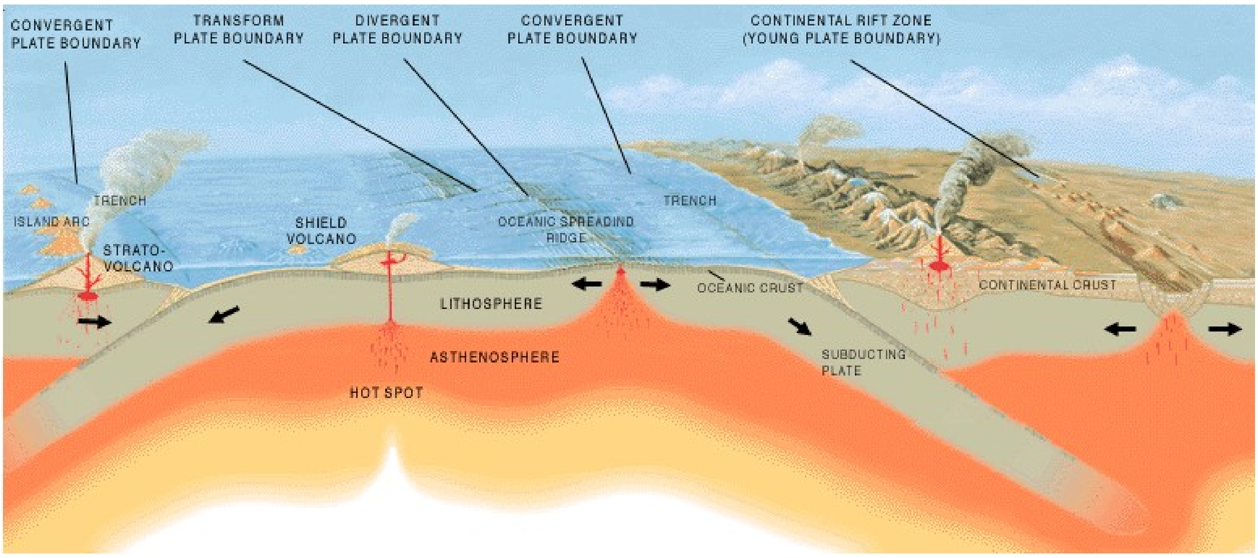


Figure 1 Imagination of double subduction zones. Black arrows mark separation in mid-ocean ridge and direction of subducted parts into depth. Surrounding continents can push closer subducted parts (Molucca), what again contradicts to reality; Phantasmagorial figure is taken from Universe Today 2.11.2009.

Double subduction and double seismic zones.
Present plate tectonics, considering mantle convection, imagines that oceanic lithosphere is separated apart in mid-ocean ridges by uprising flow and ending parts are driven to depth by convecting flow in mantle (Fig. 1.

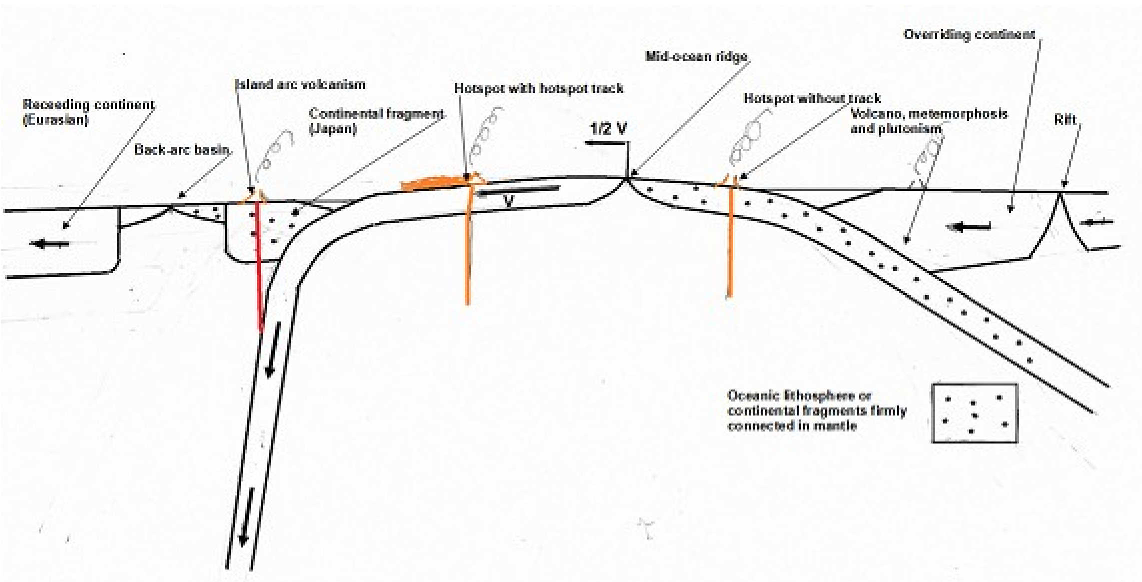


Figure 2. Real lithospheric plates movement. In figure plates move westward, only subduction zones, mantle plumes and continental fragments adjacent to subduction zone, remain fixed over mantle.

Reality is quite different. Subduction zones are firmly anchored in mantle and on the contrary, mid-ocean ridges move with half speed of the moving plate (Fig. 2).
In Ostřihanský 2021 it has been shown that lithospheric plates move westward and only Pacific. Indo-Australian and African move also with northward component. This movement is caused by tides, which act in 2 components: westward 10^{16} Nm and

stronger north-southward 10^{22} Nm, acting perpendicularly and helping by that to weak westward lithospheric component (See Appendix). As Fig. 2 shows, subduction zone in front of mid-ocean ridges (dotted part) is firmly connected to mantle; it grows by overriding continental plate and by movement of mid-ocean ridge. Therefore with extreme mantle hardness and embrittlement is no problem. Oceanic lithosphere behind mid-ocean ridge moves by tides over melted low velocity zone (LVZ). However how oceanic lithosphere passes through hard and brittle mantle being only slightly heavier than mantle, remains enigma. It is evident that gravity can help steeply dipping subduction zone and hypothetically last possibility remains that subducting oceanic lithosphere burns itself a hole in mantle. This hypothesis of burning through mantle, new discovery of **double seismic zone** extremely favorably supported.

Double seismic zone (DSZ) has been discovered by Hasegawa et al. 1978 beneath Honshu and after a publication gap, at present time almost all subduction zones are considered as double seismic zones. Figure 3 shows the most important double seismic zones.

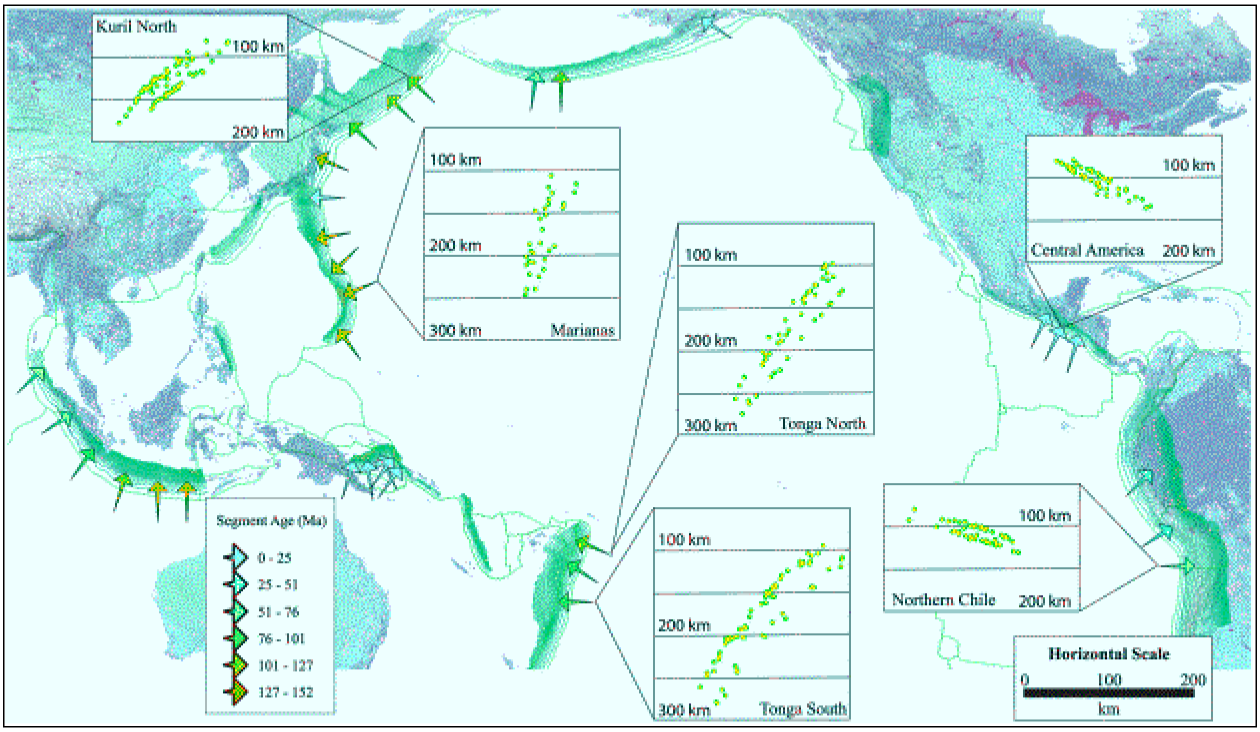


Figure 3 shows double seismic zones, as depicted by Florez and Prieto 2019. Double seismic zones occur in intermediate subduction zones in dept 100 – 300 km. Wei et al 2017 reported Tonga subduction zone reaching 450 km. As evident, subduction zones overridden by continental lithosphere are shallow and slightly inclined. Steeply dipping subduction zones are deep with wide gap between earthquake planes, with good condition for oceanic lithosphere burning through mantle, supported by gravity.

Conditions in deep Earth's interior

A variety of mechanisms have been proposed to explain DSZ earthquakes, including dehydration embrittlement, plastic shear instability, transformational faulting and fluid-related embrittlement. It is evident that dehydratation embrittlrmrnt plays important role after 100 km depth, but most important role plays decompression in greater depth and increase in temperature, which in depth 100-400 km reaches 1500-2000 ºC (Jeanloz and Morris 1986), forming ideal conditions for melting. To keep low temperature melting, decompression is necessary, because according to Clausius Clapeyron eqation, melting temperature is dependent on ambient pressure and decrease with increasing pressure. In next it will be explained that in intermediate earthquake depth there are good condition for oceanic lithosphere burning the hole into depth.

Let us present simple relations for gradient of melting point (Jacobs 1974) and adiabatic temperature gradient (Jeffreys 1929) and demonstrate how these gradients will operate in relation to gradients of temperature in given time in Earth and what follows from it for extreme hardness and strength in mantle. Effect of pressure on melting point is given by Clausius-Clapeyron equation.

$$\boxed{\frac{dT_m}{dp}=\frac{dT_m}{L}\left(\frac{1}{\varrho_1}-\frac{1}{\varrho_2}\right)}$$

where T_m is melting point, L latent heat of melting, ρ_1 , ρ_2 are densities in liquid and in solid state.

Considering hydrostatic equilibrium, change of pressure with depth is given

$$\boxed{\frac{dp}{dz}=g\,\varrho}$$

From both equations follows (*g* is constant of gravity):

$$\boxed{\frac{dT_m}{dz}=\frac{g\cdot T_m}{L}\cdot\left(1-\frac{\varrho_1}{\varrho_2}\right)}$$

In theory of convection, adiabatic gradient is very important given by relation

$$\boxed{\frac{dT_m}{dz}=\frac{g\cdot\alpha\cdot T_m}{\varrho\cdot c_p}}$$

where α is volume coefficient of thermal expansibility and c_p specific heat under constant pressure.

As far as the temperature gradient dT/dz is bigger than adiabatic, the movement of fluid occurs in direction upwards. Movement is stopped if both gradients are equal, possibly movement is reversed, as far as the temperature gradient is smaller than adiabatic.

As it follows from calculations for supposed constants (Jeffreys 1929. Jacobs 1974) the gradient of melting point is about 10x larger than adiabatic temperature gradient and from this reason the Earth solidified from core-mantle boundary upwards.

Consequences

Lower part of mantle has been exposed to enormous pressure before solidifying, resulting in extremely strong and hard medium. (Remember, diamond created from graphite under large pressure and having melting temperature over 4000 ºC). Pressure in lower mantle is 130 GPa according to the PREM model (Dziewonski and Anderson, 1981). However if this part solidifies in extremely strong and hard medium, compression strength is paralyzed. This is phenomenon named in previous author’s (Ostřihanský 2020) papers “bathyscaphe effect.“, when pressure does not act, but medium is subjected to surrounding temperature. In subduction of oceanic lithosphere, temperature plays the most Important role. According to model results (Boehler 1993, 1996) the temperature is about 1000 ºC at the base in the crust, around 3500 ºC at the base of the mantle and around 5000 ºC at Earth's center.

Pacific plate makes large movement by tides. Considering only part of Hawaii–Emperor Seamount chain, part only up to elbow, i.e. from Hawaii as far as Midway Is., equals 3000 km. long. It means that subduction from trench reached core-mantle boundary at 2900 km depth. To reach such depth is possible only by burning of oceanic lithosphere and penetration through extreme solid mantle being melted and continuing into depth, falling in still increasing temperature. Up to 400 km, mantle is not quite solid; decompression makes subducting part to burn through mantle, but forming embrittlement of surrounding parts. Deeper, the mantle is absolutely solid though that no earthquakes are created and burning to depth continuous without any embrittlement to core or remains over mantle dispersed.

Subducting oceanic lithosphere burning down to still hotter medium is melted and heavier component continues to the depth. Lighter component rises up burning mantle above forming vent in overlying mantle driven by buoyancy. This light component forms volcanics of island arcs. Formation of hot spots is similar. Hotspot, probably of meteoritic origin is melted, burns down by gravity underlying mantle and melt formed by melting rises up, forming hotspot track. Burning towards depth still continues, but scarcely hotspot reaches core-mantle boundary, nevertheless forming hotspot tracks over 10 thousands kilometers.

Note:

Burning is generally considered as chemical reaction between fuel and oxygen. In our case burning is considered as consequent melting of intruding subduction oceanic lithosphere driven by gravity to depth into medium of increasing temperature. It means that heavy part still subsides reacting with still hotter medium and lighter upraises..

Real plates movements

In 1975 Heezen and Tharp 1985 presented Geological World Atlas UNESCO and Ostřihanský 1997, 2020a revealed from it that: confirmed by curved shape of Scotia Sea basin round South Pole, by ocean sea basins situated on eastern side of Eurasian plate, by hotspots firmly anchored in mantle marking by hotspot tracks the plate movement and also by firmly anchored subduction zones, which colliding with lithosphere, mark characteristic phenomena for the plates movement. Plate driving forces are tides, sufficiently strong to move plates. They are two kinds (see Appendix) north-south strong force 10^{22} Nm and weak westward tidal friction 10^{16} Nm. North-south force is confirmed by strong earthquakes along north-south faults on Indian, American and African plates. Westward force has been confirmed by Rubinstein el al (2008) as tidal modulation of non-volcanic tremor. Idea that tides trigger earthquakes is of very old data starting with Schuster 1897, Bostrom 1971.1973, Moore 1973, Ostřihanský 1991, Doglioni 1993 and many others up to present. Topics of this paper are results of author's papers (Ostřihanský 2015, 2016a, b, 2017, 2020a, b and 2021a, b lithosphere rotates round mantle).

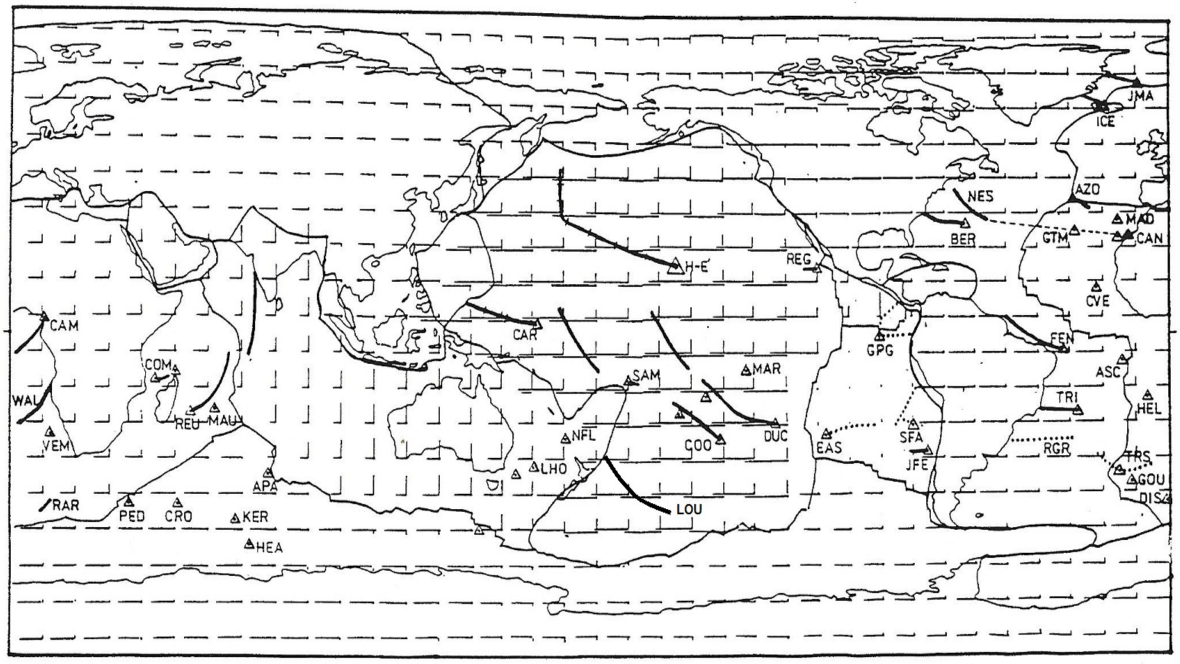


Figure 4. Real plates movement. Hotspot in Nazca plate GPG (Galapagos) represents stable position on mantle as depicted on Fig. 2, where oceanic lithosphere if firmly situated on mantle, as dotted area. In figure, vertical and horizontal line segments mark vertical and horizontal components of plates movements. Because small plates as Nazca and Cocos remain stable on mantle then calculation shows that plates move in direction of westward and northward components as depict on figure. Solid curves depict hotspot tracks, which show that originally plates moved northward (Reunion hotspot (REU), disrupted by mid-ocean ridge. Original movement of Hawaii-Emperor Seamount Chain (H-R) has been also northward but later prevailed westward component. New England Seamount (NES) shows interruption of hotspot track by Mid-Atlantic Ridge and hotspot stable position in Canary Island (CAN), (Ostřihanský, 1997).

Sumatran earthquakes

Sumatra earthquake 26. December 2004 clearly elucidated action of tides on earthquake triggering and plate movement. It has been triggered exactly on Full Moon and high Moon's declination 27°41´ and Sun's declination close to winter solstice 23°21´ resulted in summarizing effect of both tides as evident from Fig. 5.

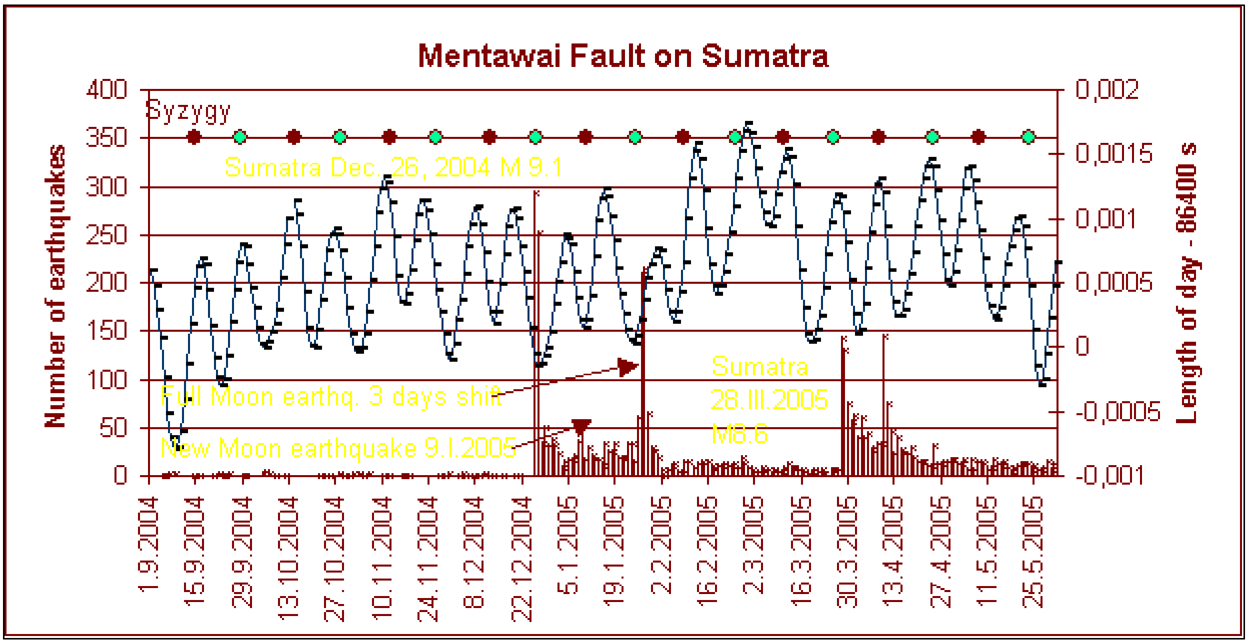


Figure 5. Great Sumatra earthquake M 9.1 has been triggered on December 26, 2004, on Full Moon, then followed by earthquake 9.1.2005 in New Moon, but in next Full Moon earthquake has been triggered for 3 days later.

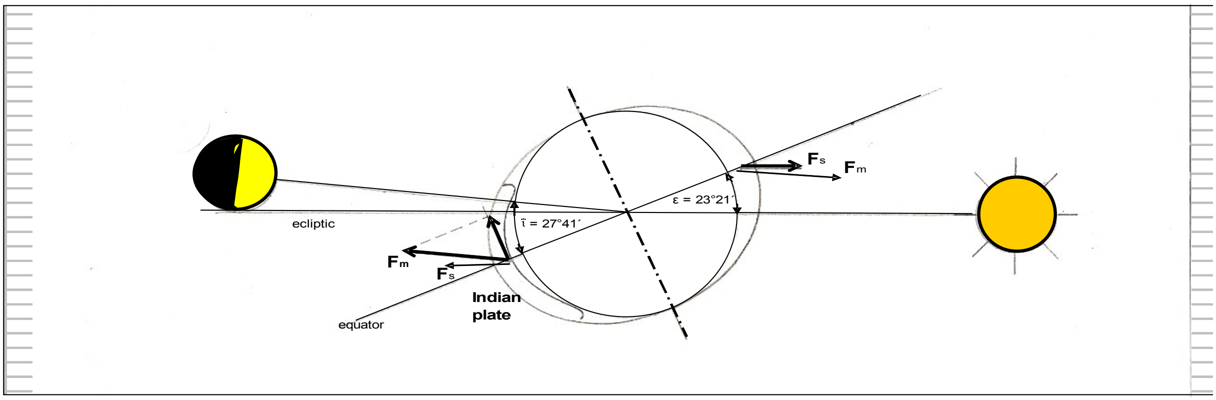


Figure 6 shows exact position of Moon and Sun during Sumatra M 9.1 earthquake. Because in winter time Sun's declination is negative, its tidal torque counterpart is added as positive to positive Moon's tidal torque.

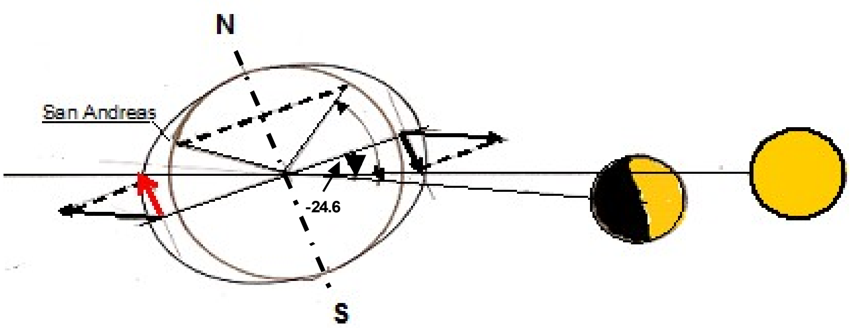
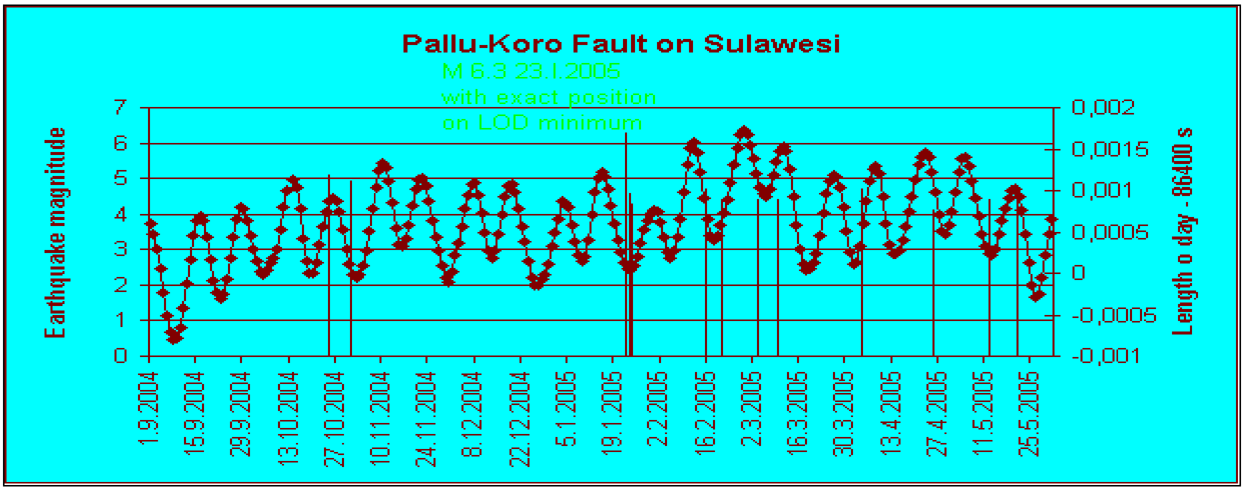


Figure 7 shows summarizing torque of Moon and Sun forces directing southward (black arrow). Next 12.42 hours counterpart torques direst northward (red arrow), what is necessary position towards subduction zone on northern hemisphere..

In following 14 days, Moon and Sun are in position of New Moon and as evident from Fig. 7, both tides are again summarized, what results in earthquake 9.I. 2005 (Fig. 5). 27.I.2005, three days after Full Moon, the next strong earthquake occurs but outside LOD minimum. Nevertheless 2000 km on east on Palu Koro Fault in Sulawesi, earthquake occurs M 6.3, 23.I.205 coinciding exactly with LOD minimum, with Moon's declination, again over 27°. This means that westward directing force has moved the plate owing to its close position to subduction zone along Sumatra shore westward, whereas till now the plate has moved northward owing to Moon's and

Sun's high declination. Calculations of northward and westward tidal forces are in Appendix.

Exact position of M 6.3 23.I.2005 earthquake on LOD minimum shows Fig. 8. Summarizing position of earthquakes on Mentawai Fault Sumatra and Palu-Koro Fault Sulawesi shows Fig. 9.



1. **Figure 8** Earthquakes on Sulawesi and LOD diagram.

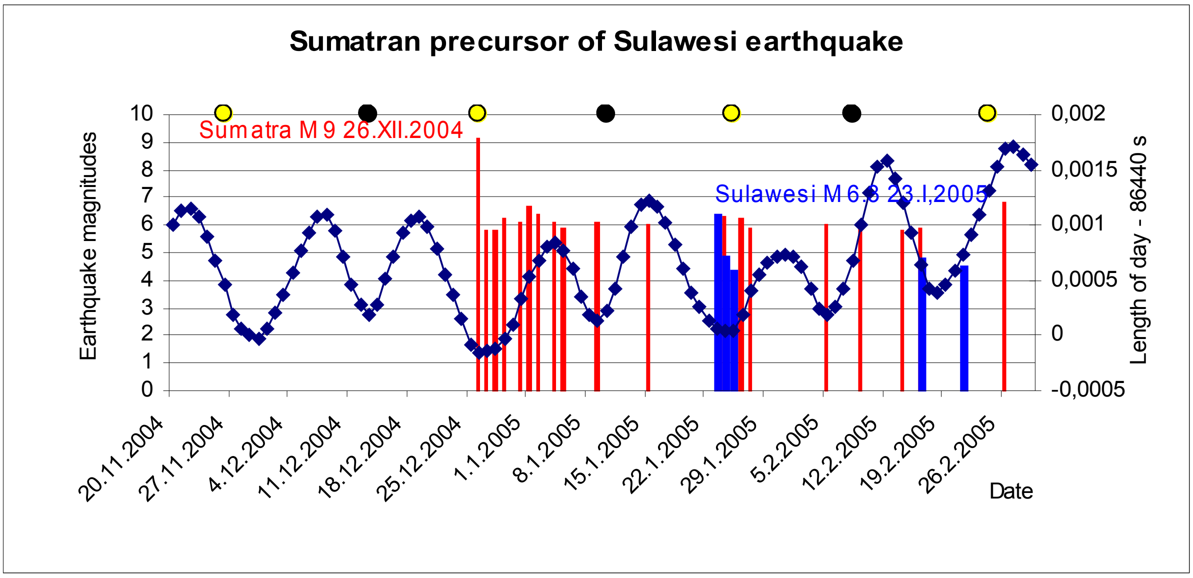


Figure 9shows earthquakes on Sumatra Mentawai fault (red bars) and Sulawesi Palu-Koro Fault (blue bars) on one LOD graph.

Figure 10 shows earthquake M 8.6 Sumatra 28.3.2005 from Fig. 5 in detail. It is evident that occurrence of earthquakes has shifted from sharp position on LOD minimum 26.12.2004 to LOD maximum (even with 2 days delay) corresponding to 0º declination. In this case owing to 0º declination the north-south tidal torques do not act and earthquakes triggering are caused by westward tidal friction force, which triggers earthquake in 12.42 hours rhythm. However Fig. 10 shows earthquakes increment in Moon's ½ sidereal rhythm 27.32 days, i.e. in 13.66 days.

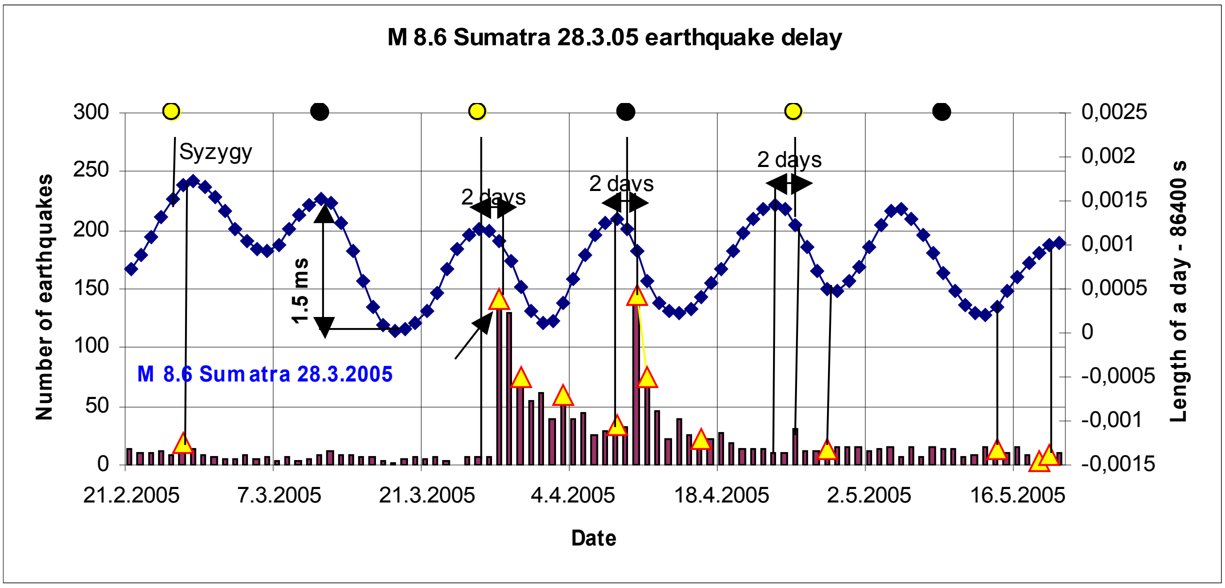


Figure 10. Earthquakes occur 3 times always after Moon's ½ sidereal 27.32 days period. Earthquakes over 6th magnitude are marked by triangle. LOD amplitudes have got settled on constant value, at the same time lithospheric plates direct westward. LOD maximums correspond to 0° Moon's declination preventing any north-south movement.

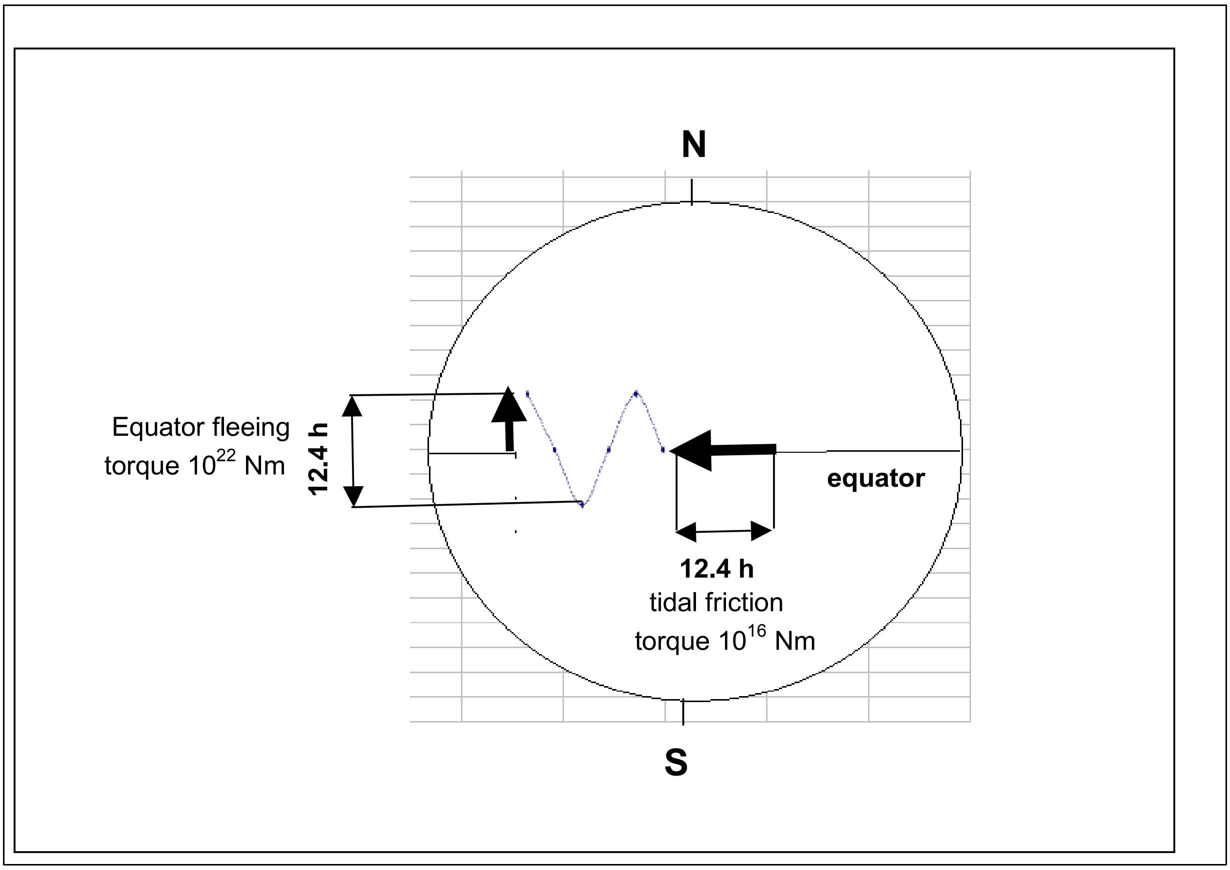


Figure 11. North-south tidal torque changes its value from 0 to 10^{22} Nm in sidereal Moon's 27.32 days rhythm and owing to Earth's rotation, it acts in positive and negative direction in

12.42 days rhythm./ However movement is possible only in northward direction (½ arrow) owning to existence of subduction zone in present time only on northern hemisphere. (Ostřihanský 2020a)

Final conclusion of Sumatran earthquakes

Sumatran earthquakes 26. December 2004, 28. March 2005 and group of earthquakes from September to December 2009 presented final solution of tidal triggering of earthquakes and correct mechanism of plate movement driven by tides.

Tidal variation of Moon's declination in nodal 18.61 years cycle, exact coincidence of earthquakes 26.XII.2004 and 27.XII.1985 (Figs 12 a, b) suggested 19 years Metonic cycle and non existence of such periodicities in past years resulted in the most probable solution of simultaneous action of both periods in beats offering enormous energy for tides triggering. Beat *s* of close periods t_1=18.61 and t_2=19 yeas occurs $s = t_1 \times t_2 / (t_2 - t_1) = 18.61 \times 19(19\text{-}18.61) = 900.6$ *years.* Therefore enormous earthquake over 9th magnitude can be expected after 900 years. (Ostřihanský 2015).

In previous section, it has been emphasized that high Moon and Sun declinations exert the strongest tidal torques, which can trigger strong earthquakes. This is not everything. It is necessary to consider Moon and Sun and Earth configuration. . The largest Moon's declination has occurred 28.IX.2006, +28°43´, in Moon's major standstill. High Moon's declination occurred also 26.XII.2004, 27.69° and again in Full Moon 31.XII.2009, 25.49°. Therefore, in both cases there are favorable conditions for earthquake triggering. Nevertheless, earthquake 31.XII. 2009 did not occur.

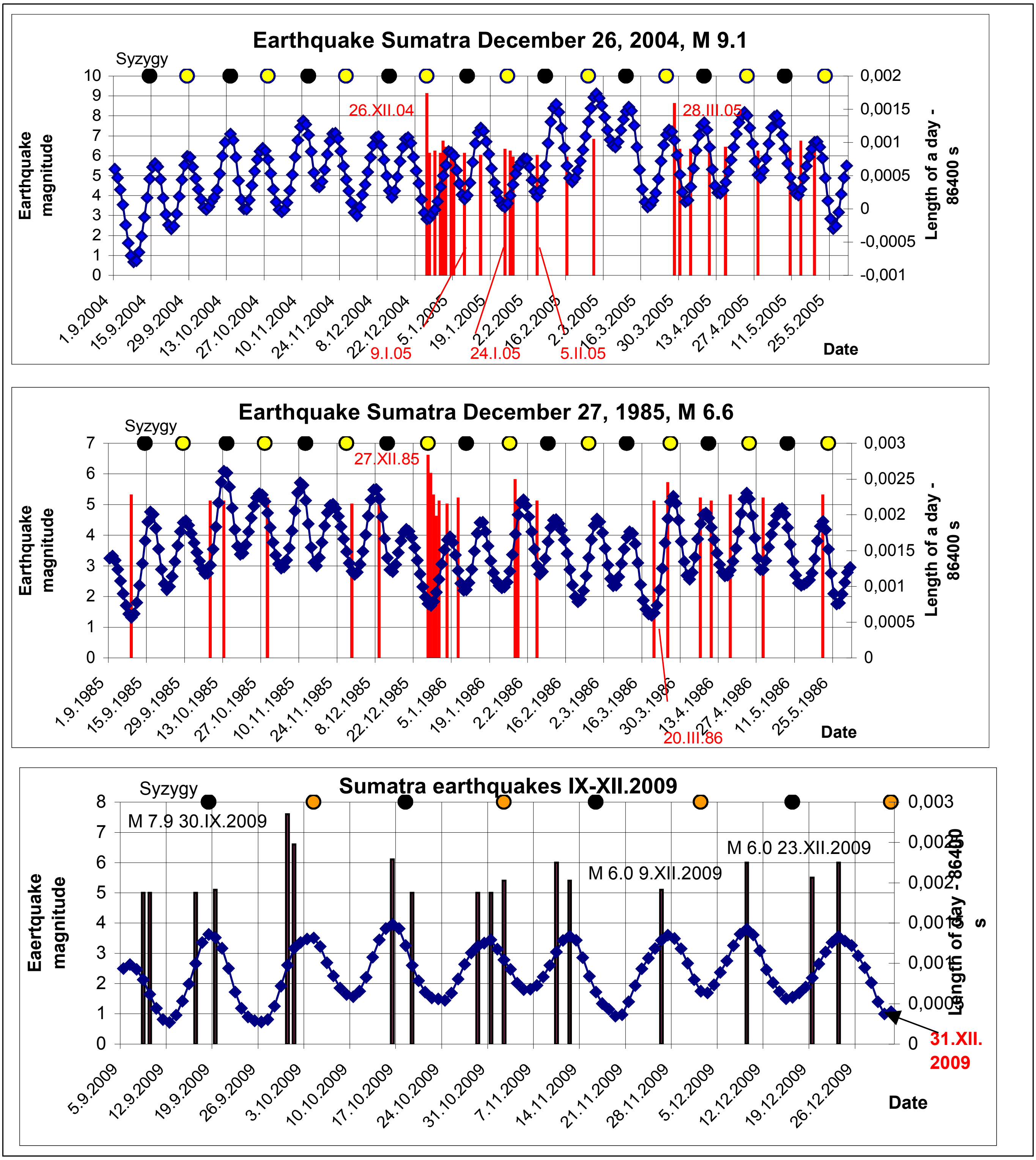
In case that Moon's declination of 31.XII 2009 were negative, the answer were easy. However Moon's declination is positive 25.49° and Moon's torque is subtracted from Sun's torque of declination –23.10° of positive counterpart (Fig 5) and resulting torque is very favorable to trigger earthquake, but no earthquake. The answer is following:

Consider Fig. 12c from beginning in detail. First strongest earthquake M 7.8 30.IX.2009 is situated outside LOD minimum and this minimum has Moon's declination –26.15° with negligible Sun's declination owing to close position of autumn equinox. However shift confirms action of westward tidal friction. All next earthquakes are situated on LOD maximums corresponding to 0° Moon and Sun declinations and maximum tidal westward torque. For this reason there is no earthquake on LOD minimum 31.XII.2009.

For full elucidation consider earthquakes close to summer solstice 2010 Fig, 13. There are no constant LOD amplitudes as on Fig. 12.c or Fig. 10. Earthquake M 7.8 6.IV.2010 is situated on LOD minimum with negative Moon's declination –24.92° with one day shift. Effect of Sun is negligible owing to close position to vernal equinox and Moon in first quarter. Torque directs southward but next 12.42 hours northward, what is necessary direction for Indian plate movement. New Moon earthquake a

b

c



Earthquake Sumatra December 26, 2004, M 9.1
Syzygy
Earthquake magnitude
Length of a day - 86400 s
26.XII.04
28.III.05
9.I.05
24.I.05
5.II.05
Date
Earthquake Sumatra December 27, 1985, M 6.6
Syzygy
Earthquake magnitude
Length of a day - 86400 s
27.XII.85
20.III.86
Date
Sumatra earthquakes IX-XII.2009
Syzygy
Eaertquake magnitude
Length of day - 86400 s
M 7.9 30.IX.2009
M 6.0 9.XII.2009
M 6.0 23.XII.2009
31.XII. 2009
Date

Figure 12. Figs a and b show distinctive similarity of both earthquakes 26.XIII.2004 and 27.XII. 1985. Both are in Full Moon, on LOD minimums and have positive Moon declination over +27° and Sun's declination -23°favourable for earthquake triggering. Close dates suggest Metonic 19 years cycle. Fig. c shows the same favorable conditions for earthquake triggering 31.I.2009 but no earthquake. Explanation presents prevailing action of westward tidal drift to Sumatran subduction zone diminishing northward Indo-Australian late movement. Evidently, such conditions are in LOD constant amplitudes for several months

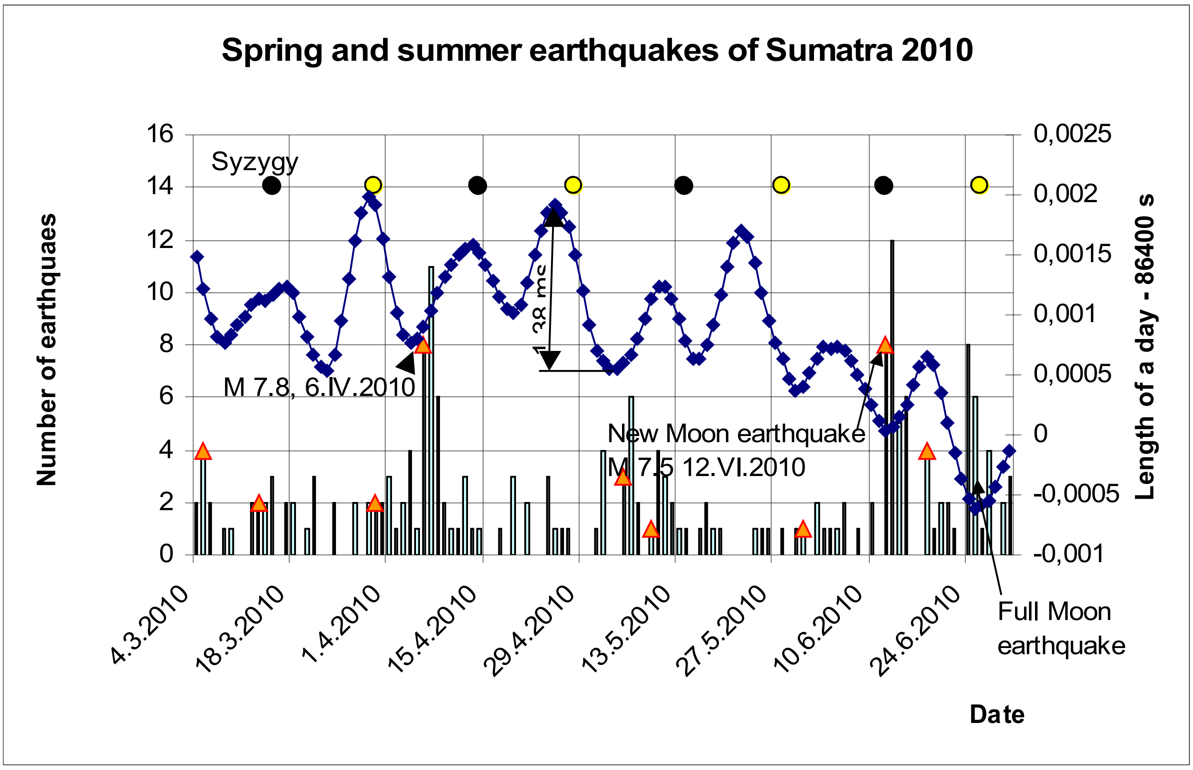


Figure 13. On contrary to /fig. 12, figure 13 shows very variable LOD amplitudes corresponding to high north-south torques. All earthquakes correlate with Full or New Moons where torques of Moon and Sun's counterpart are summarized.

M 7.6 12.VI.2010 is situated on LOD minimum with positive Moon's declination +24.94° and Sun's declination +23.13°. Summarizing both torques presents sufficient condition for triggering earthquake. Full Moon earthquake on next LOD minimum has 25.VI.2010 Moon's declination -25.01° and Sun's declination +23.39°. Because Sun's counterpart (Fig. 6) is negative, both negative torques are summarized and after 12.42 hours the torque directs northward, moving Indian plate and triggers earthquake.

Earthquakes triggered by resonance

Gorkha earthquake in Nepal has occurred in April 26, 2015 of 7.9 magnitude, causing devastating situation in vast area of Katmandu. Nobody would expect that in the lunar minor standstill, the second largest earthquake would occur. October 2015 was the time of lowest Moon's declination in 18.61-year period. Only detailed investigation of the LOD variations could reveal the answer, why this earthquake was triggered. The origin of this earthquake can be found with earthquake M 4.1 of 5. I. 2015, which was triggered in LOD winter solstice minimum, high positive Moon's declination 17.94° and exactly on Full Moon 5.I. 2015 (Fig.14). This confirms strong northward directing tidal toque. Final resonance earthquake M 7.8 is not situated exactly on LOD minimum but shifted for two days later and following after-shock earthquake May 12. 2015 M 7.3 is situated close to LOD maximum (point 6, Fig. 14) confirming increasing westward tidal torque.

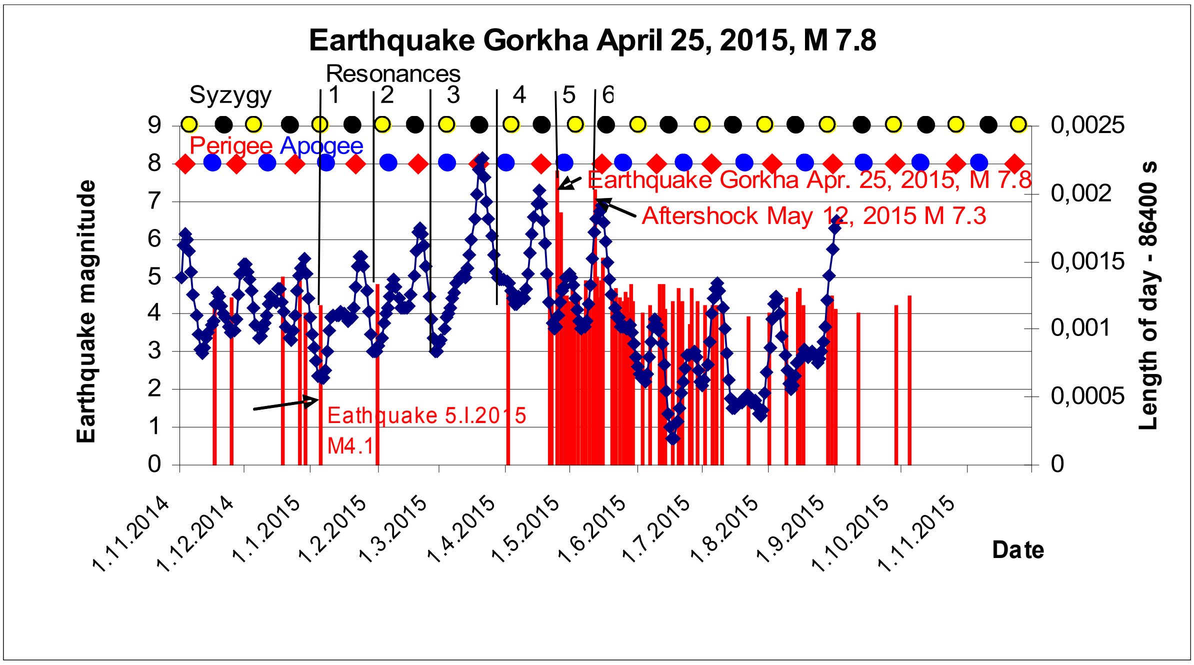


Figure 14. First earthquake of starting resonance has occurred 5.I.2015 marked by arrow and through points 1 – 5 increasing resonance effect triggered earthquake Apr. 25 2015 M 7.8.

Alaska earthquake on Denali Fault has occurred as repetition of earthquakes 1964, 1983, 2002 and 2021.It is evident as 6 maximum LOD peaks 1–6, Fig. 15. Earthquakes are situated on faults of W–E direction and therefore tidal westward component prevails and earthquakes correlate with LOD maximums. This of course is not always necessary explanation. Earthquake Chickaloon 31.V.2021 M 6.1 has been on LOD minimum whereas Large earthquake Chignik 29.VII. 2021 M 8.2 correlated with LOD maximum (see last paragraph).

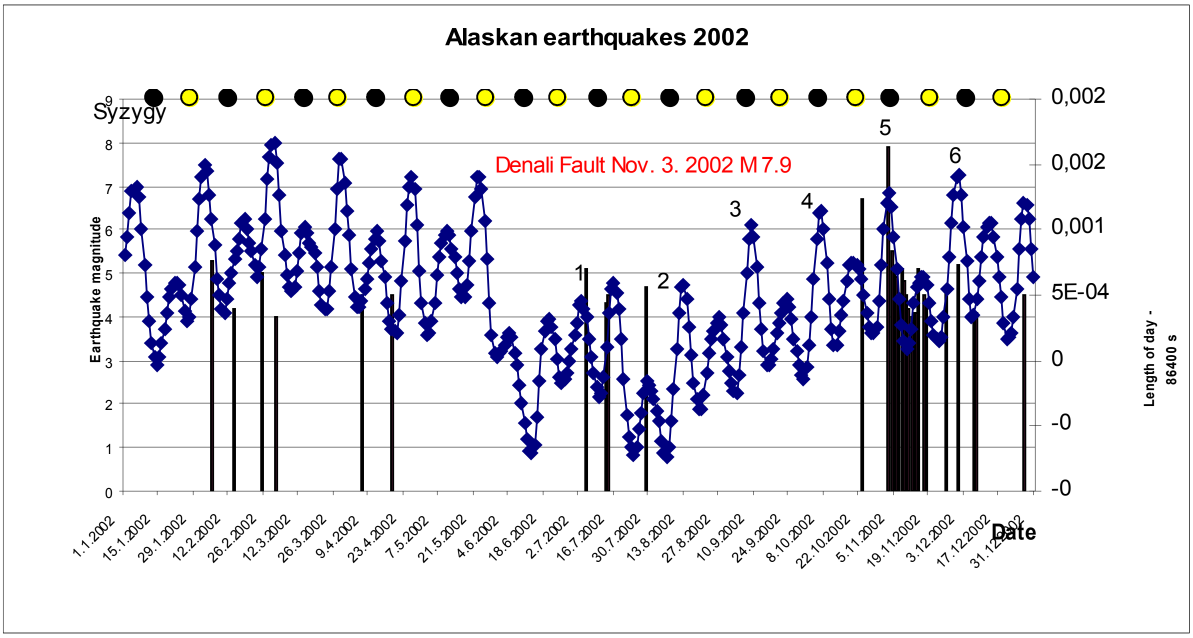


Figure 15. Numbers 1– 6 show increasing resonance effect. Number 5 corresponds to large earthquake M 7.9 3.XI.2002 on Denali Fault.

Movement along Denali Fault

18.61 years earthquakes tidal periodicity along Denali Fault or its sub parallels is caused by westward tidal component of Pacific plate movement. However, to this region the North American plate also approaches. It is very instructive to see, which different tides caused the periodic earthquake triggering, The last periodic earthquake 31.V.2021 (Ostřihanský 2021a) has been triggered on LOD minimum with Moon's declination –21.77° (effective possible 27°) and Sun's declination +21.91°, what for Full Moon 26.V.2021 gives very strong north-south torque. Following earthquake Chignik occurred M 8.2, 29.VII.2021 on LOD maximum. At that date Moon's declination –1.74° and Sun's declination 18.74° and Moon in Last Quarter convincing maximum tidal friction and westward movement of North American plate. Considering eastern side of North American plate in Haiti region, earthquake M 7.2 14.VIII.2021 (Fig. 22A), (Ostřihanský 2021b), which has been triggered at 12:29:08 UTC and Alaska earthquake M 6.9 in Alaska Gulf 14.VIII.2021 at 23:50:09 UTC, both earthquakes are on LOD maximum (Fig. 22 A red points), as well as earthquake M 5.4 14.VIII.2021 on Mid-Atlantic ridge (see Fig. 22 C), then this movement and corresponding times confirm the whole North American plate movement from mid-Atlantic ridge to its front colliding with Pacific plate.

Because movement along Denali Fault is right-lateral, it is evident that this movement is driven by Pacific plate, which has distinctive northward and westward components. Action of both components caused shift of tidal repetition for five years in minor lunar standstill of 18.61 years periodicity. All periodic earthquakes are situated on Denali Fault or its sub parallels ending with M 6.1 Chickaloon 31.V.2021, but earthquakes M 8.2 Chignik 29.VII.2021 and M 6.9 Alaska Gulf 14.VIII.2021 are directly situated on Pacific plate and not in Aleutian subduction zone, where periodicity is not evident and earthquake prediction impossible.

Repetition of earthquakes in Central Italy

The most convincing proof of tidal triggering of earthquakes in Central Italy is the periodic repetition of earthquakes: Norcia 1979, Colfiorito 1997 and Rieti 2016 in nodal Moon's 18.61 years period.

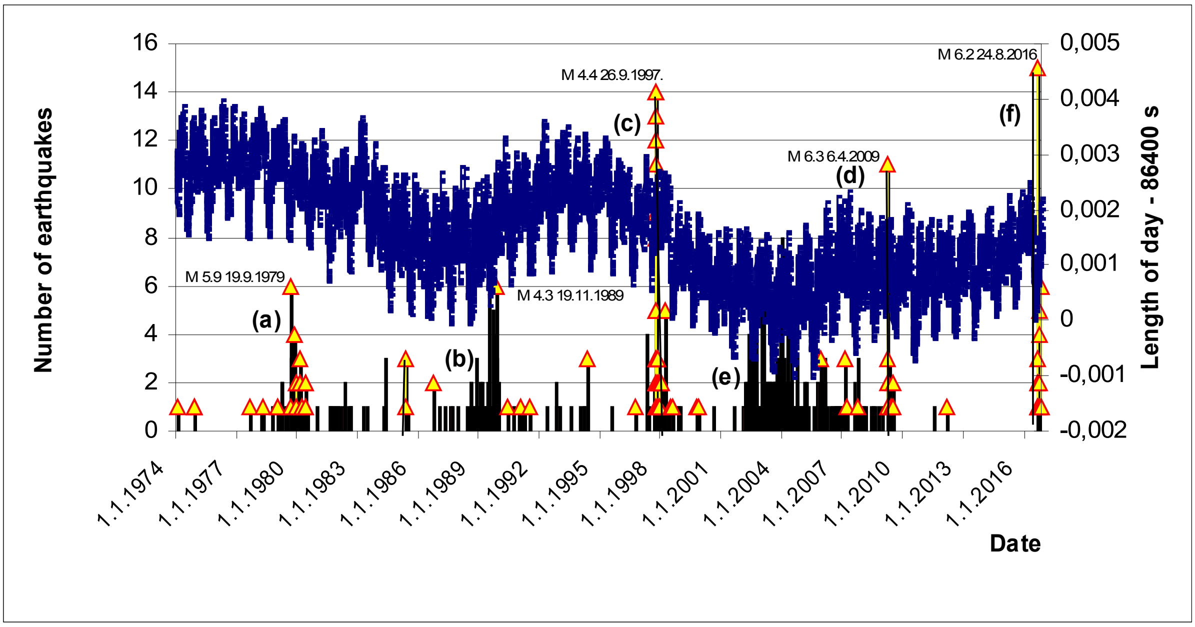


Figure 16. The length of a day record and the occurrence of earthquakes in the Norcia-Marche-Abruzzi region for the period 1974-2016. The areas of increased earthquakes activity correspond to the Norcia 1979 (a), Norcia 1989 (b), Colfiorito 1997 (c), L'Aquila 2009 (d) and Rieti 2016 (f) earthquakes and to the continuous earthquake period 2002-2005 (e) of maximum Earth's rotation. Earthquakes of magnitude M>4 are marked by triangle..

Earthquake L'Aquila 2009 M 6.3 and extreme Earth's rotation in 2002-2004 this repetition disturb. Details of repetitive earthquakes show Fig. 17. The cause of periodic earthquake repetition follows from author's tidal triggering mechanism (Fig. 11). Because the Eurasian plate does not move in north-south direction, the moving force is tidal friction, which moves Eurasian plate westward. Tidal friction is dominant when Moon acts on equator because in minor lunar standstill Moon's tidal friction acts in narrow belt ±18° along equator. This period is the most effective for earthquake triggering. To earthquake triggering also Sun's tides contribute and because Sun is situated on equator during equinoxes, earthquakes are triggered close to 21. September or March. Following table: presents review of minor lunar standstills.

Minor lunar standstills

Date	Negative declination	Date	Positive declination
1979 March 21	-18.316	1979 March 07	18.301
1997 March 31	-18.153	1997 March 16	18.142
2015 September 21	-18.134	2015 October 03	18.140
2016 March 03	-18.210	2016 March 16	18.206.
2034 September 21	-18.177	2034 September 06	18.184

Table 1.

The first member of tidal minor lunar standstill has occurred M 5.9 19.9.1979 after Moon's minimum declination 18.8° 15.9.1978, i.e. 4 days before earthquake, as evident from Fig. 17a ($LOD_{min.}$) and other parameters important for earthquake triggering in Table 2.

The second member has occurred M 4.4 26.9.1997 after minimum DE 18.2° 24.9.1997, Fig. 17b, ($LOD_{min.}$) and other parameters in Table 2. Figure 16b presents also earthquake M 5.5 14.10.1997 and LOD_{min}. 7.10. Earthquake M 5.5 14.10.1997 is evident also in details in Fig. 17c.

Conditions for minor lunar standstill earthquake triggering

Year	Date	Subject	Moon DE(°	Sun DE (°	Moon Sun AR_{differ}.(°
1979	15.9.	$LOD_{min..}$	18.822	3.342	69.3
	19.9	M 5.9 Norcia	10.866	1,771	18.7
1997	24.9	$LOD_{min.}$	18,247	-0.396	83.9
	26.9.	M 4.4 Colfiorito	15.736	-1.239	58.5
	7.10	LOD_{min}	-17.241	-5.632	-59.9
	14.10	M 5.5 Colfiorito	-0.962	-8.312	188.5
2016	14.8.	LOD_{min}.	-18.364	14.287	-123.7
	24.8.	M 6.2 Rieti	12.096	11.021	108.4
	22.10	LOD_{min}	18.060	-11.127	97.0
	26.10	M 6,1 Rieti	4.508	-12.784	41.0
	30.10	M 6.6 Rieti	-8.446	-13.932	3.8

.

Table 2. Legend: DE(° - declination in degrees, $AR_{diffwer.}$(° - difference of right ascensions in degrees, $LOD_{min.}$ – minimum on length of day curve before earthquake triggering.

The last member of earthquake periodicity has occurred as M 6.2 Rieti 24.8.2016, 10 days after LOD minimum 14.8. Table 2 last column shows angle between Moon and Sun. Extreme positions show only earthquake M 5.5 Colfiorito with 188° close Full Moon. Sun acts contra productively owing to the same sign as Moon (see Fig. 2) Nevertheless strong westward tidal friction force evoked by strong force of low declination –0.962°, with Moon situated almost on equator, is sufficiently strong to trigger earthquake. All these effects confirm author’s theory about north-south effective support movements and weak westward tidal friction, which is introduced in movement. Even tectonic map of Central Italy confirms this movement showing north-south tectonic faults, but movement is westward forming thrusts over these faults, confirming westward movement of Eurasian plate overriding subduction zone of Tyrrhenian oceanic plate.

a

b

c

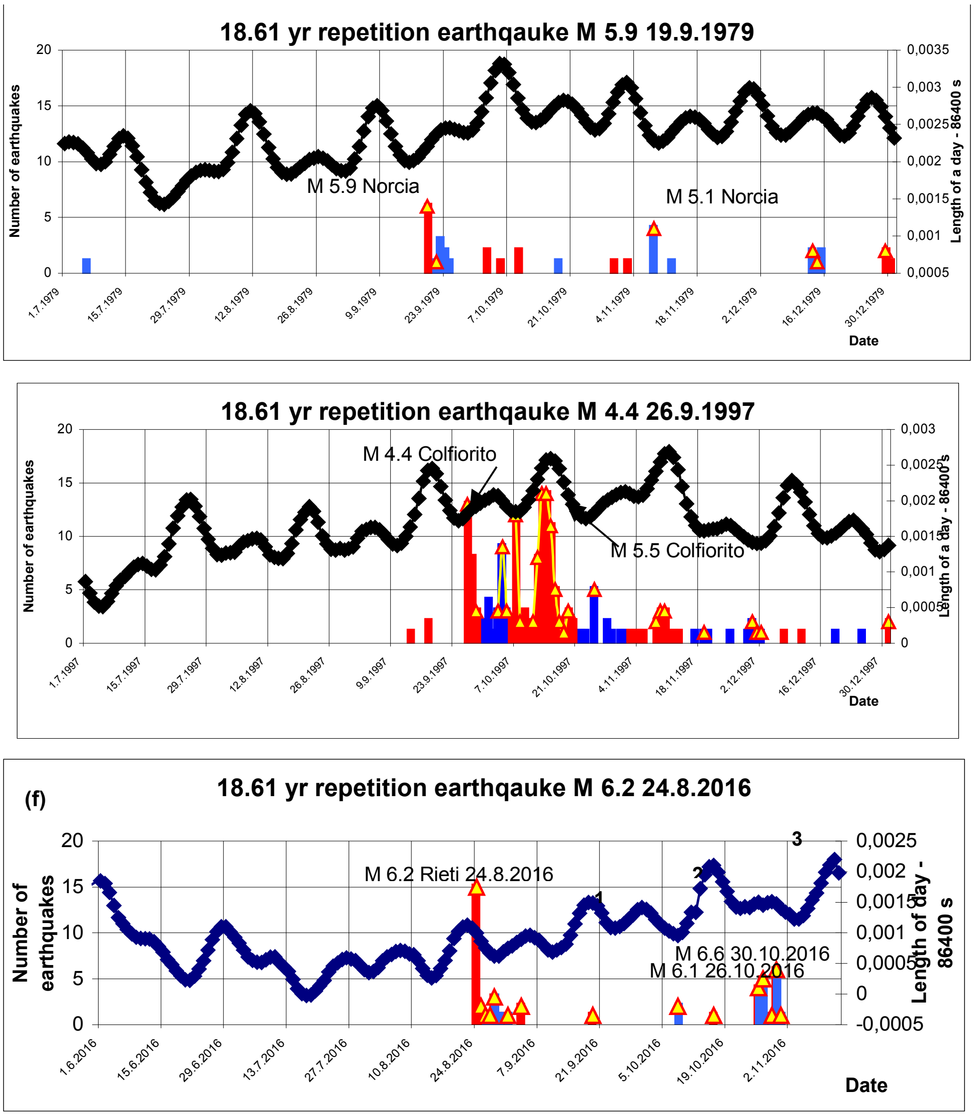


Figure 17. Members of minor lunar standstill 18.61 years repetition. Fig. a shows first member, which has occurred M 5.9 19.9.1979 after Moon's minimum declination 18.8° 15.9.1978, i.e. 4 days before earthquake. The second member has occurred M 4.4 26.9.1997 after minimum DE 18.2°, 24.9.1997, Fig. 14b. The last member of earthquake periodicity has occurred as M 6.2 Rieti 24.8.2016, 10 days after LOD minimum 14.8, Fig. c.

24.83 hours repetition of earthquakes in subduction zones

Similar 24.83 hours repetitions occur before strong earthquakes in subduction zones. This has been discovered by Tanaka (2012) confirming statistical correlation of periodic earthquake occurrence for several years (10 years) in great Tohoku earthquake 11. III. 2011. Comparison with LOD graph shows (Ostřihanský 2012) group of earthquakes concentrated in positive Moon declination of LOD minimum consequently occurring in subduction zones Sumatran, Chilean and Japan (Fig.18). Close 24.83 hours repetition before Tohoku M 9.1 earthquake 11.III.2011 earthquake is evident on Fig. 18. Dispersion of earthquakes in LOD minimums confirms number of foreshocks and of course of aftershocks.

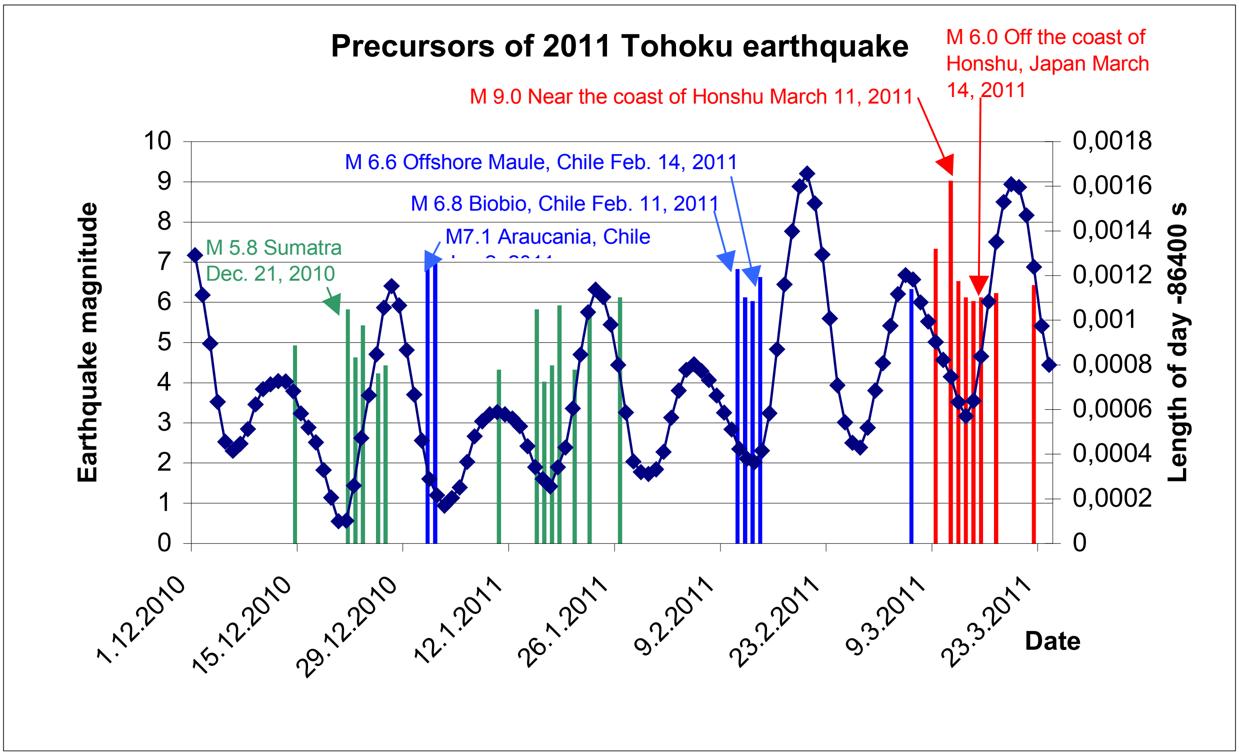


Figure 18 shows consequent earthquake occurrence of Sumatran, Chilean and Tohoku subduction zones from 2010 to 2011 in LOD minimums under Moon's positive declination. M 7.1 Aracaunia 2.I.2011 is out of correlation.

Repetition of earthquakes in South-Central Alaska

Owing to action of tidal forces acting in two components north and west, repetition of earthquakes in contrast to repetition with lunar minor standstills, earthquake along Denali Fault or along parallel faults with it, repetitions are for 5 years delayed. In Central Italy, there is only westward movement because Eurasian plate moves only westward. Because movement along Denali Fault is righ- lateral, it is evident that the Pacific plate influences this movement, moving north and west. Repetition started

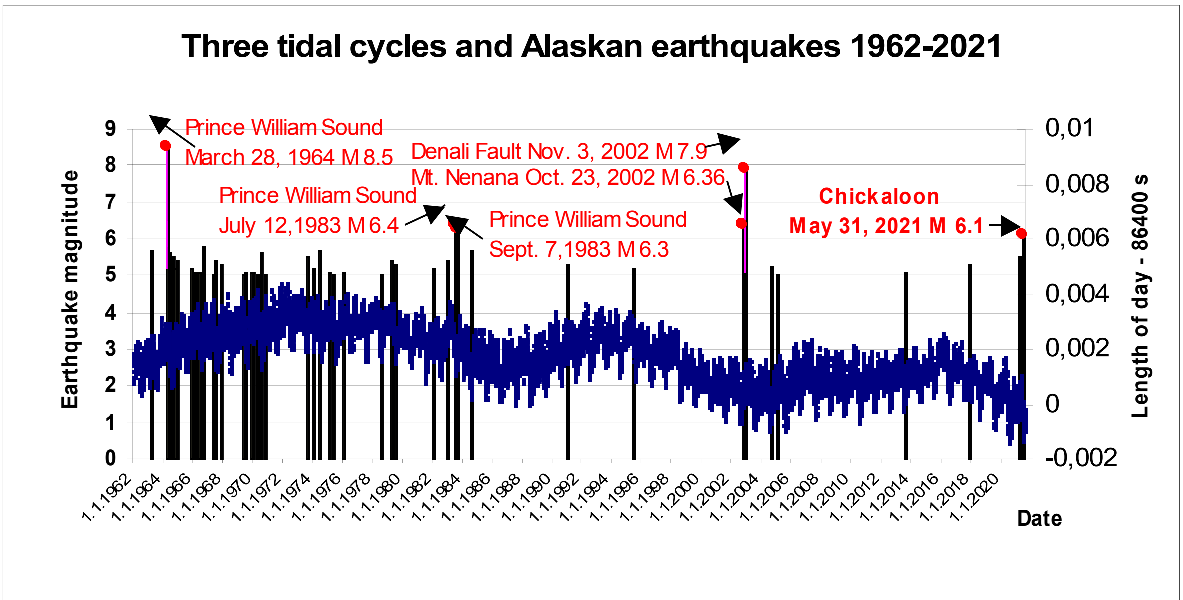


Figure 19 shows repetition of earthquakes M 8.5 Prince William Sound 28.II.1964, M 6.4 Prince William Sound 12.VII.1983, M 7.9 Denali Fault 3.XI.2002 and M 6.1 Chickaloon 31.V.2021.

with earthquake M 8.5 Prince William Sound 28.III.1964 then continued with M 6.4 Prince William sound 12.VII.1983, M 7.9 Denali Fault 3.XI.2002 and ended M 6.1 Chickaloon 31.V.2021 (Fig. 19). Details of different earthquakes show Fig. 20.

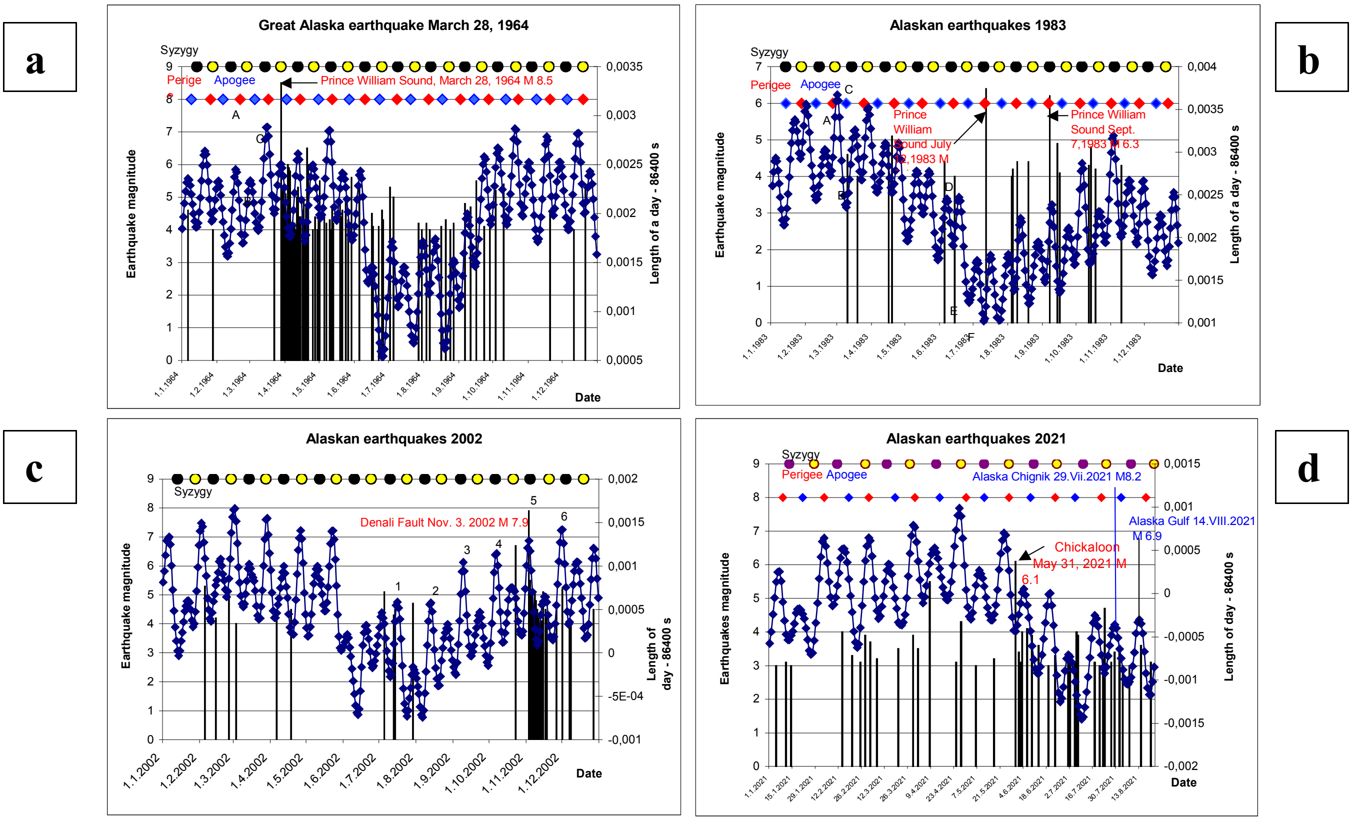


Figure 20 shows different characteristics of earthquakes South-Central Alaska 1964, 1983,2002 and 2021.

Two strongest earthquakes M 8.5 28.III.1964 and M 7.9 3.XI.2002 were triggered on LOD maximum (i.e. Moon situated on equator) and close to equinoxes, with Sun again on equator (Figs 20a,c). Earthquakes triggered close to summer solstice M 6.4 12.VII.1983 and M 6.1 31.V.2021 (Figs 20b.d) are substantially weaker and triggered on LOD minimum with high Moon' declinations +21.3° and -21.8°. Therefore, it is possible to suppose that the strong earthquakes were triggered by westward component of Pacific plate and weaker earthquakes by northward Pacific plate component driven by respective tides. In second half year 2021 two strong earthquakes outside of investigated area (see Fig. 20 d) were triggered M 8.2 Chignik 29.VII. 2021 and M 6.9 Alaska Gulf 14.VII. 2021 situated on LOD maximums, i.e. with Moon situated on equator with declinations –1.2° and –2.6°. Therefore after strong northward force, the strong tidal force followed causing westward movement, which acted also one year sooner, triggering earthquake M 7.8 Perryville 22.7.2020. This confirms strong tidal westward movement effecting not only earthquakes along

Denali Fault but also tectonic faults in the Pacific plate. More details about this problem will be solved in precursors of Haiti earthquakes in next paragraph.

Haiti earthquakes 2010 and 2021

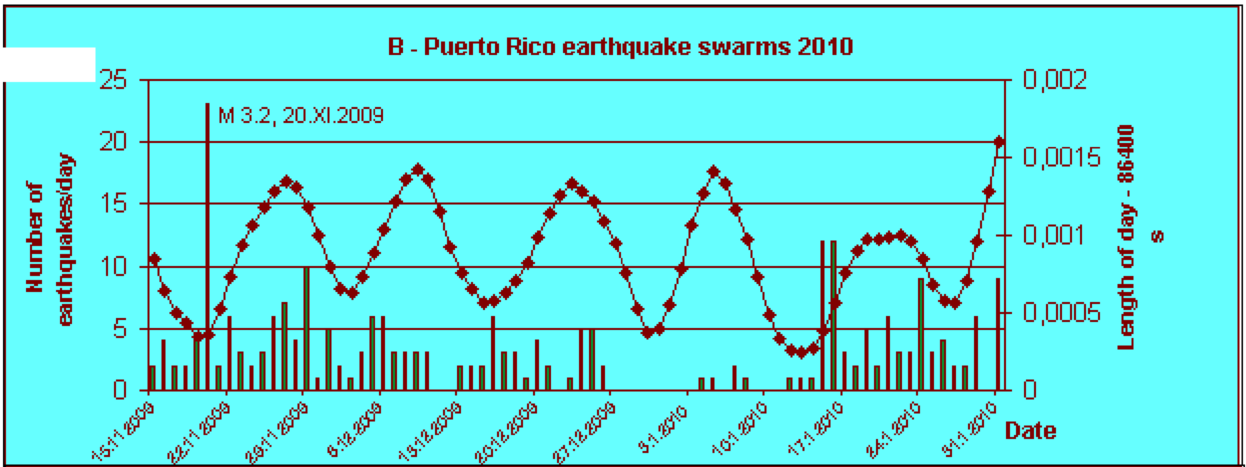
Earthquakes on Haiti and Puerto Rico earthquake swarms 2010 and 2021 could solve the problem why sometimes tidal north-south force and sometimes westward tidal drift act. Globally of course both forces act simultaneously, so earthquake occurrence is uncertain. For the first view, the earthquake Haiti 12.I.2010 is close to winter solstice when Sun's negative declination is high and if Moon's declination is high (for 12.I. 2010 is –21.5º) and if Moon and Sun are on one side close on New Moon position (15.I.), then summarizing both tidal torques earthquake can occur. However such tidal conditions could occur every year and why Haiti's both strong earthquakes have occurred after 200 years of quiet period. Solution can offer resonance effects. Resonance effects are well evident from LOD graphs. LOD graph (Fig. 21 A) shows LOD minimums, consequently increasing over small earthquake M 4.4 31.XII.2009, up to M 7.1 Haiti 12.I. 2010. Resonance effect is therefore evident after long time of quiet period. Resonance effect shows also earthquake M 7.2 Haiti 14.VIII.2021 (Fig.22 A), first correlated with LOD maximums on Mid-Atlantic ridge (Fig. 22 C), starting 18.VII.2021 with Moon's declination –0.8º and Moon's first quarter, eliminating effect of Sun and ending 14.VIII. 2021 in coincidence with triggering earthquake M 7.2, 14.VIII. 2021 on Haiti. Without resonance effect both earthquake Haiti 2010 and 2021 would not occur.

Conclusion

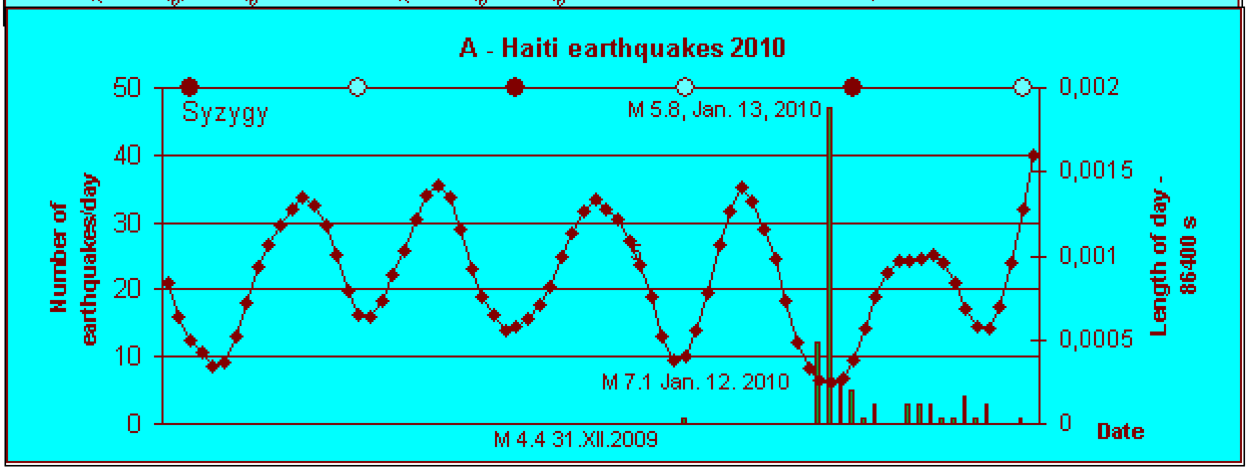
Every earthquake on the Earth has its origin in action of tides. Exceptions are in subduction zones where earthquakes are triggered by gravity subsidence and possibility to penetrate through hot mantle by bathyscaphe effect (Ostřihanský 2020a) or weak earthquakes in mountains compensating hydrostatic effect. Earthquakes are triggered by increased tidal effect in Full Moon supposing different signs of Moon and Sun and the same sign of torques in New Moon. Extreme tidal torques of north-south direction can trigger earthquakes themselves, on the contrary in westward tidal torques earthquakes are triggered if Moon and Sun are close to equator. If Moon and Sun move in narrow band ±18° of minor lunar standstill, this can create repetition of earthquakes in 1979, 1989. 2016 and 2034 of Central Italy and therefore to predict earthquake. Similar repetition but shifted for 5 years can be triggered if the plate is driven by two components northward and westward, as evident in South-Central Alaska, repetition is 1964, 1983, 2002, 2021 and 2040. These repetitions can be disturbed by resonance effect increasing earthquake triggering. Plates moving westward can collide with firmly anchored subduction zones and trigger earthquake almost daily in 12.42 hours rhythm. as in Hindu Kush, region of Puerto Rico swarms or eastern side of Aleutian subduction zone. Variation of Earth rotation do not trigger earthquakes but because they are caused by the same tides as lithospheric plates movement, their observation can point out on resonance effect triggering earthquakes. Also beats of tidal variation of close frequencies can trigger huge earthquakes occurring after 900 years in Sumatra. The greatest earthquake occurs in case when oceanic lithosphere is torn. This is the case of Krakatoa earthquake 1883 when Indo-Australian plate moving by tides northward was stopped in Indonesian subduction, but western part of the plate continued further to Himalayas (Ostřihanský 2020b).

Formation of subduction of oceanic lithosphere by overriding continental lithosphere represents no problem. Complication arises in case of steeply dipping oceanic subduction zones formed by gravity subsidence, Stumbling point is, where oceanic lihosphere is in contact with solid mantle. Conditions are created where contacting part is melted. Perhaps real burning creating large temperature being in contact with oxygen of water transfers heat into mantle and melting.. This melting continues consequently as far a core–mantle boundary. Reason is, that in contact decompression occurs, which causes melting in accordance with Clausius-Clapeyron equation and still heavier melt supports subduction.. Experience shows that subduction of oceanic lithosphere occurs either in very old oceanic part (Marianas) or in front of quickly northward moving plates Pacific or Indo–Australian, where tectonic faults were created (San Andres in America and Mentawai in Sumetra) with subsided oceanic part.

B



A



C

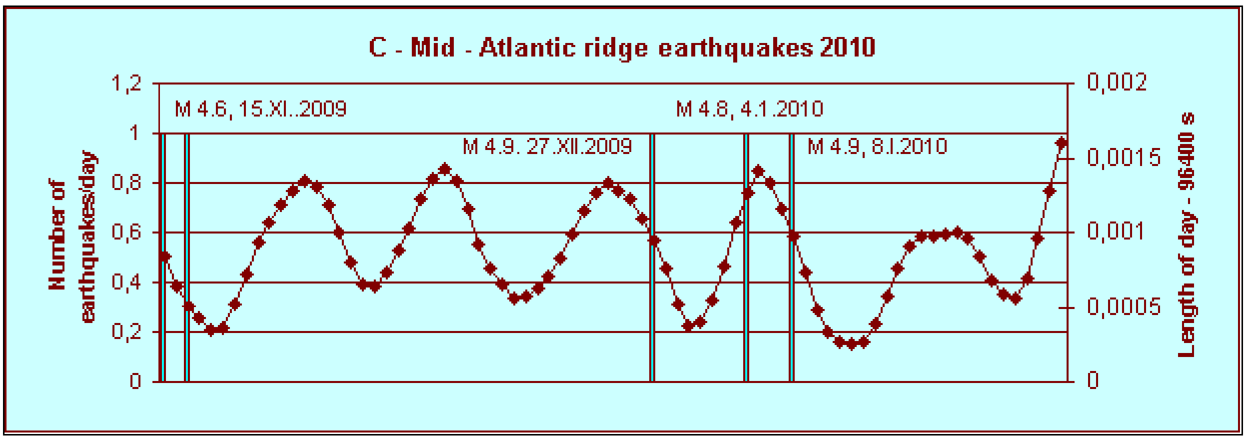


Figure 21. Haiti earthquakes during Earth's rotation acceleration (LOD_{min}). This character have also earthquakes on Puerto Rico swarms, whereas earthquakes on mid-Atlantic ridge are dispersed

.

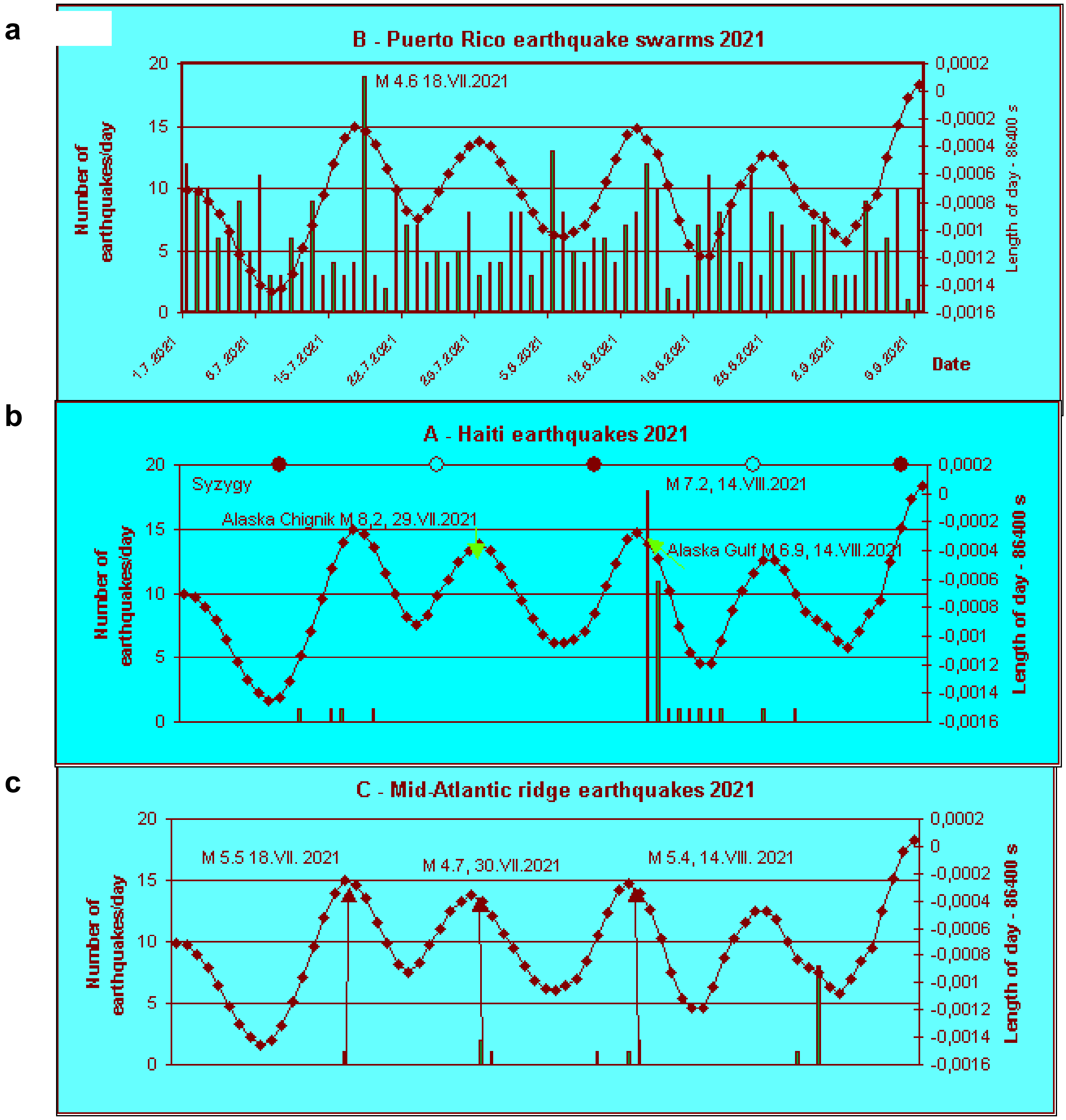


Figure 22. Haiti earthquakes triggered during Earth's rotation deceleration (LOD_{max}). Position of Alaskan earthquakes are marked by red points. All earthquakes Haiti, Alaskan, mid-Atlantic ridge and Puerto Rico swarms have the same character situated on LOD_{max}.

Appendix (Calculation of tidal forces)

Tidal forces acting on plates are following:
-Forces, which try to align the Earth's flattening to the level of acting tidal forces, i.e. to the planes of Moon and Sun orbits.
-Force, which brakes the Earth's rotation, i.e., the tidal friction.

1. Fig. 1 shows the action of the tidal force in its most effective action during the Sumatra earthquake 2004. The torque acting on the plate can be calculated in following steps (Brož et al 2012):

Earth's angular velocity $\omega = 7.29\ 10^{-5}$ rad/sec, Earth's moment of inertia $I = 8.036\times 10^{37}$ kg m^2 (Stacey and Davies, 2008). Earth's angular momentum $L = I\times\omega = 5.89 \times 10^{33}$ kg m^{2}s^{-1}. Mass of the lithospheric bulge is

$$m_{bulge} = \frac{1}{2}\left(\frac{4}{3}\pi abc - \frac{4}{3}\pi c^3\right)\rho_{crust} ,$$

where we insert $a = b = R_e \approx 6378$ km, $c = R - 21$ km, $\rho_{crust} \approx 2700$ kg m^{-3} and we get $m_{bulge} \approx 9.6 \times 10^{21}$ kg $\approx 1/624\ m_e$. (Earth's mass $m_e = 5.97 \times 10^{24}$ kg). The torque of force couple acting on the Earth is then: in case of the Sun (m_s, r_s Sun's mass and distance, G gravitational constant)

$$M_s = 2 \times \frac{2Gm_{bulge}m_s}{r_s^3} R_e \cos\varepsilon . R_e \sin\varepsilon , \qquad (1)$$

where $\varepsilon = 23.45°$ is the obliquity of ecliptic to equator. This is valid only in case if the mass of bulge were concentrated in one point on equator and the Sun were just in highest point above equator. In reality we should integrate over the bulge because some its parts are closer to the axis of rotation and to center over the Earth's rotation because the instant angle of the Sun above equator varies. We would get:

$$\overline{M}_s = \frac{1}{4} M_s \approx 5.7 \times 10^{21} \text{ N m}$$

The same calculation is for the Moon:

$$M_m = 2 \times \frac{2Gm_{bulge}m_m}{r_m^3} R_e \cos\iota . R_e \sin\iota , \qquad (2)$$

where ι is the Moon's declination (insert 23.45°). The result is $\overline{M}_m = \frac{1}{4} M_m \approx 1.2 \times 10^{22}$ N m. The torques simply summarize $\overline{M} = \overline{M}_s + \overline{M}_m = 1.8 \times 10^{22}$ N m.

This important result calculates that the torque 1.8×10^{22} N m is able to move the plate in north-south direction. The seismic moment of the Sumatra earthquake is 3.5×10^{22} N m (Varga and Denis 2010; Lay et al 2005; Stein and Okal, 2005). Because the torque exerted by tidal force acting on Earth's flattening represents the kinetic energy and also the seismic moment represents energy according to definition $M_0 = \mu AD$, where μ is the shear modulus N/m^2, D is displacement on area A, this quantity of N m dimension represents also energy, both quantities can be compared.

2. The torques of tidal friction were calculated by Burša (1987a), (1987b) on the basis of angular momentum balance in the Earth – Moon – Sun system.

$N_m = 4.2 \times 10^{35}$ kg m^2 cy^{-2} = 4.2×10^{16} kg m^2 s^{-2} = 4.2×10^{16} Nm

$N_s = 8.9 \times 10^{34}$ kg m^2 cy^{-2} = 8.9×10^{15} kg m^2 s^{-2} = 8.9×10^{15} Nm

The ratio of tidal torques of Moon and Sun therefore is

$$N_m/N_s = 4.7$$

According to Jeffreys this ratio is 4.9 (Jeffreys 1975). The Sun's share in tidal friction is only 21%.

The tidal fiction decelerates the Earth's rotation (Lambeck, 1977) and therefore it can be also considered as the force causing the westward movement of plates (Ostřihanský 2012a, 2012b Ostřihanský). The torque exerted by the tidal friction is relative low 10^{16} N m. (Burša 1987a) and considering the mantle viscosity only 2 orders of magnitude lower than the lithosphere (Cathles 1975), this force is considered as insufficient for the plate movement. But considering variable force (ad 1), acting on Earth's flattening, and tidal friction (ad 2) acting semidiurnally, then the westward movement is possible, owing to the north-south varying force ad 1, acting on it perpendicularly.

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