

Periodic Signals of the Milky Way Concealed in Terrestrial Sedimentary Basin Fills and in Planetary Magmatism?

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Abstract

Long periodic geodynamic processes with durations between 150 and 600 Million years appear to be in phase with similar galactic cycles, caused by the path of the solar system through the spiral arms of the Milky Way. This path is assumed by some authors to cause climate change due to cosmic ray fluctuations, affecting the cloud formation and the related albedo of the Earth, which periodically lead to glaciations every 150 Ma. With the glaciations, the sea level fluctuates accordingly. Subsequently, the varying sizes of shallow seas are causing periodic changes of the Moon's tidal dissipation, which affects presumably other geodynamic processes on the Earth. The Moon may therefore synchronize directly or indirectly long periodic Phanerozoic cycles (sea level, orogeny, magmatism, sedimentation, etc.) with the Milky Way. As sea level fluctuations, orogeny, sedimentation and magmatism can be described as members of a geodynamic feedback system; no apparent reasons appear to be required to assign a cause of the cyclicity to agents outside of the galactic-climatically synchronized Earth-Moon system. However, recent observations of young volcanism on the near Earth terrestrial planets may require a new understanding. Magmatic/volcanic episodes on Venus, Mars and Mercury as well as on the Earth's Moon are apparently contemporaneous thermal events accompanying increased magmatic/volcanic activities on the Earth, following a 300 myr cycle. Therefore, a collateral galactic thermal source within the Milky Way appears to be needed that only affects the interior of the planets without any recognizable direct effect on life and geology on the Earth. The search for such a source may lead to astrophysical questions, related to a spiral arm affected distribution of dark energy, dark matter or even specific neutrino sources. However, all possible astrophysical answers are outside of the author's competence.

Keywords

Milky Way, Spiral Arms, Planets, Sea Level, Magmatism, Climate Change

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1. Introduction

In the analysis of the Earth's history, including exploration activities for hydrocarbons, the investigation of geodynamic periodicities plays a crucial role (e.g. [1]-[19]). This includes obvious long-periodic processes like the repeated appearance of super-continents approximately every 600 million years [1] [20], and sea level-fluctuations (Figure 1), plate-tectonics and its magmatic and mountain-forming periods and also magnetic-field-variations, showing amplitude-maxima approximately every 300 million years with a very different phase-behavior.

Climate-fluctuations approximately every 150 million years [21]-[23] add a further dominant period (Figure 2), leaving behind anomalous sedimentary fills of evaporates [1] [24] and oolitic limestones [25] at least during the last 400 Ma (Figure 3).

During the Upper Jurassic, archived global sedimentation anomalies with the distribution of possible glacial sediments which hypothesize a temporary glaciation of areas near the poles also in the mainly warm Mesozoic [26], evaporates [27], oil source rocks and natural gas source rocks (after [28]) prove the periodic climatic control. Additionally, many further geological, geochemical and biological processes occurring over shorter periods are also very important [29]-[35].

The 150 million year periodicity of the climate cycle can be derived from two 300 million years' cycles that are phase-shifted by approximately 90° against each other, if both have a crucial influence on the climate. That is certainly the case for the global sea level fluctuations and the periodic expansion of continental mountain ranges, showing roughly such a phase-shift [36]. Very short-periodic processes that, for example, reappear in the sedimentation-pattern and in the appearance of maxima of ice age glacier expansions, are caused by planetary rotation parameters of the Earth around the Sun (Milankovic-cycles) (e.g. [37]-[41]). The short-periodic appearance of several ice ages in Europe and America during the last few hundred thousand years is used as an approximation for climate-fluctuations [42]. Also in a long-periodic view, climate-fluctuations on the Earth went along with intensive glaciations [43] [44]. The most-extreme glaciations in this view are the probable complete multiple freezing episodes of the entire Earth into "Snowballs" approximately 750 - 600 million years ago [45]-[48], plus/minus synchronously with the merging of most continents into the super-continent Rodinia and its following break-up [49] [50]. In that time, the continent-fragments of the Earth were covered with icecaps that were up to four kilometers thick. These icecaps temporarily contained volumes of up to 350 million km³ of frozen water [51] [52]. The sea was also most likely concealed by a mighty ice layer approximately one kilometer thick [53]. The water bound on the continents as ice must have led to a global drop of the sea level by several hundred meters. At this time the sea level would have possibly been approximately 300 m lower than today. The two (Neo

Sea Level Fluctuations

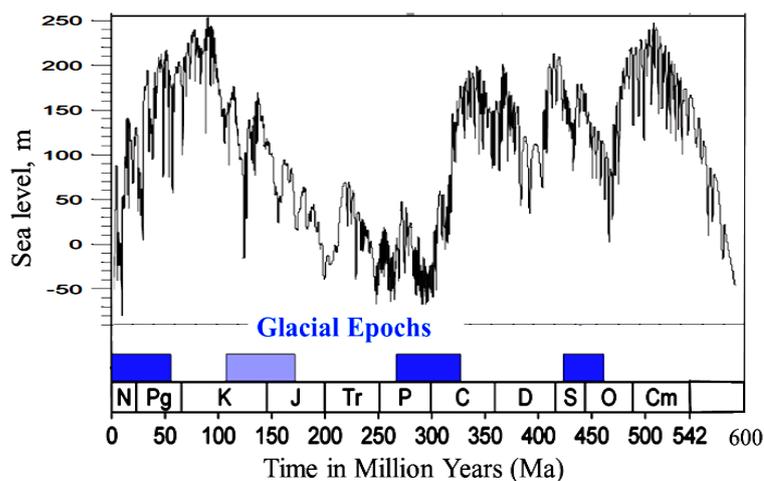


Figure 1. Exxon's sea level-curve with dominant ~300 Ma cycle (after [78]). A correlation with the sea level of influencing glacial epochs doesn't seem recognizable on the first gaze [54].

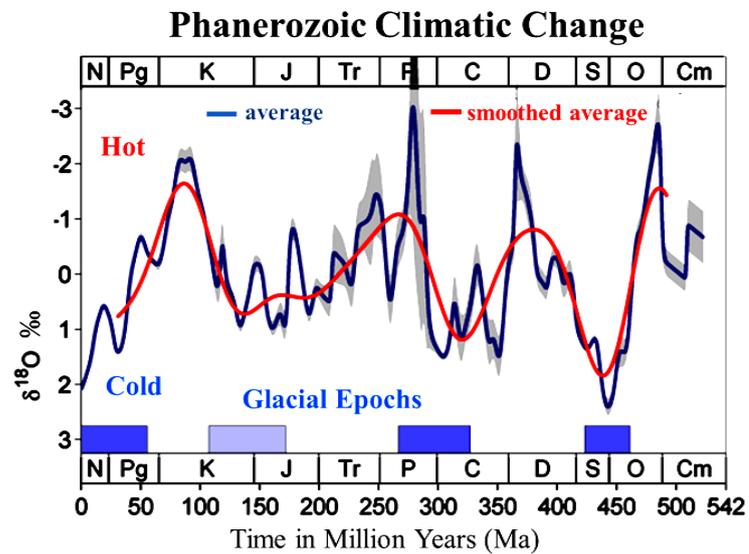


Figure 2. Climate-change in the Phanerozoic with dominant ~150 myr (million years) cycle of warm-times (greenhouse-epochs) and cold-times (glacial epochs) [58], derived from the analysis of the global distribution of oxygen-isotopes in carbonates. The relationship of the oxygen-isotopes with the mass-numbers 18 and 16 is temperature-dependent. In the evaporation-for example in the sea-water-the 16O-Isotope is preferred. The relationship of 18O:16O shifts, and the 18O-Isotope becomes relatively enriched in water. In cold-times relatively much 16O becomes stored in glaciers; in the sea-water, 18O rises relatively. Plankton stores the oxygen isotope relationship of the sea surface in its carbonate framework and takes it with its death down to the seabed as temperature-information [54].

Cyclic Evaporate- and Ooidsedimentation

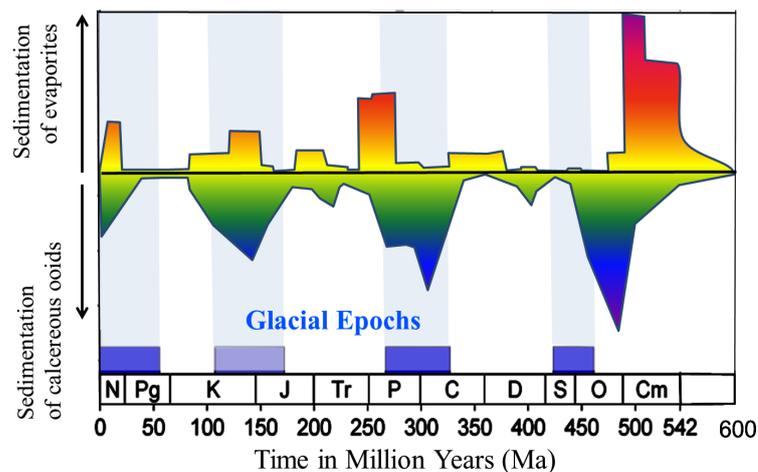


Figure 3. Sedimentation of evaporates in the Phanerozoic with ~150 myr cycle [1] [24]. Oolitic limestones show a similar distribution (scale inverted) [25]. At least, sedimentation-maxima correlate with glacial epochs for the last 400 million years [54].

proteozoic) Phanerozoic cycles, each approximately 300 million years in duration and of most different geodynamic settings, following the melting of the global “Snowball” glaciers with a noticeable time-shift, can be

linked together to an intrinsic feedback system, in which a crucial function can be assigned to the escaping Moon due to its tidal influence on shallow seas of shelf-areas (in the geological past up to four times larger than today) and the subsequent deceleration of the Earth [36]. This must presumably include also rotation-dependent slip processes at the core-mantle-boundary of the Earth. There was initially no apparent reason to assign a cause of the cyclicity to agents outside of the Earth-Moon system. However, this may be an incorrect assumption [54].

2. Galactic Periodicities

As a cause of the long-periodic climate-fluctuations of approximately 150 (range: about 137 - 176) million years references [21]-[22], [55]-[58] and others have assumed cosmic influences, derived from the oxygen isotope record of shells (brachiopods, belemnites, foraminifera) that is taken as a proxy for tropical sea-surface temperatures, and partly deduced from the exposure of iron-meteorites to cosmic radiation (Figure 4).

It is remarkable that the phase-shift attributed to this periodicity is very similar to the phase-shift of the approximately 300 million year-cycle of sea level-fluctuations with overlapping minima today. Cold periods of the Earth's climate, including glaciations, correlate with fluctuations of cosmic radiation-intensity related to the cyclic path of the solar system through the spiral-arms of the Milky Way. These spiral-arms contain dense interstellar gas and dust. They are birthplaces of stars including supernovas, whose remains serve as sources of the cosmic radiation that interact with the atmosphere of the Earth. This interaction leads to a production increase of condensation nuclei, followed by enhanced cloud formation, which creates an increase of the albedo of the Earth, enhancing reflection of solar energy back into space, which is thus connected to a subsequent cooling of the Earth's atmosphere. This cooling promotes the formation of continental glaciers and therefore a significant drop in sea level with the interplay of further influences like rotation-parameters of the Earth.

With four spiral-arms of the rotating Milky Way along the orbit of the sun (Figure 5), as suspected e.g. by [59], the circular orbit around the galactic center of the somewhat faster solar system lasts approximately $4 \times 150 = 600$ million years (range: $4 \times 137 = 548$ [21] to $4 \times 176 = 704$ million years [60]). Presently, the solar system is located in a small turn-off, the Orion-Spur, between the Sagittarius-Carina and Perseus spiral-arms [57]. Since apparently two alternating spiral-arms (Scutum-Crux and Perseus arms) with a higher gas- and dust-density exist which favors the formation of new stars and supernovas [61] and two alternating weaker ones

Spiral Arm Passageways and Glacial Epochs

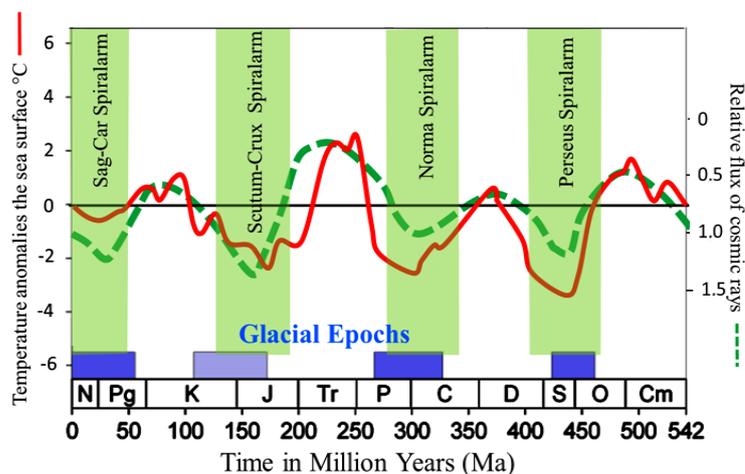


Figure 4. Phanerozoic cycles (~150 myr) of the temperatures of the tropical sea surface (red curve) with the division of greenhouse and glacial-epochs and the flux of cosmic radiation (green shaded curve, scale inverted), that correlate with the passageways of the Earth through the spiral-arms of the Milky Way. The resulting increase in the cosmic-ray-flux enhances cloud-formation by the generation of condensation nuclei. This leads subsequently to a temperature decrease. Iron meteorites are regarded as medium of the signal for the cosmic-ray-flux [21] [54].

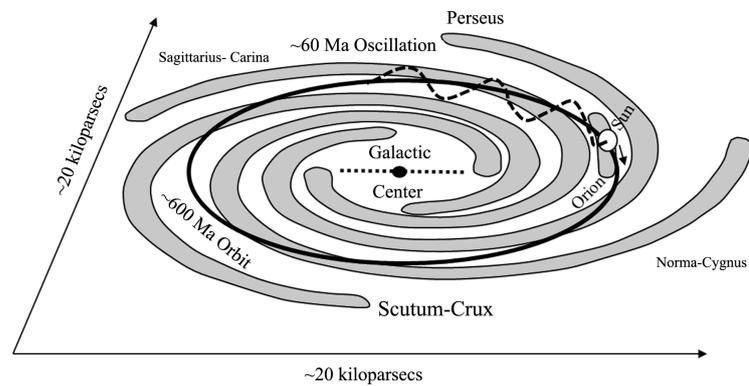


Figure 5. A depiction of the Sun's motion relative to the spiral arm pattern modified after references [57] and [60], oscillations are not to scale. Perseus and Scutum-Crux should show a higher gas and dust-density, Sagittarius-Carina and Norma-Cygnus a more inferior [61].

(Norma-Cygnus and Sagittarius-Carina arms), an overlaying spectral periodicity of approximately 300 million years emerges. The relative circulation-time of approximately 600 million years is the result of the different circulation-velocities of the solar system around the galactic center and the self-rotation of the Milky Way [57] and may cause a 600 million year spectral period, but which can also be attributed to a more elliptical orbit of the solar system. In corrected times, the solar system requires approximately 200 - 265 million years to orbit the galactic center. This value is dependent on how the distance between Sun and the galactic center is appraised (6.7 - 9.6 kpc, 1 kpc (kilo Parsec) \approx 3262 light-years), and how its rotation velocity is assumed ($195 - 255 \text{ km}\cdot\text{s}^{-1}$) [32]. Contemporarily the Sun executes oscillations with a cyclicity of approximately 60 million years which moves it out vertically from the Milky Way disk. Either it moves above the disk within the heading of the Milky Way towards the emitting galactic Virgo-cluster, or within the shadow of the Milky Way on the other side of the disk. In the first position, the solar system is the target of increased cosmic radiation due to an additional ray-flux. This movement is either regarded, or vehemently disregarded, as a cause for periods of increased extinction (e.g. [32]-[34] [57] [62]).

Approximately every 600 million years, the solar system returns back to the 'same' place in the Milky Way, and approximately every 200 - 265 million years to Milky Way independent coordinates. In a rhythm of approximately 200+ million years (apogee) the solar system gets closer to the dwarf galaxies of the Magellanic Clouds that orbit the Milky Way once every approximately 1600 million years (e.g. [63] [64]). Including the weaker influence at the perigee position within the Milky Way, an additional spectral period of 100+ Million years would occur. These Magellanic Clouds are bound by gravitational forces to the Milky Way and respond through their tidal forces by altering the shape of the Milky Way disk slightly [65].

Gravity disturbances possibly also have an influence on the path parameters of comets, asteroids and meteorites of the solar system, which can contribute to periodic frequency-maxima of cosmic impacts on the Earth and the Moon. By analyzing data from reference [66] on numbers and ages of spherules of Moon samples by a frequency-spectrum calculation, an elevated meteoritic bombardment from space took place roughly every 200 million years.

Besides possible gravitational influences through galactic rotation parameters, magnetic influences also have to be considered, since the Milky Way and its spiral-arms exhibit a complex magnetic field [67]-[69]. However, this is with strength of a few micro gauss along the solar orbit too weak in comparison to the strength of the Earth, with a value of approximately 0.5 gauss, so that a significant interaction can be negated.

The occurring periodicities in the solar system and Milky Way of approximately 600, 300, 200, 150 and 100 million years and the geodynamic cycles of the Earth show partially synchronous concurrences, which requires a detailed investigation. The assumption of random coincidence appears to be rather unlikely, however. Since the terrestrial cycles can hardly force a synchronization of the Milky Way, the question poses itself how the Milky Way can exhibit influence on the Earth. Due to their weakness, a contribution of gravity (tidal) and magnetic forces appears to be minor or unlikely. Answers can be found in the extended analysis of sea level-fluctuations

and their dependencies to climate change if one assumes climate change as a crucial cause for long-period terrestrial cycles. For this purpose, Exxon's standardized sea level-curve ([3] [10] [11] [13] [70]-[72]) will be investigated by analyzing its spectrum accordingly. Geodynamic processes, which also influence the global sea level, include the dehydration of mountain roots due to the inevitable metamorphism, varying volumes of mid-ocean ridges combined with alternating seafloor spreading rates, episodic widespread intraplate volcanism, and deposition of marine sediments (e.g. [9] [73]-[77]). All these processes are members of the global Phanerozoic feedback system of geodynamic cycles, in which the Moon is presumably involved as an external force [36].

3. FFT (Fast Fourier Transformation) of Exxon's Sea Level-Curve

In the framework of an analysis of sea level-fluctuations over 15 decades of frequency (inverse of period) reference [78] examined Exxon's sea level-curve and derived a noticeable power spectrum; however, without discussing phase-shifts assigned to related amplitudes. This paper aims to discuss these amplitudes and phase-shifts, supplementing his work. Since only longer periods are of interest here, the curve with the data of the last 600 million years is reduced by an appropriate sampling rate that appears to be sufficient for the analysis of further Phanerozoic cycles as well. Since $2n$ data-points must be available for the preparation of a usual frequency-analysis with the FFT (Fast Fourier Transformation), 64 data-points (26) can be generated by an interpolated sampling of every 9.375 million years for a period of 600 million years. Due to the Nyquist criterion that requires at least two data samples per period, the analysis terminates at a period of 20 million years. The length of the data-series of 600 million years defines the starting-period of 600 million years. The procedure determines a series of analysis-periods that were also used by reference [78] in his investigation. The length of the periods in million years follows the rule $600/n$, here with $n = 1 - 30$. The sequence is purely mathematically defined, however with the presetting of the geodynamic and galactic meaningful starting-period of 600 million years. All periods can be understood as approximations of the real period-spectrum. This type of analysis is admittedly questioned by reference [32] since time series-periods can appear as a result, even if they do not exist. From a practical standpoint, this uncertainty is hardly avoidable with a restricted observation time of an infinite time series [79]. In this work, a periodicity is assumed, if the amplitudes of (interacting) geodynamic processes vary over the available observation time (the last 600 million years) regularly.

The FFT was executed in MS-Excel[®] and the Fourier coefficients for the period-contributions of the individual sinusoidal functions were calculated. Afterwards the contributions of the individual periods, their amplitudes and phases, were investigated. To control, whether the input-curve is reconstructed again, the period contributions were summed up as a function of time under addition of the constant median value and with the necessary application of negative times (respectively negative periods). The concurrence between input-curve and output-curve was excellent. With the transformation, it became necessary to pay special attention to the calculation of the phases [80]. The analysis of Exxon's sea level-curve (for practical reasons taken from reference [78]) is shown in the following results (Figure 6):

1) Significant amplitude-contributions come from the 600, 300, 200 and 150 million year periods, where at the 300 million year period is the strongest. All periods show a range (amplitude) of approximately 100 m. The 300 and 150 million years periods are roughly in phase. The shorter periods also are important as a sum; however, per individual case, their contribution to the total-curve is in each case below 50 m.

2) The phases of the four large periods essentially govern the overall picture of the sea level-fluctuations. The width of the cyclic maximum between approximately 570 and 310 million years can be explained through the phase-shifted contiguous maxima of these periods.

3) A significant contribution of the 60 million year period that is related to the vertical oscillation of the solar system to both sides of the Milky Way disk has not been identified. The additional cosmic ray flux, generated by a galactic shock due to the motion of the Milky Way towards the Virgo-Cluster, did not change the climatic conditions on the Earth in the sense that detectable sea level fluctuations have occurred. However, muons produced within the shock bow have the capability to reach the Earth's surface and the bottom of the oceans and enhance the biological radiation dose [79].

4. FFTs of Selected Geodynamic Cycles

Similar characteristics emerge also with the analyses of plate tectonic processes like active margin magmatism and orogeny and of the history of the magnetic field of the Earth. For magmatism [18] the 300 million year pe-

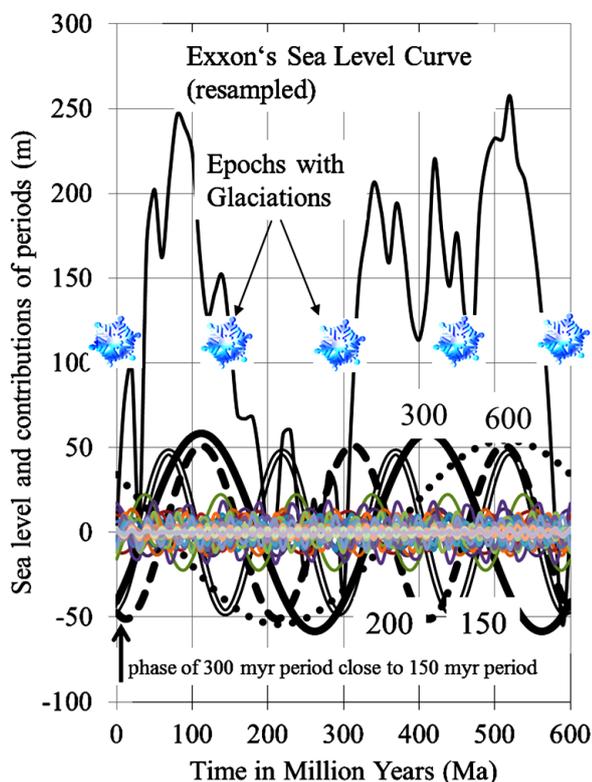


Figure 6. Analysis of Exxon's sea level curve by applying Fast Fourier Transformation (FFT), resulting in the resolution of contributing periods, their amplitudes and phases. Epochs with glaciations after references [43] and [44].

riod is significantly dominant while the contributions of the 200 and 600 million year periods are lower (**Figure 7(a)**). For the orogeny [36] the 300 million year period contributes dominantly, but also the 600, 200 and 120 million years periods deliver essential contributions to the overall picture (**Figure 7(b)**). The historic magnetic field [16] is essentially shaped by the 600 and 300 million year periods. Of middle importance are the 200 and 100 million year periods. All other periods do not show a considerable individual contribution (**Figure 7(c)**).

This is also true for the galactic-climatic period of 150 Ma. Indeed, the climate does not show any significant effect on geodynamic processes of the deeper interior of the Earth. However, the climate plays a dominant role for the sedimentation of hydrocarbon source rocks directly at the surface. This can be verified through the Fourier analysis of the Phanerozoic global distribution of organic carbon after reference [8] (**Figure 8**). The contribution of the "galactic" climate appears significantly recognizable in the amplitudes and phases of the 150 Ma period. During cold, galactic' epochs the contribution amplitudes of the organic carbon 150 Ma cycle are low, which points to restricted life conditions on the Earth. Glaciations of near pole areas and the extension of arid zones with the sedimentation of evaporates at lower altitudes may cause those conditions. However, just in these cold times the conditions for the sedimentation of later oil and gas source rocks may be preferable at selected places on the Earth. This becomes obvious by comparing the important intervals of source rocks after reference [28] with the result of the Fourier analysis of the organic carbon distribution after reference [8] (**Figure 8**). Four of the six large intervals correspond with the 150 myr (Million years) climate cycle and the remaining two with the geodynamic 300 myr cycle. In the second case the vicinity to the sea level or to the magmatic maxima appears to be so relevant that either one of them or both together govern the sedimentation process for source rocks in those times.

The concurrence between the analyzed dominant periods of the geodynamic cycles and the galactic prevalent periods is remarkable. Does this mean that a physical relationship between them exists? And if yes, what would it look like?

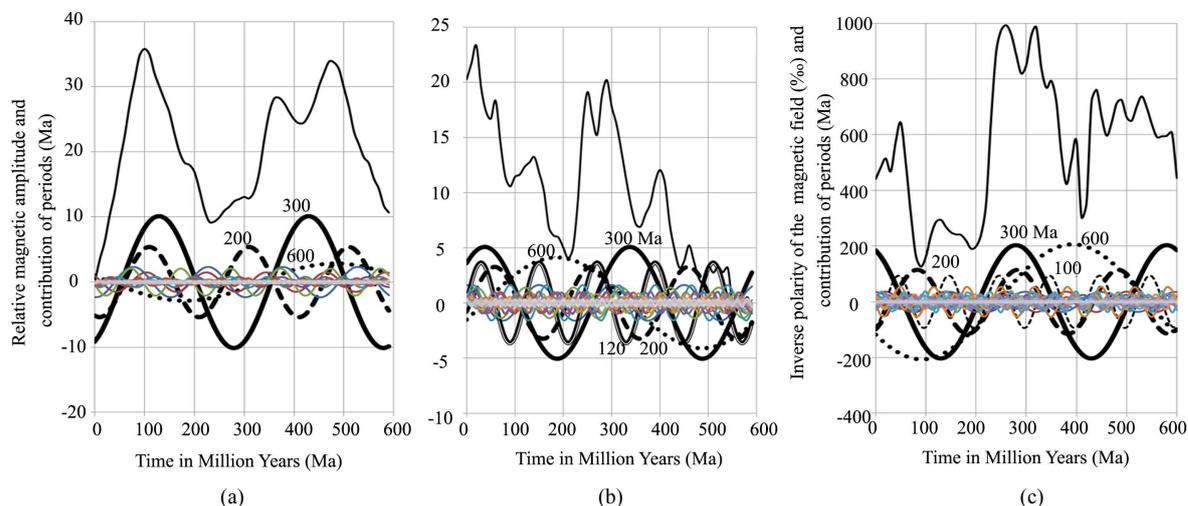


Figure 7. Geodynamic cycles and their spectral analysis [54] (a) Magmatism [18]; (b) Orogeny [36]; (c) Historical Earth's magnetic field [16].

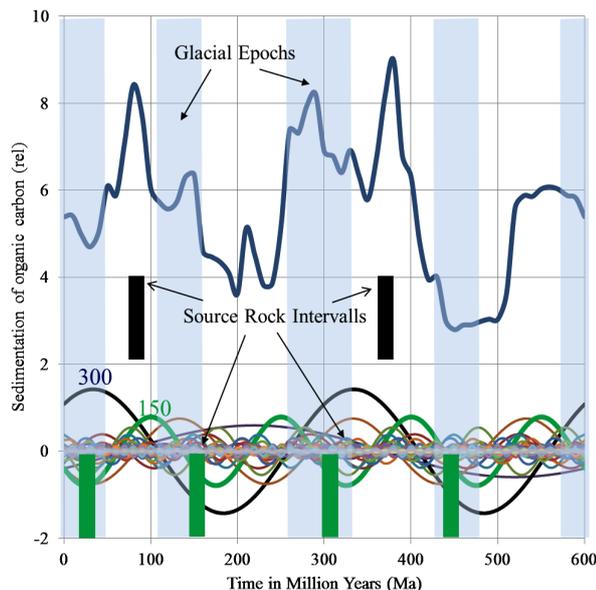


Figure 8. Fourier analysis of the sedimentation pattern of organic carbon after reference [8] and the dominant intervals for the sedimentation of petroleum source rocks after reference [28] that point to a 150 myr (climate, Milky Way; green) and a 300 myr cycle (sea level, magmatism; black) [54].

5. Planetary Magmatic Episodes

As shown above, a 300 myrcyclicity plays within the last 600 Ma a dominant role in galactic episodes as well as within (synchronized?) geodynamic processes, including sea level variations, orogenic epochs, and magmatic intensities. 2400 to 600 Ma ago a 400 myr period may have been more important as derivable from mineral ages on the Earth [19]. The Phanerozoic geodynamic processes can be seen as strongly related to forces that require the presence of oceans. However, in this sense it is certainly a surprise that volcanic activities on the ocean less Mars show intensity maxima similar to the maxima on the Earth about 100 - 200 and 400 - 800 Ma ago (Model of the Martian chronology (2008): [81]-[83]). To test whether this observation is a random coincidence, similar investigations for the other near Earth planets Venus and Mercury as well as for the Earth's Moon should be

screened. According to reference [84], the archived geologic history of Venus is governed by an event, which led apparently to a complete melting of the crust about 10% - 20% ago of her total age of about 4500 Ma. Since then, two magmatic maxima have been identified that appeared at relative times of about 0.1 - 0.15 and 0.5 of the melting time T . With $T = 900$ Ma (e.g. 20% of total age) volcanic intensity maxima have been occurred at 450 and 135 Ma ago that lie very close to the values of Earth and Mars. Also on Mercury comparable young volcanic events have been identified which age is interpreted preliminary to be around 650 Ma [85] [86]. Results of the newest satellite mission to Mercury that become available within the coming years may certainly verify or falsify this observation. Finally, newest results of an improved investigation of volcanic processes that happened on the Earth's Moon, lead to the assumption that the youngest events took place earlier than around 100 Ma ago [87]. All these compiled data contain the scientific hint that an increase of magmatic/volcanic activities on the near sun terrestrial bodies may have happened synchronously around 100 and 400 Ma ago with a time gap of the already intensively discussed period of 300 myr (Figure 9). The cause of the increased magmatic/volcanic activity may be related to the passages of the solar system through the denser spiral arms of the Milky Way, Perseus and Scutum-Crux.

Terrestrial magmatic activities [18] and mineral ages of the Earth [19] show a significant correlation for the Phanerozoic time (Figure 9). Therefore, it appears justified to use mineral ages as indication for long term global thermal events as well (Figure 10). In pre-Phanerozoic times instead of the 300 myr cycle a 400 myrcycle may have been dominant, either as intrinsic process within the Earth or possibly as galactic process, or both. Should it be a galactic process, then following changes may have happened around 800 to 600 Ma ago:

- 1) The solar system was forced to move inwards to an orbit through the spiral arms about 30% closer to the center of the Milky Way by keeping its rotational speed. A more or less constant speed appears to be required taking the effect of dark matter into account, since most stars in spiral galaxies orbit at roughly the same speed apparently in conflict with Kepler's third law ([88] and others), or

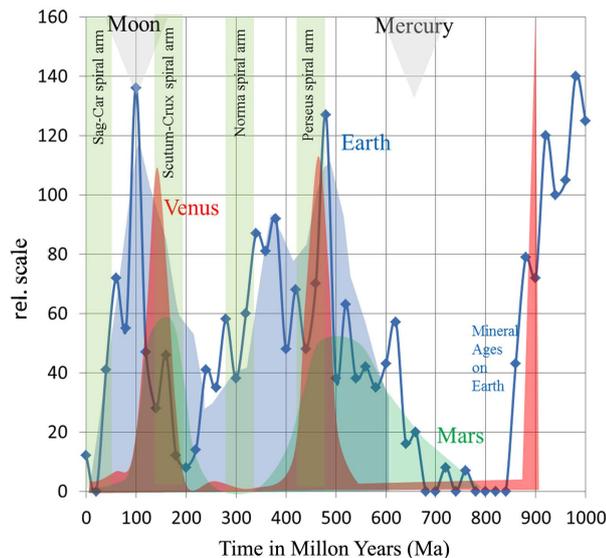


Figure 9. Compilation of magmatic/volcanic (heating) events on the Earth [18] [19], Mars (sketchy, model of the Martian chronology (2008): [81]-[83]) and Venus [84] during the Phanerozoic and Neo-Proterozoic (about the last 1000 Ma). It appears obviously that these planetary events are contemporaneous episodes that were accompanied by similar young magmatic activities on Mercury (possibly about 650 Ma ago [85] [86]) and on the Earth's Moon (possibly about 100 Ma ago, [87]), pointing to an extraplanetary (galactic) cause. The cause may be related to the passages of the solar system through the denser spiral arms Perseus and Scutum-Crux of the Milky Way with a 300 myr cycle.

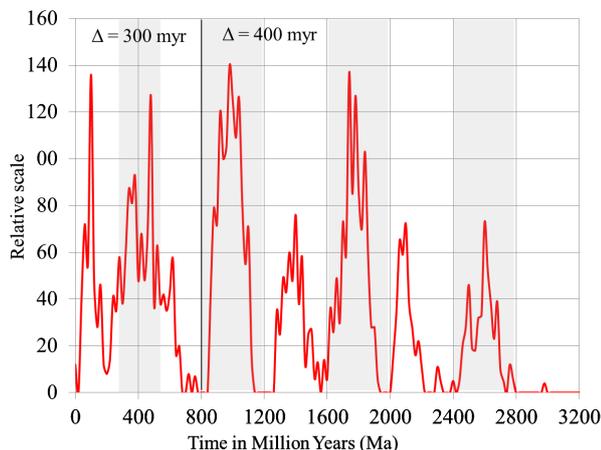


Figure 10. Mineral ages on the Earth after reference [19], showing a Phanerozoic 300 myr cycle and a preceding 400 myr cycle.

- 2) the solar system kept its orbit by getting forced to move faster, or
- 3) the rotating spiral arms were forced to slow down without affecting the rotation of the solar system or
- 4) a redistribution of the dark matter within the Milky Way, affecting the speed distribution of Milky Way and its stars, or
- 5) a combination of all, or
- 6) something else.

6. Discussion

Assuming, the approximately 150 million year cycles of climate-fluctuations on the Earth are of galactic origin, in which water is taken from the ocean in spiral-arm-controlled cold-times and subsequently deposited on the continents as ice, what would be this physical effect look like? The 150 million year cyclical-contribution of the sea level-fluctuation supports this assumption due to the similar phase between them. It is overlain by the 300 million year period with a comparable phase that results from the 2×2 -spiral-arm-structure of the Milky Way. Both together cause the sea level to fluctuate by up to 200 m. The dropping of the sea level in cold times reduces the share of the shallow-seas on the Earth and with it the tidal dissipation in shelf areas, through which the Moon influences the rotation of the Earth. This influence most likely alters the slip between the Earth's mantle and core and should consequently have an effect on the forming of the Earth's magnetic field. Interventions at the core-mantle-boundary may surely also influence the convection-cells in the mantle; however, surplus heat is transported through them from the core to the surface. Alterations of the properties of the convection-cells should influence plate tectonic processes with magmatism at active plate margins and the resulting orogeny [36]. Their cyclicity follows the sea level-fluctuations directly and therefore presumed "galactic" climate-fluctuations indirectly. The Moon acts in this sense as synchronization tool for the Milky Way, that allows the Earth to react in a common mode, and adjusts the intrinsic geodynamic processes and their phase-characteristics to the ruling galactic processes.

However, tentative contemporaneous magmatic events on all terrestrial planets including the Earth's Moon point to a ruling process outside the interior of the planetary bodies. The 300 myrcyclicity relates it presumably to properties of the rotation of the solar system around the center of the Milky Way. Heating of the planets by extraterrestrial forces and the subsequent magmatism requires processes not yet assumed. Following the discussion on dark matter and dark energy, respectively, as well as on neutrino astrophysics, a spiral arms related distribution of the dark entities or neutrino sources within the Milky Way or something else has to be assumed, should they be responsible for the observed planetary events. However, further investigations are needed to clarify any of those cosmic causes and which physical processes could have happened. Heating up the interior of the Earth by forces that do not directly affect life and geology at the surface, appears to be required. Do e.g. specific neutrinos interact with the iron inside the Earth by transferring thermal energy or are the dark entities able

to carry it out?

7. Conclusions

Data regarding global sea level-fluctuations, collected predominantly by scientists of the international petroleum industry, and compiled by Exxon (see [3] and others) to form an elaborate curve, contain long-periodic signals of the Milky Way in the period-range of 600 million years and shorter. They allow us to assume that geodynamic processes on the Earth are synchronized with solar-galactic rotation-properties via climate driven sea level fluctuations, and depending on them, tidal forces of the Moon. The investigated geodynamic cycles, sea level fluctuations, orogenic periods, rhythms of magmatism at active plate boundaries and long term magnetic field variations show a dominant period of 300 million years. Contributions of 600, 200, 150 and 100 million year periodicities vary depending on the nature of the geodynamic cycle. The processes behind these cycles may act as internal physical resonators, enhancing or attenuating specific spectral periods selectively. Climate change with a period of 150 million years is assumed to be caused by the orbiting of the solar system through the spiral pattern of the rotating Milky Way, and may certainly be influenced by synchronized geodynamic cycles and their different phase shifts in turn.

Although the spiral-arm of the galaxy that possibly contributed to the Earth's "Snowball" history should have been passed through again by the solar system, the Earth was obviously saved from comparably dramatic developments and a repetition of a cosmic catastrophe. After the total freezing of the Earth in the Neoproterozoic, life developed explosively and changed almost all geodynamic and climatic boundary conditions, partly in a negative feedback by reducing an uncontrolled warm-up that became a result of periodic magmatic degassing processes due to plate tectonic processes. This includes, for example, a cyclic deposition of the greenhouse gas CO₂ in thick faunal carbonate sequences at the sea bottom in warm periods, or, more generally, by floral reduction of geological erosion through the growth of land plants (e.g. [5] [8]), lending itself time enough for further evolution. A reduction of the emitting properties of the spiral arm in the meantime may have also contributed to the less dramatic situation. As magmatic episodes on the terrestrial planets of the Sun as well as on the Earth's Moon are apparently contemporaneous events, speculatively a galactic cause appears evident.

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