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THEORY OF CONTINENTAL DRIFT – CAUSES OF THE MOTION. OUTLINE OF THE THEORY

The theory of mantle convection currents as the cause of lithospheric plate movements has several major problems, including the absence of an adequate energy source. As shown in our previous contribution, an unbiased interpretation of geochemical data does not support the assumptions of a significant amount of radionuclides in the lower mantle or even in the core. It is our assertion that solar radiation is the primary energy source in the lithosphere. This energy is converted into mechanical energy via thermoelastic waves, even in depths with minimal temperature fluctuations. This has been confirmed by various methods of continuous stress measurement. The periodic and quasiperiodic thermoelastic reversible deformations, such as the circadian and annual cycles (including tidal periods), can also cause irreversible deformations due to the ratcheting mechanism. The 2D model showed that the strength limit is exceeded in 0.3 % of all diurnal cycles during the year. As a consequence, continents tend to extend while the oceanic lithosphere is pushed and overthrusted between continents. The middle-ocean ridges, similar to continental rifts, are filled by ascending magma which is one example of the ratcheting mechanism. The final plate movements are determined by the distribution of major continents and the overall westward drift of the lithosphere, which is slower for deep-rooted plates like the Indian one. Large asteroid impacts are important triggers (and possibly significant energy sources) of discrete events, like the formation of hotspots and large igneous provinces.

Key words: continental drift; motion of plates; mechanism; solar energy accumulation.

Introduction
Outline of the theory of the causes of lithospheric plate motion

Several important phenomena were described in the first part of this contribution. They include diurnal variations of tilt even at great depths, maximum microseisms, and deformation of the massif in winter and orogenesis in cold climatic periods. These phenomena can be explained by the irradiation of the Earth’s surface and the formation of a thermoelastic wave [Berger, 1975], which is able to penetrate into the deeper parts of the Earth’s crust. To apply enough pressure to surpass the strength limit of even the toughest rocks and cause creep, tremors, microseisms, and earthquakes, there must be a mechanism that allows for this unilateral increase, rather than just cyclical changes that balance out over time. J. Croll (1997) created a mathematical model to explain this process in relation to the deformation of pipes on the earth's surface (1997), the asphalt buckling (2006), the periglacial soil formation (2006, 2007a), and the continent movement (2007b). This mechanism is referred to as the *ratcheting mechanism*.

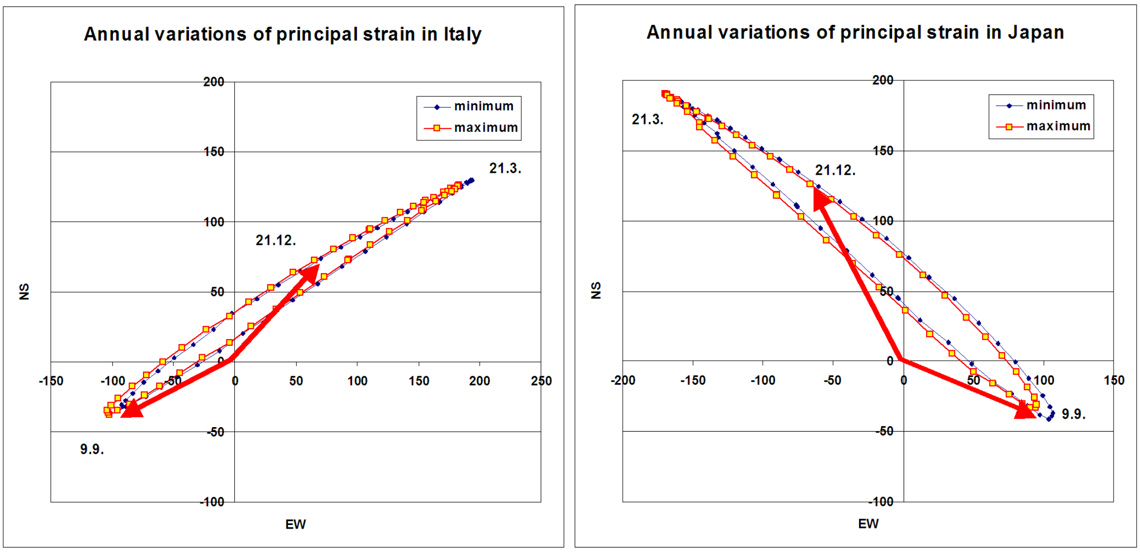
Thermoelastic waves and ratcheting thus allow the conversion of solar energy incident on the Earth’s surface into energy stored in the rocks in the form of elastic energy. The energy stored in elastic materials can be released in various ways when lithospheric plates or blocks rub against each other. This release can occur as heat through friction, causing rocks to melt at frictional surfaces in subduction zones or interlayer joints. Alternatively, it can be gradually released as creep, tremors, microseisms, or earthquakes in the form of elastic waves. These waves eventually dissipate and convert into heat throughout the rock volume around the focus. This principle of heat release from elastic energy is also consistent with the interpretation of the variation of the temperature gradient with depth reconstructed from mantle xenoliths in Cretaceous kimberlites in Africa [Keith, 1993]: The temperature gradient below the low-velocity zone (LVZ) is much smaller than above it, which would be indicative of heat sources within this layer.

Purpose

The purpose of the research is to outline the mechanism of the lithosphere plates movement that does not contradict the observations and which can explain the energy source(s) of continental drift, seismicity, and volcanic activity.

Thermoelastic wave

Qualitatively, the thermoelastic wave was described by [Berger, 1975; Hvožďara et al., 1988; Kalenda et al., 2012]. As the thermal wave penetrates from the surface to depth (the first metres to the first tens of metres), the affected layers expand, transmitting shear stress to the subsurface and to the surrounding area of the expanding block.



a b

Fig. 1. Main directions of the stress tensor in the annual variations in northern Italy (*a*) and in central Japan (*b*) (according to [Kalenda et al., 2012].

Thus, it can be observed that the Eurasian continent, for example, is (generally) extending from its centre in all directions, according to the irradiation. In Italy, the direction of the main component of the stress tensor is from NE to SW (Fig. 1, *a*). In contrast, the direction of travel in Japan is from NW to SE (Fig. 1, *b*), i.e., the largest stress acts exactly against the Pacific lithospheric plate.

We can evaluate the relative stresses induced by all the expanded (or contracted) layers at one time and compare their maximum effects. We can calculate the stretching of each layer from the temperature variation T_h, which is calculated from the equation of the temperature profile in boreholes up to depth h [Mareš et al., 1990]

$$T_h = T_0\, e^{-h\sqrt{\omega/2a}} \cos(\omega t - h\sqrt{\omega/2a}), \qquad (1)$$

where a ($m^2 \cdot s^{-1}$) is the coefficient of thermal conductivity and T_0 is the maximum temperature variation on the surface with the harmonic frequency ω. The thermal expansion can then be integrated over all layers to some depth *H*. The relative maximum stress σ in the far zone (deeper than 10 H) is proportional to the overall cumulative strain of the subsurface layers ε to the depth *H*, where strain variations are negligible in comparison with the strain on the surface

$$\varepsilon \approx \int_0^H e^{-h.\sqrt{\omega/2a}} \cos\left(\omega t - h\sqrt{\frac{\omega}{2a}}\right) dh. \qquad (2)$$

The primitive function of a certain integral from the relation (2) is [Wandrol, 2017]:

$$F(h) = \frac{e^{-h.\sqrt{\omega/2a}}}{2\sqrt{\omega/2a}} \left(\sin(h\sqrt{\omega/2a} - \omega t) - \cos(h\sqrt{\omega/2a} - \omega t)\right) + C \qquad (3)$$

We have performed numerical integration according to relation (2) up to a depth of about 100 km, when the stretching increments are negligible even for Milanković cycles. Fig. 2 (taken from [Kalenda et al., 2012]) shows the resulting relative maximum stress σ (the principal component of the stress tensor) depending on the frequency of the temperature variations on the surface and the penetration depth of thermal waves. It can be seen that the diurnal irradiation wave generates a thermal wave that reaches depths of a few cm to the first tens of cm, which agrees with observations [Čermák et al., 2000].

When intact rocks come to the surface, such as in deserts and high mountains (but also in Příbram – see above), this thermal wave is able to generate a thermoelastic wave that is detectable even at considerable depth and distance. For example, during anomalous irradiation of the Himalayan range under very reduced atmospheric humidity in early May 2008 [Singh et al., 2008], a diurnal stress wave was generated and detected not only by resistivity HRT measurements in boreholes in China (Sichuan Basin) [Qian et al., 2009], but also by a pendulum at station P7 in Příbram (Fig. 3).

The diurnal stress wave that was detected in Příbram was not caused by the irradiation. This is evident from the fact that the maximum noise and tilt did not occur during the usual afternoon local time, but instead occurred after midnight (UT), which is equivalent to morning local time in Himalayas.

Annual temperature changes penetrate depths of a few meters to the first tens of meters (Fig. 2). The maximum relative amplitude of the annual thermoelastic wave is one order of magnitude greater than that of the diurnal thermoelastic wave. Even greater stresses are induced by thermoelastic waves with the period of Milankovitch climate cycles [Čermák et al, 2000].

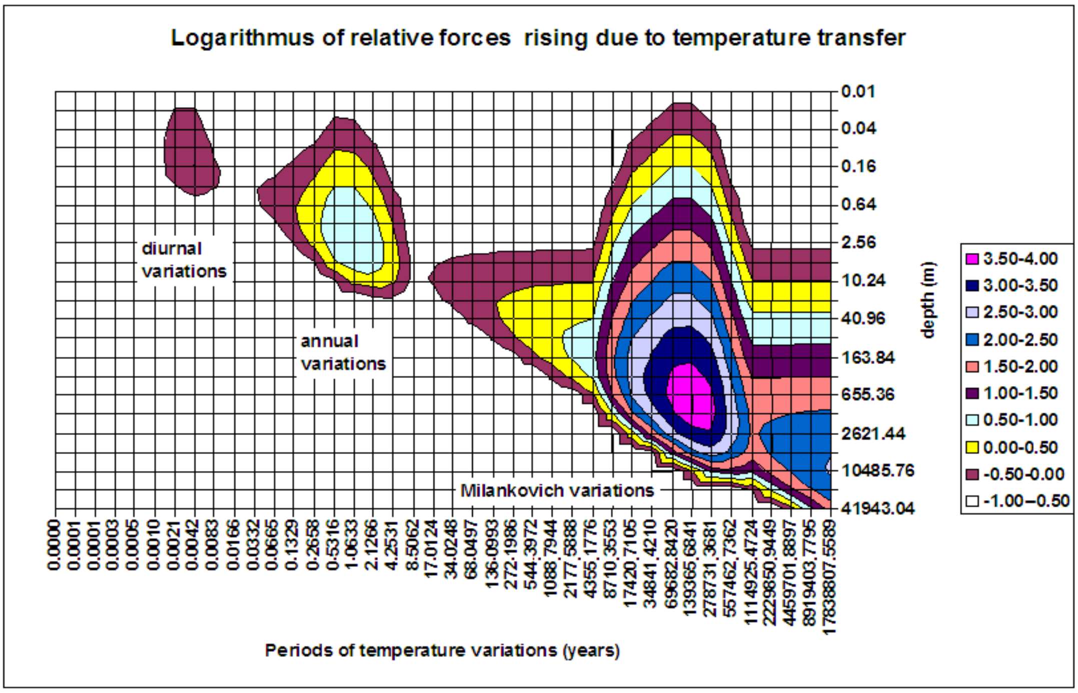


Fig. 2. Relative forces generated in the distant zone (for a hypothetic homogenous crust in a depth of 1000 km) depending on the periods of temperature variations on the surface and the penetration depths of the thermal waves on these periods.
The colour scale shows the logarithm of relative stress in the distant zone (taken from [Kalenda et al., 2012]).

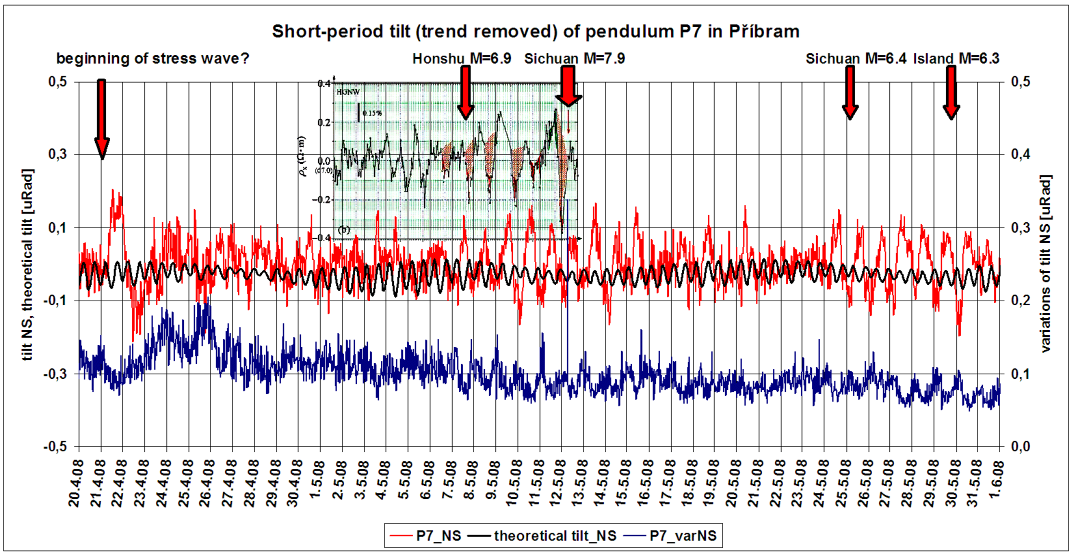


Fig. 3. Short-period tilt history at station P7 in Příbram before the May 12, 2008 Sichuan earthquake (red – NS component of tilt) and its correlation with changes in rock resistivities measured in a borehole in Sichuan at a distance of 465 km from the earthquake epicentre [Qian et al., 2009].
Black – theoretical NS component of tidal tilt, blue – variation of NS component of tilt over a 30-minute window. Arrows indicate significant earthquakes, which correlate with an anomalous diurnal thermoelastic wave.

In this case, the thermal wave itself affects the entire upper crust, but due to the relatively small change in temperature (about 10 ^{o}C / 1000 yr.), its effect is considerably smaller than that of the annual period and can be included as a secular trend. Nevertheless, J. Croll (2007b, 2019) considers these climate changes and the thermoelastic wave generated by them as the main drivers of lithospheric plate movements and associated geological processes. To accurately estimate the magnitudes of thermoelastic waves at varying depths in the Earth's crust, we developed a geomechanical numerical model. This model portrays the Earth's crust as a cylindrical beam (or intermediate ring) resting on an elastic substrate represented by a cylinder to signify the mantle. It is essential to measure both the qualitative and quantitative aspects of these waves for accurate analysis [Wandrol, 2017].

First, we used the SBRA statistical method to calculate the number of cases in which the tensile or compressive strength limits can be exceeded in the case of diurnal temperature changes at the ground surface. In the model, we used rock physical parameters such that they statistically covered their entire range occurring in nature. With a number of simulations of 10^5, it turned out that statistically in 0.32 % of the cases, one of the strength limits will be exceeded [Frydrýšek, et al., 2012; Wandrol, et al., 2012]. The conditions required to generate a thermoelastic wave and facilitate ratcheting have been met, making it possible to surpass the compressive and tensile strength limits to create free space for the ratchets. In the second step, temperature changes on the Earth's surface were simulated using real temperature series measured in the mild climate zone (2-year long series from the Blatnička station at 50°N) with a step of 1 hour. We calculated both temperature changes in all nodes of the model and deformations of the whole model and the resulting stresses between the nodes. All deformations were calculated only from the expansion parameter, which was determined apriori for each rock block and within realistic limits for crustal rocks.

The resulting dependence of the maximum amplitude of the diurnal temperature wave as it penetrated to depth could be described by the equation

$$\log\Delta T\ [K]=-0{,}6453h\ [m]+0{,}995, \qquad (4)$$

which shows that real measurable temperature changes (more than 0.001 °C) can be detected to depths of 6 m or less, even under clear skies and maximum irradiation. This equation is in perfect agreement with the real measured values of temperature changes in boreholes [Mareš et al., 1990; Čermák, et al., 2000]. The annual maximum temperature changes could still be measurable at depths of about 35 m, assuming that heat is transferred by sharing and not by convection through fluids that multiply its depth of penetration. As the modeled heat penetration values, also known as heat waves, agree with observations, it is expected that the calculated stress tensor changes resulting from the numerical model will be very close to the actual values. The model calculates the inferred strains and stresses solely from the expansion parameter of the rocks, which are modeled in realistic proportions according to their representation in the crust..

The resulting dependence of the HMH parameter on depth is analogous to the absolute magnitude of the principal component of the stress tensor. It shows that significant additive stresses (greater than 1 MPa) are generated at the boundaries between blocks with different physical properties, and at different times of the year, up to depths greater than 10 km (Fig. 4). This confirms the thesis that thermal waves that penetrate only to shallow depths below the surface are capable of generating significant stresses over virtually the entire extent of the upper crust. At the same time, the conditions are met for the activation of the ratcheting, which must repeatedly exceed both the tensile strength (creating empty spaces) and the compressive strength (creating irreversible deformation and releasing elastic energy).

In the third step, we modeled the effects of large-scale pressure lows and highs on stress and strain changes in the crust. It was shown that the largest pressure lows (below hurricanes) are able to "bulge" the surface by up to 1.6 m However, the maximum HMH stress changes in both the tangential (along the surface) and radial directions (towards the center of the Earth) in the crust are on the order of 0.1 MPa, i.e., one to several orders of magnitude smaller than a thermoelastic wave. Thus, it has been shown that pressure lows and highs can contribute to both energy accumulation and triggering of earthquakes or microseisms [Kalenda et al., 2015], but they cannot be the primary source of lithospheric plate motion mechanisms, unlike the thermoelastic wave generated by Earth's surface irradiation.

Ratcheting

There are external factors (temperature-radiation, air pressure, and tides) on the Earth that cause demonstrable cyclic or quasi-cyclic deformation of the Earth's crust, even to great, seismogenic depths. Changes in tides and air pressure alone do not have a significant impact on inducing stress changes that surpass the limits of tensile and compressive strength. However, they can contribute to triggering small, irreversible deformations, such as microseisms and tremors, as well as larger earthquakes. Thermoelastic waves, resulting from daily fluctuations in Earth's surface temperatures, have the ability to exceed the strength limits of rocks and cause stress changes greater than 1 MPa in the upper crust. These findings were reported by [Kalenda, et al., 2015; Rogers and Dragert, 2003; Heaton, 1975] for microseisms, tremors, and earthquakes, and by [Wandrol, et al., 2012] for thermoelastic waves [Wandrol, 2017].

Exceeding the tensile strength limit of the rock is a necessary condition for the functioning of the ratcheting. So what is a ratcheting and how does it work?

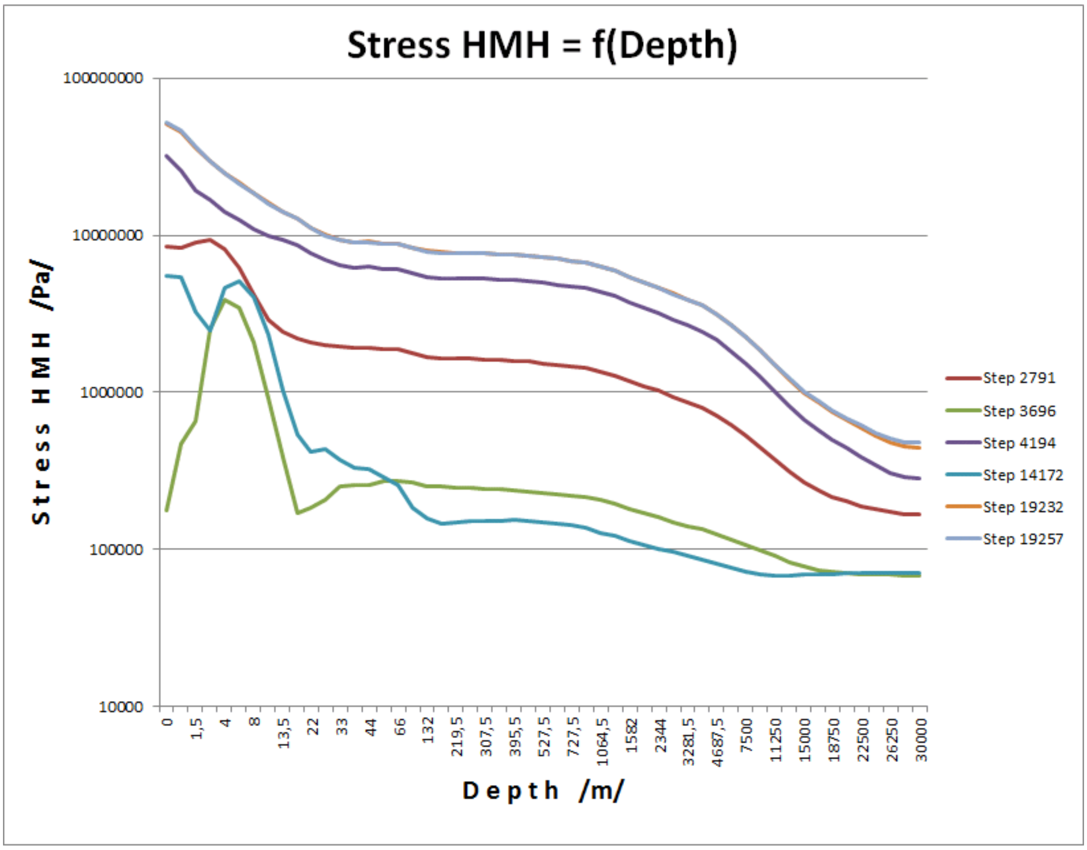


Fig. 4. Dependence of the calculated maximum amplitude of changes in the HMH parameter on depth over the annual cycle at different model calculation times (step).

One form of ratcheting has been known for a very long time. However, it is not called that – it is the creep of a glacier, where the expansion of the ice and gravity work together to prevent the material from returning to its original position (against the slope) before expansion. Solifluction works on the same principle. J. Croll (2006) described a typical ratcheting for bulging (buckling) of asphalt, whereby small tensile cracks are formed by asphalt contraction in winter. During the day, these cracks can be filled with water, and subsequent freezing at night expands the ice and further enlarges the crack. The following day, the thermal expansion of the asphalt itself causes its edges to buckle and the open spaces underneath to widen. A similar mechanism has been described for periglacial soils and the formation of both mosaic soils and ridges or mounds (pignos) [Croll, 2007a]. In addition, rock and water properties (expansion), frequent temperature changes, and gravity are involved.

In 2009, J. Croll described the formation of alligator asphalt forms (irregular polygonal cracks) directly as an example of a ratcheting, and in 2008 he pointed to the same mechanical nature of solifluction, the movement of glaciers, and the movement of blocks of rock over their bedrock due to pulsed expansion and contraction. Similar conclusions about the pulsed movement of the lithosphere along the asthenosphere were reached by C. Doglioni (2014), who, however, considered as the basis of pulses not the thermal expansion of rocks, but the tidal forces lifting the whole lithosphere, which does not return to its original position at the end of pulses but is moved a small bit westward (tidal drag), leading to a westward drift of the lithosphere [Doglioni, 1993; Scoppola, et al., 2006].

The forms of the ratcheting can be various – for example, purely geometric – wedges constrained by near-subvertical fissures that slide gravitationally into the created “space” under large tensile stresses

[Kalenda, et al., 2012]. Many examples can be found in karsts and carbonate rocks in general (possibly also including the “neptunic veins”, described mainly from reef formations – e.g., Chlupáč et al. 2002). Another form of ratcheting mechanism may be size sorting of loose sediments or weathered rocks, where smaller grains and fragments are gradually transported by gravity or water flow between larger grains and may accumulate in the lower part of the profile (see also]Procházka, et al., 2014]. At granite weathering, clay minerals and other small grains are transported into fractures deep below the weathering zone [Procházka, et al., 2018]. This happens when the gaps between the larger grains/blocks are opening, but the fillings cannot return to their original position against the action of gravity at times of increased pressure. Geological mapping of a tunnel in another granite massif lead to the conclusion that the massif has expanded by up to 4 % from the time of magma solidification to recent, based on the volume of younger fillings (including vein rocks) [Klomínský, 2008].

In summary, the most common form of ratcheting mechanism on Earth is the filling of opening fissures, either by magma or fluids from below, as in rifts, or by gravity from above. After the melt has solidified (or the dissolved minerals have precipitated), this leaves a filled fissure that has a fundamentally different compressive strength than the melt/fluid had, and the fissure is thus unable to return to its original geometric state (close). This mechanism also causes the expansion of the oceanic crust, which however is subducted below the continental crust, and also the growth of continents.

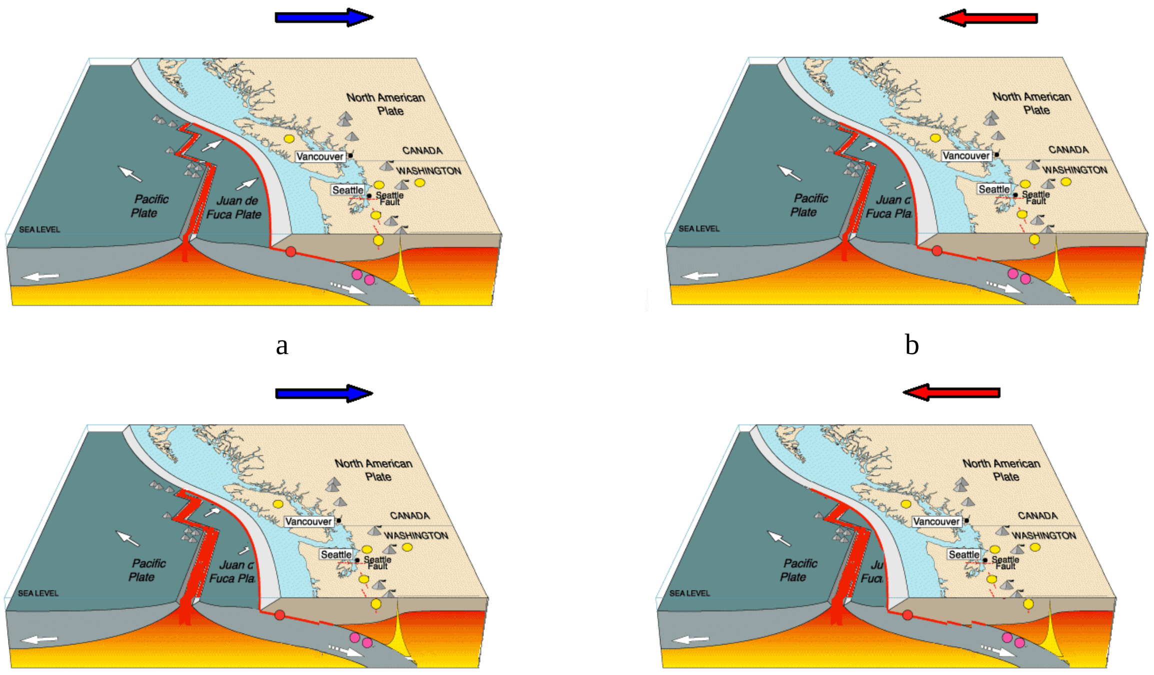
Using the Juan de Fuca plate as an example, we will show how such a mechanism works at the interface between continental and oceanic crust. Due to the ratcheting at the continental crust itself, in spring and summer, when a cold wave reaches intact rocks in the continental crust, it contracts the continental crust and, in addition to lowering the stress in the crust itself, exerts a tensile force on the subducted oceanic crust (see Fig. 5, *a*). In this case, the weakest point with the lowest tensile strength (less than the friction between the oceanic and continental crust) is the oceanic rift, which opens up and magma from the asthenosphere enters the vacated space.

In autumn and winter, when the continental crust is most expanded, the oceanic rift is compressed, but because its complete closure is prevented by solidified magma that flowed in during the previous period, the rift does not close to its original position, but the higher stress is transferred to both parts of the oceanic crust (see Fig. 5, *b*). Therefore, the Pacific plate will be forced to move westward (only by the contribution from the North American plate and the Juan de Fuca rift mechanism) and, conversely, the oceanic Juan de Fuca plate will be forced to undercut the continental crust because the shear friction at the contact surface between the oceanic and continental crust is less than the compressive stress induced by thermal expansion of the rocks. The magnitude of this stress can be estimated from measurements of strain in granites at a depth of about 100 m below the surface [Brimich, 2006]. If we assume a temperature change of 1 K at a depth of only 5 m, influencing the layers affected by the annual thermal wave (see Fig. 4), we can calculate that the rocks with a coefficient of thermal expansion of 3×10^{-5} K^{-1}would experience a deformation of the order of 30 μ strain. It would be fully compensated in rocks with Young's modulus of elasticity E = 50 GPa. However, if the rocks are capable of transmitting shear stresses, the deformation would induce horizontal stresses of about 1.5 MPa at seismogenic depths. This is significant when compared to the lithostatic pressure of about 240 MPa, which is at depths of about 8 km!

In the second year, when the continental crust is again contracted, the rift zone opens up again and is filled with more magma, which solidifies on both sides of the rift, on the Pacific plate and on the Juan de Fuca plate. This cycle will repeat until the entire rift is completely subducted and the Pacific Plate begins to subduct, but more slowly. At the same time that the Juan de Fuca plate is being subducted, the magmatic chambers that are bound to it may also be moving further east (see Fig. 5, *d*).

The subduction of the Juan de Fuca oceanic plate beneath the North American continental plate, together with the rift between it and the Pacific plate, is an example that cannot be explained by convection currents in the mantle, nor by plumes protruding in the rift zone, nor by a model of the expanding Earth.

From a global perspective, the major continents are thus playing “ping-pong” with each other with the oceanic lithospheric plates. It is no coincidence that the largest annual differential motions are between the American plate and the Eurasian plate, which together have the largest thermal expansion acting just against the Pacific Oceanic plate (see Fig. 1, b). The latter is affected most strongly in the direction from Chile to Japan and also secondarily from Alaska to New Guinea. The resulting movement of the lithosphere then corresponds to a westerly drift in the sense of B. Scoppola et al. (2006), with the largest portions of stored energy being released at the margins of the Pacific plate in the so-called “Ring of Fire”.



a b

c d

Fig. 5. Mechanism of lithospheric plate movement (block diagram taken from Wikipedia, modified): **A** – summer – contraction of the continent, opening of the rift, penetration of magma into the open spaces; **B** – winter – expansion of the continent, closing of the rift, and when the friction between the continental and subducted lithosphere is exceeded, slip occurs and the continent moves westward;, **C** – summer – opening of the rift as A; **D** – winter – as B, with the difference that another part of the oceanic plate Juan de Fuca and of the rift zone is thrusted under the North American plate.

Heat storage in the form of elastic energy

The thermoelastic wave and the ratcheting are mechanisms that can convert the energy of solar radiation into elastic energy that can be stored in the rocks and released as heat over time, especially at plate interfaces with mutual movement and high friction.

Let us try to calculate the amount of heat accumulated in the Earth's crust, how fast the heat accumulates, or how fast it radiates back into space. Consider a rock cube at depth h with infinitesimally small side lengths [Kalenda, et al., 2018]. In a short moment Δt, the temperature in the cube changes by ΔT, which is given by the sum of the effect of temperature changes on the surface of the earth on the cube $f_2(\Delta T(0, \Delta t))$ and the radiated heat to the surroundings from the cube $f_1(\Delta T(h, \Delta t))$

$$\Delta T(h, t+\Delta t) = f_1(\Delta T(h,t)) + f_2(\Delta T(0,\Delta t)) \quad (5)$$

The function f_1 shows how fast the already accumulated anomalous heat will radiate to the surroundings and has a simple "radioactive decay" form

$$f_1\big(\Delta T(h,t)\big) = \Delta T(\mathrm{h},0).\,\mathrm{e}^{-a_h.\mathrm{t}} \quad (6)$$

where a_h $/s^{-1}/$ is a material parameter that must be determined by measurement.

The function f_2 has a linear form (Fourier's law) which states that the same proportion of the anomalous surface temperature (compared to the long-term average) always penetrates to depth h in time Δt

$$f_2(\Delta T(h,\Delta t)) = b_h.\Delta T(0,\Delta t) \quad (7)$$

where b_h [1] is the coefficient to be determined by measurement. For a detailed derivation of equations (6) and (7), see, for example, [Kalenda, et al, 2018].

From Eq. (6) we can also derive the "heat accumulation/release half-time" parameter $t_{1/2}$, which is equivalent to radioisotopes as the time it takes for half of the accumulated heat to be released from a cube at depth h

$$t_{1/2} = \ln(2)/a_h = 0.693/a_h. \quad (8)$$

Now we can take a series of surface temperatures and for different coefficients a_h and b_h we can calculate the evolution of the accumulated heat for the whole crust from the surface temperatures. The coefficient b_h has no effect on the trend of accumulation, it just moves the calculated crustal temperatures higher or lower on the absolute scale. Only the coefficient a_h, which also determines the half-life of heat accumulation/release according to equation (8), affects the slope of temperature development (and thus heat) and the phase lag of crustal temperatures relative to surface temperatures.

The evolution of the calculated anomalous crustal temperatures can then be compared with global climate change because according to equation (7), the long-term variation in surface temperatures (climate change) should be proportional to the current magnitude of heat accumulation throughout the crust.

Instead of the input surface temperatures $\Delta T(0, t)$, we used Wolf solar activity numbers reconstructed over the last 11,000 years [Solanki, et al., 2004], which are proportional to the total solar irradiated energy (TSI) and thus, in the first approximation, to the surface temperature anomaly on the Earth. Using Eq. (5), we computed the series of anomalous crustal temperatures over the last 11.000 years (by successive integration) for different a_h coefficients. We then compared these series with the global climate changes over the last 1,200 years [Mann, et al., 2008]. It turns out that if we smooth the global temperatures (according to climate reconstructions) over a window of at least 50 years, then the coefficient of correlation of these temperatures with the accumulated crustal heat is maximal (r = 0.86) for an accumulation half-life of $t_{1/2}$= 270 years, indicating that a significant correlation between the two variables cannot be excluded (Fig. 6).

Discussion

The energy source for hotspots and intraplate large igneous provinces

The exogenous mechanism of global tectonics as described above can explain the seismicity, volcanism, and tectonics at the boundaries of lithospheric plates or blocks. “Hotspots” and large igneous provinces (LIPs) are other phenomena for which deep-mantle energy sources have been usually considered.

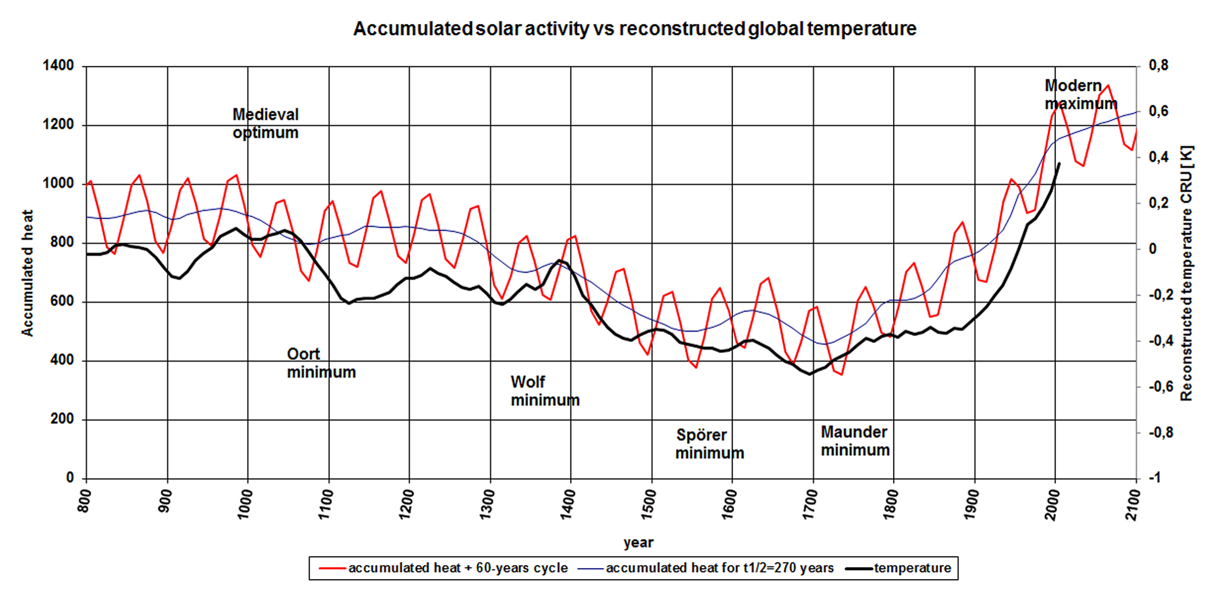


Fig. 6. Evolution of accumulated solar radiation (relative units) in the Earth’s crust (according to the Holocene solar activity series from [Solanki, et al., 2004] (purple), the same with the addition of 60-year variations in solar activity (red), and reconstructed global temperatures smoothed over a 50-year window (after [Mann, et al., 2008]) (black bold).

Both hotspots and LIPs are most commonly explained by the ascent of plumes from the deep mantle (e.g., Kellog and Wasserburg 1990; Ernst 2014; Schmidt et al. 2015). The deep-mantle plume theory, however, usually assumes complicated recycling of crustal material, leading to irregular enrichment of the lowermost mantle in radionuclides (see [Carlson, 2003] and references therein [Gonnermann and Mukhopadhyay, 2009]. We summarize some arguments as to why “external” factors, namely large impacts, are likely more relevant for intraplate magmatism.

L. Ostřihanský (1997) showed that the number of hotspots per area is approximately the same as the number of large impact craters on the Moon or Mars. Thus, they could have been formed by the same mechanism – impact (similar to the hotspot at the south pole of Enceladus). If a large meteorite hit the continental crust, a large impact crater would be formed, extending into the mantle. For example, the heat from the Sudbury meteorite impact gave rise to a melting body with huge deposits of nickel, copper, and palladium. The complex was originally considered to have formed from terrestrial magmas, however, even a small contribution of mantle-derived melt is uncertain [Latypov, et al., 2019]. If a meteorite of similar diameter hit an ocean, it would easily break through the crust, and its energy would be released prevalently in the mantle. We can calculate how large an energy reservoir may form using the simple example of the impact of an asteroid with a volume of 1 km^3, a typical density of 3500 kg.m$^{-3,}$ and a typical relative velocity to Earth of 20 km/s. The energy released is then about 7.10^{20} J, which is almost 100 times the energy of all volcanoes per year on the Earth [Smith, 2002]. There are tens of thousands of 1 km^3 impactors that will hit the oceans over the geological lifetime of the Earth, thousands of 3 km diameter impactors, and even higher tens of 10 km diameter impactors [Brown, et al., 2002]. These can release up to 10^{23} J, which is approximately 10 times the sum of the energy of all earthquakes in the world in a year.

The impact origin is also in line with the geochemistry of standard hotspot lavas, known as Ocean Island Basalts (OIB). Crustal rocks, including recent oceanic sediments rich in pore water, are buried in the transient crater. A significant portion of these rocks remains in the mantle, supporting the melting and ascent of magma due to the high content of volatile and radioactive elements. The ”mysterious” crustal component influencing the chemical and isotope composition of OIB can be simply explained in this way, instead of recycling crustal material through the whole mantle as suggested by many authors (see [Carlson, 2003] and references therein). The deep-mantle signature of noble gases (e.g., high ^{3}He/^{4}He ratios) in OIB [(Gonnermann and Mukhopadhyay, 2009] can be explained by disturbance of the mantle by the impact, reaching deep below the transient crater cavity and promoting ascent of fluids.

In cases when the energy of a large impact in the ocean is prevalently released in the crust and lithospheric mantle, oceanic volcanic plateaus can be formed. An example is the Ontong Java Plateau, the largest igneous province on the present Earth [Ernst, 2014]. There is no direct evidence for the impact origin of LIPs, but where are all the large impacts on the oceanic bottom? The mean age of the recent oceanic crust is ca. 100 Ma. For that time, five impact craters with diameters of 50 km and larger are known on the continental crust; the bodies, which formed them, had to be large enough that they would not be stopped even in deep water. As the continental crust covers only 41 % of the surface, there should be statistically at least seven large impacts preserved in the oceanic crust. The craters on the ocean floor were covered by basalt effusions – it is the only plausible explanation why none of these impacts has been found.

In general, impacts are triggers rather than the main energy source of LIPs (the decompression due to the formation of the transient crater, facilitating partial melting of peridotite, is also important [Jones, 2005]. Impacts, even on the continental crust, also could have triggered volcanism on the opposite side of the Earth [Boslough, et al., 1996], like in the case of the Chicxulub crater and the Dekkan traps.

Relative movement of the lithosphere to the mantle: the westward drift

As we examine the deepest hotspots, we notice that oceanic lithospheric plates move freely over them and are continually melting to create chains of volcanic islands, such as the Hawaiian-Emperor seamount chain. This allows us to determine the relative velocity of oceanic plate movement in relation to the (sublithospheric) mantle. [Crespi, et al., 2007]. Most of the deep hotspots have almost no motion relative to each other, indicating that the mantle moves as a whole in comparison to the lithospheric plates, which have slightly different velocities relative to each other. B. Scoppola et al. (2006) calculated a rate of lithospheric motion relative to the mantle in the range of 30–40 cm/yr. If we take the results of thermoelastic wave modeling [Wandrol, 2017], we see that with a daily cycle of expansion/contraction of the lithospheric plates by tens of cm and a 0.3 % probability of irreversible action, we get that in a year the plates will move relative to each other or to the mantle by the first tens of cm. The modeling results are thus in good agreement with observations.

Hotspots indicate a westward movement of the lithosphere with respect to the (sublithospheric) mantle (western drift) [Doglioni, 1993]. B. Scoppola et al. (2006) attempted to explain this western drift using tidal forces and their unidirectional pull, similar to [Carcaterra and Doglioni, 2018]. However, when we look at the evolution of the measured deformations resulting from the irradiation of the Earth's surface, we see that from dawn (about 6 am) to the afternoon, when the temperature of the rocks is highest (about 3 pm), the increase in temperature and induced deformations is rapid), and the decrease in temperature and deformations in the evening and at night is moderate. This induces asymmetric stress derivatives, which have the largest gradient towards the west, similar to tidal forces which, however, are only able to induce stresses of about 2 kPa [Fischer, et al., 2006], whereas irradiation is able to induce stresses in the upper crust on the order of 1 MPa [Wandrol, 2017], i.e. 500 times larger.

The western drift of the lithosphere also predetermines the inclination of the Wadati-Benioff zones, dipping into the mantle at different azimuths [Doglioni, 1993; Ostřihanský, 1997; Carcaterra and Doglioni, 2018]. Where the oceanic plate is pushed westward, it dips at a steeper angle and is often “chopped” into older pieces that have drifted eastward with the mantle and newer pieces pushing to their more westerly locations. Oceanic plates sinking to the east have a smaller tendency to fall away and are less deformed.

The Western drift together with the ratcheting allows us to explain several more global geodynamic paradoxes. One of them is the collision of India (the continent) with the Eurasian plate and the detachment of Madagascar, the Arabian Peninsula, and the eastern part of Africa from the rest of the continent. If we consider the deep anchoring of India in the mantle and the direction of apparent mantle movement in this region towards the NE [Doglioni, 1993], it cannot be surprising that the mantle was able to seemingly tear this most anchored part of the continental crust away from the African plate and transport it against the movement of the Eurasian plate, without their initially having to be any rift between India and the rest of Africa. The same is the case today between Madagascar and Africa, which seemingly lie on the same plate but have obviously already become detached from each other. As the mantle has pulled the Indian plate with it, the oceanic crust has been eroded away, and so we see now behind India a deep furrow with newly formed oceanic crust. The fact that the masses have not yet had time to “close up” behind India to fill the isostatic imbalance is evidenced by the large gravity anomaly south of India [Tsoulis, et al., 2011; Pail, 2019]. When we consider that the most stable place (relative to the Earth as a whole) is India, we have to acknowledge that India has not bumped into Eurasia, but rather the Eurasian plate has bumped and is continually bumping into the Indian subcontinent, thus uplifting and wrapping the Himalayas around it. This collision cannot be explained by mantle currents, by plums nor by degasation [Gordienko 2018, 2019], but only by differential rotation of various “peels” of Earth and spreading of ocean floor by ratcheting.

The situation is similar in Africa. At the time of greatest stress in the rocks in southern Europe (theoretically in places without cover in autumn, but realistically only in winter), Europe strikes Africa and tends to move south to southwest (see Fig. 1, *a*). Thus, as in the case of India, we can say that not Africa is pushing into Eurasia, but the Eurasian plate is still pushing into Africa, which is more anchored in the mantle. Also, the Arabian Peninsula, Madagascar and the eastern part of Africa are being passively pulled away from Africa (the ratcheting of the East African rift contributes a bit?) as the eastern part of the African plate is deeply anchored in the mantle. This process is still active, as evidenced by a number of shallow and weak earthquakes near Mayotte in 2018–2019, with nothing yet known about a developed rift zone between Madagascar and Africa. In this case, mantle drag is likely to operate independently without the aid of a ratcheting in the rift.

Earthquake triggers

The analysis of earthquake triggering also revealed the most important mechanisms that contribute to the movement of lithospheric plates. The irradiation mechanism emerged as the most important one, which was observable on all-day, annual, and 22-year periods [Kalenda, et al., 2012], as well as on “climatic” periods of 41 and 110 thousand years (Milankovitch cycles) and on global periods of about 150 million years [Kalenda, et al., 2012; Croll, 2019]. These periods are also dominant in California. For example, analysis shows that short-term irradiation cycles trigger approximately 4 times more seismic events than tidal cycles (and LOD cycles complementary to them). Many earthquakes are also triggered by hurricanes [Huang, et al., 2016] or large-scale pressure lows over continents [Holub, et al., 2013]. The effectiveness of triggering, however, is strongly dependent on the stress inside the massif (largest in winter) and thus on the season [Holub, et al., 2013]. The analysis of earthquake triggering shows the same thing as the geomechanical models of the Earth’s crust. The main driver of the Earth's plates is mainly the irradiation and the thermoelastic wave generated by it. Additionally, the energy coming from the Sun is also able to accumulate in the rocks.

Originality

In two follow-up papers, we publish a comprehensive theory of the mechanism of lithospheric plate motion and energy sources. This theory removes all the known contradictions of the mechanisms proposed so far.

Practical significance

A proper understanding of the causes of lithospheric plate movements also allows us to understand the variability of stresses in the Earth's crust, which can help predict earthquakes and volcanic eruptions. The accumulation of solar energy in the form of elastic energy in the crust is also relevant for climatic models.

Conclusions

We have presented a model of how solar energy is transformed into elastic energy in the rock mass and then released back into the atmosphere and space. It is based on measured deformations of underground rock blocks and correlations of seismic, volcanic, and solar activity and climate changes on the Earth. This model relies on the genesis of thermoelastic waves in the Earth's near-surface layers and on a ratcheting mechanism that allows for the accumulation of elastic energy, the unilateral motion of lithospheric plates relative to each other, and the motion of the crust relative to the mantle in general.

The geomechanical model has shown that although the thermal wave does not reach deeper than a few tens of centimetres in the diurnal cycle and a few tens of metres in the annual cycle, the generated thermoelastic wave reaches the entire volume of the upper crust, where it induces stresses at the block interface greater than 1 MPa. Statistical calculations on a large sample of models with real rock parameters have shown that even in the diurnal cycle, stress components can exceed the compressive or tensile strength of the material. This assumption is a necessary condition for the ratcheting mechanism to operate, preventing the massif from getting back to its initial position after the end of the stress cycle. In this way, unilateral stress increases, and unilateral movement of blocks or entire lithospheric plates then occurs during subsequent cycles. This unilateral process (mechanism) leads to irreversible deformation, creep, earthquakes, and subsequently to volcanic activity supported by friction between the moving blocks and opening the faults. Thus, most of the stored energy is released at the locations with the greatest relative motion, i.e., especially in the Circumpacific Ring of Fire, but also at the interface(s) between the upper and lower mantle, as well as the mantle and lithosphere. The ratcheting mechanism thus leads to a gradual stretching of rift zones to form new crust and, in turn, to the pushing of oceanic crust (with entire rift zones) beneath continental crust along the Wadati-Benioff zones.

The proposed theory of “New Global Tectonics” can account for various observed phenomena. They include the subduction of an entire rift under a continent, the existence of a relatively cold area beneath several rifts that does not suggest magma ascent from the lower mantle, the multidirectionality of rifts into small regions, with almost orthogonal changes in the directions of oceanic crustal expansion, the westward shift of the crust in relation to the mantle [Doglioni, 1993], the motion direction of the Pacific Plate, parts of the continental crust moving with the oceanic crust, and the expansion of the ocean floor. “New Global Tectonics” can also explain the initiation of continuous lithospheric plate motion probably only in the Late Proterozoic (750 Ma), i.e., after the concentration of greenhouse gases in the atmosphere decreased, and daily and seasonal temperature contrasts at the Earth's surface increased. The most important finding, however, is the source of energy – the Sun – because not more than 4 % of the incident solar energy is sufficient to move the continents, and is thus able to supply 100 % of the energy needs of all earthquakes and volcanism (about 1.10^{22} J/year in total). Other energy sources (residual accretion heat in the core, additional asteroid- and comet impacts after the Earth’s differentiation, radionuclide decay, tidal- and other external forces) are of minor importance.

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References

Anderson, D. L. (2000). The thermal state of the upper mantle; No role for mantle plumes, Geophysical Research Letters, 27*(22), 3623–3626.* https://doi.org/10.1029/2000GL011533.

Berger, J. (1975). A note on thermoelastic strains and tilts, *Journal of Geophysical Research, 80(2),* 274–277. https://doi.org/10.1029/JB080i002p00274.

Boslough, M. B., Chael, E. P., Trucano, T. G., Crawford, D. A., & Campbell, D. L., (1996). Axial focusing of impact energy in the Earth’s interior: A possible link to flood basalts and hotspots, in Ryder, G., Fastovsky, D., Gartner, S., eds., The Cretaceous-Tertiary event and other catastrophes in Earth history: *Geological Society of America Special Paper, 307,* 541–550. https://www.osti.gov/servlets/purl/10197028.

Brimich, L. (2006). Strain measurements at the Vyhne tidal station. Contributions to geophysics and geodesy, 36*(4),* 361–371. https://journal.geo.sav.sk/cgg/article/view/337.

Brown, P., Spalding, R. E., ReVelle, D. O., Tagliaferri, E., & Worden S. P. (2002). The flux of small near-Earth object colliding with the Earth. Nature, 420*(6913),* 294–296. https://doi.org/10.1038/nature01238.

Carcaterra, A., & Doglioni, C. (2018). The westward drift of the lithosphere: A tidal ratchet? *Geoscience Frontiers, 9(2),* 403–414. https://doi.org/10.1016/j.gsf.2017.11.009

Carlson, R. W. (ed.), (2003). Treatise on Geochemistry – 2. The Mantle and Core. Elsevier, 608 pp.

Chlupáč, I., Brzobohatý R., Kovanda J., Stráník Z. (2002). Geologická minulost České republiky. Academia, Praha, 436 pp. Geological past of the Czech Republic (in Czech).

Crespi, M., Cuffaro, M., Doglioni, C., Giannone, F., & Riguzzi, F. (2007). Space geodesy validation of the global lithospheric flow. *Geophysical Journal International, 168(2),* 491–506. https://doi.org/10.1111/j.1365-246X.2006.03226.

Croll, J. G. A. (1997). A simplified model of upheaval thermal buckling of subsea pipelines. *Thin-walled Structures, 29,* 59–78. https://doi.org/10.1016/S0263-8231(97)00036-0/

Croll, J. G. (2006). From asphalt to the Arctic: new insights into thermo-mechanical ratchetting processes. In *III European Conference on Computational Mechanics: Solids, Structures and Coupled Problems in Engineering: Book of Abstracts* (pp. 177–177). Dordrecht: Springer Netherlands. https://doi.org/10.1007/1-4020-5370-3_177.

Croll, J. G. A. (2007a). Mechanics and thermal ratchet uplift buckling in periglacial morphologies. *Structural*

Engineering, Mechanics and Computation, Vol. 3, A. Zingoni (ed.), 833–837.

Croll, J. G. A. (2007b). A new hypothesis for Earth lithosphere evolution, *New Concepts in Global tectonics,* Newsletter, 45, December, 34–51.

Croll, J. G. A. (2008). Thermally induced pulsatile motion of solids. Proc. Of the Royal Society a Mathematical, Physical and Engeneering Sciences. 25 November 2008. https://doi.org/10.1098/rspa.2008.0151.

Croll, J. G. (2009). Possible role of thermal ratchetting in alligator cracking of asphalt pavements. *International Journal of Pavement Engineering, 10*(6), 447–453. https://doi.org/10.1080/10298430902730547.

Croll, J. G. A. (2019). Phanerozoic climate and vertical tectonic cycles. UCL Press, 1–7. DOI: 10.14324/111.444/000009.v1. https://www.researchgate.net/publication/331082713_Phanerozoic_Climate_and_Vertical_Tectonic_Cycles.

Čermák, V., Šafanda, J., Krešl, M., Dědeček, P. and Bodri, L. (2000). Recent climate warming: surface air temperature series and geothermal evidence. *Studia geophysica et geodaetica,* 44, 430–441. https://doi.org/10.1023/A:1022116721903.

Doglioni, C. (1993). Geological evidence for a global tectonic polarity. *Journal of the Geological Society, 150(5), 991–1002.* https://doi.org/10.1144/gsjgs.150.5.0991.

Doglioni, C. (2014). Asymmetric Earth: mechanisms of plate tectonics and earthquakes. Rendiconti Accademia Nazionale delle Scienze detta dei XL, Memorie di Scienze Fisiche e Naturali, 9–27, https://doi.org/10.4399/97888548717171.

Ernst, R. E. (2014). *Large igneous provinces. Cambridge Univ. Press,* 653 pp. https://books.google.com.ua/books?hl=uk&lr=&id=V3pxBAAAQBAJ&oi=fnd&pg=PA2&dq=Ernst+R.+E.+(2014).+Large+igneous+provinces.+%E2%80%93+Cambridge+Univ.+Press,+653+pp&ots=KjHO2eCjZr&sig=GkmWUwqOrM41y8CeoJvNdIHpBoI&redir_esc=y#v=onepage&q&f=false

Fischer, T., Kalenda, P., & Skalský, L. (2006). Weak tidal correlation of NW-Bohemia/Vogtland earthquake swarms. *Tectonophysics, 424*(3-4), 259–269. https://doi.org/10.1016/j.tecto.2006.03.041.

Frydrýšek, K., Wandrol, I., Kalenda, P. (2012). Report about the probabilistic approaches applied in mechanics of continental plates. The 14th WSEAS International Conference on Mathematical Methods, Computational Techniques And Intelligent Systems (MAMECTIS '12), Porto, Portugal, July 1–3, 2012. *Mathematical Models and Methods in Modern Science.* 146-149. ISBN: 978-1-61804-106-7. http://www.wseas.us/e-library/conferences/2012/Porto/MAMECTIS/MAMECTIS-24.pdf.

Gonnermann, H. M., & Mukhopadhyay, S. (2009). Preserving noble gases in a convecting mantle. *Nature, 459*(7246), 560–563.

Gordienko, V. V. (2018). *About the movements of lithosperic plates in oceans and in transition zones. Geophysical Journal*, 3(40) (in Russian).

Gordienko, V. V. (2019). About the Earth´s degasation. Geophysical Journal, *3,* 41 (in Russian). https://doi.org/10.24028/gzh.0203-3100.v41i3.2019.172420.

Heaton, T.H. (1975). Tidal Triggering of Earthquakes. *Geophysical Journal International*, *43(*2), 307–326. https://doi.org/10.1111/j.1365-246X.1975.tb00637.x.

Holub, K., Kalenda, P. and Rušajová, J. (2013). Mutual coupling between meteorological parameters and secondary microseisms. *Terrestrial, Atmospheric & Oceanic Sciences, 24*(6). https://doi.org/10.3319/TAO.2013.07.04.01(T).

Hvoždara, M., & Brimich, L. (1988). Thermo-elastic deformations due to the annual temperature variation at the tidal station in Vyhne. *Studia Geophysica et Geodaetica*, *32*(2), 129–135. https://doi.org/ 10.1007/BF01637575.

Jones, A. P. (2005). Meteorite impacts as triggers to large igneous provinces. *Elements, 1*(5), 277–281. https://doi.org/10.2113/gselements.1.5.277.

Kalenda, P., Neumann, L., Málek, J., Skalský, L., Procházka, V., Ostřihanský, L., Kopf, T., & Wandrol, I. (2012). *Tilts, global tectonics and earthquake prediction. SWB*, London, 247 pp. http://seismonet.com/media_files/1/POL_Tilts_Global%20Tectonics%20and%20Earthquake%20Prediction.pdf.

Kalenda, P., Wandrol, I., Holub, K., & Rušajová, J. (2015). The possible explanation for secondary microseisms seasonal and annual variations. *Terr. Atmos. Ocean. Sci, 26*(2), 103–109. https://pdfs.semanticscholar.org/96c7/39372bb91dde027a506f02d119556c32ba0e.pdf.

Kalenda, P., Wandrol, I., Frydrýšek, K., & Kremlík, V. (2018). Calculation of solar energy, accumulated in the continental rocks. *NCGT journal, 6*(3). https://www.researchgate.net/profile/Pavel-Kalenda/publication/330225187_Calculation_of_solar_energy_accumulated_in_the_continental_rocks/links/5efad7f8a6fdcc4ca43d968e/Calculation-of-solar-energy-accumulated-in-the-continental-rocks.pdf.

Keith, M. L. (1993). Geodynamics and mantle flow: an alternative earth model. *Earth-Science Reviews, 33*(3-4), 153–337. https://doi.org/10.1016/0012-8252(93)90031-2.

Klomínský J. (ed., 2008). Studium dynamiky puklinové sítě granitoidů ve vodárenském tunelu Bedřichov v Jizerských horách – Etapa 2006–2008. MS ČGS (zpráva pro SÚRAO), 188 pp. / Study of dynamics of the fracture network in granitoids of the waterworks tunel Bedřichov in Jizerské Hory Mts. MS Czech Geological Service, report for SÚRAO for the years 2006-2008 (in Czech).

Latypov, Rais & Chistyakova, Sofia & Grieve, Richard & Huhma, Hannu. (2019). Evidence for igneous differentiation in Sudbury Igneous Complex and impact-driven evolution of terrestrial planet proto-crusts. Nature Communications. https://doi.org/10.1038/s41467-019-08467-9.

Mann, M. E., Zhang, Z., Hughes, M. K., Bradley, R. S., Miller, S. K., Rutherford, S., & Ni, F. (2008). Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. *Proceedings of the National Academy of Sciences, 105*(36), 13252–13257. https://doi.org/10.1073/pnas.0805721105.

Mareš, S. a kol. (1990). Úvod do užité geofyziky. Introduction to the applied geophysics (in Czech). SNTL Praha.

Ostřihanský, L. (1997). *The causes of lithospheric plates movement.* Charles University, Prague, 1–63.

Pail, R. (2019). *GOCE gravity models*. Institute of Astronomical and Physical Geodesy. TU München. https://earth.esa.int/documents/10174/355809/GOCEGravModels_Pail.pdf/.

Procházka V., Žáček M., Matějka D. (2014). Kontaminace zvětralého melechovského granitu. *Zpravy o geologickych vyzkumech*, 134-139. Contamination of weathered Melechov granite. Geoscience Research Reports 47, 134–139 (in Czech). https://app.geology.cz/img/zpravyvyzkum/fulltext/Zpr2013D-10.pdf.

Procházka V., Zachariáš J., & Strnad L. (2018). Model ages of fracture fillings and mineralogical and geochemical evidence for water-rock interaction in fractures in granite: The Melechov Massif, Czech Republic. *Applied Geochemistry, 95,* 124–138. https://doi.org/10.1016/j.apgeochem.2018.05.016.

Qian, Fuye, Zhao, Biru, Qian, W., Zhao, J., He S.-G., Zhang, H.-K., Li S.-Y., Li, S.-K.,Yan, G.-L., Wang Ch.-M., Sun Z.-K., Zhang, D.-N., Lu J., Zhang, P., Yang, G.-J., Sun J.-L., Guo Ch.-S., Tang Y.-X., Xu J.-M., Xia K.-T., Ju, H., Yin, B.-H., Li M., Yang, D.-S., Qi W.-L., He, T.-M., Guan, H.-P. & Zhao, Y.-L. (2009). Impending HRT wave precursors to the Wenchuan Ms 8.0 earthquake and methods of earthquake impending prediction by using HRT wave. *Science in China Series D: Earth Sciences, 52,* 1572–1584. https://doi.org/10.1007/s11430-009-0124-x

Rogers, G., & Dragert, H. (2003). Episodic tremor and slip on the Cascadia subduction zone: The chatter of silent slip. *Science, 300*(5627), 1942–1943. https://doi.org/10.1126/science.1084783

Schmidt, A., Fristad, K., & Elkins-Tanton, L. (eds., 2015). Volcanism and Global Environmental Change. – Cambridge University Press, 324 p. https://doi.org/10.1017/CBO9781107415683.

Scoppola, B., Boccaletti, D., Bevis, M., Carminati, E., & Doglioni, C. (2006). The westward drift of the lithosphere: A rotational drag? *Geological Society of America Bulletin, 118(*1-2), 199–209. https://doi.org/10.1130/B25734.1.

Singh, R. P.; Zlotnicki, J.; Prasad, A. K.; Gautam, R.; Hattori, K.; Liu, J.; Parrot, M.; Li, F. & Kafatos, M. (2008). Precursory Signals Using Satellite and Ground data Associated with the Wenchuan Earthquake of May 12, 2008. *American Geophysical Union, Fall Meeting Abstracts* (Vol. 2008, pp. U22B-06). https://ui.adsabs.harvard.edu/abs/2008AGUFM.U22B..06J/abstract.

Smith, K. (2002). *Environmental Hazards: Assesing Risk and Reducing Disaster*. Routledge, London, 392 p. ISBN 0-415-22463-2. https://books.google.com.ua/books?hl=uk&lr=&id=hOTfCgAAQBAJ&oi=fnd&pg=PP1&dq=Smith,+K.+(2002).+Environmental+Hazards:+Assesing+Risk+And+Reducing+Disaster.+3.+vyd.+Routledge,+Lond%C3%BDn,+2002.+392+s.+ISBN+0-415-22463-2&ots=CVRFtAZ99X&sig=S9CNwRoMVl_CDF38rhCEWL0qX20&redir_esc=y#v=onepage&q&f=false.

Solanki, S. K., Usoskin, I. G., Kromer, B., Schüssler, M. and Beer, J. (2004). “Unusual activity of the Sun during recent decades compared to the previous 11.000 years”, *Nature,* 431, 1084–1087. http://www.cricyt.edu.ar/paleo/pubs/solanki2004/solanki2004.html

Tsoulis, D., Ieronimaki, Z., Kalampoukas, G., Papanikolaou, D., Papanikolaou, T., Patlakis, K., & Vassiliadis, I. (2011). Spectral analysis and interpration of current satellite-only Earth gravity models by incorporating global terrain and crustal data. https://vbn.aau.dk/en/publications/spectral-analysis-and-interpration-of-current-satellite-only-eart

Wandrol, I., Frydrýšek, K., & Kalenda, P., (2012). SBRA Method Applied in modelling the Behaviour of Lithosphere of the Earth, XII. konference Spolehlivost konstrukcí 2012, Praha 25.5. 2012.

Wandrol, I. (2017). Modelování mechanického chování zemské kůry. Disertační práce, VŠB-TU Ostrava, 2017. Modelling of mechanical behavior of the Earth's crust. PhD. thesis, VSB-Technical University of Ostrava. http://hdl.handle.net/10084/127399.

Weihang Huang, Wen-Bin Shen, Wenqiang Zhang, Xiang Gu, Tianxing Jiang (2016). Statistics Analysis of Anomalous Signals Prior to Large Earthquakes. *International Journal of New Technology and Research, 2(2), 263599.* https://www.neliti.com/publications/263599/statistics-analysis-of-anomalous-signals-prior-to-large-earthquakes.

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ТЕОРІЯ ДРЕЙФУ МАТЕРИКІВ – ПРИЧИНИ РУХУ. ВИКЛАД ТЕОРІЇ

У теорії мантійних конвекційних течій, що спричиняють рух літосферних плит, є кілька основних проблем, зокрема відсутність адекватного джерела енергії. Як показано в нашому попередньому дослідженні, неупереджена інтерпретація геохімічних даних не підтверджує припущень про значну кількість радіонуклідів у нижній мантії або навіть у ядрі. Ми стверджуємо, що сонячне випромінювання є основним джерелом енергії в літосфері. Ця енергія перетворюється на механічну за допомогою термопружних хвиль навіть на глибині з мінімальними коливаннями температури. Це було підтверджено різними методами безперервного вимірювання напружень. Періодичні та квазіперіодичні реверсивні деформації, такі як термопружні добові та річні цикли (включно з припливними деформаціями), також можуть спричиняти незворотні деформації через храповий механізм. 2D-модель показала, що межа міцності перевищена в 0,3 % усіх добових циклів протягом року. Як наслідок, континенти мають тенденцію до розширення, тоді як океанічна літосфера зсувається і субдукується між континентами. Середньоокеанічні хребти, подібні до континентальних рифтів, заповнені висхідною магмою, яка є одним із прикладів храпового механізму. Підсумкові рухи плит визначаються розподілом основних континентів і загальним дрейфом літосфери на захід, який є повільнішим для глибоко вкорінених плит, таких як Індійська. Великі зіткнення з астероїдами є важливими тригерами (і, можливо, значними джерелами енергії) окремих подій, таких як утворення гарячих точок і великих магматичних провінцій.

Ключові слова: дрейф материків; рух плит; механізм; акумуляція сонячної енергії.

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