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THEORY OF CONTINENTAL DRIFT – CAUSES OF THE MOTION. HISTORICAL REVIEW AND OBSERVATIONS

The theory of continental drift was published as early as 1912, but the mechanism and energy source of this motion has not yet been elucidated. In many cases, the generally accepted model of convection currents in the mantle contradicts observations such as the spreading of the ocean floor, the extension of rifts from triple points to all sides, the more or less unilateral movement of the lithosphere relative to the mantle, and others. In the first part of the double article, the evolution of views on this issue is shown, as well as measured data that document the important role of extraterrestrial energy sources for the movement of lithospheric plates in daily, annual and long-term climate cycles. In the second part of the two-part article, the entire theory of the mechanism of lithospheric plate motion will be outlined, based on the accumulation of incoming energy from the Sun in crustal rocks, the ratcheting mechanism, and the thermoelastic wave penetrating from the Earth's surface through the entire crust.

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

Introduction

Problems of the generally accepted mechanism of lithospheric plate movements

As early as 1912, Alfred Wegener published evidence for continental drift. It was only in the early 60s that the movement of continents was finally accepted, long after Wegener's passing. The absence of an adequate mechanism for the movement of large lithosphere blocks or plates became the major problem. This explained why the whole theory was refused. The Centrifugal force generated by the rotation of the Earth [Wegener, 1912]) proved to be a wrong assumption and it was rejected at the conference in 1928.

There was progress in ocean floor mapping. Moreover, a number of pioneering studies of oceanic magnetic anomalies [Heirtzler et al., 1966; Vine & Mathews, 1963; Vine, 1966], and seismicity [Benioff, 1949] proved the formation of new oceanic crust at mid-ocean ridges. All this led to the discovery of subduction zones. At that time continental drift was basically accepted and the plate tectonics theory was formulated. So, the demand arose to quickly find the energy source for the movement of plates.

At present, the plate movements are generally explained by convection currents in the Earth's mantle, driven by thermal convection and heat transfer from the Earth's interior [Holmes, 1928, 1944]. Until now, however, there has not been any evidence for heat source(s), which could explain this convection mechanism [Garai, 2007]. The most commonly suggested energy sources include the following: heat generated by the decay of radionuclides [Holmes, 1939; Agostini et al., 2020], remaining heat after the Earth's accretion in the first stage of its formation [Ransford, 1982], gravitational separation of the Earth's material [Richard et al., 1991; Scoppola et al, 2006], tidal friction, Munk & Wunsch, 1998], and change of the angular momentum of the Earth [Garai, 1997; Doglioni, 1993; Doglioni et al., 2003, 2005; Rousseau, 2005; Crespi et al., 2007].

The theory of convective currents [Holmes 1928, 1944, Tanimoto and Lay 2000, Schubert et al. 2001] is now widely accepted as the explanation of the motion of lithospheric plates. It is based on the heat output from the lower mantle and the core, resulting prevalently from the decay of radioactive elements.. A number of contradictory facts should, however, be also considered.

The main problem is the lack of radionuclides in the Earth's mantle. All of the major radionuclides (the potassium isotope ^{40}K and the decay chains of thorium ^{232}Th and uranium ^{238}U and ^{235}U) belong to the so-called incompatible elements, which are significantly concentrated in the crust. It has been proven that the upper continental crust has a significantly higher concentration of certain elements, such as K, Th, and U, compared to the mantle (see Table 1). This has been established by comparing the composition of available crustal rocks and the total composition of the Earth, independent of any global tectonic model. It is worth noting that for most elements, including those mentioned, the deviation from primitive meteorites (carbonaceous chondrites) is limited.In the lower continental crust, Taylor and McLennan (1985) assumed radionuclide concentrations to be one-tenth of the upper crust, but according to a more recent model [Wedepohl, 1995], the content of incompatible elements, including radionuclides, is also relatively high here. Ocean bottom sediments have a similar composition to the upper continental crust, while the basalts (and probably dolerites and gabbro) that make up most of the oceanic crust typically have "only" 5–10 times higher radionuclide concentrations [Saunders and Tarney, 1984] than the mantle. A comparison of the crust with the total composition of the Earth (see also [McDonough and Sun, 1995; Allégre et al., 2001]) shows that the continental crust alone, representing only 0.36 % of the Earth's mass, concentrates about half the number of major radionuclides in the entire Earth's body (see also Table 1).

Table 1

Distribution of radioactive elements in the Earth's body**

	Source	K, %	Th, ppm	U, ppm	RHP, nW/t
CI chondrites	McDonough, Sun, 1995	0.055	0.029	0.0074	
Upper continental crust	Taylor, McLennan, 1985 *	2.8	10.7	2.8	638
	Wedepohl, 1995	2.865	10.3	2.5	601
Bulk continental crust	Taylor, McLennan, 1985 *	0.91	3.5	0.91	208
	Wedepohl, 1995	2.14	8.5	1.7	454
N-MORB	Saunders, Tarney, 1984	0.083	0.2	0.1	17.5
PAAS	Taylor, McLennan, 1985	2.89	13.7	2.9	727
Ø Mantle (max.)	calculated (this work)	0.0129	0.0266	0.0113	2.21
Bulk Earth	Allégre et al., 2001	0.0171	0.051	0.0144	3.27
Bulk Earth 2.5 Ga ago	calculated (this work)	0.0662	0.058	0.0223	6.61

* Recalculated to 100 % without ignition loss (involving H_2O, CO_2 etc.)

** Average concentrations in the upper continental crust, the entire continental crust, the basic type of ocean floor basalts (N-MORB), post-archean shales (PAAS), and the entire Earth, based on literature; Calculation of theoretical maximum average elemental concentrations in the mantle based on the composition and mass of continental crust from Wedepohl (1995) and oceanic crust consisting of a 6 km thick layer of N-MORB and 1 km of sediments; Calculation of radioactive heat production (RHP) for given concentrations of K, Th, and U from Rybach (1976), for the whole planet also for the time 2.5 billion years ago due to the decline of radionuclides over time (corrected for the evolving isotopic composition of uranium) (for chondrites the RHP is not given due to the content of relatively short-lived cosmogenic radionuclides).

Although there are a few places, such as Oklo in Gabon, with extreme concentrations of radioactive isotopes, heat production in the Earth's crust is generally not very high. Some studies have suggested that radioactive heat may contribute to the formation of granitoid magmas during events like the Variscan orogeny.[Gerdes et al., 2000]. The heat production by the major radionuclides throughout the Earth (at their content according to [Allégre et al., 2001] – see Table 1) is less than 6.2 10^{20} J/year, which is more than an order of magnitude less than the sum of the energies of all earthquakes and volcanoes in the world (10^{22} J/year [Brázdil et al., 1988]). It is also less than the observed heat flux through the crust (1.5 10^{21} J/yr [Davies and Davies, 2010]). Moreover, the heat flux data also shows that it is the greatest at lithospheric plate boundaries and not at the locations with the highest radionuclide concentrations.

Although some studies have suggested that there may be significant content of some radioactive elements in the core [Lee et al, 2004, etc.] and/or the lower mantle margin (D-zone), this assertion is largely a tautology – the radioactive elements "must" be there because a heat source must be found [Rudnick and Fountain, 1995]. On an unbiased geochemical view, there is no reason why radioactive elements should be concentrated in the core or at its margin, instead of other, (geo)chemically similar non-radioactive or low-activity elements (Na, Rb, Ba, Zr, Y, Ce, etc.). In fact, the very "need" for an unidentified additional heat source in the core or D-zone is based on the theory of convection currents in the mantle, which would strongly cool the core with the lowest mantle (e.g., [Rudnick and Fountain, 1995; Buffett, 2002]). However, if mantle convection does not exist, this mysterious heat source may not be artificially created in this way (in laboratory models), and the total energy production in the Earth's interior may be significantly less. Geoneutrinos provide some information about radioactive elements in the deep mantle and core, i.e., antineutrinos formed by β^- decay (due to minimum threshold energy, only decay of several radionuclides of the ^{238}U- and ^{232}Th chains can be detected). The first results were obtained with the KamLAND detector (Japan), indicating rather low

RHP of the bulk Earth, namely 11.2 TW for Th- and U chains only, or ca. 14 TW including K [Gando et al., 2013]. In contrast, the results of the first decade of measurement with the Borexino detector (Italy) were interpreted in such a way that the number of radionuclides in the mantle is significantly higher than predicted by cosmochemical and geochemical models, implying that RHP of bulk Earth would be 38.2 (+13.6/–12.7) TW (out of that only 8.1 TW in lithosphere) [Agostini et al., 2020]. However, the calculated amount of geoneutrinos coming from the mantle is extremely sensitive to various corrections, including the signal from the local lithosphere. Agostini et al. (2020) considered very low Th and U content in the whole 13-km thick sedimentary sequence of the local continental crust, similar to carbonate-dominated formations (very poor in Th and U) near the surface. This could lead to an overestimation of geoneutrinos from the mantle, as also noticed by Sammon and McDonough (2022), who estimated the total Earth radioactive heat production to be 20 TW (out of that 13 TW in the mantle), equivalent to 6.3 10^{20} J/yr. Data from more detectors will be necessary for reliable and representative mapping of radionuclides.

Anderson and Dziewonski (1984), Anderson (1988), and Dziewonski and Anderson (1984) have pointed out, using seismic waves, relatively hot and cold regions in the upper mantle at depths of 200–400 km that do not correspond to the expected regions of the ascent of hot material in hypothetical convective cells. Furthermore, the interpretation of seismic tomography has resulted in the realization that the formation of hot spots cannot be explained by plumes through which heat and material would exit from great depths in the lower mantle [Anderson, 2000].

Tanimoto and Lay (2000) showed that subducted oceanic plates are still detectable by seismic tomography at depths of about 2000 km, where, in addition, the thickening of crust occurs just below the Wadati-Benioff seismic zone. This is more indicative of crustal material being pushed into the lower mantle than being pulled by a convection current in the lower mantle. In addition, subducted crustal basic rocks may sink through the mantle by gravity, because they have (at the same pressure) greater density because of higher Fe/Mg ratios. Therefore, some movements in the mantle which are indicated geophysically, may represent consequences, and not causes of lithospheric plate movements.

Another discrepancy between the theory of convection currents and observations lies in the fact that oceanic rifts are moving away from each other, which would have to be conditioned by the receding centers of convection cells in the mantle, as already shown by V. V. Belousov (1962).

A similar problem around Africa and Antarctica was pointed out by S. W. Carey (1976). These continents are surrounded on all sides by mid-ocean ridges or plateaus and should be compressed on all sides according to lithospheric plate theory. However, in the example of the East African rift, we see a tensional structure that does not agree with the predicted compression.

H. Jeffreys (1974) showed theoretically that the viscosity of convection currents driven by thermal convection would be so high that these currents would have to stop very soon. According to Kery and Vine (1996), the height of the geoid above the reference ellipsoid is inconsistent with the assumption of mantle current ascent in regions of mid-ocean ridges and rifts. Many other arguments were made in a review paper by Pratt (2000).

Other problems of the convection currents theory include the origin of hostpots, the intensity of recycling of the crust in the mantle, and the duration of plate tectonics in the Precambrian [Kalenda, et al., 2012].

S. W. Carey (1958, 1975, 1976) attempted to resolve the discrepancies between observations and theoretical ideas about the functioning of convection currents by proposing a model of the expanding Earth. The hypothesis solves elegantly both the problems of an expanding ocean floor and the problems of the triple junction where three lithospheric plates meet and whose relative motion cannot be inferred from any combination of any convection currents, which should have two rather than three Eulerian poles of rotation [Scalera and Jacob, 2003]. However, the mechanism and energy source of Earth’s expansion has remained highly speculative, and the geodetic predictions failed to prove recent expansion [Rajlich, 2004]. Some authors [Rajlich, 2004] consider that the cause of expansion are phase transformations of hypothetical high-pressure modifications of metallic carbon, hydrogen, water ice, silicates in the metallic state, or “frozen” plasma (atomic nuclei without electron shell), or other hypothetical substancesby. However, sufficiently high pressures apparently did not occur in the Earth's core even during the accretion and major asteroid collisions with the Earth. So, these elements and compounds survived in high-density phases for geologically long periods of time.

G. R. Foulger (2010) tried to solve problems with Euler´s poles by separating the individual convection cells into plumes. However, most of the criticized phenomena in convective currents have been retained here and the “model of plumes” itself has become untestable due to its variability and ambiguity [Sheth, 2011]. Plumes, however, may form large igneous provinces, typically unrelated to plate boundaries. Note that any hypotheses considering the coexistence of convective currents and plumes in the mantle must overcome serious geometrical problems.

Other hypotheses consider tides, tidal drag, and other cyclic gravitational forces [Heaton, 1975] as the basis for the caterpillar-like motion of the lithosphere against the mantle and the cause of western drift [Doglioni, 2014].

However, all the proposed models of plate tectonics lack a clear and unambiguous description of a mechanism that could explain the observed phenomena and at the same time be sufficiently (energetically) powerful to satisfy all the energy demands of global tectonics. Energy sources must be found to explain the sum of the energies of all earthquakes, volcanism, folding, and other deformations of the lithosphere. They can also clarify the heat flux of the Earth for the whole period of plate tectonics (i.e. at least the last 750 Ma (millions of years), for which the continental motions were reconstructed [Scotese, 2009; Domeier and Torsvik, 2014). Radioactive isotope decay in the core and lower mantle, as shown above, is not enough to meet the energy demand even with accounting for residual heat after the Earth's accretion. Tidal friction is insufficient (about 10^{19-20} J/yr) [Denis et al., 2002; Varga et al., 2005], as are Eötvös forces 2004] or changes in the Earth's rotation rate or length of the day (LOD) [Ostřihanský, 2012]. Tides, LOD changes, Eötvös forces, or Coriolis forces can at most trigger earthquakes, tremors, or microseisms, but cannot serve as a source of plate tectonics energy because the energy output of earthquakes and volcanic activity alone is approximately 2 orders of magnitude greater [Brázdil, et al., 1988]. Sun is the only sustained source of energy large enough for orogenies, subduction of lithospheric plates, and their movement relative to the mantle. It provides approximately 10^{24} J/yr (the solar constant is about 1,366 W/m^2 and nearly half of this flux passes through the atmosphere and reaches the Earth's surface).

Purpose

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

The observed deformations of the Earth´s surface – literature data

Land surface deformation has been measured for many years. An example of data important for the investigation of exogenous forces is the almost continuous series of measured tilts at the Grotta Gigante tide station near Trieste (Italy) which covers now more than 50 years [Braitenberg, et al., 2006].

The tilt variation record of the Grotta Gigante tidal station [Braitenberg, et al., 2006] shows a clear annual period of varying amplitude. It is loaded on long-period variation (ca. 40–45 years) and has a secular trend. The direction of the annual variations is approximately NE-SW to ENE-WSW and the direction of the secular trend is approximately to the NW. The authors explained the annual variations as the response of the massif to the annual course of precipitation and the saturation of the massif to the N of Grotta Gigante by precipitation water.

Similarly, Grillo et al. (2011) showed that the short-term course of the N-S tilt in the Bus de la Genziana cave is influenced by the amount of precipitation that accumulates in the valleys to the SE and SW of the cave.

Significant influence of external forces on the Earth's crust has been also proven in studies dealing with volcanism in various periods, especially in the Quaternary where high-resolution data are at disposal. During the last 110.000 years, the deposition of volcanic material prevalently of Icelandic origin (as recorded in the GISP2 core of Greenland ice) was by far the most intensive during Late Glacial and Early Holocene [Zielinski, et al., 1996]. In the Circum-Pacific zone, the intensity of explosive volcanism during the last million years was minimal in the (middle of) interglacials, showing significant correlation with Milankovich cycles [Kutterolf, et al., 2013]. We show [see also Discussion, and Procházka, 2014] that in both cases these variations reflect the fact that the lithosphere deformation is greater in relatively dry periods with larger temporal and spatial temperature contrasts (generally corresponding to cold periods). In any case, the influence of "external" factors on "endogenous" dynamics can no more be neglected.

Evaluation of first 12 years of measurements with vertical static pendulums and their correlation with other methods: The role of solar radiation and other external factors in the deformation of Earth's surface and crust

We began to measure the deformations of buildings and underground spaces in a number of places in Europe, to decipher which mechanism is probably most involved in the Earth's deformations and in the accumulation and release of energy from the massif.

One of the first inclinometer stations, equipped with a vertical static pendulum [Neumann and Kalenda, 2010], was installed in the reinforced concrete bunker Skutina (Czech Republic) with 2 m wall thickness and a stable temperature was assumed. We supposed that the deformation of the entire bunker body from the surface to a depth of 30 m would not be affected by short-term variations in the bunker's irradiation by the sun. Measured inclinations showed the incorrectness of this assumption. The basic period observed in the record was a full-day period, clearly related to the irradiation of the southern side of the bunker shell (see Fig. 1).

According to Fig. 2, the bunker's tilt variations were predominantly in the North-South direction. Earth´s tides were also occasionally observed, but their amplitude was much smaller than that caused by solar irradiance. The daily tilt pattern resembled the number "8" [Kalenda and Neumann, 2014], with the southernmost "swing" occurring at sunrise in clear weather and the northernmost "swing" happening when outdoor temperatures initially dropped to balance incoming irradiation and radiated heat. In the case of high cloud cover and equilibrium daytime temperatures, the diurnal run had little or negligible amplitude in the N-S direction.

Station P1 in Příbram (Czech Republic) was the second inclinometer station, which showed a clear connection between near-surface deformation and irradiation. Here, the P1 pendulum was located at the entrance to the Prokop adit at a depth of about 2 m below ground. It was strongly influenced by the deformation of a light building – a cell – which covered the entire entrance portal of the adit. The greatest deformation of the adit mouth occurred on a clear day and the adit mouth tilted in the N (south) direction with maximum deformation and noise in the afternoon (Fig. 3).

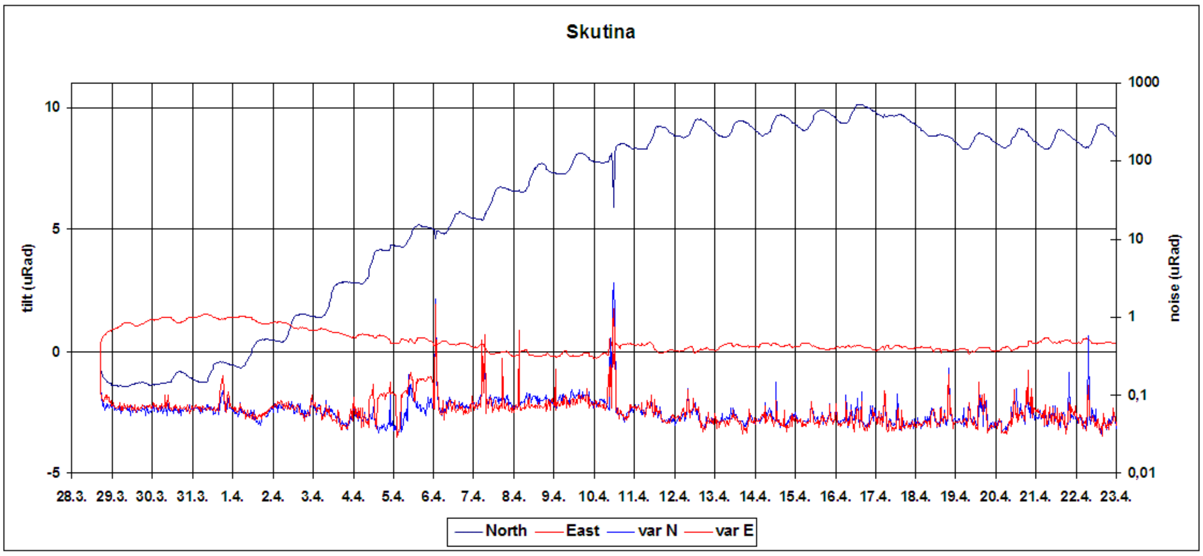

Fig. 1. Tilt (left axis) and tilt noise (tilt variation in the 30-minute window – right axis) at Skutina station from 28.3. to 23.4.2009. Blue curve – N+-S- tilt component, red curve – E+-W- tilt component.

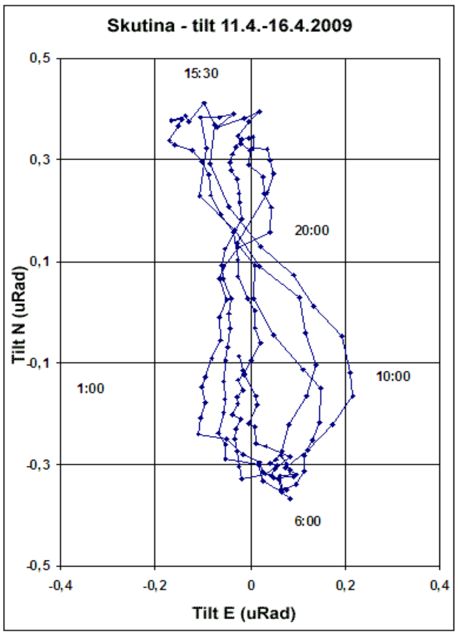

Fig. 2. Course of the tilt at Skutina station from 11.4.2009 to 16.4.2009.

The measurements at station P1 in Příbram corresponded to the results of laboratory measurements in a residential building in Prague. There, researchers measured the temperature inside and outside the building and the irradiation of the south side of the building in addition to the inclinations (measured with the same vertical static pendulum) [Neumann, 2005]. The tilt of the building (to the SE and to ESE) was proportional to the magnitude of the solar irradiance. The rate of tilt directly corresponded to the irradiance in detail even when the building was only covered by a cloud for a few minutes (Fig. 4). The tilt of the building began to respond to the change in irradiance only a few seconds after this change.

A day-long deformation "wave" is associated with the irradiation of the Earth's surface. Let us call it a thermoelastic wave in accordance with the way it was described by J. Berger and F. Wyatt in 1973 or J. Berger in 1975. Its ability to penetrate deep below the surface was evidenced by the observations of P. Melchior and L. Skalský at the then deepest tidal station in Příbram – Březové Hory in 1969. Even at a depth of about 1300 m below the surface they measured the amplitude of the diurnal wave to be an order of magnitude greater (3–10 times) than the amplitude of the theoretical S1 tidal wave at the same location [Melchior and Skalský, 1969]. Further evidence for a thermoelastic diurnal wave is the discovery of a fictitious 8-hour LS/3 wave [Skalský oral communication, 2010]. This “flows” from the Fourier transform that this wave is a third harmonic of the diurnal wave. It is due to the absence of a negative half-period in the irradiation wave, as negative irradiation is not possible physically. (see Fig. 4). It is worth noting that this discovery further strengthens the existence of the thermoelastic diurnal wave.

Based on the analysis of seismic response to external forcings, it has been found that throughout California, approximately 4 times more seismic events are triggered by diurnal thermal (irradiation) waves than by diurnal and semidiurnal tidal waves [Kalenda, et al., 2005]. The results of this analysis are fully consistent with tilt measurements at stations in central Europe, where diurnal waves with a maximum after noon have amplitudes several times larger (especially on the N-S component) than tidal waves in clear weather (see, e.g., Figs. 3 or 4).

Diurnal variations in tilt were occasionally observable even at a depth of 96 m below the surface at station P7 in Příbram. In addition to them, annual variations in tilt similar to those observed at Grotta Gigante were noted everywhere. Let us consider an example of the Ida station near Malé Svatoňovice, Czech Republic, at a depth of about 200 m below the surface (and 2 km from the entrance of the gallery). There, the annual variation in tilt had an amplitude of up to 20 μRad with a maximum tilt towards N to NNE and a maximum variation in tilt (noise) at the end of the year (Fig. 5).

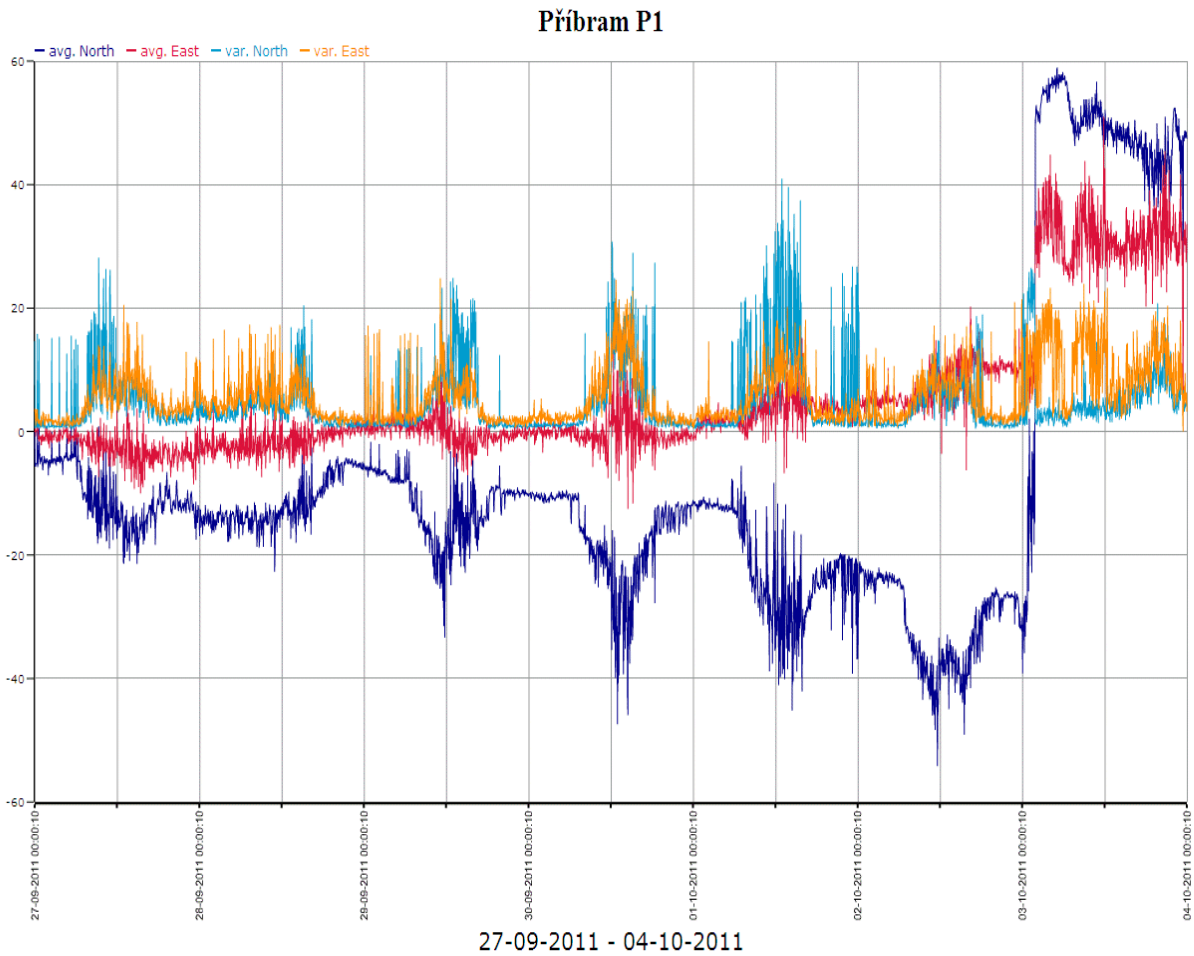

Fig. 3. Tilt and tilt noise (tilt variation in a 30-minute window) at station P1 in Příbram from 27 September to 4 October 2011 screenshot. Blue curve – N+-S- tilt component, red curve – E+-W- tilt component (vertical axis unit in μRad).

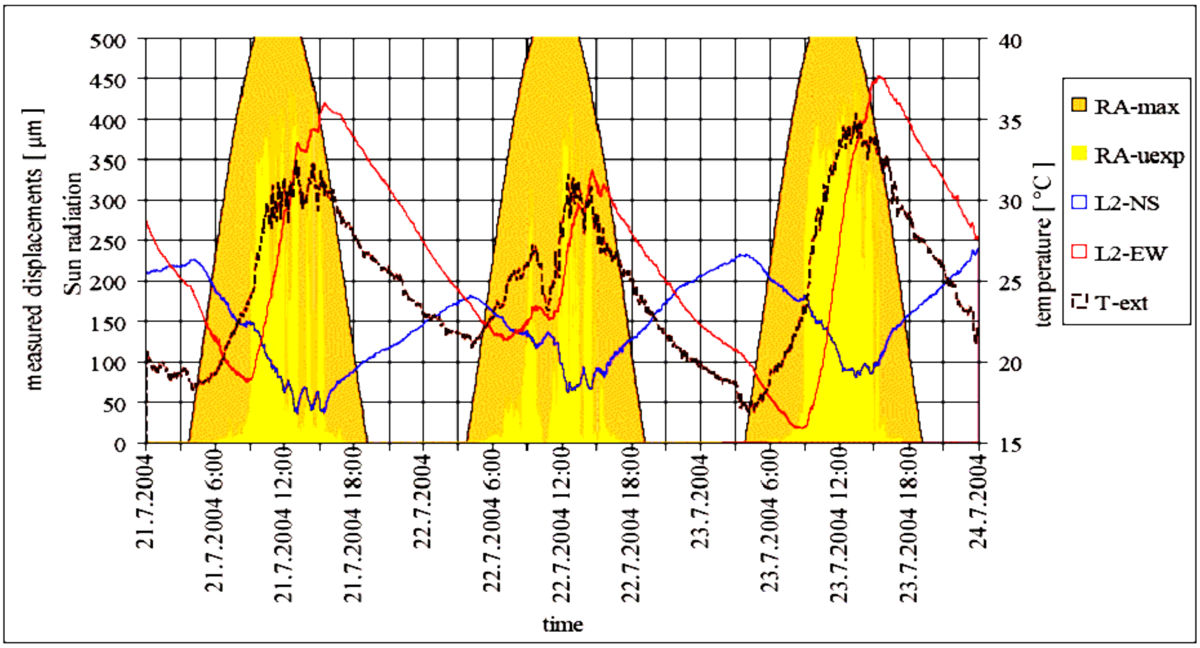

Fig. 4. Diurnal course of deformation as a function of temperature and surface irradiation [Neumann, 2005]. RA-max – theoretical maximum irradiation, RA-exp – measured irradiance, L2-NS – N-S-pendulum displacement component L2, L2-EW – E-W- pendulum displacement component, T-ext – external air temperature.

This typical annual course was also well correlated with other geomechanical measurements in the subsurface. They were conducted, for example, in Plavecká Cave, Slovakia, on active faults using a TM-71 dilatometer. Such measurements were performed in the Vyhne tunnel (Slovakia) using a strain gauge [Brimich, 2006] and even on groundwater level elevations [Stejskal, et al., 2007] (Fig. 6).

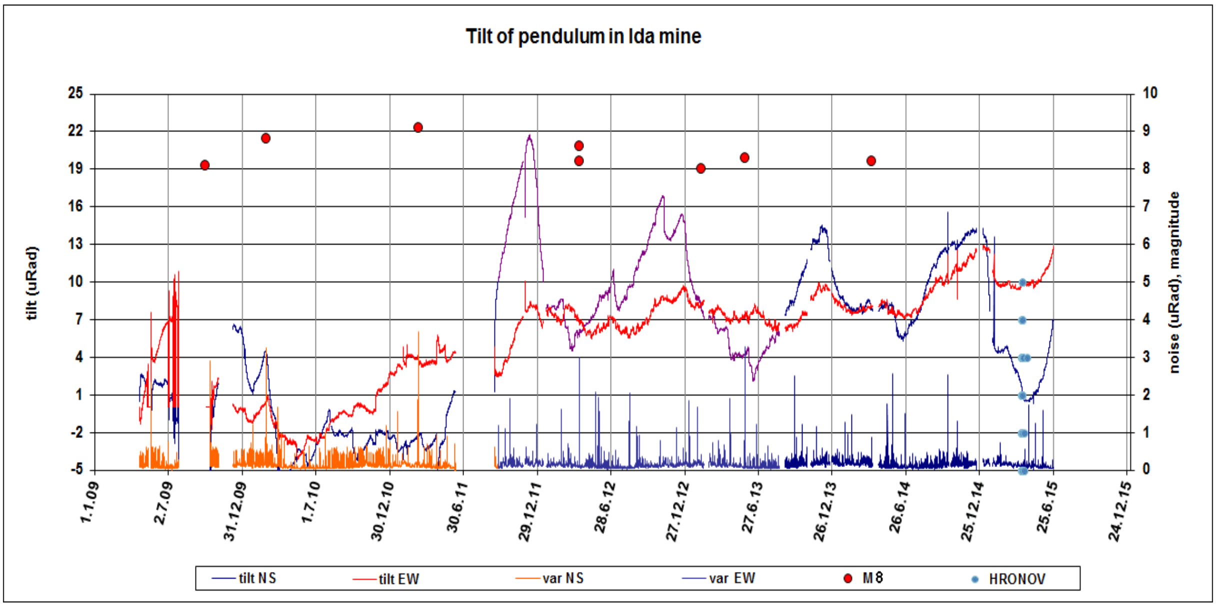

Fig. 5. Tilt and tilt noise (tilt variation in a 30-minute window) at the Ida station in Malé Svatoňovice from 2009 to 2016. Blue curve – N+-S- component of tilt, red curve – E+-W- component of tilt. M8+ are earthquakes anywhere in the world. Hronov – local seismic swarm close to the Ida station.

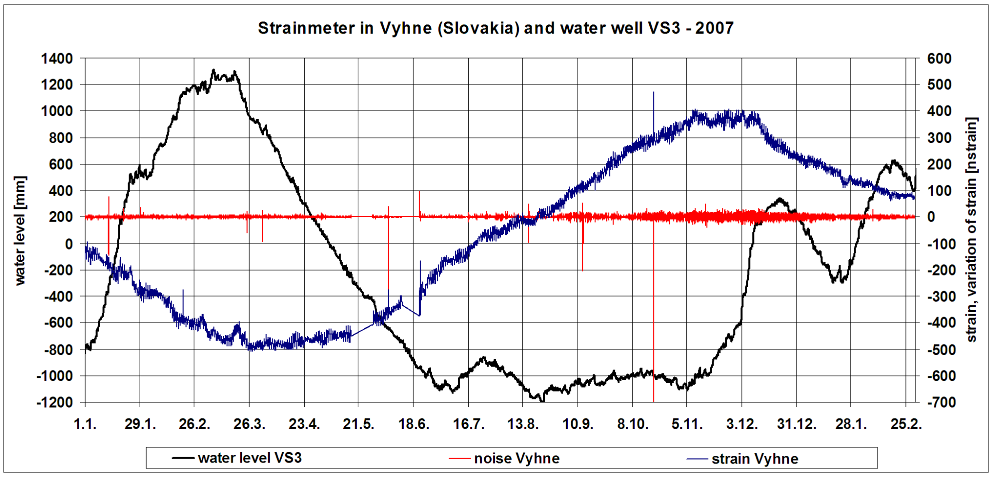

Fig. 6. Annual course of the strain gauge in the St. Padua adit in Vyhne [after Brimich, 2006] and water level elevations in borehole VS3 in the Police Basin, Czech Republic [after Stejskal, et al., 2007].

The noise was the best correlate between the different methods, whether it was variations in tilt (pendulum noise), variations in rock stretching (extension), or even seismic noise in the form of secondary microseisms [Kalenda, et al., 2015]. Peaks of noise and secondary microseisms were regularly observed at the end of a year [Zátopek, 1941; Kárník and Tobyáš, 1961], although their amplitude varied each year. This increased noise is indicative of prevailing stress maxima in rocks (and irreversible micro deformations) just at the end of the year, i.e. in winter. Hvožďara et al. (1988) have shown that the annual course of crustal deformation is induced by a thermoelastic wave. A change in temperature over the course of a year, although penetrating only to shallow depths (5–15 m), causes stretching or shrinkage of near-surface rock layers. The deeper seismogenic, layers are most stretched just at the end of the year and stresses are transmitted to deeper parts of the massif.

This principle, where stresses in rocks are greatest in the cold-winter period, can also be shown in longer – climatic – periods. Orogenesis and increased volcanic activity occurred regularly after the onset of long cold climatic periods (Figs. 7 and 8) [Kalenda, et al., 2012; Croll, 2019]. An assessment of more detailed Quaternary data has shown that volcanism is generally least intense within interglacials (including the Holocene). However, its intensity was high during periods of rapid temperature change, e.g., in the Late Glacial [Zielinski, et al., 1996; Kutterolf, et al., 2013].

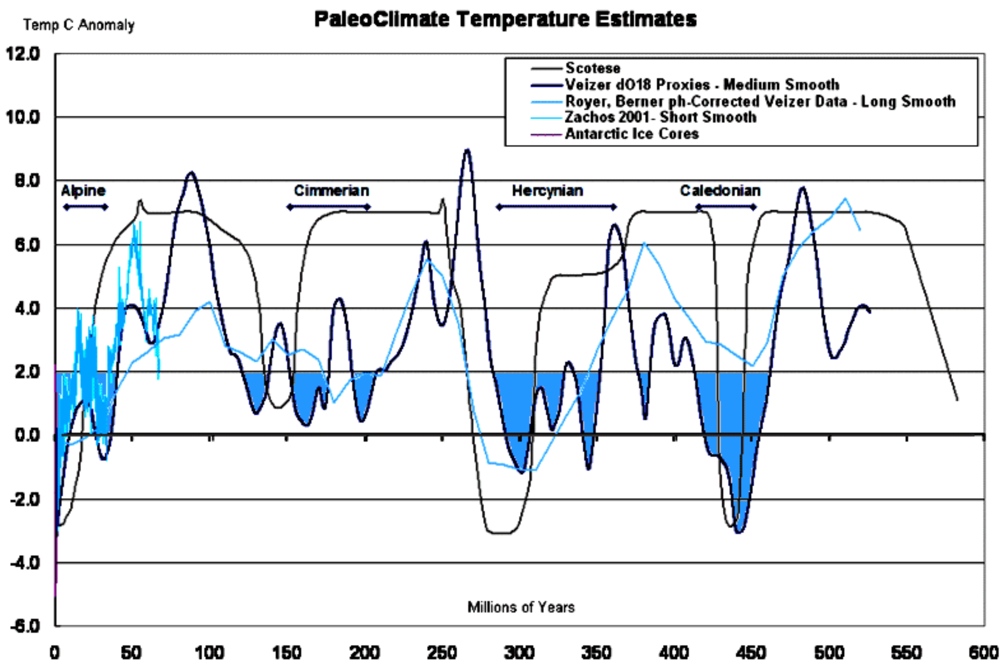

Fig. 7. Temporal correlation of orogenies [after Scotese, 2003] and cold climatic periods [compilation of Illis, 2009] [adapted from Kalenda, et al., 2012].

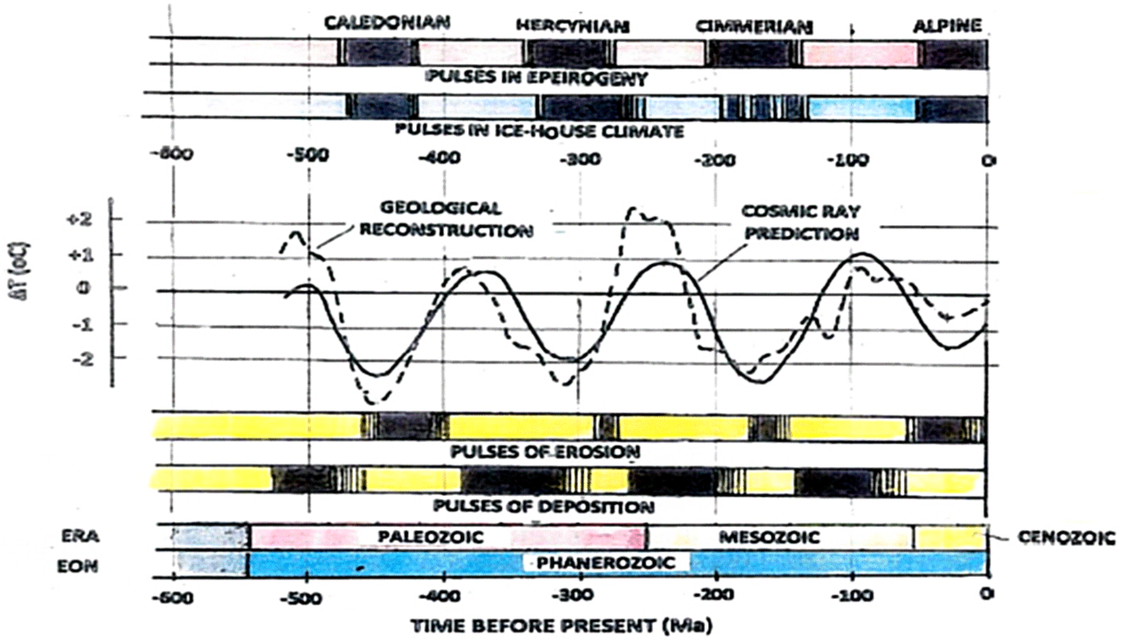

Fig. 8. Temporal correlation between orogenies (first row), cool climate periods (second row), global temperature, temperature and solar activity reconstructed from cosmic rays (third row), Grand Canyon erosional episodes (fourth row), Grand Canyon sedimentary episodes (fifth row), and geologic eras. Adapted from Croll (2019).

The Milankovich cycle of rotational axis tilt was identified in the volcanism of the Circumpacific Zone, a strongly dominant period of 41,000 years [Kutterolf, et al., 2013]. These authors have interpreted these relationships as a consequence of changes in ice pressure. As a component of lithostatic pressure, it influences magma freezing / rock melting temperature [Zielinski, et al., 1996]. There are change in mass distribution relative to the rotational axis caused by changes in polar ice volume [Kutterolf, et al., 2013]. Thus exogenous forces are recognized as at least a significant trigger and mediator of the energy of seismic and volcanic events.

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 realize the variability of stresses in the Earth's crust, which can help predict earthquakes and volcanic eruptions.

Conclusions

Although the theory of continental drift is more than 100 years old [Wegener, 1912], the mechanism of plate motion has not yet been elucidated. All proposed mechanisms (convection currents, plumes) and energy sources (radioactive element decay, accretionary heat, methane hydrates dissolution, tidal forces, rotational energy of deeper layers) have unresolvable discrepancies between theory and observed phenomena. This chapter of the two-part article showed the development of the theory of continental drift and, in particular, of the mechanism of lithospheric plate motion. The basic contradictions of all proposed mechanisms were shown, including the lack of energy resources.

Observational data, particularly crustal deformation, and climate change, point to the most likely, extraterrestrial, energy source for lithospheric plate motion. This is the Sun that supplies approximately 10^{24} J per year to the Earth's surface. Thus, only 4 % of solar energy, including energy losses, is sufficient to move the lithospheric plates, to cause all earthquakes, volcanic activity, and slow movement between blocks (creep), crust and mantle because the sum of all tectonic and volcanic events is about 10^{22} J per year. Observational data show a high correlation between global temperature (or solar activity) and tectonic activity, which coincides with cold periods (or low solar activity) on all time scales from one-day to hundred-million-year long periods (geological eras) over the last 500 million years.

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ТЕОРІЯ ДРЕЙФУ МАТЕРИКІВ – ПРИЧИНИ РУХУ. ІСТОРИЧНИЙ ОГЛЯД І СПОСТЕРЕЖЕННЯ

Теорія дрейфу материків була опублікована ще в 1912 р., але механізм і джерело енергії цього руху досі не з’ясовані. Загальноприйнята модель конвекційних течій у мантії в багатьох випадках суперечить таким спостереженням, як розпоширення дна океану, розтяг рифтів від потрійних точок на всі боки, більш-менш односторонній рух літосфери щодо мантії тощо. У першій частині статті відображено еволюцію поглядів на цю проблематику, а також дані вимірювань, які документують важливу роль поза-земних джерел енергії для руху літосферних плит у добовому, річному та довгостроковому кліматичних циклах. У другій частині статті буде викладена вся теорія механізму руху літосферних плит, яка ґрунтується на накопиченні енергії, що надходить від Сонця, в породах кори, храповому механізмі та проникненні термопружної хвилі із земної поверхні через всю кору.

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

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