

INFLUENCE OF NON-RADIOGENIC COSMIC HEAT GENERATION IN THE BOWELS OF THE EARTH AND PLANETS ON MUTUAL DISPLACEMENTS OF PLANETARY SHELLS

Article 1. The Earth

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We considered the influence of supposed planet non-radiogenic energy source of cosmic (galactic) origin on the process of mutual displacements of planetary shells. We found that the convection configuration in the Earth's bowels has simultaneously three variants of topology of convective flows (single-cell, double-cell of open and closed types), a one-time existence of which is conditioned by nonuniform in space and time heating the bowels by an energy source of cosmic origin. Movement of masses during convection leads to mutual nutation of shells relative to the Earth's axis of rotation. Such swings are characteristic of both the outer stone shell and the inner core of the planet. The motions of the shells are probably gravitationally synchronized, and certain resonances exist in these motions. Nutations occur in the certain corridor, which lies in the middle between the superplumes (African and Pacific), which are antipodally located on the equator. The axis, around which the shells are displaced, roughly coincides with the axis of equatorial maximum moment of inertia and passes through superplumes and positive geoidal undulations corresponding to them. Its existence is conditioned by general mantle isostatism, which causes the emergence of heated segments of the stone shell, forming the Earth's figure and the distribution of its rotational moment.

Key words: mutual displacements (nutations) of Earth's shells; true motion (drift) of the poles; superplumes; general mantle isostatism; non-radiogenic energy source of the Earth's (planetary) bowels of cosmic origin.

ВПЛИВ НЕРАДІОГЕННОГО КОСМІЧНОГО ТЕПЛОВИДІЛЕННЯ В НАДРАХ ЗЕМЛІ І ПЛАНЕТ НА ВЗАЄМНІ ЗСУВИ ПЛАНЕТНИХ ОБОЛОНОК

Стаття 1. Земля

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Розглянуто вплив передбачуваного внутрішньопланетного нерадіогенного джерела енергії космічної (галактичної) природи на процес взаємних зсувів планетних оболонок. Встановлено, що конфігурація конвекції в земних надрах має одночасно три варіанти топології конвективних потоків (однокоміркова, двокоміркова відкритого і закритого типів), одномоментне існування яких обумовлено нерівномірним у просторі і часі нагріванням надр джерелом енергії космічного походження. Переміщення мас у ході конвекції призводять до взаємного похитування оболонок щодо земної осі обертання. Такі коливання властиві як зовнішній кам'яній оболонці, так і внутрішньому ядру планети. Рухи оболонок, ймовірно, гравітаційно синхронізовані, існують певні резонанси у цих рухах. Похитування відбуваються в певному коридорі, який розташовується посередині між антиподально розташованими на екваторі суперплюмами (Африканським і Тихоокеанським). Вісь, навколо якої зміщуються оболонки, приблизно збігається з віссю екваторіального максимального моменту інерції і проходить через суперплюми і відповідні їм позитивні ундуляції геоїда. Її існування зумовлене загальномантією ізостазією, котра змушує спливати розігріті сегменти кам'яної оболонки, формуючи фігуру Землі і розподіл її обертового моменту.

Ключові слова: взаємні зміщення (гойдання) земних оболонок; істинні рухи (дрейф) полюсів; суперплюми; загальномантія ізостазія; нерадіогенне джерело енергії земних (планетних) надр космічної природи.

ВЛИЯНИЕ НЕРАДИОГЕННОГО КОСМИЧЕСКОГО ТЕПЛО ВЫДЕЛЕНИЯ В НЕДРАХ ЗЕМЛИ И ПЛАНЕТ НА ВЗАИМНЫЕ СМЕЩЕНИЯ ПЛАНЕТНЫХ ОБОЛОЧЕК

Статья 1. Земля

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Рассмотрено влияние предполагаемого внутрпланетного нерадиогенного источника энергии космической (галактической) природы на процесс взаимных смещений планетных оболочек. Установлено, что конфигурация конвекции в земных недрах имеет одновременно три варианта топологии конвективных потоков (одноячейная, двухъячейная открытого и закрытого типов), одномоментное существование которых обусловлено неравномерным в пространстве и времени нагревом недр источником энергии космического происхождения. Перемещения масс в ходе конвекции приводят к взаимному покачиванию оболочек относительно земной оси вращения. Такие качания свойственны как внешней каменной оболочке, так и внутреннему ядру планеты. Движения оболочек, вероятно, гравитационно синхронизированы, существуют определенные резонансы в этих движениях. Покачивания происходят в определенном коридоре, который располагается посередине между антиподально расположенными на экваторе суперплюмами (Африканским и Тихоокеанским). Ось, вокруг которой смещаются оболочки, примерно совпадает с осью экваториального максимального момента инерции и проходит через суперплюмы и соответствующие им положительные ундуляции геоида. Ее существование обусловлено общемантийной изостазией, которая заставляет всплывать разогретые сегменты каменной оболочки, формируя фигуру Земли и распределение ее вращательного момента.

Ключевые слова: взаимные смещения (качания) земных оболочек; истинные движения (дрейф) полюсов; суперплюмы; общемантийная изостазия; нерадиогенный источник энергии земных (планетных) недр космической природы.

1. Introduction

Previously, we have already stated in the Geological Journal [Макаренко, 2011а, 2011б, 2012а, 2012б, 2013, 2014] and substantiated by comparing geological, astronomical and physical data the assumption about the probable existence of an energy source of cosmic nature in the depths of Earth and other planets (“space heater”) driven by factors that are external relative to the Solar System. Multiple authors have previously expressed in the literature the hypotheses that such a cosmic energy source could exist in the depths of Earth and other cosmic bodies based on theoretical considerations [Carriган, 1980; Arafune et al., 2001; Drobyshevski, 2004; Jørgensen, 1981; Mack et al., 2007; Brans, Dicke, 1961, etc.]. Physicists most often assume all kinds of hypothetical all-pervading particles of the so-called dark matter, which, in the opinion of physicists and astronomers, constitutes the main part of the substance of our Galaxy and the Universe in general, to be “fuel”. However, these hypotheses have never been tested before by analysing geological and other observational data. Our comparisons of the properties of “space heaters” postulated by theoretical physicist with the properties of the non-radiogenic part of the heat release in the depths of the planets observed in geology and planetology

show that the dark matter warms Earth and planets with high probability.

A little later, independently and based on the analysis of a completely different data set, M. Rampino a famous researcher in the field of external (galactic) influences on terrestrial processes, came to similar conclusions that the dark matter of the galactic disk heats the planetary depths. Results of this study were published in the highly rated *Monthly Notices of the Royal Astronomical Society* [Rampino, 2015].

Unlike radioactive isotopes, which have signs of lithophilous properties and are concentrated closer to the Earth’s surface, the supposed energy source of cosmic nature acts predominantly in the deepest parts of our planet [Макаренко, 2011б]. At comparable capacities of cosmic and radiogenic energy sources, the space one has a more convenient spatial arrangement in terms of its contribution to the warming of the Earth’s depths, the convective flows formation and, accordingly, the subsequent geological processes. An assumed cosmic energy source has higher geological significance. Therefore, it would be interesting to consider, at least in very general terms, the peculiarities of the impact of such a specific phenomenon as an energy source naturally moving in space over time on any intra-terrestrial processes.

Spatially and timely uneven heating of planetary depths is a distinctive feature of this energy source. There is a “hot latitude” where the current release of energy is maximized, regularly shifting over time from era to era [Макаренко, 2011б]. Uneven in time, regularly modulated heating at this latitude leads to excess energy release when it intersects the equatorial zone, which contributes to the formation of the subequatorial belt of excess warming of the planetary depths [Макаренко, 2011б]. There is also an asymmetry in heating between the Northern and Southern hemispheres, which is related to the direction of movement of Earth in the galactic space [Макаренко, 2011б]. Alternatively, the heat release of cosmic nature occurs predominantly in one or the other hemispheres with different intensity and duration. For the present moment the Southern Hemisphere has been overheated for several hundred million years. The probable nature of these processes and the relevant data are discussed in details in [Макаренко, 2011б].

Processes of uneven heating should lead to the formation of the planets relatively warm (and therefore less dense) and relatively cold (higher density) zones in the depths, which should be accompanied by the formation of convective flows and mutual flows of matter between zones of uneven heating. Thus, regular redistribution of masses should occur in planetary depths.

Mass redistributions are caused by convection. According to [Monin, 1991], there are three seemingly mutually exclusive variants of the topology of convective flows in the Earth’s mantle: 1) single-cell convection (shown in Figure 1a) assumes the existence of a hemisphere with an ascending heated convective flow and an antipodal hemisphere where the cooled substance descends; double-cell convection occurs in two forms: 2) with an open configuration,

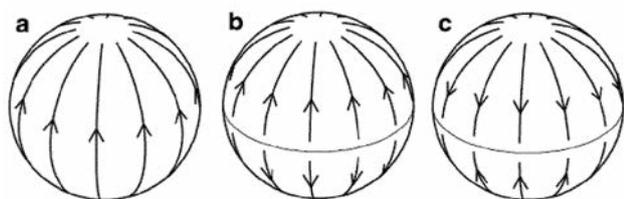


Fig. 1. Models of possible convection variants in the bowels of the Earth according to [Monin, 1991]: a) single-cell convection; b) double-cell with open configuration; c) double-cell with closed configuration

Рис. 1. Модели возможных вариантов конвекции в недрах Земли по [Монин, 1991]: а) одна ячейка конвекция; б) двухъячейка с открытой конфигурацией; в) двухъячейка с закрытой конфигурацией

where the substance rises and descends in two antipodal zones in the intermediate zone (Figure 1b); 3) with a closed configuration, where two global antipodally located upstreams are divided by the strip where the substance descends (Figure 1 c).

This may seem improbable from the point of view of thermodynamics, if we assume that the heat release in the depths of Earth is laterally uniform, but all three mutually exclusive variants of convection were realized in nature simultaneously. It follows from this claim that, in our opinion, the heating in the depths of Earth is laterally non-uniform. In addition to that, it is not uniform regularly. The question arises: why is that?

The most global single-cell convection follows from the existence of the so-called northern drift of lithospheric plates. There are also many other indirect indications of the current relative overheating of the Southern Hemisphere compared to the Northern Hemisphere. They are given in our previous paper [Макаренко, 2011б]. Direct measurements of heat flow also show that the Southern Hemisphere is overheated. According to [Wang, Wang, Ma, 1998], the heat output from the Earth’s mantle (minus losses from the Earth’s crust, where they are determined by distribution of continental masses and the radioactive isotopes contained in them) totals $22.1 \cdot 10^{12}$ W for the Southern Hemisphere, which is approximately twice higher than the same indicator for the Northern Hemisphere, which is $10.8 \cdot 10^{12}$ W.

The second model of the convective flows topology follows from the existence of a subequatorial hot belt of matter in the depths of the planet. The arguments in favour of the existence of this belt in the depths of Earth and other planets are given in our earlier works [Макаренко, 2011б, 2012a], as well as in even earlier works by other authors.

Both the overheating of one of the hemispheres and the presence of the subequatorial heating zone have astronomical reasons and follow from the peculiarities of the interaction of the galactic medium (the flow of dark matter heat-producing particles supposed by many physicists) with the Solar System in general and planetary depths in particular. Models of this interaction are given in [Макаренко, 2011б, 2012a, 2013].

The third variant of the convective flow topology is observed in the existence of long known and actively discussed African and Pacific superplumes located antipodally. Clarifying the nature of this phenomenon is one of the objectives of this study.

According to the laws of mechanics, displacements of masses must inevitably be accompanied by corresponding shifting of the Earth's "solid mass" as a whole relative to the axis of its rotation. Isaac Newton wrote about it in the first volume of his "Mathematical principles of natural philosophy": "If we place a new amount of matter collected as in the form of a mountain somewhere between the pole and the equator, it will break the correctness of the globe's motion and will make the pole move on its surface, which will begin to circle around their original locations."

The objective of this phase of our study is to explore the effect of non-uniformity of heat release by the assumed energy source of cosmic nature on the mutual shifts of planetary shells (observed as true motions (drift) of the poles true polar wander (TPW), since these shifts are one of the most common, global processes studied by geology (such shifts are rheologically possible, since there is a liquid "layering" in the form of a outer core of the planet between the hard shells: the rock crust and mantle, and the inner core).

The work consists of two papers. The first paper considers these issues in relation to Earth, and the second one considers them in relation to planets.

2. Movements of the Earth's shells and poles

True movement (wanderings, drifts) of the poles (TPW) are understood as the total shift of the planet's surface relative to its rotation axis on geological time scales (minus the partial movements of tectonic plates).

This phenomenon is caused by the effects of centrifugal forces on the anomaly in the distribution of masses either on the surface of the planet or in its quasi-liquid depths.

Figure 2, borrowed from [Evans, 2003], illustrates this. It shows how the Earth's shell (mantle) shifts when the rotation axis is fixed. On the left in Figure 2a, you can see how in the course of general mantle convection, which initiates plate tectonics and the appearance of density inhomogeneities (submerged compacted and floating rarefied masses are shown in dark and light grey colours, respectively), due to the viscosity of the mantle material, the vertical displacements of the lower surface lead to deformation of the upper and lower boundaries of the mantle. On the right in Figure 2b you can see how the rises appeared turn the rock shell towards the equator, and the lowers turn the rock shell to the poles.

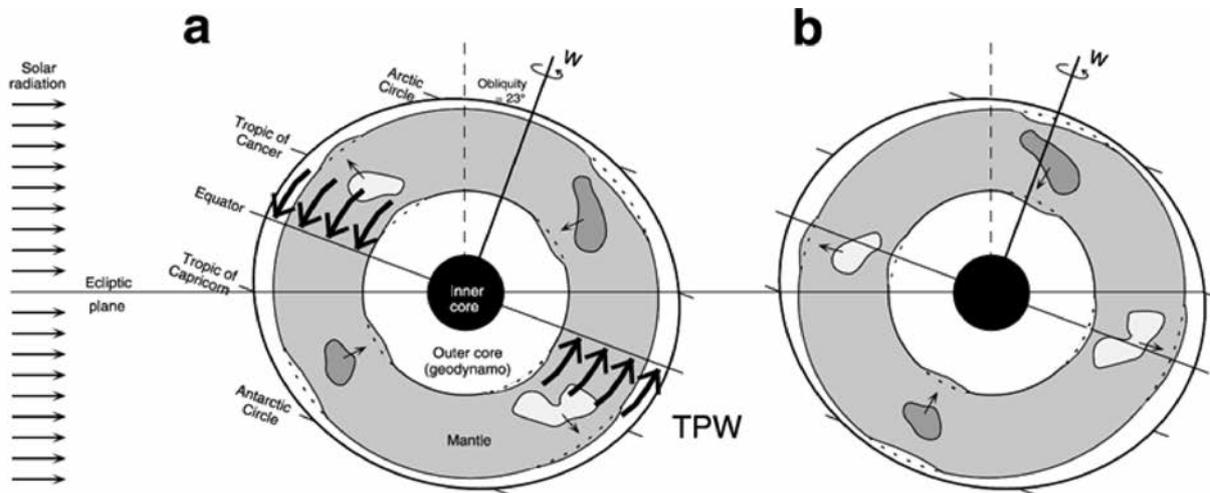


Fig. 2. Turn due to emersion of hot and immersion of cold areas of stone shell [Evans, 2003]

On the left side a) it is shown how in the course of general mantle convection initiating a plate tectonics and emergence of density inhomogeneities (submerged compacted and emerged rarefied masses are indicated by dark and light gray gradations, respectively), due to the viscosity of mantle substance, the vertical movements of anomalies lead to deformation of upper and lower boundaries of mantle. On the right side b) it is shown how the occurred elevations shift the stone shell to the equator, and depressions – to the poles

Рис. 2. Разворот вследствие всплытия горячих и погружения холодных участков каменной оболочки [Evans, 2003]

Слева а) показано, как в ходе общемантийной конвекции, инициирующей тектонику плит и возникновение плотностных неоднородностей (погружающиеся уплотненные и всплывающие разреженные массы показаны темной и светлой градациями серого, соответственно) из-за вязкости мантийного вещества, вертикальные перемещения аномалий приводят к деформированию верхней и нижней границ мантии. Справа б) показано, как возникшие поднятия поворачивают каменную оболочку к экватору, а опускания – к полюсам

Figure 3 shows the equatorial hot belt in the Earth's mantle and the space-time displacement of the hot latitude forming this belt.

Similar formations are present within the inner and outer cores of the planet, as well as in the depths of other planets [Макаренко, 2011б, 2012а].

As we can see in Figure 3, there are two antipodally located African and Pacific superplumes or ascending hot convective mantle flows within the hot belt that form an integral part of the belt. Superplume centres are located quite strictly in the plane of the equator. Plain, ordinary plumes, which are rooted deeply into the mantle, are grouped in the areas of manifestation of these superplumes.

Figure 3 also shows that the hot belts outside the central points of the superplumes, manifested by both the rheological properties of the mantle and the location of ordinary plumes, are located in planes that are slightly offset relative to the present geographical equator, and by different angles. It is in the places of greatest shift where belts are thinned, "spread" the most.

At the same time, according to our ideas about the cosmic origin of hot belts in the depths of plan-

ets [Макаренко, 2011б, 2012а], heat should mostly accumulate in zones adjacent to the equator. As we see that these zones are somewhat displaced in reality, we can assume that here we deal with manifestations of displacement of the planet as a whole, or rather, of its rock shell relative to the liquid iron core of Earth, caused by the convective redistribution of masses in the depths of the planet. Ancient hot subequatorial belts, which appeared in the course of the "space heater" operation during maximums of heat release, and are dated using the astronomical method, can be conveniently used as a reference point for the study of such movements.

Prior to the present work, when studying the true motion of the poles, the tying to the location of mantle plumes was used as a reference point (it is assumed that they almost do not change their position in the mantle space); the centre of mass of the continental plates for the reference point is also used as a reference point (in the hope to separate the true motion of the poles from the local drift of the continental plates). Location of the geomagnetic poles is also taken into account. Current true pole drift is studied using star observations and satellite measurements.

It is striking that the mutual location of the continental segment of the Earth's crust and the structure of the equatorial hot belt of Earth are not coincidental. It is obvious that continents tend to move as far as possible from superplumes, the ascending convective flows of mantle matter, which is natural though, since they themselves move under the influence of convective flows. Continents are grouped mainly on meridians, where the shifts of equatorial hot zones relative to the modern geographical equator are maximum, which suggests that we, in fact, are dealing with different sides of the same phenomenon.

This peculiarity is confirmed by quantitative data on the meridional distribution of land. Figure 4 taken from [Федоров, 2007] shows the distribution of land by longitudes (%) in the Northern Hemisphere. There is a pattern that other researchers note as well: the continental crust concentrates near the selected "continental" meridians, forming a meridional belt

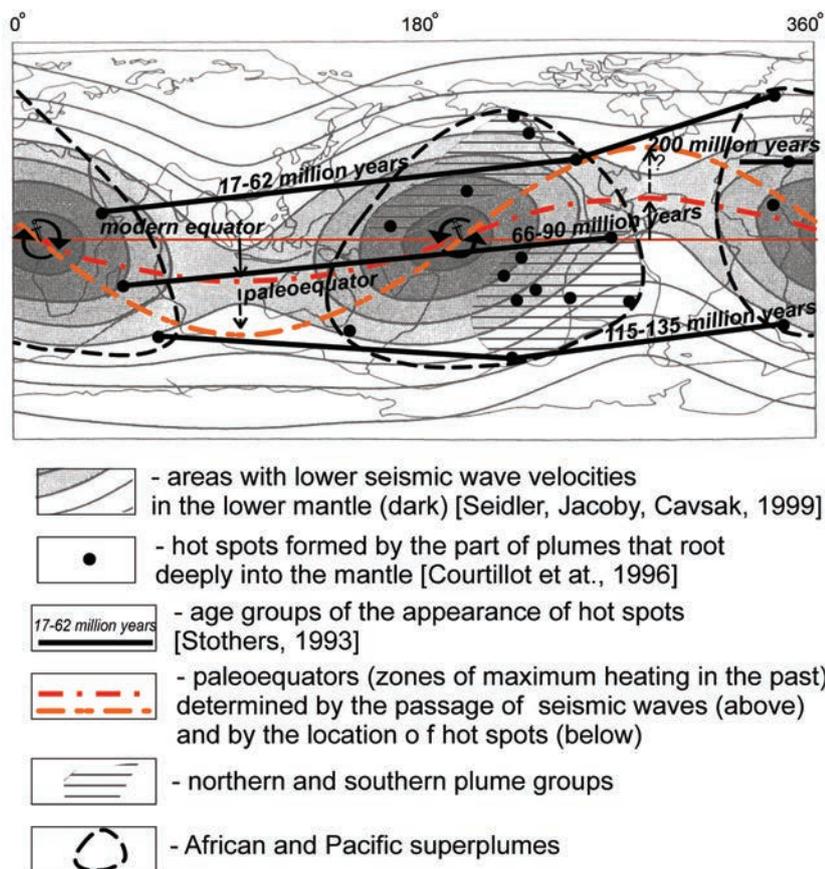


Fig. 3. Equatorial hot belt of the Earth's mantle

Рис. 3. Экваториальный горячий пояс мантии Земли

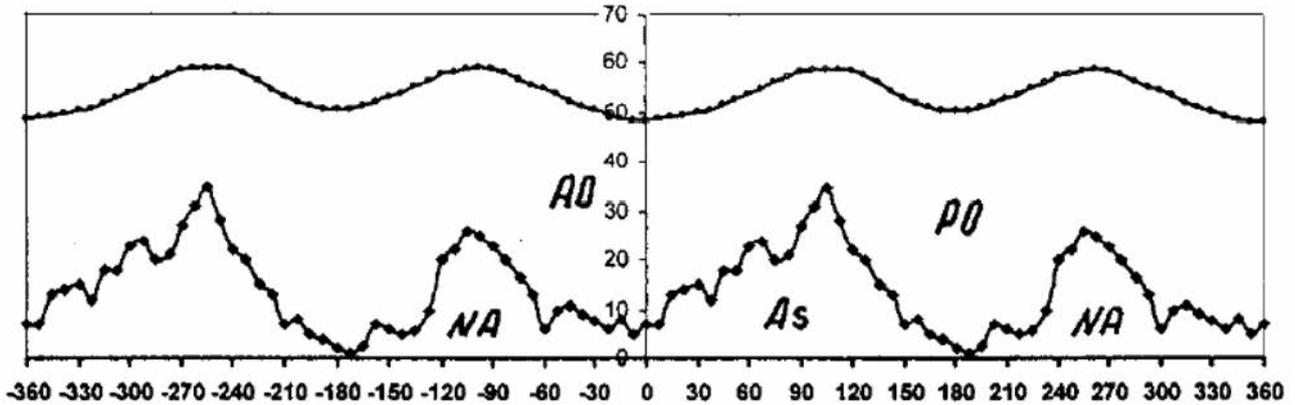


Fig. 4. Distribution of land (in %) in the northern hemisphere by longitudes (lower line): North America (NA), Eurasia without the Arabian Peninsula and without the Southwest Hindustan (As); the upper line in the figure: the averaged tension of the Earth's magnetic field by meridians (T, in oersteds) [Кондратович, 1992] taken from [Федоров, 2007]

Рис. 4. Распределение суши (в %) в Северном полушарии по долготам (нижняя линия): Северная Америка (NA), Евразия без Аравийского полуострова и без п-ва Индостан (As); верхняя линия на рисунке: осредненная по меридианам напряженность магнитного поля Земли (Т, в эрстедах) [Кондратович, 1992], взято из [Федоров, 2007]

that envelops the Earth globe and crossing the equatorial belt of high temperatures in its thin parts, at the equal distance from the superplumes. The same figure shows the distribution of the Earth's magnetic field strength averaged by meridians, which is similar to the distribution of land.

Figure 5, taken from the same source, shows a generalized picture of the geoid surface. Comparing these figures, we can see that the ascending convective flows in the mantle spatially correspond to the excess height (so-called positive undulations or waves) of the geoid over the rotation ellipsoid, and continents have gathered in the depressions (negative undulations) over the downward mantle flows.

Mass distribution on Earth is not spherically symmetric. Earth is a triaxial ellipsoid. Bumps of the Earth's shape, formed by ascending mantle flows, determine the location of the equatorial major axes of inertia moments. In accordance with the accepted notation, axis c coincides with the rotation axis, axes a and b lie in the plane of the equator and are perpendicular to each other, while $a < b$. Axis b passes through the centres of equatorial superplumes and is located on the meridian 14.93° west longitude and 165.07° east longitude respectively; axis a is located on the meridian 75.07° east longitude and 104.93° west longitude [Liu and Chao, 1991] (Figure 5).

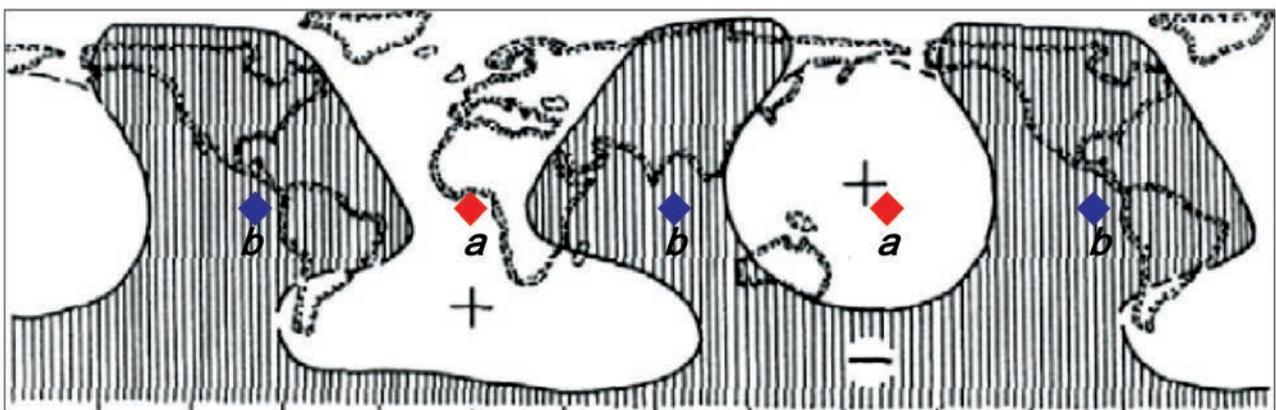


Fig. 5. Surface of geoid by gravimetric and satellite data of the Goddard Space Flight Center (USA), generalized figure [Федоров, 2007]. Elevations over ellipsoid (the first tens of meters) are shown in white, and depressions are showed with hatching. In addition, the main equatorial axes of moments of inertia are also shown in color [Liu, Chao, 1991]

Рис. 5. Поверхность геоида по гравиметрическим и спутниковым данным Центра космических полетов им. Годдарда (США), генерализованный рисунок [Федоров, 2007]. Превышения над эллипсоидом (первые десятки метров) показаны белым цветом, понижения – штриховкой. Также цветом дополнительно показаны главные экваториальные оси моментов инерции [Liu, Chao, 1991]

In a stable state, the axis of the greatest moment of inertia of the planet coincides with the rotation axis. The redistribution of masses on the surface or inside the planet is a disturbing factor and can lead to the reorientation of the largest axis of the moment of inertia relative to the planet's body. During this process, the planet as a whole, or rather, its shell, since the depths contain an intermediate liquid layer, the rheology of which allows relatively independent displacements, shifts relative to the rotation axis so that the axis of the greatest moment of inertia and the rotation axis coincide. On the outside, it looks like wandering of geographical poles on the surface of the planet.

It is known that the surface of the boundary separating the mantle from the Earth's core also correlates well with the geoid surface [Сорохтин, Ушаков, 1991] dents at this boundary correspond to downward convective flows of the mantle, and rises correspond to ascending flows, which is natural as the ascending flows are composed of superheated substance of increased buoyancy, while downward flows are composed of a cooled substance, which is more dense, and slightly recessed into a liquid iron core. Deviations from the average level are about 6 km.

The phenomenon of isostasy is known for the Earth's crust. That is, it has been established that its individual blocks float on the mantle substrate, subject to the action of the Archimedes force. The same phenomenon, apparently, is also typical for the entire mantle as a whole. Mantle segments, with the ascending convective flows of the African and Pacific superplumes located inside them, are heated and have increased buoyancy. The same segments of the mantle, which contain descending cooled convective flows, are characterized by a higher density and, accordingly, less buoyancy; they are somewhat "sunk", "subsided" into the dense iron core of the Earth on which they float. It is for this reason, the geoid surface has two global rises in the areas of superplumes. For the same reason, the surface separating the core from the mantle correlates in general with the geoid surface.

It can be assumed that the irregularities of between "core-mantle" and "bumps" boundary determine the nature of the currents of the conducting substance in the core, which affects the peculiarities of magnetic field generation and its structure. It is believed that in such places the magnetic field will be forced out beyond the boundaries of the core,

forming magnetic anomalies tied to certain geographical regions. Electric currents in the mantle are negligible in comparison with currents in the core, and the magnetic field is practically not generated there. A magnetic field is generated in the core, but only 1% of its energy is distributed outside the core. Satellite observations revealed that a significant part of the field that goes out is formed in four vast areas at the boundary of the core and the mantle.

Figure 6a taken from [Кузнецов, 2008] shows the general spatial structure of the geomagnetic field. It can be presented as the sum of the fields from two sources: basic source, dipole source and one of

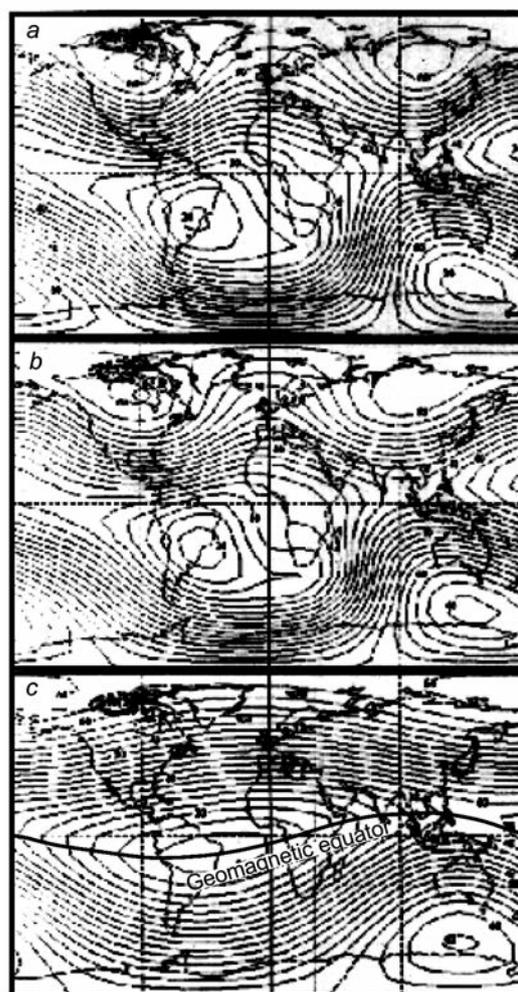


Fig. 6. Structure of magnetic field of the Earth [Кузнецов, 2008]. Module of the geomagnetic field intensity (in nT) (a); computer model of the geomagnetic field as an amount of sources: dipole field and four global magnetic anomalies (б). Dipole field without sources of anomalies (в)

Рис. 6. Структура магнитного поля Земли [Кузнецов, 2008]. Модуль интенсивности (в нТл) геомагнитного поля (а); компьютерная модель геомагнитного поля как суммы источников: дипольного поля и четырех глобальных магнитных аномалий (б). Дипольное поле без источников аномалий (в)

magnetic anomalies. Figure 6б shows the field of four main global magnetic anomalies: Canadian, Siberian, Brazilian and Antarctic; and Figure 6в shows a dipole field without sources of anomalies. It should be noted that these anomalies are confined to the regions of descending cold convective flows

in the mantle, that is, precisely to those places where the core-mantle boundary goes deep into the core. Such interconnections are especially clearly seen in Figure 7, which shows the topography of the boundary between the core and the mantle and the location of the centres of magnetic anomalies.

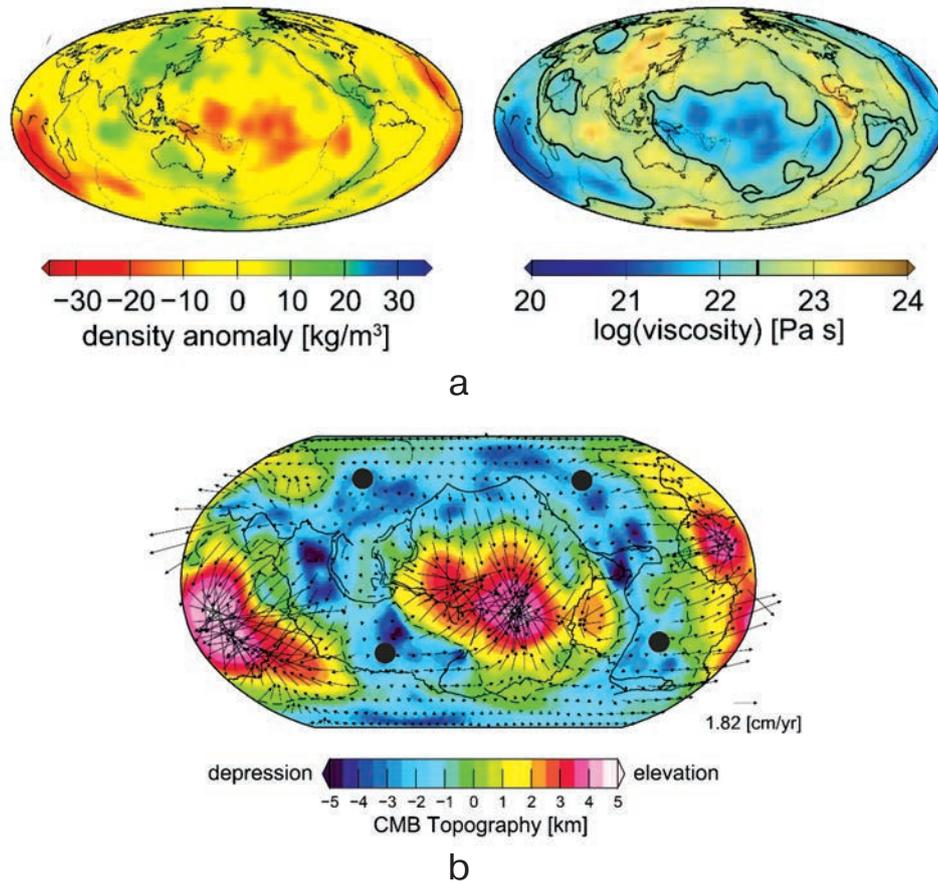


Fig. 7. Conditionality of main anomalies of the geomagnetic field and topography of boundary between the core and mantle of the Earth by mantle rheology

a) Distribution of anomalies of the mantle substance density at the depth of 2598 km (left) and distribution of viscosity at the same depth (right), according to [Yoshida, 2008]. The substance of the African and Pacific superplumes is characterized by lower density and viscosity

б) Topography of the boundary between the earth's core and mantle (according to [Yoshida, 2008]) and major anomalies of the geomagnetic field (see fig. 7). Red feeling indicates the elevation of the boundary, blue - its depression. Arrows are the flows of the mantle substance in the lower part of the mantle. The black dots are the centers of the major anomalies of the geomagnetic field, which are confined to the depressions in the relief of the earth's core. It is evident that the topography of the boundary between the mantle and the core is caused by convection in the mantle. Those mantle segments, which involve superplumes (areas of heated substance) are elevated because they are characterized by increased buoyancy

Рис. 7. Обусловленность главных аномалий геомагнитного поля и топографии границы между ядром и мантией Земли мантийной реологией

а) Карты распределения аномалий плотности мантийного вещества на глубине 2598 км (слева) и распределения вязкости на той же глубине (справа), по [Yoshida, 2008]. Веществу Африканского и Тихоокеанского суперплюмов свойственна более низкая плотность и вязкость

б) Топография границы между ядром и мантией Земли (по [Yoshida, 2008]) и главные аномалии геомагнитного поля (по рис. 6). Красной заливкой показаны повышения границы, синей – ее понижения. Стрелки – потоки мантийного вещества в низах мантии. Черные точки – центры главных аномалий геомагнитного поля. Они приурочены к понижениям рельефа земного ядра. Видно, что топография границы между мантией и ядром обусловлена конвекцией в мантии. Те сегменты ее, которые включают в себя суперплюмы – области разогретого вещества, приподняты, так как обладают повышенной плавучестью

One of these anomalies, Brazilian, has been studied using archaeomagnetic methods. It was revealed that the anomaly practically did not change its position over the last 4,000 years and did not participate in the western drift of the main geomagnetic field [Кузнецов, 2008], which proves again that the magnetic field of the anomalies is generated in the regions of turbulence on irregularities of the core-mantle boundary. There are also data (on the history of inversions) that indicate the existence of magnetic anomalies located for many millions of years in about the same place. Figure 6*б* also shows that the geomagnetic equator does not coincide with the geographic one and is inclined relative to it; moreover, the points where both equators intersect coincide with the centres of the ascending convective flows in the mantle. We have already encountered a similar coincidence in Figure 3: the subequatorial belt of the hot masses of the mantle also intersects with the Earth's equator in the same places. This, of course, is not accidental.

Despite the apparent randomness of the geomagnetic poles' drift, they have preferred directions of motion, which is especially pronounced at the

moments of inversions and excursions. Magnetic poles drift from north to south or vice versa in the same designated directions or "corridors" [Constable, 1992; Kuznetsov, 1999]. These corridors are shown in Figure 8. As we see, they coincide with the continental meridians (Fig. 3, 4), i.e., they are confined to the descending cold convective currents in the mantle.

The same meridians are characterized by a higher magnetic field strength and they also contain global magnetic anomalies. You can also notice that the magnetic poles rotate around a certain axis, the poles of which lie on the Earth's equator and coincide spatially with the global ascending convective flows in the mantle, the Pacific and African superplumes.

The hot belt of mantle matter (manifested in its rheology) is turned by 15° relative to the modern equator around the same motionless axis. It should, according to the theory, be located exactly on the equator, but it lies on a plane that is rotated relative to it by some, albeit small, angle. Isn't the hot belt we are observing a "footprint", a "shadow of the past" of the ancient equator of Earth?

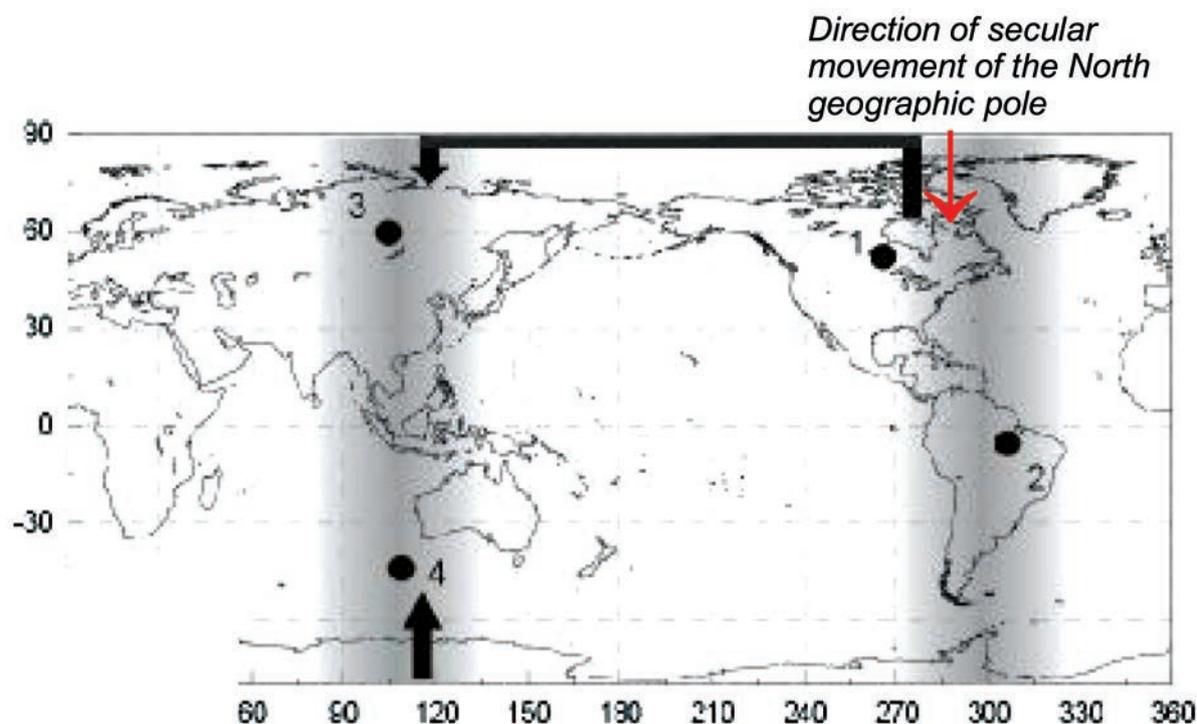


Fig. 8. Paths of drift of magnetic poles during inversion periods [Constable, 1992; Kuznetsov, 1999] Numbers – global magnetic anomalies: 1 – Canadian; 2 – Brazilian; 3 – Siberian; 4 – Antarctic. The current direction of movement of the northern geographic pole is shown

Рис. 8. Трассы дрейфа магнитных полюсов в периоды инверсий [Constable, 1992; Kuznetsov, 1999]. Цифры – глобальные магнитные аномалии: 1 – Канадская; 2 – Бразильская; 3 – Сибирская; 4 – Антарктическая. Также показано современное направление движения северного географического полюса

It is known [Hospers, 1954] that virtual magnetic poles averaged over several thousand years coincide with geographic poles, which is caused by the decisive role of the Coriolis force in the movements of a conducting substance inside the core. However, this does not mean that the geographic poles perform the same global movements during inversions and excursions as well. Nevertheless, let us follow the current movements of the geographic poles of Earth.

Geographical poles make forced and free fluctuations with an annual period and a period of about 14 months relative to a certain average position. The movement of the instantaneous pole occurs in a spiral, which periodically winds or unwinds. At the same time, the middle pole free of these oscillations, shifts as well. There is a secular movement of the geographic pole. For about 120 years of observations, it moved with the speed of about 10 cm per year toward North America (in the direction of 70° to 76° west longitude, Figure 8). As we can see, this movement occurs in the same corridor along which the magnetic poles move and where the downward mantle convective flows are concentrated. Therefore, the axis connecting the Pacific and African superplumes can be called *the axis of true motions (wander) of geographical and magnetic poles*.

If we continue to extrapolate this movement millions of years back to the past, it turns out that *approximately 17 million years ago the position of the equator coincided with the position of the belt of hot mantle matter*. What was happening at that time? *It was that era when the mantle temperature was maximum* [Макаренко, 2011б]. *Heat of cosmic origin that was released both in the mantle and in the core with maximum intensity at the equator about 60 million years ago, accumulated in the mantle* [Макаренко, 2011б]. The previous maximums are 100 million years older [Макаренко, 2011б] and it is now difficult to find their traces in the spatial distribution of intraterrestrial temperatures (maybe the hot spot fields shown in Figure 3, which formed in the first hundreds of millions of years, inclined in respect to the modern equator and to the supposed paleoequator, are the evidence of an even older paleoequator).

It is still difficult to say anything about the degree of regularity of this motion. Connection with the distribution of temperatures and, therefore, distribution of densities makes us look for the causes of these motions in the convective movements of

matter in the depths of Earth. The approximate correspondence of the velocities to the velocities of mantle convection can be additional confirmation of this. *The general layout of convection in the depths of Earth (Fig. 9) is determined by cosmic reasons.*

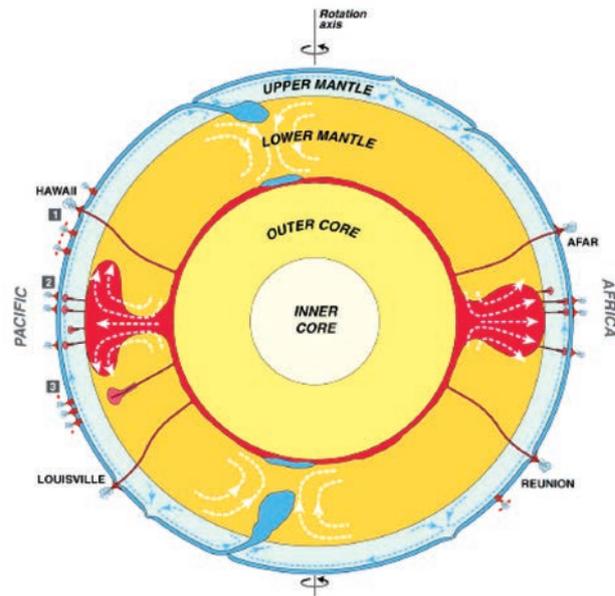


Fig. 9. General configuration of the mantle convection relative to Earth's rotational axis [Courtilot et al., 2003]. The flows of ascending heated substance of superplumes (African and Pacific) are confined to low latitudes

Рис. 9. Общая конфигурация мантийной конвекции относительно оси вращения Земли [Courtilot et al., 2003]. Потoki восходящего разогретого вещества суперплюмов (Африканского и Тихоокеанского) приурочены к низким широтам

We are talking more about the mutual shifts of the liquid core and rock shell of Earth rather than about the actual movement of the rotation axis of the Earth. Such relative shifts of the shells (to explain the westwardly drift of the Earth's magnetic field) were suggested by E. Halley back in 1692. There is nothing incredible about them. There are supporters of such movements in our time [Gold, 1955; Goldreich, Toomre, 1969; Willeman, 1984; Pavlenkova, 1995; Dolitsky, 2000; Maloof et al., 2006 and many others]. Similar shell shifts were also proposed for other planets, [Kite et al., 2009; Ivanov, Melosh, 2003 and others].

If the rotation axis actually turned out to be on the place of the former equator, lying in or near the ecliptic plane, this would have most seriously affected the nature of the climate on Earth, making it less suitable for life. One side of Earth would be turned to the Sun for half a year, and the night

would reign on the other side. However, nothing of the kind is observed neither in geological sediments, nor in the growth layers of ancient corals. We can only talk about shifts of the near-polar areas of the rock shell towards the equator and vice versa. The rotation axis remains on average approximately perpendicular to the plane of the ecliptic on extended time scales, as required by the law of conservation of angular momentum (neglecting precession).

The mechanism of relative shift of the shells may have internal causes (redistribution of masses inside Earth during convection, as was pointed out earlier by J. Darwin; or causes on the surface, i.e. the growth and destruction of mountains, redistribution of water masses and glacial isostatic alignment during glaciations), and external causes (differential gravitational influence of the Moon, the Sun and planets on the density inhomogeneities of the Earth's depths).

We know from mechanics that the rotation of the planet is stable if the most of the substance is concentrated near the equator. Any redistribution of masses in the depths of the planet can cause a change in the position of the planet relative to the rotation axis. As a result of the reorientation, the excess mass will again be at the equator, since it is affected by the polar-fugal force, which appears due to the difference in the values of centrifugal forces in the meridional direction. And since the adhesion between the mantle and the liquid core is low and allows relative displacements, these shells can make such movements autonomously.

The observed displacement of the Earth's hot belt relative to the equator is the result of the movement of the mantle relative to the axis of Earth. The modern hot belt is the paleoequator of the era of the last maximum heating of the mantle. Shift of the equatorial zone warmed up by the factors of cosmic origin is an unambiguous indication of the reality of the autonomous movements of the rock shell of Earth.

The presence of a hot equatorial belt is observed, in addition to the rock shell of Earth, in its central part.

This can be confirmed by the anisotropy of properties of the Earth's inner core discovered two decades ago. This phenomenon consists of the fact that the velocity of seismic waves passing through the inner core along the rotation axis of Earth is about 3 to 4% higher than the velocity of waves passing in the equatorial plane, which indicates the

relative weakening of the subequatorial zone. In addition to latitudinal, there are meridional differences in the velocities of waves passing along the equator.

Figure 10 can also be a good illustration of these patterns. Here we have a picture absolutely similar to the double-plume convection picture of the mantle. At the same time, convection in the inner core is considered unlikely [Yukutake, 1998]. After all, there seems to be no sources of internal heat, and it is homogeneous in composition.

The convection configuration in the mantle and inner core is exactly the same! We can note that the hot belt in the core is also slightly inclined relative to the Earth's equator, but at the different angle. According to [Creager, 1992], the anisotropy axis of the Earth's inner core is tilted by 5° relative to the rotation axis of Earth, and its pole is still in the same corridor of relative shifts of the Earth's shells.

Despite the fact that there is an extensive layer of liquid matter between the inner core and the mantle, the axes of the ascending convective flows practically coincide, which can be either a coincidence or, more likely, the result of mutual gravitational attraction of the bumps of the Earth's inner core and similar formations in the shells over it.

Since the mantle is apparently characterized by global isostasy, regions of its African and Pacific superplumes are elevated, which should form similar bumps of the dense iron matter of the Earth's outer core beneath them. These bumps gravitationally interact with the heterogeneous inner core of Earth and may prevent its autonomous rotation, which could be the case without this.

The observational data on the rotation of the Earth's inner core are very contradictory and at the current level of accuracy and duration of observations in general do not confirm its autonomous rotation. The observed movements may not be the result of a real rotation, but only oscillatory movements relative to the line connecting the convective crests. Possibility of oscillatory motions caused by the gravitational interaction between the topography of the surface of the inner core and density anomalies in the mantle has been considered in the literature [Buffett, Glatzmaier, 2000]. It is possible that the rotation of the inner core is in the same type of gravitational resonance with the outer shells, which are observed in some cases between the individual planets of the Solar System. We know that the Moon in general, is turned one side to Earth as a result of tidal friction (there are also small fluctuations,

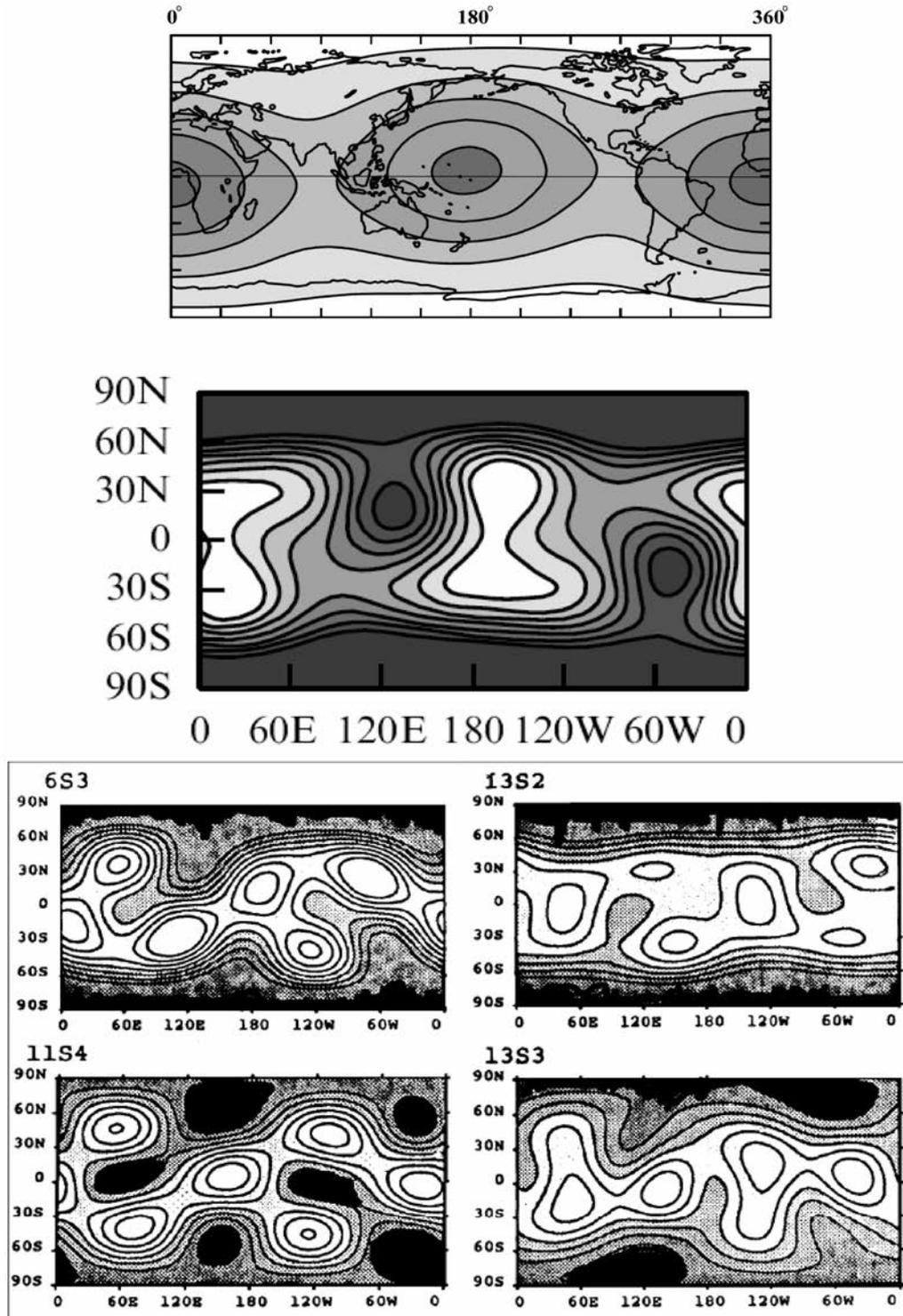


Fig. 10. Equatorial hot belt in the Earth's core

a) Anisotropy of P-wave velocities in the inner core. Dark colors indicate low P-wave velocity [Morelli, Dziewonski, Woodhouse, 1986]

б) Splitting functions of the inner core (above) and the outer core (bottom). The intensity of the function varies from -0.2% (white) to $+0.2\%$ (black) [Кузнецов, 1997]

Рис. 10. Экваториальный горячий пояс в ядре Земли

а) Анизотропия скоростей P-волн во внутреннем ядре. Темные тона – низкая скорость P-волн [Morelli, Dziewonski, Woodhouse, 1986]

б) Splitting-функции внутреннего ядра (вверху) и внешнего ядра (внизу). Интенсивность функции меняется от $-0,2\%$ (белый цвет) до $+0,2\%$ (черный) [Кузнецов, 1997]

librations), which corresponds to resonance 1:1. Here we have a very similar picture. Thus, the “outer” and “inner” Earth gravitationally interact as two different planets!

In this context, we cannot but mention another movement of the Earth’s inner core. Gravimetric observations established its probable drift towards the Taimyr Peninsula, i.e. in the direction of the coldest and densest mantle masses in the corridor along which the poles shift. It can be assumed that the gradual accumulation of cold and dense slabs (fragments of plates of the oceanic crust) at the bottom of the mantle produces an increasing gravitational effect on the inner Earth’s core, leading to its drift towards attracting masses.

We can judge about movements of the outer core, or rather, in the outer liquid core, by the displacements in the picture of the geomagnetic field that is generated there. Figure 6b shows the location of the geomagnetic equator. It is inclined to the geographic equator at a certain angle, intersecting with it at the locations of superplumes, and drifts along with geomagnetic poles along the corridor between the African and Pacific superplumes, as shown in Figure 8. It appears that these trajectories are apparently determined by the topography of the boundary surface separating the core and the mantle, which, in turn, is determined by convection in the mantle, namely, the structure of the equatorial hot belt of the mantle.

The Earth’s magnetic centre is eccentric with respect to its geographical centre, shifted relative to the latter by approximately 540 km in the direction of the northern tip of the Mariana Islands in the Pacific Ocean (data as of 2000) and moves in time to the west along the trajectory shown in Fig. 11. This trajectory is close to the current position of the geomagnetic equator, although it does not coincide with it. Westward drift of the geomagnetic field as

a whole takes place in the nearly same direction.

It is likely that all these movements are related to convective mass movements in the outer core of Earth. Obviously, they are spatially attached to the axis connecting the ascending convective flows in the mantle and the Earth’s inner core. Convection in all the shells of the Earth, where it is developed, has a uniform structure due to the presence of a single subequatorial belt of active heat release. This belt has a cosmic nature. As a matter of fact, this belt is, to a large extent, a “space heater” of the Earth’s depths, which moves the geospheres, and it is convenient to count their movements from this “heater”.

As already mentioned, during the study of such movements, the we can take as a reference point the coordinate system associated with conditionally motionless mantle plumes, the centre of mass of continental plates, and geomagnetic paleopoles. It would be interesting to compare the results obtained using these essentially different reference systems.

Work of [Torsvik et al., 2012] made an attempt to isolate from general motions a certain common turn of all continents relative to their common centre of mass in a paleomagnetic coordinate system. It was determined that the centre of mass of all continents is located in the area of the African continent. This position is quasi-stationary and coincides approximately with the centre of the African region of low velocities of seismic waves in the mantle. The same way, antipodal point approximately coincides with a similar formation in the area of the Pacific Ocean (the African and Pacific Large Low Shear-wave Velocity Provinces, LLSVPs). These structures (superplumes) are associated with large-scale excesses of geoid heights associated with the axis of the minimum moment of inertia and have not changed their position for at least the last 300 million years (relative to the system of trappean and

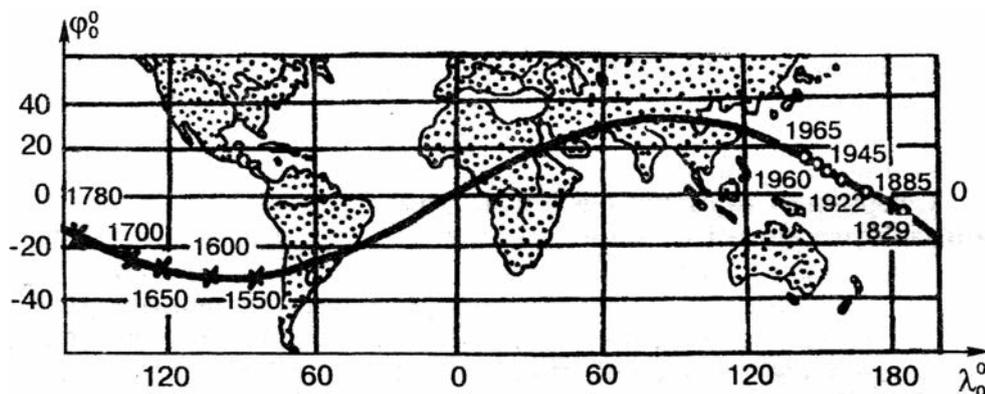


Fig. 11. Plane of drift of the eccentric dipole (closest from the magnetic center of the point on the Earth’s surface), according to [Пудовкин, Валуева, 1972]

Рис. 11. Плоскость дрейфа эксцентричного диполя (ближайшей от магнитного центра точки на поверхности Земли) по [Пудовкин, Валуева, 1972]

kimberlite provinces, i.e., external manifestations of mantle plumes, the position of which is considered as quasi-stationary). The resulting reconstruction of the shifts of the Earth's "solid mass" relative to the rotation axis in various geological eras is shown in Figure 12.

In total, four episodes of the shifting of the Earth's surface relative to the poles were discovered: 1) 250 to 200 million years (towards the modern Western Hemisphere); 2) 200 to 150 million years (in the opposite direction); 3) 150 to 140 million years, almost in the same direction, although slightly different; 4) 110 to 100 million years, again in the direction of the Western Hemisphere. The turning axis is located perpendicular to the rotation axis, and its poles are close to the centre of mass of all continents, as well as to the position of the centres of the African and Pacific superplumes and the axis of the greatest equatorial moment of inertia.

Typical velocities of shifts of the Earth's surface relative to the rotation axis of Earth during the last 320 million years range from 0.45 to 0.8° per million years. However, the total shift for the same period of time is zero. That is, we are dealing not with a certain permanently unidirectional movement, but with the swaying of the Earth's "solid mass" relative to the rotation axis. These sways are not chaotic; they occur along a rather strictly defined corridor. The amplitude of such sways can probably be large and reach almost 90°, as suggested by [Kirschvink et al., 1997] for the Early Cambrian period.

It is rather obvious that the results of our works basically coincide.

It can also be noted that climate change is another channel through which the impacts on the movements of planetary shells external to the solar

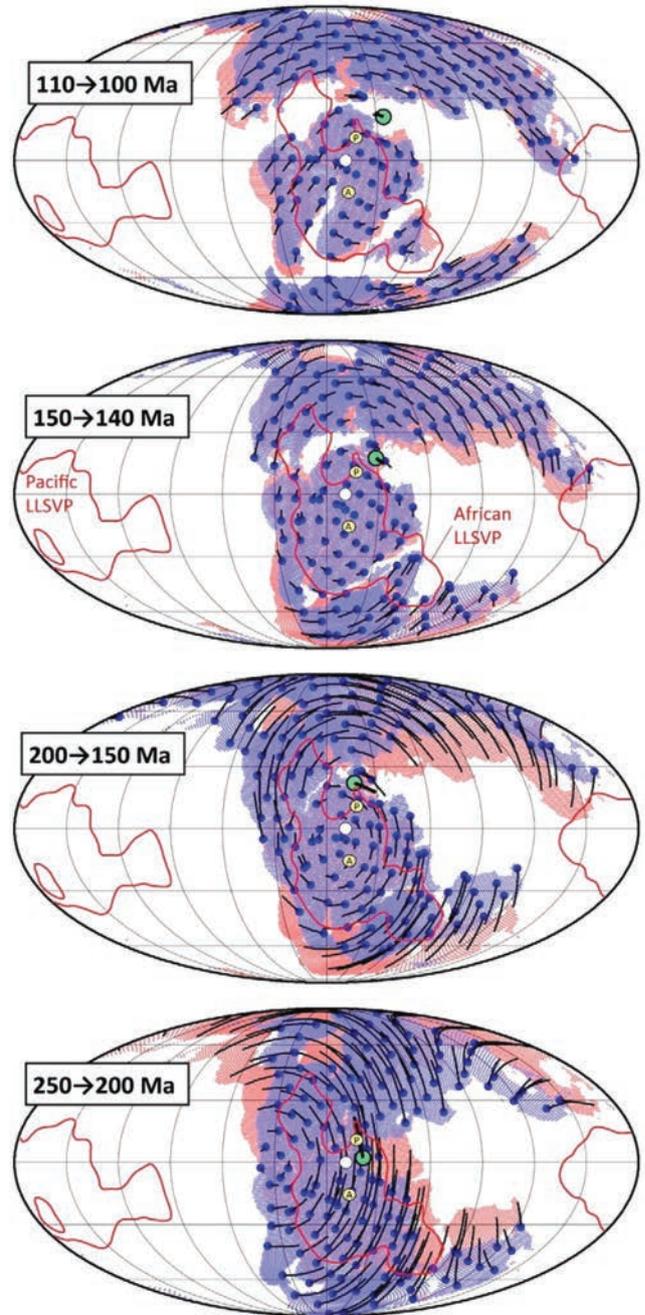


Fig. 12. Reconstruction of continental motion in the paleomagnetic coordinate system (four time intervals) [Torsvik et al., 2012]. The general motion is shown by black lines connected to the blue dots, which indicate the position at the beginning of the time interval). Large green dots with thick black lines show position and movement of the mass center of all continents. Yellow dots – A and P – centers of regions of low velocities of seismic waves in the mantle (i.e., heated substance of superplumes), their contours (by one of the models) are shown with red lines. White circles are axis poles, around which the true displacement of geographic poles takes place. Blue and pink fillings are positions of continents at the beginning and at the end of each of detected episodes of the true displacement of geographic poles

Рис. 12. Реконструкция движения континентов в палеомагнитной системе координат (четыре временных интервала) [Torsvik et al., 2012]. Общее движение показано черными линиями, соединенными с голубыми точками, которые показывают положение в начале временного интервала. Большие зеленые точки с толстыми черными линиями – положение и движение центра масс всех континентов. Желтые точки – А и Р – центры областей низких скоростей сейсмических волн в мантии (т.е. разогретое вещество суперплюмов), их контуры (по одной из моделей) показаны красными линиями. Белые круги – полюсы оси, вокруг которой происходит истинное смещение географических полюсов. Голубая и розовая заливки – положение континентов в начале и конце каждого из обнаруженных эпизодов истинного смещения географических полюсов

system is performed. We are talking about the redistribution of masses during the formation of cover glaciations on such planets as Earth and Mars (after all, there are polar caps too, and there are distinct traces of climatic fluctuations, even if the mechanism of these fluctuations is different from the mechanism on Earth). In fact, this is exactly the “mountain” that can be built up and removed from the surface of the planet, which Newton mentioned.

The galactic theory of climate is very popular and has a wide evidence base. The essence of this theory is as follows. Particles of cosmic rays coming here from galactic space ionize the atmosphere, facilitating the increase of cloud cover density and increasing the albedo (reflectivity) of Earth and, thereby, contributing to the climatic cooling. According to some studies, this factor is responsible for about 60% of climatic changes, including the glaciation epochs, which are linked to the intersections by the Solar System of the spiral arms system, where the effect of cosmic rays is especially significant.

Glaciers occupying vast spaces, with the thickness sometimes reaching several kilometres, are not symmetrical with respect to the rotation axis of the

planet, and changes in their location, as well as accompanying changes in the level of the ocean, which is also not symmetrical with respect to the rotation axis, glacial isostatic alignment of the lithosphere when changing the associated load, is accompanied by oscillations of the rotation axis of the planet.

Figure 13 taken from [Nakada, Okuno, 2003] shows the expected fluctuations of the pole locations for various conditions of glaciers melting and growth, obtained from the simulation results. It can be seen that the directions of oscillations in general coincide with those expected in the case of mass redistribution in the course of mantle convection. This is natural, since the meridional distribution of sheet ice is close to the distribution of the continental crust. The amplitude of oscillations during the Quaternary glaciation did not exceed 5° , but the pole drift velocity could significantly exceed that which follows from mantle convection, i.e., the climate plays a role of an amplifier of this process to an extent. In the 20th century, the true pole drift velocity was about 10 cm/year.

These oscillations are sensitive to the rheology (partially determined by cosmic causes) of the lithosphere and mantle [Peltier, Wu, 1983].

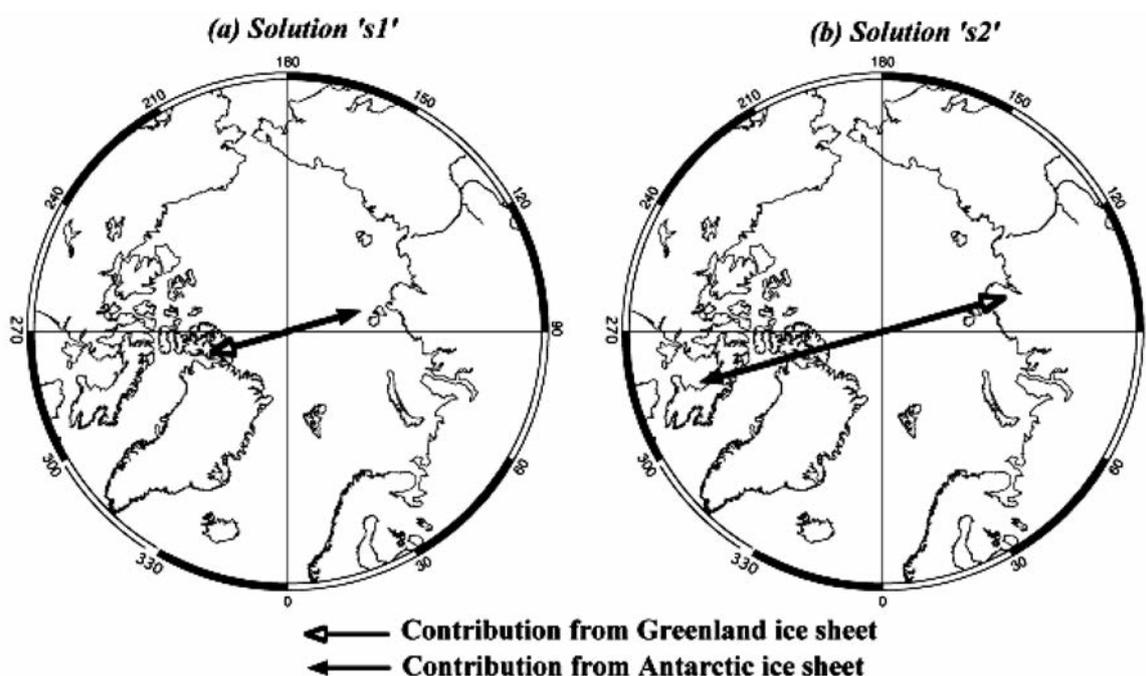


Fig. 13. Influence of glacial redistribution of masses on the Earth's rotation. Relative contribution (not absolute values) to the pole movement given by the Antarctic and Greenland glacial shields for different melting and growth conditions (simulation results) is shown [Nakada, Okuno, 2003]. We can see that the movements of pole occur in the same direction as the inter-mantle redistribution of masses

Рис. 13. Влияние гляциальных перераспределений масс на вращение Земли. Показан относительный вклад (не абсолютные значения) в движение полюса, даваемый Антарктическим и Гренландским ледниковыми щитами для различных условий таяния и роста (результаты моделирования) [Nakada, Okuno, 2003]. Можно видеть, что движения полюса происходят примерно в том же направлении, что и при внутримантийных перераспределениях масс

Consequently, our location in the Galaxy also influences in this way the features of the relative swings of the Earth's shells. The energy spent on swinging the shells, in this case, is of solar origin; galactic cosmic rays play a role of a trigger. Shifts of the rock shell relative to the core lead to friction and the release of thermal energy in the contact zone. The mechanism of "pumping" solar energy deep into the depths of Earth is obvious. These issues have not yet been studied completely. Comparing the scale of shell swings due to endogenous heat release with similar swings of climatic nature, we can assume an "injection" at the scale of fractions of terawatt or several terawatts, which, in general, is comparable to the tidal friction energy, which is estimated at the level of around one terawatt.

3. Discussion and conclusions

According to the situation revealed, everything so far looks as if the distribution of the heated zones in the Earth's shells is cosmically determined. These heating zones set simultaneously three seemingly mutually exclusive convection regimes: single-cell between Southern and Northern hemispheres and double-cell of open and closed type associated with the subequatorial hot belt of Earth's depths African and Pacific superplumes included into it. Initially non-uniform cosmically modulated heating of the depths follows from considerations of thermodynamics.

Shifts of the Earth's shells caused by the movement of masses of matter during interplanetary convection occur in certain corridors located perpendicular to the axis connecting the ascending convective flows (African and Pacific superplumes), which is firmly held at the equator. Accordingly, the central points of the equatorial superplumes are the poles of the axis around which the shells oscillate.

The variant of double-cell convection with superplumes could be explained with the help of the tectonics of floating continents, quite popular and developed by many scientists. The continental crust is assumed to be a damper for heat flow. Once the crust formed a super continent above the descending branch of convection, it prevents the release of heat from the Earth's depths; the substance under the super continent is heated, convection stops and then changes direction to the opposite one. The super continent, appearing above the ascending convective flow, falls apart; its individual fragments, following the convective flows, gather on the opposite side of Earth, and then the cycle repeats.

The following may be objected against this kind of explanation. There is no double-cell convection in the well-mixed liquid outer core of Earth, but completely similar picture of mantle convection is observed in the inner core of Earth. There are no plates there which serve as thermal dampers, as there is no continental drift. A completely similar structure of convection is observed on other planets of Earth group that are close in structure, and not only on planets of this group. There is no continental drift as well, and apparently there never was. Finally, the planets vary significantly in size, the rheology of the depths, which, from a thermodynamic point of view, suggests the existence of five-cellular and other convection regimes on other planets. However, actually the same is observed as on Earth. Questions of comparative planetology will be considered in details in a separate paper, which continues the study. We should also add that the tectonics of floating continents suggests an inequality in the capacities of both ascending flows. Observations show that the heat flows of both geotectonic hemispheres are equal, which requires explanation. According to [Wang, Wang, Ma, 1998], the heat output from the Earth's mantle (minus losses from the Earth's crust, where they are determined by the distribution of continental masses and the radioactive isotopes contained in them) totals $16.9 \cdot 10^{12}$ W for a hemisphere with the centre at the equator and zero degree longitude (that is, closely coinciding with the African geotectonic hemisphere). For the opposite hemisphere with the centre at 180° longitude (that is, closely coinciding with the Pacific geotectonic hemisphere), the similar heat output totals $16.0 \cdot 10^{12}$ W. From this it follows that the African and Pacific superplumes have equal heat output capacity with the high degree of accuracy.

Our opinion on double-cell convection of the closed type is as follows. Both antipodal superplumes are relatively motionless and evenly warmed up segments of the cosmically determined equatorial hot belt of planetary depths. Superplumes play the role of a kind of anchor that hold the shell exactly in this place near the equator, which leads to permanent heating of this zone, which is constantly held at the equator, and long-term stabilization of the process (at least over the last several hundred million years). Due to the relative swings of the shells, the intermediate segments are regularly removed from the heating zone and therefore they are less pronounced, as if they are spread.

The general mantle isostasis, which forces the heated segments of the rock shell to emerge, forming the shape of Earth and the distribution of its rotational moment, plays the key role in this process.

It is enough that at least one density anomaly stably held in the equatorial zone is formed once (a mass concentration as a result of a mega impact, non-equilibrium processes during the formation of Earth's core, etc.), and the superplume anchor will appear in its place during the subsequent heating of the near-equatorial zone, and soon an antipodal to it appears as well. The whole question is, as a result of what processes an anomaly can occur. An antipodal superplume occurs automatically. We will return to this issue in the paper dedicated to the planets that continues the study.

In the aspect of the double-plume configuration of convection of the planetary depths, the question of the formation of the Earth's core itself is interesting and does not have an exact answer yet. According to modern concepts, based on a number of isotopic systematics, it was formed mainly as a result of gravitational differentiation of the depths of the planet, and already in the first 100 or even 30 million years of its existence. This conclusion also applies to such differentiated planets as Mars, the Moon and Vesta asteroid. Thus, the gravitational separation of the planets continued and ended to a large extent even during their accretion from the protoplanetary cloud. There is no reliable theory that would describe the mechanism of the core creation. There is a well-known hypothesis [Wood, Walter, Wade, 2006], according to which gravitational differentiation occurred in the magma ocean (the existence of which during the accretion is supported by many scientists) near the surface of the planet. In the course of this process, a layer of iron melt was accumulated at its bottom, which, was gravitationally unstable

due to the high density of its constituent matter and, when it reached a certain mass, gathered in a giant "megaglobule" and collapsed towards the centre of the planet. It is possible that such a process, if it occurred, had a certain cyclical nature. However, it is completely unknown how and in what ways the iron melt descended to such great depths through the rocky strata. Have superplumes, the formation of which dates back, perhaps, to the same distant times, played a special role in this?

Shell shifts themselves occur meridionally along the corridor between superplumes. From the outside, it looks like a secular drift of poles (both geographical and magnetic ones). The amplitudes of such shifts are very large (tens of degrees).

Such swings are typical for both the outer rock shell and the inner core of the planet. Motions of the shells are probably gravitationally synchronized; there are certain resonances in these motions.

Such is the likely effect of the "space heater" on the relative shifts of planetary shells.

Just as sailors once encountered difficulties in determining geographic longitude, researchers involved in reconstructing the longitudinal position of continents in the distant past face similar difficulties as well. Taking into account the location of such global and relatively motionless structures as superplumes will facilitate the solution of this problem.

In the paper that continues the study, it is supposed to consider similar sways of shells in other planets.

The heat source, which naturally changes in space and time, should undoubtedly affect other geological processes, such as the movements of lithospheric plates, the generation of a geomagnetic field, etc. However, these issues require further research (we note that a preliminary study shows that such influences do exist).

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