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Thermonuclear Reaction as the Main Source of the Earth's Energy

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ABSTRACT

The article shows that neither radioactive decay of long-lived radioactive isotopes nor the Earth's "primordial" heat supply can explain a huge energy formed in the Earth's core. A hypothesis is introduced that the main source of Earth's energy is the thermonuclear reactions in the solid inner Earth's core which consist of hydrides of irons and other metals.

Keywords: Energy of the Earth's Core; Radioactive Decay; Thermonuclear Energy

1. Introduction

The source of the Earth's internal energy has a fundamental importance for understanding Earth's structure and composition. According to current data, the temperature gradient is equal to d*T*/d*r* = 0.025 − 0.03 degrees/meter (the temperature rises, according to different estimates, approximately by 25 - 30 degrees per km of depth). Clearly, the magnitude of the heat flux through the Earth's surface is equal to:

$$F = \mathrm{d}T/\mathrm{d}r \cdot \kappa \cdot S, \quad (1)$$

where κ is the coefficient of thermal conductivity of the Earth's crust. One can assume the value of the coefficient of thermal conductivity for the upper layer of the Earth equal to the coefficient of thermal conductivity of the basalt rocks, *i.e.* $\kappa \approx 2\left[J \cdot m^{-1} \cdot \sec^{-1} \cdot K^{-1}\right]$, $S = 4\pi R^2$ is the square area of the Earth's surface. $S = 5.1 \times 10^{14}$ [m^2]

These calculations give the magnitude for $F \approx (2.5 - 3.1) \times 10^{13}$ W or (25 - 31) TW.

Naturally, in order to know the exact value of the heat flux, one should carry out experimental measurements. Such measurements were made possible only recently when Bullard [1] took several measurements of the heat flux in South Africa for the fist time beginning in 1939, and Benfield [2] did similar measurements in England. Such measurements under the ocean surface were initiated in 1956. Currently, there are twenty thousand points of measurements around the globe. The information about these measurements can be obtained from the Global Catalog of the World Center of Physics of Solid Earth [3]. However, as it turns out, it is also difficult to estimate a precise magnitude of the integral heat flux using experimental data. The thing is that the local heat flux from the inner part of the Earth is estimated using shallow wells and by measuring temperature coefficients and also thermal conductivity. Obviously, the Earth's coverage with these "measuring" wells is by far not homogeneous. Rather simple averaging of all obtained experimental data is a relatively crude method which gives some approximate value of the integral heat flux. In order to increase the accuracy, one should not only do the summation of data but also correct raw data themselves. Examples of these corrections could be following: introduction of the additional cooling in the oceanic measurements by forecast models of the ocean currents, adding some constant heating or calculated heating by the convective thermal fluxes which are well measured only at the ocean rifts, removal of the non-stationary effects of the tectonic and magmatic evens; and also removal of measurements from so-called "hot" areas.

Thus, this non-uniform correction mechanism results in measurements of the integral heat flux that could differ drastically from different authors. According to the latest fundamental monograph about Earth by Anderson [4] the absolute heat flux passing through the Earth's surface based on the averaging of experimental measurements is estimated at 30 TW. However, some scientists consider this number being underestimated, and taking into account various corrections [5], they think that the integral heat flux passing the Earth's surface is equal to $F = 44.2 \pm 1.0$ TW. In a more recent study [6] the larger magnitude of the integral flux (e.g. $F = 46 \pm 3$ TW) was calculated. Considering that results of both meticulously conducted studies essentially coincide within a degree of experimental accuracy, one can consider that the value of the thermal flux passing the Earth's surface is calculated $F = 45$ TW (1.42×10^{21} J/year). This is a huge value exceeding the total energy released during earthquakes and volcanic activities by one or two orders of magnitude.

2. Analysis

Currently, there are several hypotheses to explain this huge energy generated by the Earth: Moon's tidal influence, chemical segregation, heat generation in the Earth's core by friction forces between rotating layers of different viscosities in the liquid core, etc. and even cosmic sources by influences from some Galactic processes (e.g. [7]). The hypothesis of the radioactive heat caused by long-lived radioactive decay of isotopes such as ^{238}U, ^{235}U, ^{232}Th and ^{40}K received one of the best circulations in the scientific community. However, even approximate calculations show that the energy of the radioactive decay of these isotopes is not sufficient to explain internal Earth's energy considering that there is a trend of lowering concentrations of the radioactive elements in the layers of crust and mantle with depth, and possibly, this radioactive effect is not present at all in the Earth's core. To support this, there are many arguments, first of all, so called "the helium-heat flow paradox" [4]. The thing is that with the radioactive decay, the isotopes U and Th generate ^4He and anti-neutrinos as well as heat. The observed flux of ^4He to the oceans from the mantle is an order of magnitude less than the flux of ^4He through the continental crust. At the same time the heat flux under continents and under oceans are approximately the same which was a sensation for geophysicists. This phenomenon could be explained if one can assume that the heat fluxes are formed in their majority in the deep Earth's layers while the Earth's radioactivity is determined by the Earth's crust. The Earth's crust over oceans (4 - 7 km) is almost order of magnitude thinner than the Earth's crust over the continents (30 - 50 km and thicker).

In addition, it was established that many times in the Earth's history there were short-lived (years, ten years, hundred years) catastrophic thermal expulsions from the internal Earth to upper mantle, crust, atmosphere and hydrosphere. This doesn't agree with the radioactive nature of the Earth's heat as it would be a rather monotonic process slowly changing with time.

3. Discussion

Recent experimental measurements of the magnitude of the heat flux from the Earth to space, caused by decay of radiogenic isotopes, and in particular uranium, thorium and potassium, in the planet's interior were conducted [8]. The magnitude of the radioactive decay was determined based on precise experiments of the geoneutrino flux from the Kamioka Liquid-Scintillator Antineutrino Detector, Japan, with existing measurements from the Borexino detector, Italy. It was founded that that decay of Uranium-238 and Thorium-232 together contribute 20 TW to the Earth's heat flux. The neutrinos emitted from the decay of Potassium-40 were below limits of detection in the experiments, but are known to contribute 4 TW. Summarizing, the heat from radioactive decay contributes about a half of the Earth's total heat flux, which authors of that study assumed equal to 44.2 TW. Authors of that study explained their results introducing a hypothesis that the Earth's "primordial" heat supply has not yet been exhausted.

However, one cannot agree with this conclusion for several reasons. First of all, these authors underestimate the Earth's internal energy. Obviously, the heat flux passing through the Earth's surface is not all energy generated by the Earth. First of all, in order to estimate the total energy generated inside the Earth, it is necessary to determine what energy is required to sustain the Earth's magnetic field. Otherwise, the magnetic field which has been in existence for a minimum of 3.5 billion years would disappear relatively quickly (on the order of ten thousand years) without any re-generation. There is a significant uncertainty in estimation of the energy needed to sustain the Earth's magnetic field. If scientists can now determine the magnitude of the Earth's magnetic field (e.g. [9,10] with various degrees of confidence; then to calculate the energy, one needs to know initial relative permeability μ/μ_o (and its value can vary from 1 (magnetic lines outside of the Earth) to 100 (values for the solid Earth's core)). Respectively, if one uses different values for μ/μ_o, the calculated energy of the Earth's magnetic field could be in a range of 1.7 TW - 170 TW. Let us assume the average value of 85 TW. Thus, the total energy of the Earth is a sum of 45 TW (the energy passing though the Earth's surface) and 85 TW (the energy that is required to sustain the Earth's magnetic field). Therefore, the total Earth's energy could be estimated as equal to 130 TW. According to study [8] the energy caused by radioactive decay is 24 TW. There is also about 10 TW of non-radioactive heat sources such as cooling and differentiation of the core, contraction of the mantle, tidal friction, etc. [4]. In summary, there is a significant discrepancy as 34 TW is generated and 130 TW is actually utilized.

There are serious reasons to doubts that the Earth's "primordial" heat supply could supply this extra energy. One can easily calculate the Earth's energy loss. The main insulation layer ("thermal shirt") is the Earth's crust. For the rocks composing the Earth's crust, the temperature distribution inside large space objects with the radial distance Δl is estimated using dimensional formula by Zharkov [11]:

$$\Delta t \sim (\Delta l)^2 / \chi, \quad (2)$$

where Δt—time to for temperature to equalize in tow point at distance Δl,

$\chi = \kappa / c_p \rho$—coefficient of temperature conductivity, [m^2/sec],

where κ—coefficient of thermal conductivity, [$J \cdot m^{-1} \cdot sec^{-1} \cdot K^{-1}$],

c_p—heat capacity under constant pressure, [$J \cdot g^{-1} \cdot K^{-1}$],

ρ—density [g/m^3].

On average for the Earth' crust under continents we can assume $\Delta l \approx 40 \times 10^3$ [m], and $\chi \approx 5 \times 10^{-7}$ [m^2/sec] (typical value for the rocks). Thus, Formula (2) gives us the time for complete cooling of the Earth's core of $\Delta t \approx 1 \times 10^8$ years. This is significantly shorter than the Earth's whole existence (4.5×10^9 years). One should account that under oceans taking 71% of the total Earth's area, the thickness of the Earth's crust is an order magnitude smaller, therefore Δt would be two orders of magnitude smaller. Thus, one can state that the period of the Earth's cooling as a result of the conductive energy loss could be measured only as 10 - 20 million years. As far as the Earth's mantle is concerned, its thermal conductivity is much higher than the Earth's crust and that's why it doesn't affect the cooling time much at all.

The thing is that currently it is clearly shown in many studies that the energy transport from Earth's core to the Earth's surface is governed mostly by convective hydrogen-gas plumes in Earth's mantle rather than heat conductivity [12,13]. Naturally, these processes must be sustained by the constant energy source coming from the Earth's core. This source cannot be Earth's "primordial heat" supply. Based on presented above arguments, neither Earth's crust no mantle can preserve Earth's primordial heat for over 100 million years. As a results, the Earth's temperature must decrease (if not cooled completely), however the latest measurements show that the temperature of the Earth's core is approximately 1000 K higher than a scientific community thought before, and it is estimated at 6230 K ± 500 K [14]. Besides, one cannot forget about existence of the Earth's magnetic field which could disappear on the order of tens of thousands years without any external energy sources.

4. Conclusions

Summarizing everything reported in this paper, one can state that there must be a powerful source of constant and stable energy inside the Earth's core. As shown in studies [15,16], the main source of the Earth's energy is thermonuclear processes in the inner Earth's core consisting of metallic hydrides (mostly iron hydrates). This theory is indirectly confirmed by the concentration of the helium isotopes in the Earth [17]. It was found that the ratio of $^3He/^4He$ in the Earth's mantle is stable and thousand times higher than that in the Earth's crust. This effect is understood if we assume thermonuclear processes in the inner Earth's core when proton-protonic reactions produce some quantities of ^3He. One should note that ^3He cannot be "primordial" helium which was a part of Earth's matter 4.5 billion years ago as in this case one should assume that the maximum Earth's temperature during its creation did not exceed 800 K - 1000 K which is clearly unreal.

The ratio of $^3He/^4He$ in the Earth's core drops abruptly because ^3He mixes with the isotope ^4He which is formed as a result of radioactive decay of U and Th. Then the helium seeps to the atmosphere through the faults and cracks in the Earth's core and then disappears into space. Considering much higher fluidity of the light isotope ^3He in comparison with heavier isotope ^4He, the relative concentration of ^3He in the Earth's atmosphere is much higher. The experimental data show that the ratio of $^3He/^4He$ in the atmosphere is hundred times higher than that in the Earth's core. One can assume that there are some local areas that are formed sporadically, and they would be so called centers of thermonuclear reactions. One can think of the Earth's core as slowly "boiling". The temperature must abruptly increase in those locations; the hydrides would break out creating hydrogen in the form of the protonic gas. The pressure in those zones would increase as well which would result in expulsion of large quantities of the hydrogen plasma in the form of currents outside of the Earth's inner core. Under these conditions, the chain thermonuclear reaction should not happen as any excess energy would be lost with hydrogen outside of the Earth's core (e.g. deep hydrogen streams) and temperature would, therefore, as a result decrease. As a result of the Earth's rotation and presence of Coriolis force, the hydrogen streams (or protonic gas) would twirl into spirals in the outer Earth's core. According to seismic research data the outer Earth's core is liquid, and it most likely consists of hydrogen solution in metals (e.g. iron) with high electrical conductivity. The spiral hydrogen streams as a conglomerate would form a solenoid and, as a result, create a dipole magnetic field of the Earth.

Suggested hypothesis of the thermonuclear nature of the Earth's energy flux corresponds quite well to known experimental data and would open new ways to study not only our planet but other planets of the Solar System. One should note that according to accepted concepts, the dipole magnetic field could exist in planets with sufficient rotation and a possibility of thermonuclear reactions in their cores. None of the planets such as Mercury, Venus, Mars and Moon could satisfy these conditions. Accordingly, these planets don't have dipole magnetic fields.

One should especially stress that suggested hypothesis of the thermonuclear nature of the Earth's energy flux assumes, as presented above, the presence of deep hydrogen streams transporting energy released from the thermonuclear reactions towards the Earth's surface. This energy exceeds by far the total radioactive energy. The thermonuclear source of energy is responsible for endogenic geodynamic and tectonic process during the whole history of the Earth. This statement agrees with the established by now theory of influence of rising deep currents (plumes) of most gases (with dominant hydrogen) on the magmatic, metamorphic and rock formation processes [18]. A presence of rising hydrogen deep currents (plumes) of hydrogen could theoretically justify a theory about possible non-organic origin of some hydrocarbons. Surely, if there is degassing of hydrogen from deep areas of the planet, hydrogen once presented in the carbon rich areas would result in the hydrogenising reactions potentially forming layers rich with hydrocarbons. Respectively, hydrocarbons (non-organic) could be formed now and will be formed until the source of hydrogen ceases in the Earth's core.

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