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Geophysical Processes, Solar Energy, and Biosphere as System Factors of the Evolution of the Earth

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Abstract—The concept of the role of the biosphere in the evolution of the Earth is proposed and confirmed by calculations. According to this concept, in the prebiosphere period, a shell structure was formed, the global convection occurred in the form of tectonics of small plates, and the absence of continents excluded the involvement of water in the oxidation of igneous rocks. In the biosphere period, photosynthetic organisms began to supply free oxygen and organic matter (OM) to the environment. Oxygen began to take part in the geochemical processes of ore conversion, the formation of the nitrogen–oxygen composition of the atmosphere, and the generation of granitoids from volcanic rock. Global systems for the generation of granitoids of the continental crust and hydrocarbons (HCs), which are formed during subduction–collision absorption of the oceanic crust, have been identified for the first time. On the transit route to the Benioff zone, granites are melted out from oxygen-enriched halmyrolysis products and the thermal metamorphism of OM yields solid allotropic carbon compounds, oil, and combustible and other gases and is accompanied by the release of OM decomposition energy. This is one of the ways to convert biosphere solar energy into the endodynamic processes of the evolution of the Earth. The average annual precipitation of the primary OM in the ocean is 785.5 Mt, and 1.7 km^3 of the continental crust are generated. Over the biosphere period, the World Ocean became shallower by 904.5 million km^2. Geodynamic and geophysical processes, primarily global convection, in conjunction with biosphere factors, have resulted in the current state of the Earth's shells and the existence of HCs and continental-crust generation systems in them.

Keywords: geospheres, convection, halmyrolysis, photosynthesis, biosphere, geophysical processes, evolution

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INTRODUCTION

To a great extent, the development of the Earth is due to physical and chemical transformations in the interior, which are revealed in the study of geodynamic processes (Dobretsov, 2010). The geochemical model can be constructed only taking heat and mass exchange into account.

The formation of granitoids by biochemical weathering of basalts of the oceanic crust is justified by Zavarzin (2001). Khan (2007, 2010) insists on sialic granite formation. The continental crust and living organisms appeared on the Earth in the interval from 3.8 to 3.5 billion years (Khain, 2007, 2010). The beginning of the iron ore cycle is attributed to the same period. Zavarzin (2001) associates its appearance with the development of the oldest autotrophs, blue-green, and other inferior algae, as well as with the formation of stromatolites.

The Earth is a system of shells (geospheres), each of which has its own chemical composition, phase state, and internal dynamics. The geospheres interact with each other and penetrate each other (Pushcharovskii, Yu.M. and Pushcharovskii, D.Yu., 1999). The geospheres interact and exchange matter and energy by the mechanism called *global convection* whose intensity can change with time (Khain and Goncharov, 2006; Dobretsov, 2010a, 2010b; Khain, 2010). The available approaches to the development of models of geodynamic evolution of the Earth do not fully show the ways and means of changing the chemical composition of the geospheres, the mechanism of convergence of matter and energy between geospheres, and the role and importance of the biosphere in the overall evolution of the Earth. In the paper on V.I. Vernadsky's scientific activity, A.V. Lapo chose to separate the productive living part of the biosphere from its geodynamic past and the biogeochemical present (Lapo, 1987).

The evolution of geospheres can be refined using system factors, such as geodynamics, geophysical and geochemical processes, solar energy, and the biosphere, to explain their dynamics. We will try to identify and analyze the cause-and-effect relationships between the evolution of the Earth's shells and the leading system development factors. Particular attention will be paid to assimilated solar energy and matters involved in photosynthesis or its products. These are matters that, according to (Vernadskii, 1960), can be called components of the biosphere. These include H_2O, CO_2, organic matter (OM), and O_2. Their dynamics depends on the intensity of photosynthesis and the amount of solar energy absorbed by plants.

DATA AND RESEARCH METHODS

The paper contains reference data on the atmosphere, hydrosphere, lithosphere, and continental crust from (*Geologicheskii*..., 1973; Milovskii, 1973; Polevoi, 1989; *Fizicheskie*..., 1991; etc.).

According to the model of the geodynamic evolution of the Earth (Khain, 2007, 2010; Dobretsov, 2010a,b), at the early stage of its development, the whole mantle convection predominated. It existed until 2.7–2.6 billion years ago. It could be cellular (Alekseev, 2012) or roller (Zharkov, 1983), but it was whole-mantle (Dobretsov, 2010a, 2010b) convection. Then convection began to appear in the form of tectonics of lithospheric plates, although relics of large-cell convection lasted until 2.0–1.8 billion years ago (Khachatryan, 2013; Baryshev and Khachatryan, 2015). In the interval from 3.8 to 3.5 billion years ago, autotrophs appeared on the Earth (Zavarzin, 2001, Rozanov, 2010).

Autotrophs that live through photosynthesis using water and carbon dioxide from the hydrosphere and the atmosphere, as well as solar energy, introduce new matters into the general heat and mass transfer, i.e., free oxygen (O_2), organic matter (OM), and solar energy converted into them. In accordance with the above and one of the theories, the prebiosphere and biosphere periods as well as the prebiosphere interval are distinguished in the evolution of the Earth.

The value of convection in the prebiosphere period should be considered inseparable from the weathering of volcanic rock, the formation of deposits, their transformation into sedimentary rocks, and the involvement of these rocks in the convective heat and mass exchange system and thermobaric metamorphism with the formation of new minerals and rocks.

The World Ocean and primitive atmosphere formed in the interval 4.55–4.40 billion years ago (Khain, 2007, 2010). Atmosphere, hydrosphere, lithosphere, and mantle were involved in global convection for 0.9 billion years of the prebiosphere period. There is no geological evidence of oxidation of the lithosphere during the prebiological period. The composition of the mantle matter was relatively homogeneous. It can be assumed that the mantle matter acted as a coolant in the case of whole-mantle convection, while the upper mantle and lower mantle reservoirs geochemically separated only in early Karelian (2.0–1.8 billion years ago), i.e., already in the biosphere period.

Considering the fact that the "consumables" of photosynthesis—the main process in the biosphere—are H_2O, CO_2, and solar energy, information on the prebiological state of the atmosphere and hydrosphere are necessary for assessing their involvement in the evolution of geospheres, as well as the conversion of matters and energy. Note that there is no convincing geological evidence for the formation of the continental crust in the prebiosphere period and for the use of photosynthetic oxygen to increase the proportion of silicic acid in the rocks of the continental crust in the biosphere period.

MODEL OF THE EVOLUTION OF GEOSPHERES IN THE PREBIOSPHERE PERIOD

The geological data on the state of the magmatic ocean, mantle, and composition of rocks in the prebiosphere period presented in (Khain, 2007; Dobretsov, 2008, 2010a, 2010b) give an idea of the nature of the global processes of shell evolution before the appearance of autotrophic organisms. The prebiosphere period begins with the main accretion of planetesimals and covers the interval from 4.55 to 3.5 billion years ago (1050 Ma).

The main events in this period are as follows: 4.55–4.40 billion years ago, the formation of the World Ocean and the primitive ammonium–carbon dioxide atmosphere (Drozdovskaya and Snezhko, 1989), convection in the magmatic ocean, and the beginning of the formation of the continental crust represented by tonalite-trondhjemite gneisses at 3.9 billion years ago and relics of the magmatic ocean with the thickness up to 1000 km (Zharkov, 1983; Khain, 2007, 2010; Shkodzinskii, 2009; Dobretsov, 2010b; Alekseev, 2012; Khachyatryan, 2013; Baryshev and Khachyatryan, 2015). Magmatic intrusive and volcanic rocks of this age mostly have ultrabasic and basic composition (SiO_2 content is less than 50%).

In the case of a convection depth of 1000 km, the diameter of the convective cell could reach 1400 km (Zharkov, 1983; Alekseev, 2012); the total length of the paleoridges reached 840000 km with an equal length of paleotrenches. Paleoridges and paleotrenches with a coefficient of expansion of rocks of $L = 2 \times 10^{-5}$ K^{-1} and a temperature gradient of 1000 K had a height difference of about 2 km. Under these conditions, effusions and intrusions were exposed to weathering in an aqueous medium (halmyrolysis) and formed a layer of deposits that were then entrained in convection and were metamorphosed in the oceanic crust. Calculation of the possible amount of deposits formed by halmyrolysis on diving cells shows that, at a rate of accumulation of mineral deposits at an average of 5 mm per 1000 years (*Geologicheskii...*, 1973), the deposit volume in the prebiosphere period should be 1150 Pm^3 or 16.8% of the modern continental crust. However, in basite-ultrabasic rocks with an age of 4.4–3.5 billion years, there are no signs of oxidation. Consequently, the effect of the prebiosphere ocean and the prebiosphere atmosphere on the physicochemical transformations of the lithosphere rocks in the prebiosphere period were negligible.

PHOTOSYNTHESIS AND RESPIRATION (OXIDATIVE DEGRADATION) ARE THE LEADING PROCESSES IN THE BIOSPHERE

Autotrophs used H_2O, CO_2, and solar energy on a planetary scale and introduced a new phenomenon of photosynthesis into geophysical and geochemical processes and new matters, oxygen and OM.

The general equation of photosynthesis is as follows:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2.$$

Equation of respiration (degradation):

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2875\ \text{kJ}/\text{mol}.$$

From these equations, as well as from the law of conservation of energy, it follows that the resources of H_2O of the hydrosphere and of CO_2 of the hydrosphere and the atmosphere should be used in photosynthesis with solar energy. With the impossibility of complete oxidation of the synthesized OM, the Earth's interior began to be replenished by organic deposits. The basis for organigenic sedimentogenesis is laid in the ontogeny of autotrophs and the duration of their existence as organisms (Zavarzin, 2001).

In the hydrosphere, photosynthetic oxygen first oxidizes dissolved matters and then suspensions and sludges. Oxygen can be sorbed from the hydrosphere by silicates, aluminosilicates, and other rocks (for example, zeolites). The amount of oxygen used on geochemical processes during the biosphere period can be calculated from its content in oxidation products, and this value can be used to determine the amount of H_2O, CO_2, OM, O_2, and the solar energy of photosynthesis involved in dynamics of the geospheres.

DETERMINATION OF THE MASS OF PHOTOSYNTHETIC OXYGEN SPENT ON OXIDATIVE PROCESSES IN THE BIOSPHERE PERIOD

Globally, photosynthetic oxygen is used for the formation of (1) the nitrogen-oxygen atmosphere, (2) ferruginous silicates, and (3) the continental crust.

The nitrogen–oxygen atmosphere is formed by the oxidation of ammonia dissolved in the ocean water by the $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$ reaction. The atmosphere contains 3.87 Pt of N_2 and 1.19 Pt of O_2 and 7.82 Pt of O_2 were released for its formation. Oxidation of 4.7 Pt of NH_3 was accompanied by the formation of 7.46 Pt of water.

The formation of iron ores (the lithosphere contains 661.0 Pt of them in the form of Fe_2O_3) occurred by the oxidation of iron(II) hydroxides to iron(III) oxide by $4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O$ reaction with the use of 66.2 Pt of photosynthetic oxygen.

The use of photosynthetic oxygen in a volume of 68 550 Pm^3 and a mass of 18 851 Pt on the formation of the continental crust was accompanied by the absorption of 3310.9 Pt of O_2. The mass of absorbed oxygen was calculated from the excess of SiO_2 in the continental crust over the SiO_2 content in the sial of the asthenosphere, the value of which is assumed to be 32 wt % or 6216.5 Pt of SiO_2, in which there are 3310.9 Pt of O_2.

In total, during the biosphere period, 3384.9 Pt of photosynthetic oxygen were used on the above and accountable purposes. It could be obtained by the photosynthesis of 3173.3 Pt of primary organic matters, from which oceanic deposits formed. The photosynthesis of such an amount of OM required the removal of 1904.0 Pt of H_2O from the ocean and 4654.2 Pt of CO_2 from the ocean and atmosphere, as well as the assimilation of 50.7×10^{27} J of solar energy. The accumulation of these OM as deposits was accompanied by the oxidation of 4.7 Pt of NH_4 in the ocean, the emission of 3.87 Pt of N_2 into the atmosphere, and the formation of 7.46 Pt of water. It should be noted that, before the appearance of plants on land in the early Devonian, photosynthetic oxygen was produced only in the oceans. Therefore, all oceanic processes were carried out in solutions of $Fe(OH)_2$ and NH_3 or hydrated matters, i.e., the sorbed oxygen could accumulate with the deposits formed by halmyrolysis.

EVOLUTION OF THE EARTH'S SHELLS IN THE BIOSPHERE PERIOD, BIOCHEMISTRY OF THE OCEAN AND ATMOSPHERE, AND CONVECTION

The following events occurred in the biosphere period of the Earth's history. At the turn of 3.8–3.5 billion years ago, ferruginous quartzites began to form, and the epoch of the iron ore cycle ended at 1.7 billion years ago, replaced by the formation of red-colored rocks. This is associated with the appearance of autotrophs and then cyanobacteria, stromatolites, and ancient protists (Zavarzin, 2001; Khain, 2007, 2010).

During the biosphere period, 2749.3 Pt of oceanic and 424.0 Pt of continental organogenic deposits were formed. The oxidation products were distributed between the atmosphere, the hydrosphere, and the lithosphere (oxidized deposits formed by halmyrolysis and Fe(III) in the form of ores).

The formation of oceanic deposits in the biosphere period assumes their organomineral composition. The ratio of organic and mineral parts in the deposits varies greatly, since photosynthesis takes place in the near-surface part of the World Ocean, and halmyrolysis occurs in the bottom part. Oceanic deposits were first involved in whole-mantle convection, which was replaced by a two-layer tectonics of lithospheric plates 2.0–1.8 billion years ago. For both types of convective processes, diving rocks undergo thermobaric metamorphism. In contrast to deposits of the prebiosphere period, mineral deposits of the biosphere period contain oxidized forms of matters and sorbed oxygen. These rocks are with a significant predominance of silicic acid. OM deposits, which were absent in the prebiosphere deposits, undergo significant metamorphism. The main matters of OM metamorphism, wt %, are CO_2, 36.7; H_2O, 30.0; hydrocarbons (HC), 25.7; and allotropic carbon compounds, 8.0. The composition of these metamorphism products corresponds to the conclusion of D.I. Mendeleev (Mendeleev, 1877; Mendeleev, 1949) about the equal distribution of oxygen between carbon and hydrogen in solid fossil fuels. It can be noted that, under conditions of prebiosphere convection, magmatic rocks only acted as a coolant during thermal convection, while in the biosphere period convection is a means of energy and mass exchange between the geospheres (atmosphere, hydrosphere, lithosphere, and asthenosphere) and cosmic energy sources (internal heat of the Earth and solar energy). For example, in the case of the OM metamorphism in the deep interior of the Earth, about 1.5×10^{18} J of energy is released annually in the exothermic pyrolysis reaction, which is comparable with the energy of earthquakes.

Biosphere evolution factors introduced certain material and energy components into the convective energy and mass exchange system. These include the removal of 1904.0 Pt of H_2O and 4032.3 Pt of CO_2 from the hydrosphere, 621.9 Pt CO_2 from the atmosphere, the emission of 7.8 Pt of O_2 on the formation of the nitrogen–oxygen atmosphere; and the "placement" of 66.2 Pt of O_2 in ferruginous silicates and 3310.9 Pt of O_2 in the rocks of the continental crust, as well as 3173.3 Pt of OM in geological deposits. In OM of deposits, 50.7×10^{27} J of solar energy was converted, of which 12% was released as pyrolysis energy during the OM metamorphism.

The physicochemical properties of the matters newly synthesized during the convection of the biosphere period and the convection of the prebiosphere period also differ significantly. For example, N_2 of the atmosphere is less soluble in water when compared to NH_3 and CO_2 that are melted from oxidized mineral rock deposits and contain 25–30% more SiO_2 than ultrabasites of the asthenosphere. These new effusions and intrusions predominate in the continental crust with an average density of 15–20% lower than that of the rocks of the oceanic lithosphere. Thus, having buoyancy, they are excluded from global convection. Continents are platforms and islands floating above the asthenosphere which violate the kinematic system of the prebiosphere whole-mantle convection. The peculiarity of OM thermal metamorphism during convection consists in the separation (defluidization) of steam-gas fractions which are filtered on the way to the day surface and divided into condensate and noncondensable gases. The solid phase of OM metamorphism represented by allotropic carbon compounds is involved in the mantle flows. It is carbon CO_2 converted by photosynthesis into OM composition and included in the lithosphere and asthenosphere as a result of convection and deep metamorphism.

The above results of the effect of collective system factors on the evolution of geospheres in the biosphere period make it possible to determine the prebiosphere state of the outer shells of the Earth using an actualistic approach. For example, in terms of water consumption for photosynthesis, its return under OM metamorphism, and the formation of ammonia during oxidation, the volume of the prebiosphere World Ocean is determined at 2283 Pm^3. Since the existence of continents by the beginning of the Archean has not been geologically proven, the average depth of the prebiological ocean could be 4476 m. In the same way, it is possible to calculate the average rates of processes that characterize the dynamics of evolution and obtain a general idea of the state of the geospheres in a certain geochronological period. The results of the calculations are tabulated and recalculated for the periods of the stratigraphic scale of 1993 based on the average values of the dynamics of matters (Zhamoida, 2015).

In the biosphere period, convection was characterized by the generation of the continental crust floating on the asthenosphere and formation fragments significant in terms of area, volume, and mass. This led to a change in the kinematics of the whole-mantle convection in the interval from 2.0 to 1.8 billion years ago, when the tectonics of lithospheric plates was formed. Plumes and superplumes appeared somewhat earlier (2.6–2.7 billion years ago). The plumes were formed by the subduction of the oceanic crust under the continent along its entire perimeter and by the cold slab piling at great depths down to the core surface (Khain, 2007, 2010; Ivanov, 2006). The formation of continents and supercontinents by the fusion of terranes is confirmed by mathematical models (Bobrov and Baranov, 2014), according to which the whole mantle velocity throughout the volume is 1.65 cm/yr and the velocity at the surface is about 5 cm/yr.

The cold slab piled at the boundary of the core and the mantle eventually heats up. Its vertical overheated fluxes give rise to plumes and hot spots and lead to a split of the supercontinents, the formation of a rift system (Khain, 2003, 2007, 2010), and may be the cause of endogenous cyclicity with a period that is a multiple

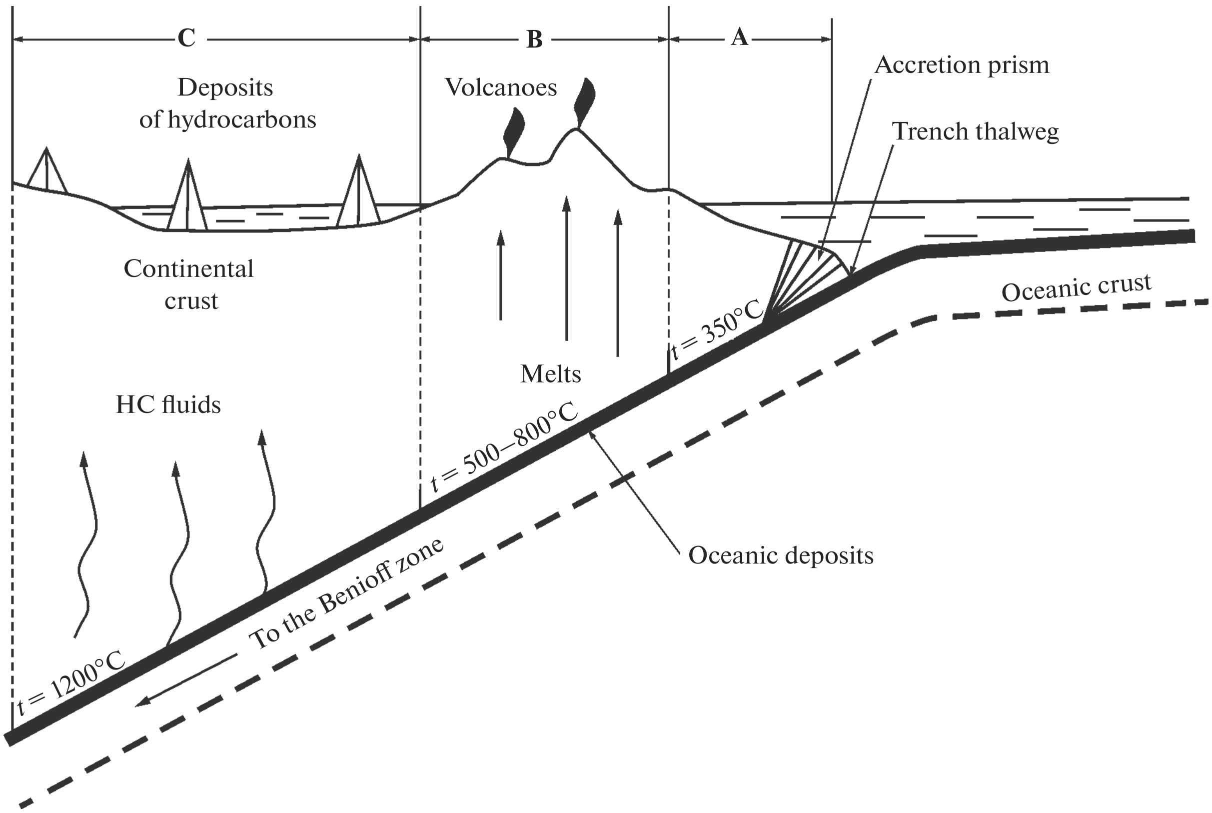

Fig. 1. Scheme of the metamorphism of oceanic deposits during subduction (using data from (Dobretsov, 2010a; Tikhonov and Lomnev, 2012; Savchenko et al., 2015)).

of 30 and 120 Ma (Dobretsov, 1994, 2008). The matter of the plumes is rocks of deep thermal metamorphism of the oceanic crust with a solid carbon phase of the OM metamorphism. The thermal conditions of the mantle do not contradict the possibility of generating diamonds from the solid phase of the OM metamorphism. The biosphere nature of diamond carbon is confirmed by the presence of biogenic associates in their composition (Khachatryan, 2013; Baryshev and Khachatryan, 2015).

The constancy of convection processes is due to the cooling of the Earth after the main accretion of planetesimals and the continuing generation of heat from radioactive sources (Zharkov, 1983). OM of oceanic deposits began to become involved in global convection 3.5 billion years ago. From this moment, convection resulted in the formation of rocks of the continental crust and products of metamorphism of OM of oceanic deposits. In the Archean (3.5–2.5 billion years ago), 24.7% of the continental crust was formed, which apparently was insufficient to change the kinematics of convection. The nature of convection changed after the appearance of tectonics of lithospheric plates 2.0–1.8 billion years ago (Zharkov, 1983; Zonenshain and Kuz'min, 1993; Dobretsov and Kirdyashkin, 1995; Kotelkin and Lobkovskii, 2008). By this time (Lower Proterozoic), the volume of the continental crust reached 3128.5 Pm^3 and amounted to 45.5% of the current volume (see Table 1). Supercontinents formed. It is difficult to find the remains of geological structures formed in the Archaean as a result of general anatomical convection in the composition of modern continents. There are indications of the cratonization of rocks of the Siberian platform in the Lower Proterozoic (Turkina et al., 2011) and their relation to the diamond protoliths (Baryshev and Khachatryan, 2015) formed as a result of the ancient subduction of the oceanic crust.

Using the schemes developed earlier, it is possible to present subduction as the passage of several stages of thermal metamorphism by the subducted plate by the example of the northwestern part of the Pacific plate that began to enter the Benioff zone of the Japan–Sakhalin island arc in the Lower Proterozoic (Fig. 1).

In our case, the velocity of the subducted plate is 2 cm/yr. The angle of dip in the Benioff zone is 10°–15°. The deposit age is 180 Ma. The total deposit thickness is 1100 m. The concentration of organic deposits is 400 million $\mathrm{t/km}^2$. The concentration of mineral deposits is 650 million $\mathrm{t/km}^2$. The concentration factor of HC (C), defined as the ratio of the subduction length of the ocean plate (closure value) to the value of the horizontal distance over 180 Ma of subduction, is 5.

Table 1. Involvement of components of the biosphere in the evolution of the Earth's geospheres

Components of the biosphere, mass	Geological periods, Ma*						Total for the biosphere period
	Archaean (3500–2500)	Lower Proterozoic (2500–1650)	Riphean (1650–650)	Vendian (650–570)	Phanerozoic (570–400)	Phanerozoic (400–present)	
Emission of photosynthetic O_2 for oxidation processes, Pt	857.6	727.4	816.7	65.4	138.8	779.0	3384.9
Including							
for the oxidation of the atmosphere	7.8						7.8
for the formation of iron ores	33.1	33.1					66.2
for the formation of the continental crust	816.7	694.3	816.7	65.4	138.8	779.0	3310.9
OM deposition, Pt	804.0	681.9	765.5	61.3	130.1	730.3	3173.3
Including							
in the oceans	804	681.9	765.7	61.3	130.1	306.3	2749.3
on the land						424.0	424.0
Removal of water from the hydrosphere for the OM deposit photosynthesis, Pt	482.4	409.2	459.4	36.8	78.1	438.2	1904.0
Removal of CO_2 for the OM deposit photosynthesis, Pt	1179.2	1000.1	1123.0	90.0	190.8	1071.1	4654.2
Including							
from the oceans	1179.2	1000.1	1123.0	90.0	190.8	449.2	4032.3
from the atmosphere						621.9	621.9
Absorption of solar energy for the OM deposit photosynthesis, 10^{27} J	12.5	10.7	12.5	1.0	2.2	11.8	50.7
Metamorphism products of OM of oceanic deposits							
Mass of the OM deposits of the oceans, Pt	804.0	681.9	765.7	61.3	130.1	306.3	2749.3
Including							
mass of CO_2 (36.7 wt %)	295.1	250.3	281.0	22.5	47.8	112.4	1009.1
mass of pyrolysis water (30.0 wt %)	241.2	204.6	229.7	18.4	39.0	91.9	824.8
mass of total hydrocarbons (25.3 wt %)	203.4	172.5	193.7	15.5	32.9	77.5	695.5
mass of allotropic compounds C_{org} (graphite, graphene, fullerenes, and diamond) (8.0 wt %)	64.3	54.5	61.3	4.9	10.4	24.5	219.9
Dynamics of ocean volumes, Pm^3	2043.8	1834.9	1611.2	1555.3	1593.3	1338.5	–
Energy of the exogenous reaction of thermal metamorphism, $n \times 10^{27}$ J	1.5	1.3	1.5	0.1	0.3	1.4	6.1
Continental crust dynamics, Pm^3	1690.9	3128.4	4819.2	4954.7	5242.0	6855.0	6855
Crust accumulation, %	24.7	45.5	70.3	72.3	76.5	100	100

* According to the Common Stratigraphic Scale of 1993.
** The volume in the prebiological period was 2283 Pm^3.

Thus, the concentration of hydrocarbons will be fivefold in comparison with the source.

In Fig. 1:

Sector **A** (the horizontal distance of the subducting slab path to the temperatures of metamorphism of 300–350°C, the depth of the plate subduction is 25 km, and the position of the trench thalweg is 150–200 km). Accretionary prism.

Sector **B** (the horizontal distance of the subducting slab path in the temperature range of 350–800°C, the subduction depth is 25–40 km, and the distance from the trench thalweg is 200–250 km). The beginning of the formation of acid magma; the loss of 55–60 wt %. of OM on the formation of H_2O, CO_2, and eruptive gases; the release of 10^{18} J/km^2 yr of exogenous OM pyrolysis energy; the explosion of gases and magma; and eruptions.

Sector **C** (the horizontal distance of the subducting slab path in the temperature range of 800–1200°C, the subduction depth of the plate is 40–80 km, and the distance from the trench thalweg is 500–700 km). Emission of hydrocarbon fluids at 25.3 wt %, filtration into the suprasubduction roof, and formation of the HC system. The solid phase of C_{org} (8.0 wt %) continues to be involved in mantle currents.

Steam-gas OM decomposition fluids are released along the subducting slab path, which are filtered on the way to the surface and are separated into condensate (liquid HC and water), noncondensable gases (CH_4, CO_2, N_2, and NCH), and another 300 individual matters with a total mass of 1–3% of OM. The resulting matters are involved in many processes of metallogeny and oreogenesis. For example, carbon dioxide can weather the silicates by the equation $CaSiO_3 + CO_2 \rightarrow CaCO_2 + SiO_2$, i.e., form a genetic series of carbonates and silicon. Oxygen-containing deposits formed by the halmyrolysis of basites and ultrabasites on the subduction path to the Benioff zone are remelted into granitoids and form fluxes of effusions and intrusion. Figure 1 shows that the thermal OM metamorphism occurs mainly at depths of 30–40 km, where basically dry distillation (pyrolysis) of OM occurs with the release of energy in an amount up to 1.94 MJ/kg of OM, which is about 12% of the energy spent on photosynthesis. The graphite solid phase continues to dive and reaches the lower (500–700 km) convection boundary, where diamonds and other allotropic carbon compounds can be generated from graphite as part of the protolith.

The values of the formation of the outer shells of the Earth calculated by us make it possible to assume the following sequence of events in the biosphere period.

The prebiosphere World Ocean had all the necessary biogenic substances (NPK, Ca, Mg, S, Fe, CO_2, etc.) in the form of solutions. The first autotrophs appeared in the World Ocean in the photic zone with a depth down to 50 m (modern picoplankton, 200 m).

One feature of photosynthetic hydrobionts is that they release oxygen directly into the environment, where in the first stages it is used to oxidize ferric hydroxide and ammonia when fed with the release of N_2 and the formation of deposits of Fe_2O_3. The unlimitedness of NPK and CO_2 at the first stages and the removal of O_2 as a necessary OM metabolite led to the uncontrolled growth of the primary algae flora (an explosion of biological productivity).

Considering the OM deposition rate for the formation of the nitrogen–oxygen atmosphere and the depletion of NH_3 resources in the ocean, it took no more than 10 Ma. Then the iron ore stage began, the main phase of which ended in the Lower Proterozoic, i.e., 1.5 billion years after the appearance of phototrophs. This long duration can be explained by parallel processes of formation of the continental crust, ferrous silicates, and the atmosphere. Taking the emission of O_2 at 837.8 Mt/yr into account, the "pure" iron ore process would have taken only about 80 Ma.

The specific consumption of O_2 on the formation of the continental crust is 0.483 t O_2/m^3 of the crust. This means that the rate of formation of the continents depends on the emission of O_2. Before the formation of land and the appearance of terrestrial plants, the O_2 emission was 837.8 Mt/yr, which could lead to the formation of 1.74 km^3 of the crust and, after the appearance of land and plants on it, 4.07 km^3/yr.

The appearance of photosynthesis and its involvement in geodynamic events of evolution of the geospheres was caused by the following linked parallel processes:

(1) Photosynthesis of organic matter and parallel galmyrolysis of volcanic rock during spreading and similar processes.

(2) Formation of organogenic oceanic deposits and the parallel accumulation of oxidized halmyrolysis products, the formation of an organomineral stratum of oceanic deposits.

(3) Subduction of the oceanic crust with a sedimentary organomineral cover in the zone of paleo- or existing oceanic trenches, as well as the absorption of the oceanic crust as a result of collision during the closure of the oceans, thermal metamorphism of the sedimentary cover of the oceanic plate during movement to the Benioff zone during collision, and the appearance two parallel systems:

(i) Hydrocarbon generation system.

(ii) Continental-crust generation system.

Both these systems are united by a global convection supersystem.

The hydrocarbon generation system includes OM photosynthesis, the accumulation of OM deposits in the oceans and on land, the subduction of these deposits into the interior, OM thermal metamorphism, the separation of the steam-gas fraction, metamorphism fluids, their filtration through the roof to the surface, condensation, the accumulation of condensate and gases in the reservoirs (i.e., the accumulation of water, oil, and gas), the inclusion of a solid phase of metamorphism into asthenosphere mantle currents, and the generation of allotropic modifications of C_{org} up to diamonds. The specific saturation with total hydrocarbons of the continental crust reaches 0.101 t/m^3 or 37 kg/t of the crust.

The continental-crust generation system includes the formation of volcanic and intrusive structures of the spreading zone and their halmyrolysis with the associated oxidation of halmyrolysis products and the formation of an oxidized sedimentary rock mass, the movement of the sedimentary cover along with the oceanic crust into the Benioff zone, the thermal metamorphism of deposits along the diving path, the fusion of the continental crust with predominance of silicic acid ($SiO_2 > 75\%$) from oxidized rock deposits, the separation of basic acidic melts, the change in magma rocks, and the formation of the continental or island arc of crust.

According to geological data, the vegetation cover on land appeared in the Early Ordovician. Taking the mechanisms of the increase in crust volume and global shallowing of the World Ocean into account, the assumption that land has not been inhabited for a long time by plants due to multiple acts of transgression and regression is, in our view, wrong. In fact, the rapid development of vegetation cover led to the formation of carbon coals only 50 Ma after the beginning of land colonization.

We have no reason to assume that the subterrains of Rodinia and Gondwana or earlier Karelian were deserted and lifeless emerged land areas with a river network. It can be assumed that even in the Ordovician the continents were vast guyots reshaped by the breaking waves of tides. With the advent of terrestrial vegetation, the growth of the continents has increased both due to the increase in OM deposits in the ocean and due to the formation of coal caustobiolites.

With regard to the influence of the biosphere on the paleoclimatic environment, one can note the cooling on the Earth after the formation of the nitrogen–oxygen atmosphere, which we associate with the reduction (and, perhaps, a catastrophic one) of the content of the main greenhouse gas, CO_2, in the atmosphere.

There were several planetary glaciations in the biosphere period. Chumakov (2015) distinguishes the following glacioeras: Kaapvaal, from 2970–2909 Ma ago, with several glacial episodes; Huronian, 2400–2200 Ma ago, can be traced in southern Canada, South Africa, and Western Australia; African includes Late Riphean and Vendian; Gondwanan includes the Early Paleozoic, Late–Early Carboniferous, Middle Carboniferous, and Late Permian glacial periods; and the Antarctic, beginning with Oligocene glaciation in Antarctica 34 Ma ago, includes several dozen episodes (15 episodes in Europe only) and has lasted up to the present.

There are no geological materials on glaciations in 2200–754 Ma ago. Identified glacioeras have a duration from hundreds of Ma to 5–10 Ma and are characterized by the glaciation of cratons, the presence of marinoglacial deposits, and traces of glaciers (see (Chumakov, 2015) and the references therein).

Our research shows that, by the time of the beginning of the first glacioera, the biosphere period lasted for 750 Ma, and only about 20% of its present volume of the continental crust was formed. There was no land in the Archaean. The volume of continents at the time of land formation in the Silurian–Early Devonian was 76.5% of the current value. In this regard we propose the following glaciation scenario.

At the early stage of the Earth's development (4.55–4.40 Ma ago), the World Ocean was formed, followed by the formation of the carbon dioxide–ammonia atmosphere. The temperature regime of the atmosphere predominated by CO_2, NH_4, and water vapor did not have zonal features in the global sense. As the Earth cooled down, the temperature of the atmosphere and the ocean decreased to values optimum for photosynthesis. The decrease in the overall temperature also increased the solubility of CO_2 and NH_4 and reduced volatility and cloudiness, which in turn increased the atmospheric permeability for the spectra of sunlight absorbed by chlorophyll. Latitudinal climatic zones appeared. According to calculations, a total of 884.1 Pt of CO_2 was used for the photosynthesis of OM deposits, which resulted in a decrease in the CO_2 content in the atmosphere and a further increase in its permeability.

As was indicated above, in the Late Archean, about 25% of the continental crust was formed. The change in convection regimes with the appearance of fragments of unsinkable continents led to the restructuring of the underwater terrain, the formation of ocean currents, the appearance of circulation in the atmosphere, and the manifestation of various types of cyclicity (including the frequency of glaciations).

Thus, glaciations result from endodynamically collective and interdependent action of the biosphere, hydrosphere, atmosphere, and geodynamic processes. In other words, the development of the biosphere led to glaciations, rather than glaciations changing the course of biosphere processes, as is argued by Chumakov (2015).

RESULTS AND DISCUSSION

The results of a brief analysis of the global evolution of the Earth are as follows.

Full-scale convection that accompanied the cooling of the young Earth prepared the temperature conditions in the ocean and the physical state of the atmosphere (permittivity for the light of such spectra that can be absorbed) appropriate for the implementation of the possibility of the appearance of autotrophs.

The prebiosphere ocean was a single shell with an average depth of about 4476 m. Convection in the mantle to a depth of 1000 km created a convective cell with a diameter of about 1400 km. In this case, the length of the paleoceanic ridges was equal to the length of the paleotrenches and amounted to about 840000 km. Paleoridges were up to 2 km higher than paleotrenches, which implies underwater erosion and weathering (halmyrolysis). In the prebiosphere period, the composition of the mantle magma was relatively stable and homogeneous. Magma served as a coolant in convection for more than 1 billion years.

Photosynthesis on the Earth originated in the ocean, where there were solutions of all the necessary biogenic substances. The consumption and accompanying substances of photosynthesis were included in the heat and mass exchange processes of global convection. CO_2 and H_2O began to be extracted from atmospheric and hydrosphere reservoirs; O_2 and OM were involved in geochemical processes of oxidation and metamorphism.

The present state of the atmosphere, hydrosphere, and continental and oceanic lithosphere is caused by the interaction of geodynamic, geophysical, geochemical, and other endogenous processes with the biosphere. It is important that photosynthesis, the most important function of the biosphere, attracts cosmic and solar energy to participate in the evolution of the Earth, first by converting it into photosynthetic matters and then by separating it in the form of exogenous energy of OM thermal metamorphism in an amount equal to the energy of earthquakes that occurred in a year, 1.5×10^{18} J.

CONCLUSIONS

All the above allows us to draw the following conclusions.

(1) Geodynamic and geophysical processes, primarily global convection, together with biosphere factors, led to the formation of the modern state of the lithosphere, hydrosphere, and atmosphere. The influence of these factors is interdependent and mutually conditioned. They are in a causal relationship with each other.

(2) Evolution of the biosphere was accompanied (and is accompanied) by the formation of a continental-type lithosphere, which resulted in the tectonics of lithospheric plates, the formation of the nitrogen–oxygen atmosphere, and the appearance of glacial periods.

(3) The hydrocarbon system and the system of continental-crust generation were formed in the biosphere period of the evolution of the Earth. It resulted in the annual shallowing of the World Ocean by 0.7–1.0 km^3 and the increase in the continental crust to 3.8 km^3/yr.

(4) The estimated annual generation of hydrocarbons in the interior of the Earth reaches 198 million t. The interior is saturated with oil and gas, the deposits of which are associated exclusively with the history of the evolution of individual blocks of the continental crust and geodynamic events in the oceanic and continental lithosphere, under which geophysical processes were carried out along with the biosphere evolution of the Earth's shells. The relative oil and gas content of the interior should increase with depth.

(5) During the development of the tectonics of lithospheric plates, about 100 Pt of allotropic modifications of carbon of the OM thermal metamorphism entered the upper mantle.

(6) The exploration of the prospects of oil and gas and diamond contents should be based on the paleogeodynamic reconstruction of the evolution of specific regional geological structures.

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