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Introduction

To understand the global carbon cycle, it is necessary to nd out the meaning of the two terms - "global photosynthesis" and "living matter". "Living matter" – is a term, introduced by Vernadsky in 1926 [1], which he de ned as the total biomass of all living on Earth organisms. Global photosynthesis is the process of synthesis of organic matter from carbon dioxide and water under sunlight, carried by all living on the Earth organisms with special photosynthetic apparatus. Formally, the global equation of photosynthesis can be written as it is written for any photosynthetic organism.

$$CO_2 + H_2O \xrightarrow{hv} CH_2O + O_2$$

Since the global photosynthesis involves all of the photosynthesizing organisms living on the Earth, then given they constitute the beginning of all food chains, the total biomass of all living organisms, including photosynthesizing biomass and biomass of all consumers in trophic chains, can be regarded as a product of global photosynthesis. According to Vernadsky, it is the "living matter".

Another product of global photosynthesis is an oxygen molecule in the Earth's atmosphere. With a good approximation it can be regarded as such if to neglect the quantity of oxygen, which was in atmosphere prior to photosynthesis emergence [2].

What is common and what is the di erence between global photosynthesis from regular photosynthesis of individual organism?

 e regular photosynthesis of individual organism is described in detail in the literature [3]. What is common and what is the di erence between global photosynthesis and regular photosynthesis of individual organism? At rst we'll see the common features. Considering that each photosynthesizing organism has CO_2 assimilation and photorespiration, let's assume that the same ability inherent in global photosynthesis. e rst is responsible for the total biomass growth on the Earth, while the second is used in oxidation of part of the assimilated carbon to cover the energy costs of organisms partly to e control over the ratio of assimilatory and photorespiratory uxes in a photosynthesizing cell, is carried out, as known, by the key enzyme of photosynthesis is ribulose bisphosphate carboxylase/oxygenase (Rubisco) having carboxylase and oxygenase function and has a working feedback mechanism [5]. Functions oscillate, switching over depending on the ratio of CO_2/O_2 in the environment. e switching time determines the duration carboxylase and oxygenase phases [6] and contribution to the biomass of both processes. We accept that the same principle lies in the basis of the synthesis of the total photosynthetic biomass on the Earth.

Each photosynthesizing organism has a so-called CO_2 compensation point, which corresponds to the state when the quantity of carbon assimilated in photosynthesis is equal to the quantity of carbon oxidized in the photorespiration. e state below the compensation point makes the physical existence of the organism is impossible, while the excess of the assimilated carbon over the oxidized means the growth of the biomass. Global photosynthesis has the same feature. e analog of CO_2 compensation point in global photosynthesis termed as ecological compensation point. It corresponds to the state when the total amount of the assimilated carbon (total photosynthesizing biomass) becomes equal to the amount of organic material returned back completely to the oxidized inorganic form. Above this point the excess of carbon assimilated in photosynthesis turns into organic matter deposited in the Earth crust. With oxygen growth in the course of photosynthesis evolution the carbon cycle system spontaneously strives to ecological compensation point. On achieving this point the system goes into stationary state. Oxygen and carbon dioxide begin to oscillate around the steady meaning. It means that in the course of evolution oxygen the environmental factors exerting an impact on photosynthesizing organisms have the same e ect on the carbon isotope composition of organic matter.

Below we show the examples of impact of di erent environmental parameters on carbon isotope composition of photosynthetic biomass. Natural observations and *in vitro* experiments showed that the carbon isotopic variations depending on CO_2 concentrations in the environment may achieve 25‰ [20]. It was also found [21] that the ^{12}C enrichment of biomass turned out to be much less than the carbon isotope e ects of RuBP carboxylation on the enzymes isolated from the biomass of these organisms. e e ects were about 60-65‰. Such a great di erence was found later to be mainly a result of photorespiration [22].

Environmental factors have di erent e ects on carbon isotope composition of biomass. Among them the variations of CO_2 concentration in the environment exerts the strongest e ect. High CO_2 concentrations results in ^{12}C enrichment of biomass in the *in vitro* experiments [11,20,23]. Similarly pH manifests itself in aquatic environment. e low pH values, corresponding to high CO_2 concentrations, provided ^{12}C accumulation in biomass of marine alga *Cyclotella*, whereas high pH values resulted in abrupt enrichment in ^{13}C [24,25]. In nature one can see the same picture [17].

e e ect of environmental oxygen concentration on carbon isotope composition of biomass was rstly considered to be insigni cant [26,27], since the role of photorespiration was underestimated and the reciprocal relation of assimilation and photorespiration was unknown. Later the role of carbon isotope e ect of photorespiration was recognized as important [22,28] and some researchers have indicated the role of oxygen concentration on photorespiratory function of Rubisco [23,29]. It was shown that low O_2 content caused the observed enrichment of organic matter in ^{12}C [30].

Numerous data showed that the environmental parameters, directly or indirectly a ecting the CO_2 uptake by photosynthesizing cells or facilitating CO_2 availability, result in ^{12}

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the relatively small isotopic variations due to other parameters are explained by indirect impact of them. In general, the relatively small scale of isotopic variations observed in photosynthesis is due to a strong coordination of different photosynthetic processes in a cell to ensure optimal conditions for Calvin cycle functioning.

It was shown [3,40] that the coordination includes energy (ATP) and reducing equivalents (NADPH) formation coupled with electron transport chain associated with photosystem II. Thus, various environmental parameters determine CO_2/O_2 ratio inside a cell. The latter controls carboxylase/oxygenase activity of Rubisco and determine assimilation and photorespiration and, hence, carbon isotope composition of biomass.

Global photosynthesis in space and time

Global photosynthesis is manifested in space and in time in the form of facial isotopic shifts and temporal isotopic shifts of sedimentary organic matter correspondingly [41]. The difference between these two terms is the same as the difference between a photograph and a video. Facial isotopic shifts reflect the conditions of photosynthesis at this time in this location. That is why we attribute them to organic matter in rocks of the same age. As shown before, the main environmental parameter, exerting an impact on carbon isotope composition of organic matter, is the CO_2/O_2 concentration ratio in the surrounding.

It is known that in the course of photosynthesis evolution the CO_2/O_2 ratio on the Earth permanently changed from maximal value at the photosynthesis origin to minimal value at the ecological compensation point [7]. The changes of the ratio in the course of evolution were a saw tooth with gradual decrease of the average value to the ecological compensation point. It means that if to compare samples of organic matter separated by large time intervals they would correspond to different CO_2/O_2 ratios and have different values of carbon isotope composition.

Facial isotope differences: Following the above definition we assert that a set of environmental parameters makes within a cell a certain ratios of assimilatory and photorespiratory fluxes, which form carbon isotope composition of "living matter" and further of sedimentary organic matter. It was confirmed by many researchers, who disclosed distinctive links of organic matter with the assumed zones of organisms' habitats differing in CO_2/O_2 ratios and corresponding to marine, fresh water, terrigenous and salt marshes' conditions [42-44]. They evidence that the initial isotopic discrepancies are remained, despite of transformations, and inherited at different stages of organic matter transformations [16,44]

The correspondence of zones with different CO_2/O_2 ratios to isotopic differences of carbon isotope composition can be traced not only for organic matter but for oils as well. As said before, oils origin is associated with the lipid fraction of the "living matter" which is enriched in ^{12}C relative to other parts of biomass. If compared the difference between carbon isotope composition of "living matter" and its lipid fraction with the corresponding difference in the carbon isotope composition of organic matter and genetically related oil, it is easy to see that both values are very close. It allows concluding that the latter difference is inherited from the "living matter". From this fact it follows that no noticeable carbon isotope fractionation occurs in oil generation and the role of kinetic isotope effect of C-C and C-H bonds cleavage in oil formation is strongly overestimated [45,46].

It follows from this standpoint that the observed ^{12}C enrichment of oils is a result of initial enrichment of lipid fraction due to intracellular carbon isotope fractionation [15,47]. One more important point should be explained. It is the cause of the dependence of carbon isotope composition of fractions and metabolites of "living matter" on isotope effect of photosynthesis. The thing is that carbon isotope effect of photosynthesis arises at the entry into any photosynthesizing cell. It means that all intracellular isotope effects that appear later and result in carbon isotope heterogeneity of biomass, including isotopic shifts its fractions and metabolites, should be summarized with photosynthesis effect and hence should reflect photosynthesis conditions. Thus the facial isotopic differences reflect a variety of photosynthesis conditions on the Earth at the same time.

Temporal isotope differences: If two samples of organic matter relating to the rocks of different ages and this time interval comprise one or more orogenic cycles, it is necessary to take into account the change in CO_2/O_2 ratio arising due to photosynthesis evolution. Naturally, it is more correct to compare temporal isotope differences for the samples of the same faces.

Data of Hayes et al. [48] disclose distinctive ^{12}C enrichment of sedimentary marine organic matter relating to different intervals of geological time. They studied carbon isotope discrimination (the difference in carbon isotope composition of organic matter and carbonates, $= {}^{13}{}_{org} - {}^{13}{}_{carb}$):

Neoproterozoic	from 800 to 750 Ma	< -32‰
	from 685 to 625 Ma	-32< < -28‰
Phanerozoic	less than 625 Ma	-28< < -22‰

Distinct reduction of carbon isotope discrimination with time was found.

The same regularity one can find by studying carbon isotope composition of oils and their fractions in time comprising Neoproterozoic and Phanerozoic [49]. The study disclosed a similar change of carbon isotope composition of oil fractions C

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with advent of photosynthesis to resist oxygen action (the mechanism of photorespiration) later was transformed into mechanism of adaptation to all stressors.

How long oxygen content in the atmosphere could increase? e analysis allows concluding [7] that the rise of oxygen could last as long as the amount of the reduced carbon derived in photosynthesis doesn't become equal the amount of carbon return back into oxidized inorganic form. is state is called the ecological compensation point, when the system achieves steady state. In case of deviation from this state under the action of any reason, the system spontaneously returns back to the initial state. Miocene was likely the time when the ecological compensation point was achieved. Two facts give indirect arguments in favor of this conclusion. First is the emergence of C_4 plants having a new mechanism of CO_2 assimilation. e second is the last wave of oil generation indicating the formation of rocks rich in organic matter. Both arguments evidence about low environmental concentration of CO_2 and high concentration of O_2 and indicate the end of orogenic cycle. Further any signs of orogenic cycles were not detected. e long-term orogenic cycles were completely replaced by short-term climatic oscillations. It was refection of the fact that the equilibrated system became sensitive to collisions of separate lithospheric plates [7].

Conclusions

Global photosynthesis has all the features typical to the normal photosynthesis of individual organism of C_3 type, excepting ontogenetic features. ey include: the existence of reciprocal processes assimilation and photorespiration, the possession of the key enzyme Rubisco having carboxylase/oxygenase activity, the existence of oscillatory mechanism switching over assimilation to photorespiration and back, carbon isotope fractionation in CO_2 assimilation and photorespiration with opposite signs of isotope e ects and some others.

Taking into account these features of global photosynthesis, the mechanism of formation of carbon isotope composition of "living matter" and of sedimentary organic matter in the frames of global carbon cycle model is suggested. e main photosynthetic enzyme Rubisco, having carboxylase/oxygenase activity, plays the key role in this mechanism.

e analysis of the natural carbon isotope data in conjunction with the mechanism of global carbon cycle functioning shows that environmental conditions of photosynthesis play a dominant role in formation of carbon isotope composition of "living matter" and

sedimentary organic matter as well. Among them the content of CO_2 and O_2 in the environment are the most important. Many others

6. Dubinsky