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ORIGINAL PAPERS

The Emergence and Evolution of the Ecosphere

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Abstract. *The ecosphere is a natural construction, the development of which fundamentally differs from the way the other planets in our solar system evolved. Life emerged consequently to the connection between non-living factors and macromolecules – complex carbon-based compounds. Living beings had the capacity of creating a new type of informational pattern, which soon assumed the coordination of major processes at the planetary level, and the non-living components – the atmosphere, the hydrosphere and the lithosphere – were substantially modified by the biosphere. Our approach regarding thr evolution of life is an ecological one; emphasis is put on the interrelations between the living and the non-living worlds: the emergence of metabolism, interspecific relations, the use of multiple energy sources; the emergence of life generated biogeochemical cycles and evolutionary processes characterized by self-control, self-organization and self-improvement. A special role was played by the transition from the use of chemical energy to the use of light energy, with the release of oxygen, which, owing to oxidative reactions, became the main element in the global development of most energetic processes. Life progressed from self-reproducing organic macromolecules to protoorganisms, then single-celled organisms (prokaryotes) and finally eukaryotic organisms emerged. In time, they populated all environments: the marine, the brackish, the freshwater, the terrestrial and the underground one. Living beings created two planetary covers: the biosphere and the pedosphere. The interconnection of the biosphere with the non-living covers (the atmosphere, the hydrosphere, the lithosphere and the pedosphere) resulted in the emergence of the ecosphere.*

Keywords: ecosphere, biological information, biological processes, ecological processes, evolution.

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1. Introduction

The constitution of a functional ecosphere at the Earth's level is the result of several millions years of evolution, during which several forms of evolution of the organic matter and of different types of nonliving matter (physical, chemical, mineral etc) functioned concomittently (but at different speeds) [9], [11], [12] [13]. In the meantime, a multitude of complex relations and interrelations occurred between the various kinds of nonliving environments and the living one. The major part was played, since the beginning, by the information which directed biological processes (and which can be named biological information).

In romanian literature, the main authors who approached the theme of the emergence and evolution of life were Botnariuc [1], [2] and Soran & Borcea [14].

Based on their ideas, but supplementing them with more recent data [3], [5], [6] we shall attempt to trace the way leading to the present ecosphere.

2. The emergence and evolution of life

The physical and chemical characteristics of the water in the primeval planetary ocean, as well as its high temperature (caused by the very thin, barely formed terrestrial crust) were propitious to the emergence of the first forms of life. Since primary beings were very simple, similar to organic macromolecules (hence, to precellular formations), the environment they existed in had, for a long time, a major influence.

Due to the great variety of anorganic and organic, solved or colloidal, substances present in the ocean, the food these protoorganisms used was easily obtained and, in addition, very diverse. The way of feeding was through osmosis. This allowed the concurrent development of a large number of organisms, which coexisted without competing. No relations have been established among primary beings – or they were at an incipient stage (the pattern is similar to the way a collection of different bacteria starts developing in a liquid, rich culture medium). These organisms could be called osmotrophs.

As their number and their diversity increased, the amount of matter they extracted from the environment diminished. Consequently, protoorganisms started competing for food sources.

This competition resulted, on the one hand, in the beggining of a specialization concerning the way of feeding (hence, the emergence of organisms needing different kinds of assimilable substances) and on the other hand, in the development of new ways of feeding. The first one was phagotrophy.

Depending on the way protoorganisms collected the substances necessary to their metabolism and on the more and more diverse modalities of assimilating and metabolizing these substances, two other new categories of organisms joined the already existing osmotrophs:

a. consummers of substances eliminated by existing protoorganisms, as incomplete disassimilation products (i.e., detritophagous organisms);

b. soon after detritophagous, other organisms emerged – the ones feeding on other (already present) protoorganisms – i.e., consumers of other living entities (predators). If, to start with, predators were not selective regarding their food, a specialization gradually occurred (they started selecting certain preys, mainly by size). The catching was made by phagocytosis.

These new ways of feeding led to the development of the first interspecific relations which in turn caused the formation of the first trophic chains, at the bottom of which stood the osmotrophs, which were consumed by different predators; all these organisms were becoming – after their death – the food of detritophagous organisms.

Thus, primary biological information, the one necessary to achieve the first forms of metabolism, bettered and led to the first interindividual relations, which we can call primal ecological relations.

The multiplication and the diversification of protoorganisms caused the diminution of the substances utilized by osmotrophs. As a consequence, these organisms had two alternatives: to restrict their numbers (which would have resulted in a pressure put upon them by predators and the danger of extinction) or to adapt to a new way of feeding. The most efficient alternative consisted in starting to synthesise their own organic matter – to biosynthesise). It was therefore necessary to find and to utilize an external source of energy [6].

In consequence, osmotrophs turned to the energy obtained by oxidizing sulfates (a mechanism of anaerobic oxidation).

Thus, primary living beings diversified and new organisms, specialized in the production of energy, emerged – chemosinthesizers.

Until that moment, it was no question of true interpopulational relations, and no well-differentated system of ecological organisation existed. Neither was it question of the presence of a planetary ecosphere (life hardly existed, confined to the waters of the primeval ocean). Soran and Borcea (1985) named this state, in which organisms do not form real ecologycal systems, „protobiosphere" (Fig. 1). At this stage of the evolution of life, biogeochemical cycles were not fully constituted. Only a linear flow of living matter existed at the planetary level, due to the fact that the living component, being confined to oceans, was irrelevant and no real biosphere existed.

In this process, biological information became more and more complex and „evolved" in a wide variety of forms, which were still imperfectly organised. However, one can speak of retroactions and of self-regulating informational processes.

In time, a lack in simple, chemically synthesized organic compounds occurred in the ocean.

Willingly or (rather!) unwillinlgy, a series of organisms acquired the capacity of fixing free nitrogene (first from the water, then from the primordial atmosphere, too), since organic compounds containing nitrogene (an essential element for generating proteins) were becoming the main limiting factors in the synthesis of living organic material. Life became more complicated, consequently to the increase and diversification of chemosynthesizers, which moreover belonged to the ecological category of primary producers.

It goes without saying that informational processes within the living world were also expanding and diversifying.

During about the same period – estimated to have taken place three billions years ago – linear geochemichal processes (which at that time characterized the protobiosphere) gave way to cyclic ones, with the first attempts of achieving biogeochemical processes [14] (Fig. 1).

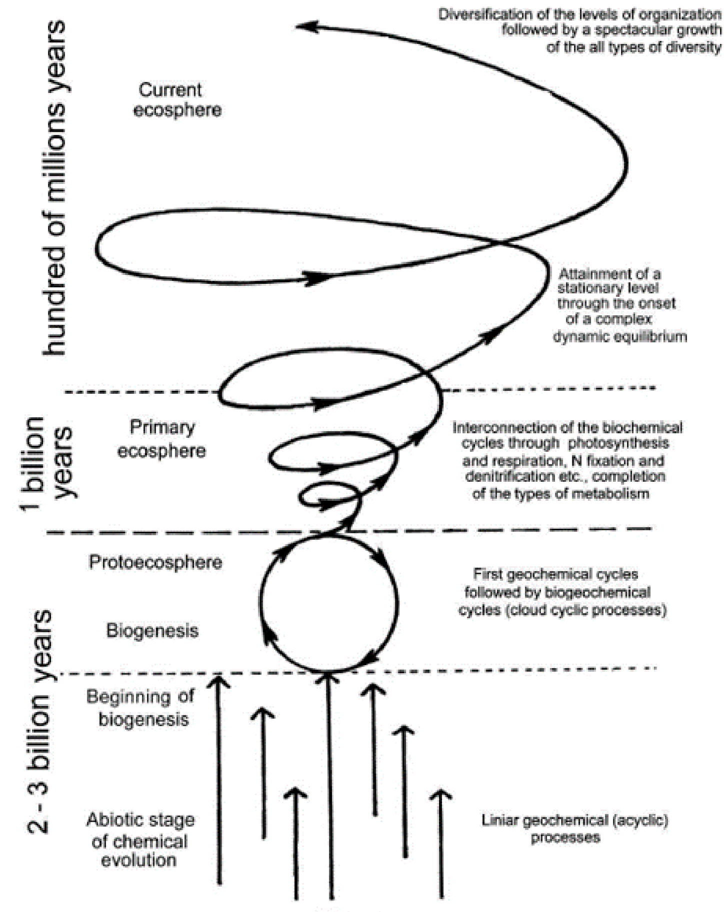

Fig. 1. The flow of matter at different stages of evolution and complexity of the life on Earth (after Soran & Borcea, 1985)

3. The evolution of the Earth in an ecological insight

The development of photosynthesis (a process in which light – as a new source of energy used by living beings – intervened in the synthesis of simple organic substances (such as cyclic carbohydrates – for instance, glucose) led to the release of free oxygen, first in water then, after this one reached its degree of saturation, in the atmosphere. It is thought that the emergence of photosynthesis represents the first great ecological revolution [14], which started about three billions years ago (Fig. 2).

Consequently to the activity of photosynthesisers, the composition of the atmosphere began changing: the amount of free oxygen (a very reactive element) incresed, while carbon dioxide, carbon monoxide and methane diminished more and more. The chemical composition of the primary atmosphere (consisting of gaseous emissions following a previous long-lasting and intense volcanic activity, which were anaerobic and reducing) changed increasingly, becoming aerobic and oxidant (Fig. 2).

This new atmosphere was a totally different one, whilst toxic for the prokaryotes which, by then, constituted the oceanic protobioshere. This fact considerably delayed the conquest of the terrestrial environment (and the covering aerial one) by living organisms [4], [5], [7],[8], [3].

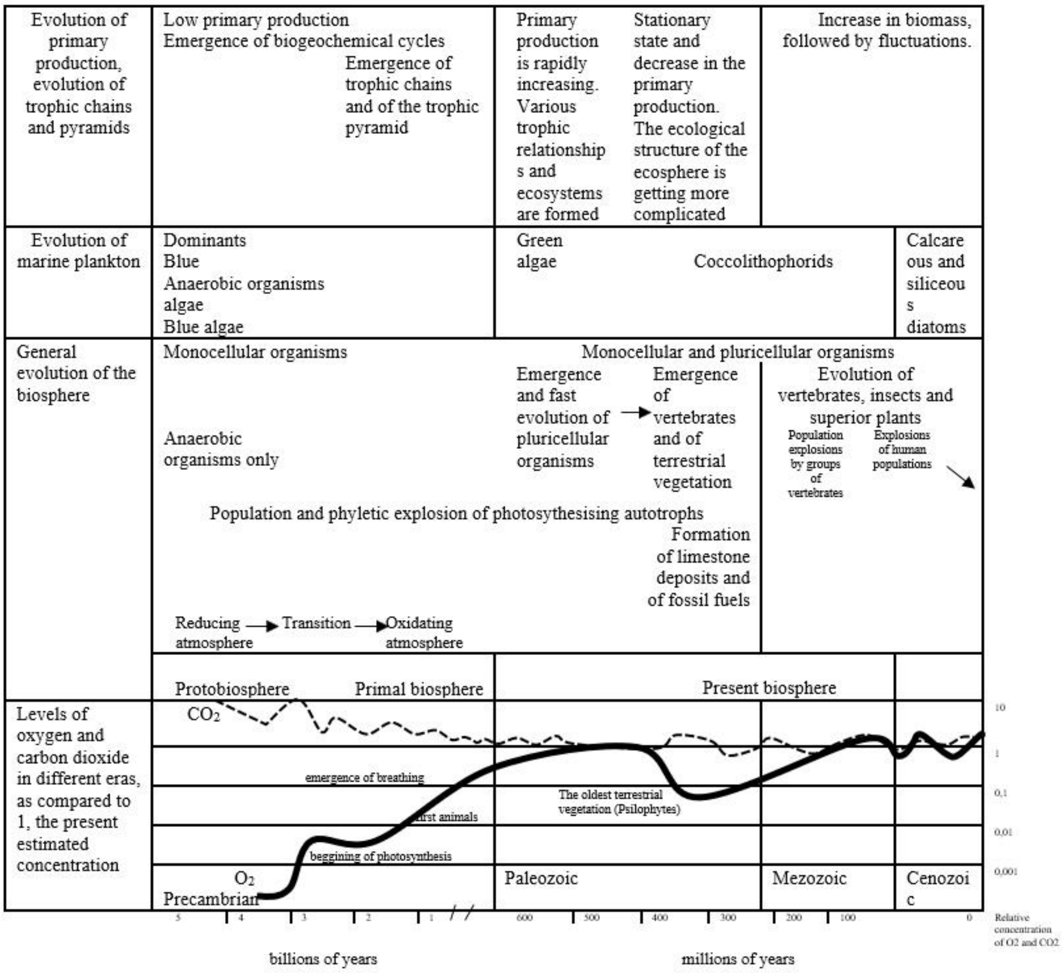

Fig. 2. The major moments in the evolution of the biosphere and ecosphere
(Soran & Borcea, 1985, modified)

Photosynthesis induced the development and the establishment of new biochemical processes, totally different from the preceding ones, which were fermentation and anaerobic processes. It is from that moment on that one can speak of the emergence of the first biogeochemical cycles (Fig.1). The first to start were the water and the carbon ones.

Concurrently with the emergence of these new types of organisms (photosynthesizing prokaryotes), a gradual decrease in the ratio of the bioproduction performed by chemotrophic and anaerobic organisms (which did not disappear, but withdrew in still favourable environments) took place.

Photosynthesisers became the main trophic link (primary producers) and induced the reorganisation of all trophic relations. To start with, as newly emerged beings, they had no consumers, only decomposers. As a result, an excessive increase in their number took place, followed by an accumulation of detritic material – a large amount of necromass at the bottom of stagnant water-bodies which attracted anoxic organisms – hence, the development of marshes or swamps which gradually dried out, generating incipient semiterrestrial grounds favorable to the development of already existing photosynthesising plants.

Two directions in the matter flow and two distinct energetic flows already existed in the planetary ocean one billiard and a half years ago [14] (Figs. 1 and 3):

- on the one hand, the ancient flow – the one within the existing (and very functional) trophic chains, which had as starting point osmotrophs and chemosynthesisers;

- on the other hand, the new trophic chains, starting from photosynthesisers, began gaining ground.

The two directions combined and became more complex (through possible interconnections between first-degree consumers) and stabilized as prokaryotic consumers – which fed both on living, chemosynthesised organic matter as well as on newly-emerged photosynthesisers – diversified.

Thus, anoxic biosphere was gradually replaced by the current one, which is much more complex and balanced. The production of non-biogenic substances became less and less important, while the production resulting from photosynthesis continued to grow exponentially.

This process triggered in turn a change in the role played by degrading anaerobic bacteria, which had to adapt to the new conditions – i.e., to degrade dead photosynthesisers, too. Anaerobic bacteria and fungi did not disappear; even today, they remain a particularly important category of the trophic chains, that of the degraders, ensuring the decomposition of organic matter to its simple component elements, the ones primary producers take over from the environment. Thus, the continuous functioning of the biogeochemical cycles involving most chemical substances which the lithosphere consists of (carbon, nitrogene, sulfur, phosphorus, water) was ensured. This process started in the precambrian and lasted till the beginning of the paleozoic.

It is obvious that biological information was developing and was enriching by new relations; moreover, a new biological way of storing emerged – the genetical one.

Until about two billions years ago, the primeval biosphere existed only in the waters of the planetary ocean. Its evolutin depended solely on external forces, namely on geological, hydrological amd climatic factors.

After the diversification and the continuous specialization of prokaryotic organisms, unicellular eukaryots emerged, followed by the first pluricellular ones – the metaphytes and the the metazoans. Beside the already mentioned external factors, internal ones started playing a more and more important part in the evolution of the biosphere; these factors were specific to the activities taking place in the biocenoses which were beginning to constitute the first marine and oceanic ecosystems (especially in shallow waters, where the influence of solar light was stronger). Intraspecific relations (and, from this moment on, interspecific ones, too) became more and more complicated and complex;

consequently, new biocenoses emerged, which not only interacted much stronger with nonliving factors, but eventually altered the chemical composition of aquatic environments and modified their physical and chemical agents; gradually, these changes affected the air above, too (Fig. 2).

Starting with the precambrian (about 1,0-2,0 billions years ago), one can speak of the existence of semiaquatic and fresh-water ecological systems – the precursors of the Earth's ecosphere.

About one billion years ago, unicellular eukaryotes (protistes) assumed most of photosynthesising unicellular prokaryotes (cyanobacteria) activities. This prompted a new evolution of primeval ecosystems.

After the emergence of eukaryotic multicellular organisms (at about the end of the precambrian), the biocenotic structure became even more complex, so that during the cambrian the niches of all the species were better and better structured and were occupied of an increasingly large array of living beings. A lengthening of trophic chains took place at the level of all ecosystems, more diverse trophic webs emerged, the utilisation of energetic transfers which took place in the biomass of living organisms became more efficient.

As food was more sparingly utilized in the metabolical processes of different organisms, its efficiency (hence, that of material and energetic resources) gradually increased. This was a consequence of the way the informational capacity incessantly improved at the level of the living matter.

Ecologists established that the current efficiency of the energy transfer is as follows [13]:

- energetic efficiency in chemosynthesisers: 0,2-0,5%,
- energetic efficiency of photosynthesisers increased to 1-5%,
- energetic efficiency in primary consumers reached 5-10%,
- energetic efficiency in secondary consumers reached to 10-20%,
- energetic efficiency in tertiary consumers reached 30-40%.

Until the silurian, life existed and diversified only in seas and oceans – i.e., in a liquid environment characterized by a rather high salinity. The „ecosphere" was confined to the planetary ocean, while the atmosphere and the terrestrial environment were devoid of living beings (considering that these ones lacked the capacity of living in environmental conditions totally different from the ones evolution had taken place until then).

The first important step was performed by aquatic synthesisers which, by prompting the change of the chemical composition of the atmosphere, led to an intensification of the oxidative processes occurring in terrestrial rocks. Thus, all kinds of salts emerged, through linear oxidative processes, in the lithosphere and hydrosphere; these salts accelerated the erosion processes and, owing to precipitations and air currents, generated the first deposits of sedimentary material. Several factors favored even more the tendency of marine creatures for conquering new environments: a concentration of free oxygen close to the one in today's atmosphere, the emergence of the protective ozone layer in the stratosphere, an important nebulosity and the high amount of precipitations which characterized the climate of that period.

Anaerobic processes played (and and still do) an essential part in the development and the evolution of ecological processes, their existence being particularly important not only at great depth in the planetary ocean, but also in standing fresh water, in fresh- and brackish water swamps, in the depth of soils and especially in underground ecosystems.

The first living beings to leave the planetary ocean were photosynthesisers – microscopic prokaryotes (cyanobacteria) to begin with, then photosynthesising eukaryote protistes (algae), which inhabited stagnant brackish waters; afterwards, more primitive pluricellular eukaryotes emerged, followed by inferior plants (Psyllophyta and Pteridophyta), which were growing in rather shallow freshwaters, then in swamps and wetlands. These organisms continued for a long time to use aquatic environments for the reproduction of their gametes and the development of their spores. In order to leave water, plants had to acquire a way of strengthening their bodies and to develop antigravitational systems which allowed their arising from the ground – characteristics not needed in the water. The last plants which moved to the terrestrial environment were mosses and superior plants (Angiosperms and Gymnosperms). Nowadays, these groups of autotrophes are clearly the dominant primary producers in terms of diversity. With their arrival, the foundation of the true terrestrial ecosystens (the ones which generated the Earth's actual vegetal carpet and constitute the first link in the trophic chains and networks in today's ecosystems) was laid.

At first, in the absence of terrestrial consumers, primary producers generated very large amounts of vegetal matter; this necromass fed only decomposers – since, once watered by precipitations, it became a wet material propicious to the development of degraders (even anoxia conditions – which degraders already exploited – were present). Consumers of semiterrestrial and terrestrial plants came from aquatic and semiaquatic environments, too, but much later. The first to develop the capacity of living and feeding (as adults) in an aerial environment were the ones which continued to reproduce and perform their ontogenetic develoment in the water (amfibians). It was only afterwards that air-breathing organisms, connected with very wet environment to start with, then the actually terrestrial ones (tolerating more or less moisture-free environments), emerged.

Only from that moment on (the silurian period) did paleontologists find the first fossils of animals inhabiting swamps ant actual terrestrial environments. (Figs. 2 and 3).

About 600 millions ago, after optimal ecological conditios were established, a second explosion of morphological biodiversity took place; the result was an expansion of the three current major kingdoms: plants, animals and fungi. This process was achieved consequently to a tight coevolution of primary producers, their consumers and degraders.

Emphasis must be placed on the importance of decomposers in recycling vegetal necromass in terrestrial environments. Once processed and mixed with fragments of eroded terrestrial rocks, necromass largely participates in generating soils and consequently to the development of the terrestrial vegetation and in the same time of a very important cover of the Earth – the pedosphere.

Due to precipitations, necromass and part of the soil sank deep in the lithosphere (through gaps and cracks in the rocks), where they laid the ground to a type of particular ecosystems – the ones that now form the subterranean environment. These ecosystems still depend upon allochthonous matter and energy (supplied by surface environments).

The concquest of the terrestrial environment resulted in the emergence of new interspecific relations, in an important variety of ecosystems – from the ones confined to wet regions to the ones populating deserts, mountain picks etc.

A particularity of the most evolved beings (all main groups included) is the adoption of social life. This was a new way of living, by which survival and the exploitation of natural resources reached a higher stage of biological intelligence.

Over time, the biosphere assumed its current extent, whilst the ecosphere reached a remarkable diversity.

The high diversity of the biosphere controled and conditioned the state and the quality of the ecosphere and of its components – supraecosystemic levels. Within the ecosphere, biodiversity was the main factor regulating all biogeochemical cycles, hydrological processes, climate (to a great extent); it had a deep influenced on local climates, it controled the chemical composition of air and water, it contributed to the stability of soils etc. All this was possible precisely because biological information is the major factor of all informational processes at a planetary level.

Ecogenesis is tightly connected with the phylogenetic diversity of living organisms and with the degree of perfection of interspecific relations, as well as with the relations between organisms and their nonliving environment.

The emergence of new species led to the development of new ecological nishes, to an increased stability of ecosystems. The competition for occupying niches accelerated phylogenetic evolution. In all cases, the chances to gain this competition (which aims to the development and perfecting of ecological systems) go to the organisms with the greatest capacity of adaptation to actual life conditions.

The highest progress must be connected with the complexity of interspecific relations and with the stability of the system – hence, with the reaching of a cenotic homeostasis, which would allow a more harmonious cooperation of all mechanisms of conservation and perfecting implying life in a more complex environment (both the non-living and interconnected living one) work together in a more harmonious manner. This homeostasis is achieved only through an incessant improvement of the retroactivities operating inside a given ecological system and in the conditions of a very high biodeversity.

The above-mentioned statements are illustrated by the evolution of the living matter, as given in Fig. 3 [14].

As a result of a long-term evolution of the biological and ecological systems, of the formation of confirmed and distinct systemic levels in biology and ecology, a very high degree of stability and resilience has been reached in present times – which unfortunately is now threatened by a more and more agressive (and atypical) species, *Homo sapiens*, the actions of which have effects of an unparalleled amplitude and are in the same time very difficult to counteract, considering the almost pathological egocentrism of the given species.

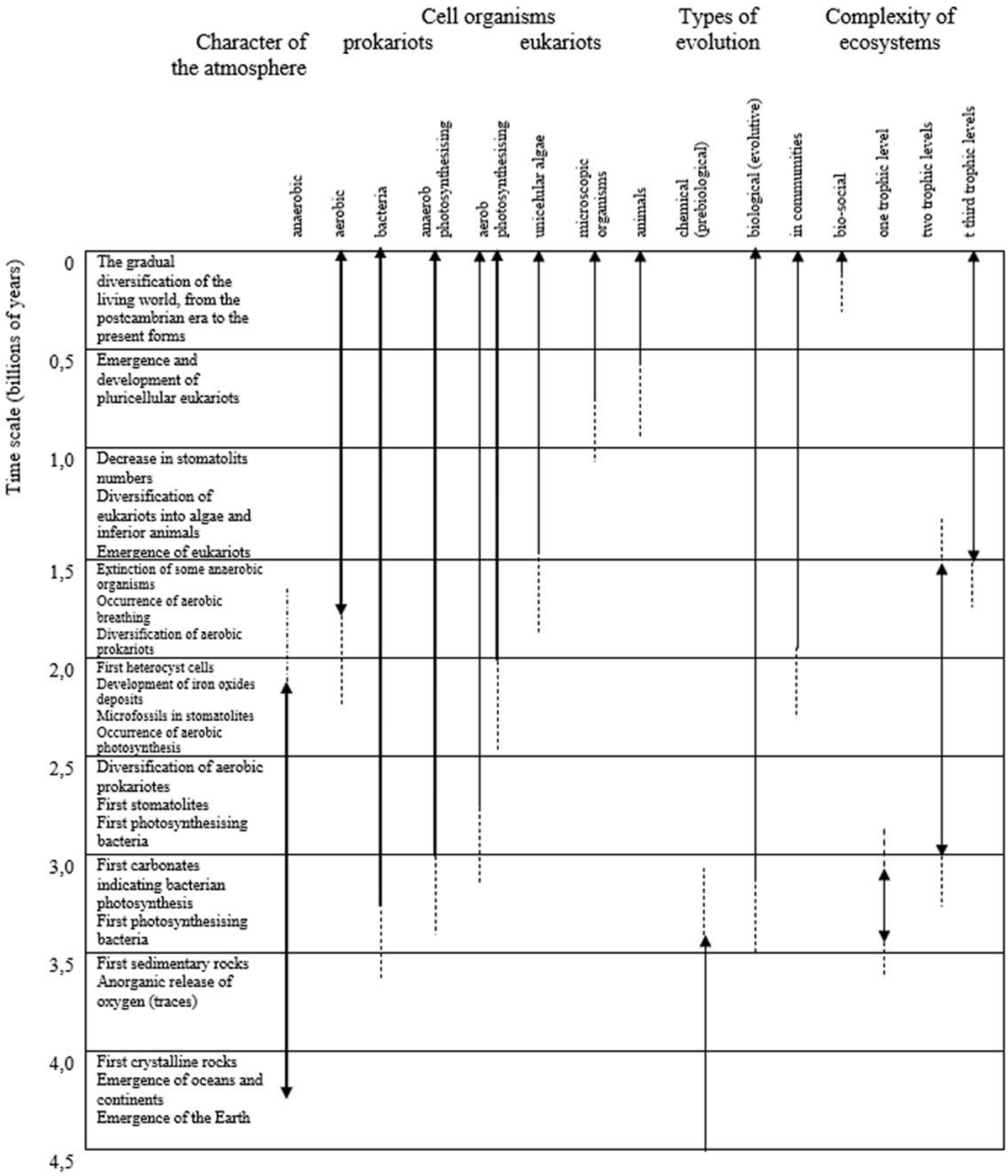

Fig. 3. The evolution of living organisms, from macromolecules to the biosphere (Soran & Borcea 1985)

Conclusions

The ecosphere is a natural construction fundamentally differing from the way evolution of the other planets in our solar system took place.

It emerged soon after the Earth formed and its solid crust developed. Life did not originate on land, but in the primeval planetary ocean, as a result of the interactions of non-living factors, which initially did not differ too much from the ones on other planets.

Life has a special capacity to creat a new type of informational pattern. It is characterized by selfregeneration, selfregulation, redundancy, a great capacity for storing (memory) and for processing informations. Through its representations (living organisms) life assumed very soon the coordination of the main processes which take place at a planetary level.

As a result, non-living components – the atmosphere, the hydrosphere and the lithosphere – were greatly modified by the biosphere. Their interaction led to the genesis of the Earth's ecosphere.

In order to illustrate these processes, we present the emergence and the evolution of the biosphere – from organic macromolecules to its current state. The evolution of life is traced by emphasising the interrelations between the living and the non-living worlds: the emergence of metabolism, of interspecific relations, of the way in which living beings started using more energy sources and generating (in a controllable manner) new organic substances (by using photosynthesis) as well as generating biogeochemical cycles (moving from linear matter and energy flows – specific to mineral matter – to spiral cycles and evolutions characterizing biogeochemical processes, but mainly to evolutive processes, defined by self-control, self-organisation and self-perfecting.

A special part was played by the passage from the utilisation of chemical energy to the one obtained by simple chemical reactions, then to the one obtained by reducing processes and finally by moving to the utilisation of the most active chemical element – oxygen – which (as a free element) was scarce in the primeval matter of our planet, but which was intensely produced by living beings through the intake of cosmic luminous energy. Thus, oxygen became the main element in the development (at a global scale) of most energetic processes.

Life passed from self-reproducing organic macromolecules to protoorganisms, then to prokaryotic unicellular organisms and finally eukaryotic ones. All these kinds of organisms still exist today; they moved from the primeval marine environment to the brackish one, then to freshwaters, land and underground.

Living beings have created two planetary covers: the biosphere (the living cover) and the pedosphere (dead, decaying organic material which, mixed whith litosphere fragments, became the main support of life in the terrestrial and subterranean environments).

The interconnections between the biosphere and the non-living covers of the Earth (the toposphere, the atmosphere, the hydrosphere, the litosphere and the pedosphere) generated the ecosphere, wich continues to evolve and improve and is coordinated by biological information. The ecosphere changed the ways cosmic energy manifests itself currantly on our planet, as well as the functioning of the living and non-living matter.

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