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Yu. P. GALCHENKO [1], *Research Manager, Expert of Research Center for Applied Geomechanics and Convergent Technologies in Mining, Doctor of Engineering Sciences, Professor, schtrek33@mail.ru*
G. V. KALABIN [2], *Chief Researcher, Doctor of Engineering Sciences, Professor*

[1] *NUST MISIS College of Mining, Moscow, Russia*
[2] *Academician Melnikov Research Institute of Comprehensive Exploitation of Mineral Resources, Russian Academy of Sciences, Moscow, Russia*

NATURE-LIKE MINING TECHNOLOGY AS A POTENTIALLY MONUMENTAL RESOLUTION OF ENVIRONMENTAL CONTRADICTIONS DURING THE DEVELOPMENT OF SOLID MINERAL DEPOSITS

The antagonistic contradiction between the biological essence of man and the abiological ways in which he obtains energy from the Sun for the creation of a food base and personal habitat is the determining factor shaping the image of our technocratic civilization. In order to address this contradiction in the development of the mineral and raw materials complex, it is necessary that the requirements for environmental security not be imposed on individual operations or processes but form the basis of a promising technological paradigm. In this way, the conservation of the Earth's natural biota becomes a requirement and an inherent feature of the technologies created and applied. It seems abundantly clear that from a methodological point of view, technological responses to environmental challenges should be sought in the study of systems where these answers have already been obtained. Namely, these answers present themselves in biological systems taking form in nature-like technologies.

Recent changes in public consciousness have inevitably led to the greener thinking in all spheres of human activity. The most illustrative ref lection of this phenomenon is the growing interest in nature-like technologies, which are associated with the main aspirations in the settling of a global environmental crisis generated by a long-term antagonistic confrontation between the technosphere and the bio- sphere.

In considering the concept of nature-like technologies as a designation of the principal trend in the modernization of the general technological paradigm, it is necessary to distinguish two specific areas. Depending on whether or not the technologies that we use are present or absent in wildlife, we must first consider the construction of technologies by duplicating effective processes already observed in wildlife in the technosphere (nature-reproducing technologies) and, secondly, the creation of technological systems by transferring the effective functional structure of the circulation of matter and energy in biological systems to the technosphere (convergent technologies).

The general theory of the creation of "similar to nature" technologies is presented, based on the well-known principles of homeostatics - methods of maintaining the vital parameters of the interaction of natural and technical systems by controlling the contradictions between antagonists. The main directions of the structural and functional convergence of technical and biological sciences are identified when updating the technological paradigm of industrial development, based on the reproduction in the technosphere of systemic solutions that ensure the functioning of complex biological systems.

Regarding the ecologization of the technological paradigm of the mineral resource complex, the methodology of creating an ecologically balanced technology as a multiobject cluster is based on the well-known principles of homeostatics, i.e., on the phased formation of a technological homeostat on the basis of the structure of a biological homeostat with the replacement of its essential elements with geotechnological target analogues. The result of this transformation is the construction of a convergent mining technology for integrated field development. Its use will ensure the development of technical systems that make it possible to limit external environmental impacts owing to the postexploitation self-restoration of natural biota phytocoenoses.

Keywords: *lithosphere, integrated subsoil development, naturelike technologies, hypothesis, homeostatics, biotechnological principles, convergent mining technology, natural–technical systems, clusters, environmental performance.*
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Introduction

The main distinguishing feature of the current stage of development that we have built a consumer society is the rapid destruction of the Earth's biosphere against the background of no less rapid growth in the cost of its conservation. The presence of this paradox is due to the fact that the whole face of our technocratic civilization is formed under the influence of a fundamental antagonistic contradiction between the biological essence of man and the abiological ways of obtaining solar energy to create a food base and his living environment [1–3]. The current technological paradigm of industrial production provides for the innovative development of technologies based on highly specialized knowledge solely with the aim of ensuring the economic efficiency of any production. At the same time, environmental problems are usually solved on a residual basis, as a system of post-operational measures for monitoring and partial elimination of the entire complex of consequences of man-made changes in the geophysical state of the lithosphere [4, 5].

This approach allows us to solve individual environmental problems exclusively by applying additional environmental technologies, but does not solve the whole range of problems associated with biological diversity and structural features of protected natural systems. Therefore, in methodological terms, environmental safety requirements should be laid down in a promising general technological paradigm so that the conservation stability of the lithosphere of the Earth's natural biota becomes an integral property of the technologies being created and applied.

Definition of concepts

In its most general form, the general idea of constructing such technologies was expressed by academician V. I. Vernadsky. It

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was he who formulated the "noospheric" task of embedding technological processes in the cycles of the natural circulation of matter in the biosphere and their non-destructive interaction [6]. It is quite obvious that the solution to this general problem is possible only by creating and applying technologies with new properties that provide the ability to preserve the above-mentioned cycles of the natural circulation of matter in the biosphere. This means that, methodologically, technological answers to environmental challenges should be sought in the study of systems where these answers have already been received, that is, in biological systems.

The development of the technosphere, as the basis of modern civilization, can be defined by a simple triad: knowledge-skill-result, or – in a more specific form: science-technology-product. The qualitative characteristics of the elements of this triad become clear when viewed in the reverse order – the product properties necessary for us determine the internal content of the technology, which, in turn, indicates which part of the general knowledge we should use when creating such a technology. Therefore, the phrase "of similar to nature technologies" often used today should be interpreted as determining the vector of application of search efforts and as an indication that we intend to find new ways of purposeful transformation of technologies on the basis of knowledge about wildlife.

It is known that in its most general form, technology is "... the practical application of knowledge to create methods of production activity ...". Then, from a technological point of view, technologies should be considered **similar to nature, the creation and development of which is based on knowledge of living nature.**

This comprehensive concept can be divided into two parts according to the internal content of technologies:

• "similar to nature" solutions for technologies that have analogues in wildlife;

• "similar to nature" solutions for technologies that have no analogues in wildlife.

In the first case, we are talking about the fact that the innovative development of a certain group of technologies is based on duplication of processes already existing in wildlife. This direction has a rather long history, which, apparently, begins with the advent of bionics. Here there are serious results and enormous prospects that will constantly expand as our knowledge of the material world deepens. Such technologies can be called **nature-reproducing and define them as technologies based on the reproduction of processes that ensure the existence of organisms in the biota of natural ecosystems.**

Man, gaining intelligence in the course of evolution, continued his further development outside the natural balance of solar energy. Therefore, the foundation of the technocratic civilization created on this path has become processes and technologies that have no and cannot have direct analogues in living nature. Almost all technologies that provide the opportunity for human habitation in territories previously occupied by the Earth's natural biota fall into this group.

The modern system of environmental knowledge has an extensive axiomatics and covers all levels of macroecological organization. The main methodological principles, theorems, and rules established in ecology reflect the action of the fundamental laws of the dialectics of natural science and therefore can be considered private applications of these laws or their consequences. Then, when considering the problem of using knowledge of wildlife to create technologies that do not have direct analogues in biological systems, the search goal is not individual technological solutions, but a form of a systematic approach to ensuring the ecologically balanced or co-evolutionary [7] interaction of the antagonistic components of the techno- and biosphere as a part natural-technical production systems. In this case, the necessary qualities of the technical component should be provided due to the convergence of its functional structure with the functional structure of biological systems that already possess these qualities. In this setting, one can determine the second type of nature-like technologies – **convergent, as technologies in which anthropogenic processes interact with each other in a bi-like functional structure, taking into account the limitations of the biological imperative.** Such a complex configuration of convergent technology opens up a real prospect of protecting the natural environment by matching the level of the integrated technogenic impact on the biosphere with the conditions of the natural self-restoration of its phytocenosis in the process of development of secondary succession.

Obviously, the first step to creating this type of similar to nature technologies is to determine the principles of functioning of biological systems as a methodological basis for substantiating the functional structure of convergent technology.

The principles of functioning of biological systems

The main functional unit of the Earth's biosphere is an ecosystem. In [8], it is designated as a set of different types of living beings interacting with each other and with the environment in such a way that this set can remain indefinitely. In turn, the biota of these ecosystems is a developing dynamic structure of producers, consumers, and detritophages linked through food chains and non-food relationships**.**

The general direction of this development is determined by the ecological law of unidirectional energy flow, the action of which is the basis of *the principle of irreversibility of the process of biological evolution under the action of periodic natural factors* (designated as the law of Louis Dollo.

It is known that each organism consumes only that and in the amount that it needs for development (the law of conservative consumption of Daniel Chiras [9]) Therefore, the movement of biomass and energy in a living system is repaired by the law of Raymond Linderman, which is the content of the second *principle of functioning biosystems: at each trophic level, only a new biomass is produced, the amount of which is inversely proportional to the length of the food chains*.

The existence of natural-equilibrium ecosystems is based on the large and small circle of biotic exchange - as a continuous process, but uneven in time and space, the redistribution of matter and energy. Therefore, taking into account the nature of the interaction and the purpose of the main categories of organisms in ecosystems, the third principle of the functioning of biosystems (Daniel Chiras recyclability law) [10] can be formulated: *the use of resources and disposal of waste occur within a closed circuit of matter*.

The most important property of natural ecosystems is their stability, which is ensured by the fact that the ratios of all components are determined by the dynamic equilibrium between the biological potential of populations and the impact of their environment. A change in these conditions causes

the development of succession, which ends with the stage of the climax ecosystem. At this stage, all species, reproducing, retain a relatively constant abundance, and the ecosystem – species diversity. Moreover, plant communities of producers are always the cornerstone of the ecological pyramid, the resistance of which to external influences is regulated by the law of R. Shelford [11].

Then, *the fourth principle* of ecosystem functioning can be formulated as follows: *ecosystem sustainability is determined by species of the first trophic level*.

The flow of energy in natural ecosystems is fully consistent with the principles of thermodynamics. The energy of sunlight is converted into chemical energy as a result of photosynthesis, and the chemical energy into other forms during the passage of food chains. From here follows *the fifth principle* of the functioning of ecosystems: *they exist due to non-polluting environment and almost eternal solar energy, the amount of which is relatively constant and excessive*.

Methodological approach to the conversion of biosystem principles into technical

Given the antagonistic nature of the general contradictions between the techno and biosphere, it is advisable to build a methodology for solving this problem on the well-known principles of homeostatics on how to maintain functionally significant parameters of interacting systems by managing contradictions. Homeostatic mechanisms can be represented as the result of the integration of two forcedly interacting antagonists in such a way that the system as a whole can function stably even if each of these antagonists turns out to be an unstable formation [12]. As a result, it becomes possible to synthesize opposites when two antagonists are not opposed to each other, but are combined into a single functional system. As a result, a controlled balance between the two incompatible components is achieved by limiting the impact of one of them to the range of possibilities of preserving the identity of the second. The end result of this form of management can be the construction of a natural-technical system for a specific regional biome. In this case, global contradictions between the techno- and biosphere as a whole can be locally resolved by limiting the level of external impact that ensures the conditions for the survival and self-healing of biological systems (**Figure)**.

The methodological approach to converting the given biosystem principles into engineering ones is determined both by the ways of connecting the lower level hierarchies with their contradictions and by the algorithm for managing these contradictions (See figure).

Therefore, biological information can be transferred to the technosphere by constructing a technological homeostat, based on the functional structure of a biological homeostat with the replacement of its content elements with technological target analogues.

The main environmental hazard and a distinctive feature of the development of mineral resources of the subsoil, as the material and energy basis for the development of the anthroposphere, is the active, large-scale and simultaneous change in the state of all the main geospheres of the Earth. Mining can be represented as a process of formation and development of zero-density inhomogeneities in the lithosphere with a concomitant change in the ecological state of mountain ranges without changing their density (secondary

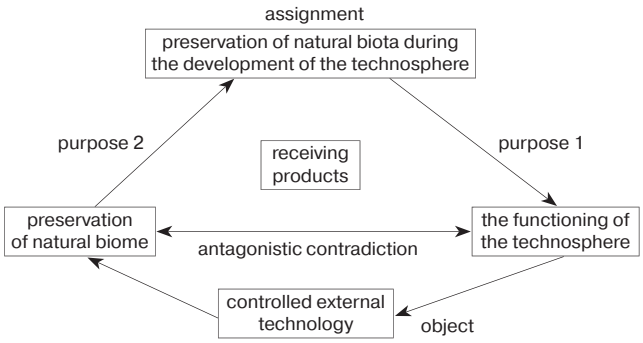

Figure. A block diagram of homeostatic regulation of the interaction of an industrial-technical system and a natural biome, expressed through purposes

stress field) [13]. Therefore, it is advisable to consider the possibility of transforming the principles of the functioning of biological systems into the technosphere using the example of creating convergent technology for the development of mineral deposits.

Justification of the principles of the functioning of convergent technology for the development of mineral resources

The law of irreversibility of evolution reflects the ability of natural systems to evolve from simple to complex in a constantly changing environment. The nature of this development is determined by the law of the theory of bifurcation [14,15]. The biota of natural ecosystems, as a self-organizing system, can be in a stable dynamic state until, as a result of random changes in external conditions (fluctuations), it reaches an unstable position (reaches the bifurcation point). The further evolution of biota after the bifurcation point no longer depends on these fluctuations [14]. Replacing the concept of biota in the homeostat of the evolution of the biosystem with the semantic analogue – the lithosphere, fluctuations – with technogenic factors, and the evolution of the system with the technogenic change in the state of the subsoil, we obtain the technological homeostat of the functional structure of the technology: the developed section of the lithosphere is in a stable dynamic state until, as a result accumulation of the effects of technogenic factors will not lead to an unstable position at the bifurcation point. Since the development of a deposit is possible only with the constant maintenance of the stability of technologically variable subsoil, the functional principle of preventability can be formulated: *the influence of negative factors provoked by the technogenic destruction of the lithosphere should be eliminated or minimized before the mass extraction of lithosphere material on the basis of a targeted change in the structure of the used mining technology in time and space*.

When implementing the existing technological paradigm for the development of the mineral resource complex, mining operations in almost all geological types of ore deposits are carried out with an absolute predominance of gross ore extraction. In combination with the ever-decreasing quality of ores and with the technologically determined extraction of waste rocks to the surface, this leads to the fact that from 50 to 90% of the material extracted from the lithosphere remains on the earth's surface in the form of technogenic formations

vast from the occupied area from solid wastes of various dispersities. All this indicates that in the promising technological paradigm based on the idea of nature similarity, the principle of selectivity of the extraction of minerals becomes a necessary element. Its content is easily transformed from the second functional principle of the self-organization of biological systems by replacing the content element in the biological homeostat – "produced biomass" with its semantic technological analogue – "mineral". Then the second functional principle of the formation of nature-like mining technology is defined *as the selective extraction of minerals at the mining stage*.

The development of any mineral deposit is accompanied by the movement of huge masses of rocks, which leads to the formation of two large-scale anthropogenic neoplasms that radically change the state of the lithosphere and biosphere of our planet. The first of these is the technologically altered bowels – areas of the lithosphere that have lost their identity as a result of mining and the formation of developed space. The second technogenic neoplasm, which poses a direct environmental threat to all geospheres, is lithosphere material extracted to the surface. Therefore, effective protection of the natural environment is possible only by filling the created underground space, and the preservation of other geospheres by stopping the deposition of unused in the technosphere part of the substance extracted from the lithosphere. This implies the third principle of functioning of convergent technology for the development of mineral resources, which determines the need for *a closed cycle of circulation of the extracted but not used material of the lithosphere*.

The fourth and fifth principles of self-organization of natural-equilibrium ecosystems do not relate to the internal circulation of the produced biomass, as the first three principles, but reflect the properties and nature of the interaction of parts of the system as a whole. Therefore, the transformation of biological principles into technological ones does not require a homeostatic approach, but can be performed on the basis of the logical construction method with the replacement of the goal.

Apparently, no special evidence will be required for the proposition that different biological communities react differently to the same effect. Therefore, for each type of ecosystem, there must be a limit to the magnitude of each impact, beyond which irreversible changes in the ecosystem begin. The search for these limits, including methods for their determination, in relation to different industries and different types of ecosystems, is today a fundamental problem of ecology in general and industrial ecology, in particular, solved at the intersection of biology and technology. In scientific and methodological terms, this means that the permissible level of technogenic disturbance of the abiota of a particular ecosystem should be determined from the conditions of conservation of its biota. That is, each type of ecosystem should have its own scale of limitations of action for each technogenic factor. Then, the transformation of the fourth principle of the functioning of biological systems into the technosphere means that effective protection of the natural environment during the development of mineral resources will be ensured if, along with the transformation of mining technologies, a system is created to regulate the *interaction of the techno-and biosphere according to indicators and criteria that reflect the properties and reaction of the Earth's natural biota on technogenic factors of mining*.

The fifth of the biological principles outlined above is easily transformed into the proposition that any mining technology, ideally, *should fully function due to the energy of global and local renewable sources*.

According to the generally accepted definition of the concept of renewable energy sources, sources on the basis of permanently existing or periodically occurring energy in the environment fall into this category.

In relation to the problem of integrated subsoil development, the construction of mining technology based on these principles means that the components of the existing natural-technical systems that are antagonistic in their internal content are not opposed to each other, but are combined as part of a convergent technology for the integrated development of the deposit. At the same time, controlled harmony between incompatible components is achieved due to the similarity of their functional structures and limitation of the level of technogenic impacts to the tolerance range of species-edificators of biota of natural ecosystems.

The arrangement system of biotechnological principles for the formation of convergent mining technologies, shown in the reference [16], reflects the hierarchy of their functional differentiation by the nature of their participation in an environmentally balanced process of field development. The first two principles (1–2) form a new face of mining technology, which arises as a result of homeostatic transformation into the technosphere of the corresponding principles of the functioning of biological systems that determine the change in the state of matter in these systems.

The third, biotechnological principle (3), reflects the need for a new organization of the functional structure of the mining engineering system for the development of the field, corresponding to the nature of the circulation of the substance in biological systems. The other two (4 and 5) determine the nature and conditions of interaction of the components of the entire natural-technical system for developing the resources of the subsoil area, ensuring the preservation of the stability of its natural component, as well as the environmentally acceptable energy supply of the technical component.

The simultaneous implementation of all biogenic principles will allow us to structure the process of obtaining minerals in time and space in full accordance with the limitations of the environmental imperative and sustainable development

The mineral resources of the lithosphere are essentially the set of mineral deposits that have been discovered and identified. The use of the above-formulated principles opens up the prospect of creating a new paradigm for the technological development of the mineral resource complex, aimed at cardinal decisions on the conservation of the Earth's natural biota, and determines the executive structure of the main object of technological research, the natural–technical system of developing mineral resources located in the Earth's lithosphere.

To identify the concept of the natural–technical system of developing the lithosphere reserves, it is necessary to determine the dynamics and features of the internal development of the natural and technical sub- systems, as well as to consider the character of their interaction to ensure conditions for the "optimal functioning of the natural–technical system" on the basis of an "environmentally friendly placement of elements of the technosphere" in developing a specific site of the lithosphere [17].

The natural component in this case is not formed according to the principle of accumulating and stating data on the extent and intensity of the technogenic disturbance of the Earth's main geospheres in the process of extraction of minerals; it should be a system of actions and limitations on assessing and overcoming the biological consequences of these disturbances on various time scales; i.e., it can be considered as a multiobject cluster. Proceeding from the well-known definition of the concept of a production cluster as a "mechanism of concentrating efforts" [18], it can be argued that the main elements of the natural technical system of developing the reserves of a field are two multiobject clusters that concentrate efforts in different directions. The industrial cluster aims at effective and safe mining, while the environmental cluster is formed as a system of actions and restrictions to pre- vent irreversible environmental consequences of the inevitable local destruction of the lithosphere. Each of these clusters consists of several lower order mono- clusters, which, in turn, are formed from functional systems of various assignments [16].

The interaction of these components, as in every complex system, is determined by the fact that one of them is controlling and the other is executive [19]. The executive (in our case, technical) component directs the main function of the system, mining, while the controlling one regulates its implementation with account for the changing environmental conditions and the requirements on maintaining the Earth's natural biota [16]. It follows that the functional effectiveness of the technical component in the entire system will always be determined by the nature of the interaction of the natural and technical clusters according to the criteria of environmental security and the effectiveness of the technologies used.

In general, the modernization of the technological paradigm for the development of the mineral resource complex in the direction of a gradual transition to convergent technologies will make it possible to resolve the global antagonistic contradiction between the technosphere and the biosphere in this field of activity by transforming it into a chain of local contradictions between a particular mining enterprise and a real eco- system. Each local contradiction is overcome through the targeted creation and application of technological solutions, the level of environmental impact of which does not go beyond the tolerance range of edificator species of the phytocoenosis of the disturbed ecosystems.

Conclusion

The general theory of the creation of similar to nature mining technologies based on the well-known principles of homeostatics on methods of maintaining the vital parameters of the interaction of natural and technical systems by way of managing contradictions between antagonists is substantiated and developed. The most important conceptual provision for environmental industrial ecology is formulated that criteria limiting the level of exposure to anthropogenic factors should be formed only on the basis of the biological consequences of this impact, regardless of the interests of a person and the capabilities of the technologies created by him. The use of such technologies will help protect the environment by limiting external environmental impacts by the conditions of post-operational self-restoration of phytocenoses of the Earth's natural biota. For the first time, on the example of solving environmental problems in the development of mineral resources, the concept of creating, for the development of solid minerals, convergent mining technologies, the organizational principles of which are formulated based on the principles of functioning of biological systems, is proposed.

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