ГИАБ. Горный информационно-аналитический бюллетень /
MIAB. Mining Informational and Analytical Bulletin, 2021;(3-1):338—349
ОРИГИНАЛЬНАЯ СТАТЬЯ / ORIGINAL PAPER

УДК 622:504 DOI: 10.25018/0236_1493_2021_31_0_338

# ГЕОЭКОЛОГИЯ И ГОРНЫЕ ГЕОТЕХНОЛОГИИ — ЭЛЕМЕНТЫ КОНЦЕПТУАЛИЗАЦИИ И ОЦЕНКИ

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***Аннотация:*** С помощью геоэкологического подхода выявлены комплексные системные связи, показывающие, что горнодобывающие предприятия оказывают негативное воздействие на ландшафты только в небольших масштабах (обычно на уровне Geotop и Geofacies). Воздействие снижается с ростом и развитием природного потенциала, однако это не дает оснований для уклонения или прекращения капиталовложений. Следовательно, комплексный мониторинг ландшафтов, прилегающих к зоне действия горнодобывающего предприятия, способен предоставить всю необходимую информацию для оценки возможностей или несостоятельности капиталовложений в обеспечение существования географической среды в районе размещения горнодобывающего предприятия. Путем преобразования структуры концепции «Геосистемы» и ввода точных границ областей воздействия горных работ, в статье предлагается Геоэкологическая Пентаграмма как модификация вышеупомянутой концепции и полуколичественный метод геоэкологического анализа. Статья предназначена для специалистов для обсуждения текущего статуса (парадигмы) отрицательного воздействия на окружающую среду. В работе развернуты геоэкологические перспективы горнопромышленного комплекса с позиции обеспечения правильных методов производства работ.

***Ключевые слова:*** геоэкология, географическая среда, геоэкологическая пентаграмма.

***Для цитирования:*** *Николае Илиаш, Сорин М. Раду, Юлиан Оффенберг, Виктор Арад, Сусана Арад*. Геоэкология и горные геотехнологии — элементы концептуализации и оценки // Горный информационно-аналитический бюллетень. — 2021. — № 3-1. — С. 338–349. DOI: 10.25018/0236_1493_2021_31_0_338.

## Mining geoecology and geotechnologies — conceptualization and evaluation elements

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***Abstract:*** Geoecological approach highlights the multiple links between systems that shows most mines can affect the landscapes only within low geographical scales, usually Geotop or Geofacies level (rank); effects are reduced as extension and with natural potential of evolution, which not justify avoiding or stopping the investments. Therefore, holistic monitoring of landscapes around mining perimeters can provide all information required for assessing the abilities or inabilities produced by investments on the Geographic Environment where are located. Reorganizing the structure of the concept of "Geosystem" and introducing exact boundaries for areas affected by mining, the authors propose a Geoecological Pentagram as a reorganized concept and a semi-quantitative Geoecological method of analysis. The manuscript is addressed to specialists for the purpose of discussing the current state (paradigm) regarding the environmental impact and develops the Geoecological perspective for industrial/mining sector, as a good practice.

***Key words:*** geoecology, geographic environment, geoecological pentagram.

***For citation:*** Nicolae Iiaş, Sorin M. Radu, Iulian Offenberg, Victor Arad, Susana Arad. Mining geoecology and geotechnologies — conceptualization and evaluation elements. *MIAB. Mining Inf. Anal. Bull.* 2021;(3-1):338—349. [In Russ]. DOI: 10.25018/0236_1493_2021_31_0_338.

## Introduction

The famous statement "Cogito ergo sum" ("I believe; therefore, I exist!"), which Descartes published in "Discourse on Method" (1637) (Renaissance era), reduces the essence of human nature to sure knowledge, realized through intuition and deduction. Descartes considers that only the material elements that we perceive and / or conceive clearly, from an intellectual point of view, through a direct (intuitive) act of knowledge and an exhaustive (deductive) explanation about complex or true things are real. His philosophical vision of nature and his conceptual method marked a turning point in the scientific approach and the beginning of the modern era in science [1]. The Academic environment embraced the analytical conceptual model as the only scientific truth in evaluations by introducing reference systems (Cartesian) and transferred this reductionist paradigm to the civil society. Natural, this approach becomes quickly the conceptual basis of academic debate and institutional decisions in many evaluations, including the impact of human activities in landscapes.

Over time, reductionist approach generated mechanistic decomposition of the concepts and issues, using smaller and smaller parts, followed by a continue rearrangement of resulting sequences in order to preserve the logical, intuitive, deductible, synthetic and verifiable order in research. Thus, this paradigm began to produce imbalances in evaluations by excessive fragmentation of overall picture trying to conceptualize specific complex phenomena based on other much simple, but nonspecific, individual properties, using linear characteristics such as:

— Proportionality, the multiplier factor of input and output values are identical;

— Superposition, the sum of the input values determines the amount of output values;

— Visibility, the entries (causes) and the outputs (the effects) are observable;

— Predictability, the effect is predictable by planning, monitoring and actions control.

But system's holistic conceptualization focuses on the analysis of the parts that are relational interconnecting and integrating into a whole. This concept consider that the properties of the specific phenomena related to complex systems cannot be reduced to individual properties of their simple parts, smaller in extent but nonspecific, because it's arisen from their interaction and mutual interdependence. The holistic approaches consider that by reductionism the properties of a system may be distorted and even dysfunctional; the whole will have different manifestations from the sum of its components due to its dynamic intrinsic nature. In the same time, manifestations are not rigid but flexible because the basic processes tend to stabilize, and are expected holistic systems to be characterized by the fact that, generally, input values are not proportional with output values, holding the following characteristics:

— Heterogeneity, conceptualization of systems as mosaics composed by a number of homogeneous and steep fundamental components with uneven distribution of features;

— Irreducibility, whole is not identifiable by its parts but the quality and quantity of the overall image;

— Self-organization, corresponding to a territorial complex, well individualized, where the focus is on thereof overall dynamics;

— Self-control, multiple links within it, causes and effects of processes are not obvious, require restrictions in conventional planning.

**About the landscape and the environment**

it may be noted that, the sustainable development based on knowledge generates continuous review of both definition of landscape, as generic intuitive notion that refer to human perception about a given territory and newest directions of study, pushing forward the frontiers of engineering disciplines. We observe the evolution of landscape typologies by cultural metabolizing and fundamental traditional elements integration (customs, culture and/or tradition) to those of modern and contemporary sciences (Geoecology, imaging and/or informatics). The landscape typologies continue to develop over time and at all spatial scales of geographical environment through a variety of new ways, dictated by new lines of engineering research and interdependence of scientific hybrid branches that occurred [2]. At the same time, we recall the preamble of the European Landscape Convention (EPC 2000) which states that "the landscape contributes to the formation of local cultures and is a basic component of Europe's natural and cultural heritage, contributing to human well-being and strengthening European identity". By default, the EPC accepts that, in the European context, the evolution of the landscape over time remains an expression of the past heritage and a projection of the future perspective; this bivalent relationship is affirmed because the landscape is considered indispensable both for the modern world and for the legacy left to future generations. Landscape is "the outer side, the physiognomy collected by the sensors directly to the earth's surface in the form of a portion of an area defined by the homogeneity of natural and anthropogenic features" [3]. Geographical Landscape must be distinguished from Geographical Environment, that is defined by heterogeneity of its natural and human (cultural) features, also notes Cocean. Due to cultural changes of the development of any society, conceptual level changes continuously, developing new hybrid types of landscapes such as historical and social, rural and urban, industrial and residential, material and immaterial or perpetual and ephemeral and these are just some of the endless possibilities created by knowledge [2]. A particular case is the industrial landscape, arising from the need for technical and technological development of the society, starting with mining and processing mineral resources (gold, silver, copper, iron, etc.) and ending with the consumer goods. These activities have generated unprecedented vertical and horizontal development for cultural landscapes, introducing more and more industrial elements in the geographical systems. Thus, landscape becomes a universal term used in a holistic sense, not only as a simple terminology, but a link between different scientific fields, a major concern and a priority of modern society in terms of landscape ecology [2].

Carl Troll (1971), the leading representative of Landscape Ecology, defines the concept as "a combination of horizontal (geographical) spatial analysis and vertical (ecological) functional analysis" [4]. As a science, it structures the causal relationships between biota (living communities) and the environment, in the form of a landscape mosaic [5]. Turner improves Troll's definition, suggesting that landscape-specific analyzes should focus on "interactions of mutual understanding between spatial heterogeneity and ecological processes." Turner practically reformulated the notion of "environment", considered vague, by introducing a new vision called "spatial heterogeneity" [6]. Turner emphasizes the practical importance of quantifying these unequal distributions of geographic elements found in a complex landscape. Therefore, spatial heterogeneity, also called mosaic, refers to a number of basic elements also called "patches" (spots), discrete or continuous that make up the landscape [7, 8].

In other words, landscape is an intuitive generic notion that refers to the human perception, more or less diversified, on the physical environment represented by the different sensory manifestations and the spatial organization of the geographical environment; the elements and structures of both natural and anthropogenic components, are individually analyzed as distinctive features of different systems, as follows:

— Structure, depending on the organization in space (scale) and the physical shape of the parts,

— Changes in the structure, determined both by dynamics (organization, development) and by the function of different energy flows (photo-solar, wind, hydraulic, chemical, etc.) over time.

Because landscapes can represent physical, ecological and geographical organizations that incorporate specific (distinctive) sets of characteristics of their natural processes (biotic, abiotic) or that are generated by a human (cultural) intervention, they can be influenced by:

— Main factors, including natural topography and climate evolutions,

— Secondary factors or derivatives, including: wildlife development, human intervention and according to some authors natural phenomena as wildfires, flooding's, eruptions etc.

The basic level (framework matrix) is the abiotic component, including changes to the "natural landscape gradient" (relief, lithology, pedology, topography, hydrography and climate), while the biotic component is defined by the complex interactions between flora, fauna and their basic level (matrix). On the other hand, the cultural component is represented by the level at which the human factor manifests itself (positive / negative) in the landscape.

Understanding the evolution of geosystems is achieved through Geoecological monitoring, systematically monitoring both natural changes but especially their transformation, for natural and technical reasons. Monitoring of small systems is very varied and may or may not be useful for a territory or for people, instead, Geoecological, holistic monitoring means detecting the flows and trends of geographic systems in the extension, composition, structure and operation, being different from simple inventory, which is a specific activity for measuring the time needed and quantify the presence, abundance and distribution of ecological factors. Academician and professor I. P. Gherasimov groups the issue of environmental monitoring on three levels [9]:

(1) Bioecological (hygienic-sanitary, toxicological), including abrupt influences

(impacts) on human health generated by the environment,

(2) Geoecological (geosystemic and natural-economic), including changes in natural systems and their transformation due to natural-technical causes, and

(3) Biosphere, including evolution on a global scale.

**Geosystem and ecosystem**

The rapprochement between geographical sciences and ecological sciences, resulting from the development of humanity, has generated wide areas of intersection, reaching the definition of the concepts of "ecosystem" and "geosystem". The difference between the two concepts is fundamental because the Ecosystem has a functional character [10], small number of structural and relational connections, concentrated on individuals and /or populations, while the Geosystem, belonging to physical geography, has a heterogeneous spatial character and a large number of connections [11] (fig. 1).

Whether are mining or oil operations, extractive activities induce various types of inabilities that affect the natural balance of geographic environment (by remodeling the terrains) and ecosystems (by altering natural balance between organisms and their surroundings).

For these reasons, extractive activity has been associated by the public with the most publicized landscape disabilities (described as impacts) and human health hazards, including: landscape transformations, soil erosion, deforestation., land use, watercourses blocking/moving, pollution or living deterioration.

Mass-media has increased the pressure, in the pursuit of sensationalism, leading the authorities to the adoption of policies and measures materialized by processes of restructuring for extractive activities without taking into account all Geoecological aspects (both natural and technical).

**Discussion**

Geoecology enables the analysis of dynamic combinations for natural (biotic, abiotic) and anthropic (technical) factors occurring within a territory where natural resources are extracted.

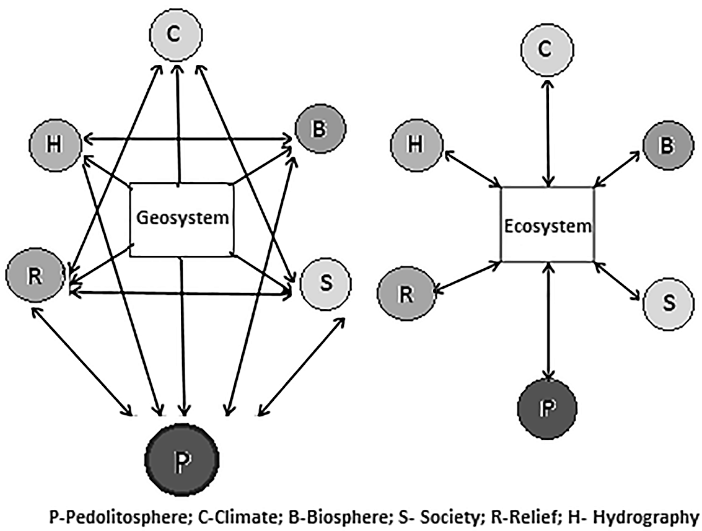


*Fig. 1. Geosystem vs. Ecosystem*

In terms of spatial scale (as it is shown in Figure 2) [12] geographical levels increase from Geotop to Zone. The superior level is consisting by three subdivisions (ranks): Region, Domain and Zone. The inferior level also is consisting by three subdivisions (ranks): Geotop, Geofacies and Geosystem.

For mining activities' extent, the most important level is the inferior one, described by:

(1) Geosystem, which corresponds to a territorial complex, well individualized and dynamic,

(2) Geofacies, which insists on physiognomy of the landscape, and

(3) Geotop, which is the smallest geographical unit and the lowest level of this scale.

In this respect, Geosystem consider the geographical complex and its dynamics occupying areas from tens to hundreds km$^2$, the Geofacies will reflect the features of local ensemble and corresponds to a homogeneous area, characterized by its own physiognomy, whose spatial extent will be lower (one to tens km$^2$) and the Geotop represent the lowest level of analysis (lower than one square kilometer) [13].

Using a measuring scale, we can observe that most of the mines can affect limited areas (from Geofacies to Geotopes), in terms of geographical extent. Therefore, mining perimeters and nearby surroundings can provide most of the valuable information's, required for assessing the Geoecological effects in the Geographical environment [13].

For geographical purposes the environment is an expression, a manifestation of quality of the Geosystem as a dimension of its load with life resources. Life resources are those reserves and sources that we find in our living landscape, which are likely to be used, at a time, to support life. In Anglo-Saxon literature taxonomic units are delimited on the basis of "functionality" and "anthropogenic recovery", making the landscape an operational concept where is a correlation between physiognomy of the landscape and its contents [7].

It is necessary to integrate information's provided, not only by geography and ecology, also by abiotic, biotic and cultural (construction) activities. Reorganizing the structure of "Geosystem" concept, presented in fig. 1, after introducing the specific Abiotic, Biotic and Cultural (ABC) patches, Offenberg (2019) proposed a concept named Geoecological Pentagram (fig. 3) [9, 13].

This concept can be adapted to the specific natural/technical activities developed inside industrial perimeters. In most of the cases, analysis of the geographical area (physiognomy) can provide sufficient information's for assessing the effects of mining activities, while the bioecological analysis provides the details, most of the times to clarify technical and administrative requirements. G. I.S. and remote sensing development extended the landscape research by making visible specific elements of the geographical environment (limitation, heterogeneity) in conjunction with *Patch —*

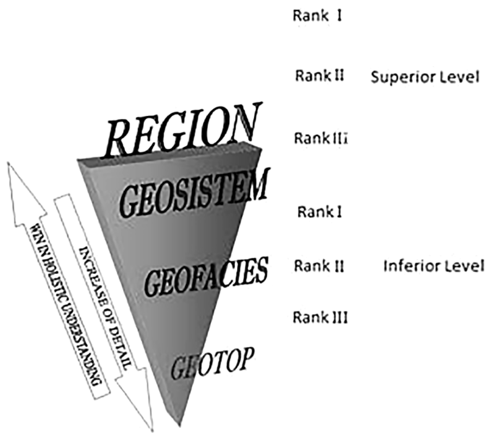


*Fig. 2. Geographical scale model*

*Corridor — Matrix* (P — C — M) concept; this approach conceptualizes mining activities as mosaics, composed of a number of fundamental elements named patches (spots), discrete or continuous, linked together by corridors within the pedolitosphere.

That is why, Iliaș & Offenberg (2019) recommended to identify the patches and the optimal set of Geoecological parameters, selected to be monitored, as the best available technique, not only for specific mining but also for industrial perimeters analyses.

Given complexity, the mining perimeters, for example, are considered heterogeneous due to the special constructions within (mines, quarries, sinkholes, ponds, landfills, deposits etc.) [13].

In the same time, the mining operations are located in the pedolitosphere, corresponding to the inferior level of atmosphere and superior level of lithosphere so can be placed in the second level indicated by Gherasimov — Geoecological level, corresponding to geographical approach at different spatial scales in ecology studies. Usually, the geographical complex occupying areas of tens square kilometers to hundreds square kilometers are the Geosystems, one to dozen square kilometers are the Geofacies, while less than one square kilometer

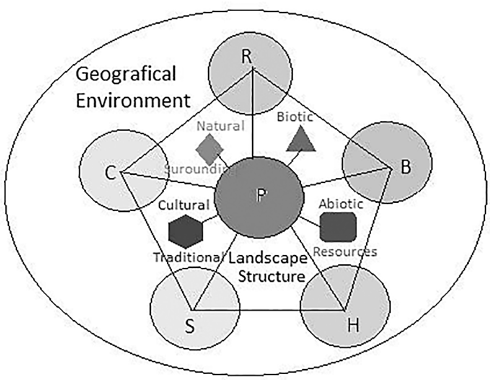


*Fig. 3. Geoecological Pentagram*

is the Geotop. Within the methodology for assessing the Geoecological factors may be used specific landscapes indicators, such as: the number of industrial perimeters, overall stability, naturalness, human pressure, environmental transformation, support capacity of the territory, artificiality of the landscape, and so on. Ecological indicators (environment) can measure different physical-chemical properties and/or biological, showing in a systemic manner the relationship between natural ecosystems and human activity. Environmental indicators are very diverse even if they monitor the same process, being the data frequently used for complex environment assessment.  Therefore, it must take into account the main favorable and unfavorable elements of the important factors such as geo-topography, air, water, biota, soils and anthropogenic component that generate ability/inability of the landscape considered. In addressing environmental problems of minerals extraction Geosystem analysis requires a better understanding of the system structure. Identifying several types of information that should be of interest, such as: contaminant discharges, landforms, groundwater flow, seismic movements, amount of wastewater generated, soil type, energy and consumption of raw materials, accidents / incidents with significant release of contaminants, land use, roads and / or others, we could get the picture of the physiognomy of the landscape. Then, by corroborating the landscape information from areas with specific mining activities, considered potentially dangerous, the general behavior of the bigger system can be highlighted.

Also, the anthropogenic influences resulting from other technical-natural measures must be revealed, such as climatic phenomena, deforestation, grazing, etc. For example, different patches (spots) from mining sites showed that by removing woody vegetation (forest inability) due to secular accumulation of humus (pedological ability) grasslands has a high yield (vegetation ability). In the same time, because edaphic regression (soil inability) and under the influence of climate changings (natural inabilities), lands are degraded and became unproductive with no vegetation (natural resources inabilities) which arose debris or landslides with wild fields of natural rolling stones (touristic abilities) etc. As a result, lands that cannot present any economic interest are abandoned (social and cultural inabilities). Generally, for matter exchanging corridors are considered hydraulic, aerial and geo-mechanic vectors. Gravitational sedimentation of the fine material due to natural topography (terrain inability), water flow (hydraulic inability), the windy climate (aerial inability), the frost-thaw phenomenon (surrounding environment inability), allowed the onset of secondary successions of the vegetation (biocoenosis ability) with the replacement of specific natural vegetation (territorial identity inability) and so on [7, 8].

The structure of geographical landscape is influenced by two factors: (1) main, which includes topography and climate, and (2) secondary (derivatives), which includes soils, vegetation, wildlife, hydrology, human intervention and according to some authors, fires vegetation (natural). Integrating inside the pentagram all the elements for abiotic, biotic and cultural environment, the condition of the landscape can be described more precisely. The abiotic element represents the basic level (within the matrix) that modify "the gradients of natural landscape", on the one hand, such as those related to soil, topography, lithology, climate, hydrography, whether biotic element represents the complex interactions that exist between the flora and fauna, and the base matrix and culture are the elements that sometimes interfere (positive or negative), in the landscape, with the humans, on the other hand. Given the complexity of the mining evaluation, the intersections of action (with a lower or higher decomposition) and any amendments (more or less detailed), following the *source-pathway-receptor* principle, can be done using both a matrix conceptual model and a network (graph).

Thus, Offenberg (2019) recommended a succession of matrixes where information regarding to elementary actions are crossing different changes (successive increasing depth phases). Starting from these findings and analysis options, the Geoecological assessment for mining takes the form of a Complex (Coaxial) Matrix, consisting in a set of simple matrixes of interactions coaxially arranged, as a sequence of decomposition for a number of specific actions regarding to natural-technical mining activities. They must be properly grouped to reflect the development stages of mining projects, starting with natural actions (changes, transformations, trends and others), prospecting, exploration, mine construction, mining and land reclamation. Certainly, mining generates not only disabilities but also generates skills in the geographical environment, depending on the type of system. So, factors can be replaced by the landscape structure and impacts by changes in the structure of landscape [13].

For mining, the geographical environment (matrix) is a succession of sequences (simple matrix):

I. first sequence — relevant natural & technical actions with the abilities or inabilities generated in the affected geographic areas, considering the landscape's structure;

II. second sequence — put in relation the landscape's structure, different types of land use and changes created by changes

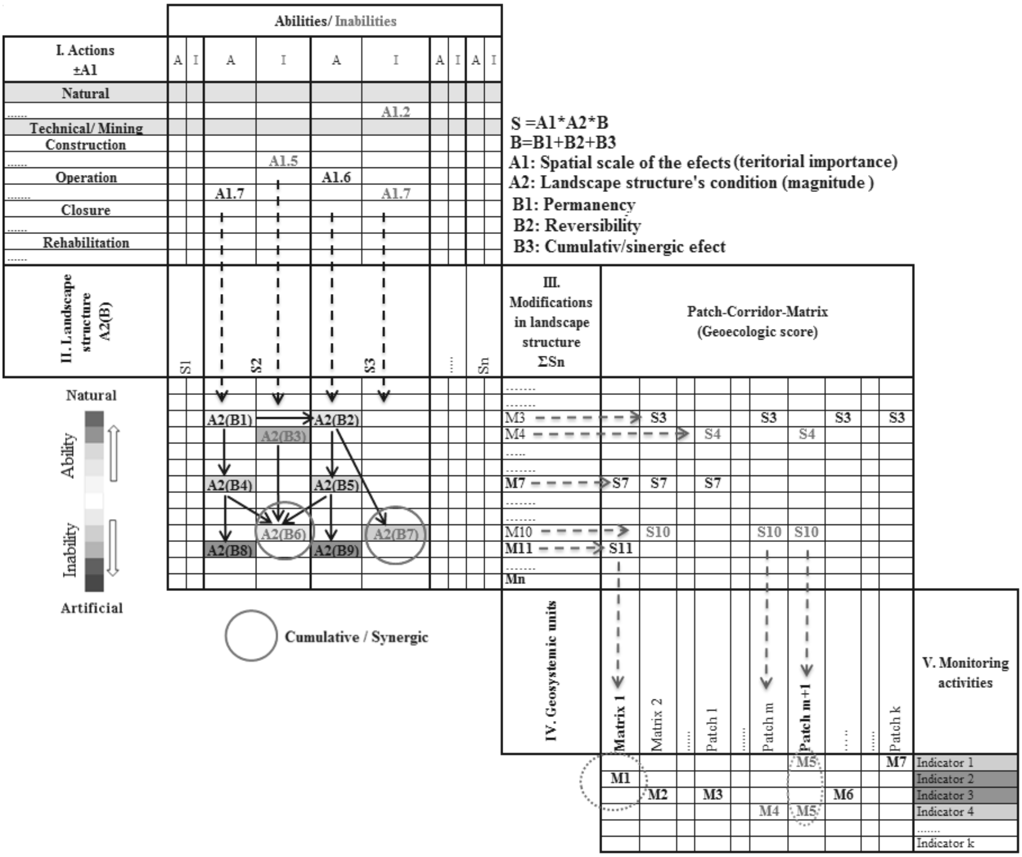


*Fig. 4. Geoecological Coaxial Matrix — Conceptual Model [13]*

*Table 1*
***Specific criteria for the scoring in Geoecological Matrix***

| Matrix/ Criteria | | Score | Description |
|---|---|---|---|
| I | A1. Spatial scale of the potential effects arising from change/ transformation | | |
| | Spatial scale of changes/ transformation | 6 | Zone |
| | | 5 | Domain |
| | | 4 | Region (over 100 km$^2$) |
| | | 3 | Geosystem (10—100 km$^2$) |
| | | 2 | Geofacies (1—10 km$^2$) |
| | | 1 | Geotop (10 m$^2$ — 1 km$^2$) |
| | | 0 | Without systemic importance (under 10 m$^2$) |
| II | A2. The magnitude of landscape's structure change/ transformation | | |
| | Condition of the landscape structure | +3 | Excellent (major positive) |
| | | +2 | Very good (significantly positive) |
| | | +1 | Good (positive) |
| | | 0 | Null (no changes) |
| | | −1 | Medium (negative) |

*Окончание табл. 1*

| Matrix/ Criteria | | Score | Description |
|---|---|---|---|
| | | –2 | Bad (significantly negative) |
| | | –3 | Very bad (major negative) |
| III | B. Status of changing / transformation | | |
| | B.1 Permanency | 1 | no change / not applicable |
| | | 2 | modified (temporarily) |
| | | 3 | transformed (permanent) |
| | B.2 Reversibility | 1 | no change / not applicable |
| | | 2 | reversibly |
| | | 3 | irreversibly |
| | B.3 Cumulative | 1 | no change / not applicable |
| | | 2 | non-cumulative / unique |
| | | 3 | cumulative / synergic |
| IV | C. Geoecological score | | |
| | $S_G$=A1*A2*B | As Table no. 2 | |

*Table 2*
***The landscape seen to the distance***

| Geoecological change/ transformation | Status (patch/ matrix) | Description |
|---|---|---|
| major positive | Natural | No changes (virgin, untouched by man or inaccessible) |
| significantly positive | | Completely historical changes |
| moderate positive | | Discontinuous, irregular or selective changes, without transfer corridors |
| positive | Almost natural | Almost to the potential without restrictions |
| light positive | Semi-natural | Almost to the potential with some restrictions |
| no change/ not applicable | | |
| light negative | Semi-natural | Almost to the potential by restrictions and interventions |
| negative | Relatively natural | Disappearance of natural components by involution and transfer of mater / energy |
| moderate negative | | Replacement of some components keeping natural characteristics (human intervention) |
| significantly negative | Artificial | Replacement of the majority natural components with artificial ones |
| major negative | | Complete transformation of the landscape |

in the structure (abilities/inabilities); by representing the network of interactions, is simulated the events chain, cumulative effects and/or synergies [14];

III. third sequence — represent the spatial differentiation of the landscape; put in relationship all the changes with patch/matrix (as disrupted systems);

IV. fourth sequence — represent the functional differentiation (disrupted systems), generated by various restrictions or favorability's, highlighting the monitoring indicators [13].

The evaluation is similar to Rapid Assessment Matrix but is using Table no.1 and Table no. 2 [7, 15].

## Conclusions

Mining problems and its science are becoming more urgent and vital. Mineral raw materials are needed, and sciences should show the direction and way of developing industrial production, because the society impose new and new restrictions on traditional mining technologies, even if in recent decades has been a significant depletion of rich deposit reserves. In this context, J. Arens (2020) anticipate an apocalyptic scenario of the future needs of mineral raw materials and for the survival of mankind. That is why, the mining problems are global and their solutions are not only economic but also political. But in the same time, the situation requires the development and implementation of new methods and technologies to continue extraction, even from today's poor and non-level deposits, Arens says [16].

For this goal, Geoecological activities includes tracking changes of natural systems and their transformation from natural and technical causes, referring to landscape ecology (natural, human pressure, environmental transformation, hemeroby), geomorphology, geophysical, geochemical, hydrography (hydrological, hydrogeological), geography (environmental, land use, perception, history of place, local economy), geo-mining (topography, geology, stability, underground geometry, seismic movements, landscape physiognomy, energy of the relief), climate and weather, as appropriate [17]. The Complex Geoecological Matrix can be expanded with other specific sequences considered important by the assessor, to put into one logical guide the conceptualization. The authors propose introduction of the exact Geoecological delimitation when analyzing the changes in the landscape (assimilated with impact factors) generated by mining operations (technical but also natural). The actions characteristic of the different types of skills / disabilities generated can also be illustrated with the help of a Sørensen-type sequence.

Using Geoecology, it is easier to visualize primary changes in the structure of the landscape and correlate with secondary changes to highlight the relationships between them. Basically, the Geoecological score will represent the "landscape seen to distance".

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Получена редакцией 23.11.2020; получена после рецензии 04.02.2021; принята к печати 10.02.2021.
Received by the editors 23.11.2020; received after the review 04.02.2021; accepted for printing 10.02.2021.