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Evaluation technique of non-ferrous metal ore deposits

Técnica de evaluación de yacimientos de mineral de metales no ferrosos

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ABSTRACT:

The purpose of this study is to develop and improve basic methodological provisions of the rational use of mineral resources of the country's ferrous metallurgy industry based on the economic evaluation of its integrated development.

Keywords natural resources, multicomponent ore deposits, mineral raw resources, mining and geological resources

RESUMEN:

El propósito de este estudio es desarrollar y mejorar las disposiciones metodológicas básicas del uso racional de los recursos minerales de la industria metalúrgica del país en base a la evaluación económica de su desarrollo integrado.

Palabras clave recursos naturales, yacimientos de mineral multicomponente, recursos minerales crudos, minería y recursos geológicos

The relevance of the problem of the integrated use of mineral raw materials and the need for a scientifically grounded approach to its solution is determined by the limited and irreplaceable reserves of mineral raw materials as well as their rapid depletion in conditions of constant consumption growth. This especially refers to the evaluation of multicomponent ore deposits, both developed and planned for development.

The relevance and insufficient study of some main issues of the economic evaluation of mineral deposits and related problems of the rational and integrated use of raw materials in the context of paid nature management predetermined the choice of the research question.

The purpose of this study is to elaborate and improve the main theoretical and methodological provisions of the rational use of mineral resources of the country's ferrous metallurgical industry based on the economic evaluation of its integrated development.

The study presents new provisions, conclusions and recommendations, the most significant of which are the following:

- a constructive classification of types and methods of the economic evaluation of mineral

resources is given;

- the economic evaluation technique of the reserves of non-ferrous metal ore deposits is improved, and it is proposed to determine the value of annual production according to the established list of effectively extracted components with regard to the effect of prevented environmental damage.

The theoretical and methodological basis of the study is formed by dialectical methods of obtaining knowledge, legislative and normative acts of the Republic of Kazakhstan, as well as reports of relevant ministries and departments. The achievements of economic theory in increasing the efficiency of production, in the field of rational nature management and environmental protection, reflected in the works of domestic and foreign economists, are also used.

The main research components involved the results of studies of the technological and economic indicators of obtaining associated components from various raw material sources, their analysis and generalization in dynamics over a number of years, systematization of the obtained indicators and grouping of associated components with regard to geological, technological and economic parameters, calculation of the cost of production of joint facilities, modeling of the minimum allowable content of associated components and summary indicators to evaluate the achieved and potentially achievable level of the integrated use of mineral raw materials.

Research results were obtained with the help of analytical, abstract-logical, computational-constructive, economic-statistical, comparative, sociological and other methods of economic studies by using the development of schemes of the main directions and plans for the development of the national economy as a whole, as well as by regions and sectors. The materials of theoretical researches and the author's practical developments (Tleubergen, 2004: 169) were also used.

The need for the evaluation of natural resources. In the context of the growing demand for mineral resources and the scarcity of the existing raw material base, significant resources for improving the efficiency of the mining industry are determined by the selection of rational options for the use of deposit reserves, which ensure a minimum of total costs to meet the demand for products, prospectively. This task can be solved by the economic evaluation of mineral resources in the subsoil.

Scholars and practitioners have faced the problem of the evaluation of natural resources for more than a decade. It is quite obvious that since natural resources are involved in the economic circulation, they should be valued, like any other commodity. In general, the need for the evaluation of natural resources is determined by the following circumstances:

1. The need to accurately take into account the real costs and benefits of projects intended for implementation, the importance to take into account all the environmental consequences of each project, which contributes to the realization of activities that promote the sustainable development of society.
2. The need to implement the adequate price regulation of nature management, aimed at stimulating the rational use of natural resources by establishing payments for their use. There are different approaches to the evaluation of natural resources. The most theoretically grounded is the approach oriented to the rent evaluation of natural resources, since it makes it possible to take into account all the benefits and costs of its use (Upushev, 2002: 247).

The economic evaluation of deposits is carried out at different stages of deposit exploration and its involvement in industrial use. The objectives and nature of this evaluation vary depending on whether it is being carried out at the stage of preliminary exploration, when the geological aspect prevails and conditional solutions of technical issues as well as a purely valuation approach to determining economic parameters are allowed, or at the stage of bringing the proven reserves into exploitation, which dictates the need for a detailed study of technical issues related to the use of deposits, and, if possible, more scrupulous justifying calculations for

all economic indicators.

A variety of sub-sectors of non-ferrous metallurgy imposes an imprint on the evaluation of their raw material base. This study describes the issues in relation to the conditions of heavy non-ferrous metal deposits (copper, lead, zinc). The rational use of non-renewable natural resources must be based on the need to achieve two goals: 1) to ensure the maximum economic benefit from the exploitation of these resources, achieving a minimum of costs per unit time; 2) to ensure the more complete and profound use of available resources.

The economic evaluation of any deposit cannot be considered a static section of applied economics with well-established ideas, methods, or calculation techniques. At the same time, it is necessary to outline ways for the further development of the theory of deposit evaluation and the improvement of the methodology and technique of performing technical and economic calculations. The analysis of literature on deposit evaluation makes it possible to conclude that to date, the main provisions of the theory of deposit evaluation have been created, which allowed the solution of certain issues to be connected to a single system (Baymbetov, 2007: 64-65).

The situation is more complicated with the concretization of these principal provisions with reference to the conditions of the raw material base of individual sub-sectors of non-ferrous metallurgy and the elaboration of calculation methods that ensure the obtaining of sufficiently reliable results. More objective is the economic evaluation of natural resources on the basis of differential rent. It allows for a monetary evaluation of natural resources in accordance with their economic effect. The conditions for the emergence of differential rent are directly related to the differences in natural and climatic management conditions in nature-intensive industries (limited land, the level of its fertility, the location of enterprises, the conditions of production in extractive industries), as well as to the availability of commodity-money relations and the operation of the law of value (Lukyanchikov, 2004: 55-56).

In the mining industry, the concept of differential rent is synonymous to differential mining income, which is often called mining rent. The reasons for the emergence of differential mining income are, firstly, the natural features of the deposit (the scale of mineral reserves, the content of useful components, the chemical and mineral composition of the mineral product, its physical properties and textural features, the content of harmful impurities, the depth of mineral deposits, the degree of water content, etc.); secondly, the economic and geographical conditions of the deposit (the climate of the region, the remoteness from the enterprises of consumers and suppliers, the economic and social development of the region, energy and transport conditions, water resources, etc.). The difference in natural and economic-geographic conditions for the development of deposits leads to inevitable differences in the final results of production. When the costs of production resources are equal, the prime cost of producing a unit of output at the best deposits will always be lower, and the volume and quality of the final product from the use of minerals is higher than at the moderate and worst deposits. It follows that when using minerals of the best deposits, an additional income appears, which is the material basis of differential mining income (Hill, 1993).

The results of the economic evaluation of natural resources and foreign experiences of all types of management decisions.

In accordance with the nature of the market economy, an absolute evaluation of deposits has become widespread. It is of interest to get acquainted not only with the actual evaluation formulas, but also with the general methodology of economic calculations used in foreign practice, as well as with the system of prices for non-ferrous metals that have developed in the world market. The basic formulas for the economic evaluation of resources used in developed market countries are presented in Table 1.

The objects of the economic evaluation of resources in conditions of the market system of management include promising land plots for the search of deposits, identified deposits located at various stages of their exploration, fully explored deposits, as well as mining complexes

consisting of actual deposits and extractive enterprises. The economic evaluation of promising land plots is the basis for determining the appropriateness of their purchase or lease.

For identified deposits, the results of this evaluation serve as a criterion determining the need for continuing geologic exploration activities. Finally, when the owner of the explored deposit does not plan to invest in its development, the question of whether it is worth selling or buying is decided based on the results of the evaluation.

Table 1. The main formulas for the economic evaluation of deposits used abroad

Method	Formula	Designation
Hoskold formula	$V_p = \frac{A}{\frac{r}{(1+r)^n} + r'}$	V_p – total present value of the deposit; A – average annual profit; n – time of deposit development; r – normal profit; r' – profit taking into account the degree of risk
Method of direct discounting	$V_p = \sum_{t_i=1}^{t_i=n} \frac{A_{t_i}}{(1+r)^{t_i}}$	A_{t_i} – annual profit; t_{t_i} – deposit development
Morkill formula		Idem
The ratio of present values (profitability index)		I_{t_i} – annual capital charge; t_i – construction time of a mining enterprise from 0 to R years; – deposit development time from 0 to n years
Net present value (at a changing annual profit)		I – capital investments
Net present value (at a constant annual profit)		Idem

It should be noted that although the development of specific measures is carried out centrally, their effectiveness is provided through the legislative system. In Canada, most of the state land is administered by the provinces, controlled and managed by the provincial authorities. The provincial ownership of the natural resources of these lands has developed historically and was legally enshrined in the Constitution of Canada, according to which water, forests, minerals, coal, oil and natural gas remain in provincial ownership. Therefore, the revenues from the transfer of the right to extract mineral resources to private companies enter the treasury of the provinces. A similar situation has developed in the United States, where land resources can be publicly and federally owned. However, here all lease payments go to the federal treasury, and then about 37% are diverted to the states where the deposits are being developed.

The results of the economic evaluation of mineral deposits are primarily used to identify the rational sequence of their development and exploitation, in determining the economic efficiency of extractive industries, associations, enterprises for their use, protection, and justification of mining extraction and processing standards.

Summarized, the results of the economic evaluation of natural resources should be taken into account when justifying all types of management decisions that cause changes in the reserves and quality of minerals, establishing the sales prices for natural resources and payments for their use as well as concluding various types of contracts. It is essential that costs and results in the exploitation of natural resources should be correctly measured, otherwise it is impossible to find the best way for their industrial use, and, consequently, to organize a system of measures to ensure and stimulate the optimization of nature management (. Lukyanchikov and Potravnyy, 2002).

All of this explains the complexity of the scope of the studied problem, taken as a whole, the

argumentativeness of the methodology of deposit evaluation as an economic aspect, as well as the inefficiency of certain issues in the evaluation technique. The point is that the purpose of the evaluation determines the technique for its implementation. If the evaluation was carried out timely with the aim of selecting primary deposits for development, the evaluation itself consisted in comparing them between themselves; accordingly, the system of indicators by which deposits were compared was determined, and the methodology for such a comparison was developed (Golub, 2001: 245).

In terms of the prevalence of environmental criteria over economic criteria, all approaches can be divided into three main ones:

1. man of sense should not rely solely on economic rationality, but, rather, should pay closer attention to the benefits of common use;
2. a new approach to economic development requires the reproduction of the economic system itself and all its components on a sustainable basis (sustainable development);
3. in the course of time, economic development must become increasingly neutral with respect to the environment, and the impact on it must be minimized.

From this position, D. Pearce and K. Turner divide scientists into two large groups: technocentric and ecocentric (Pearce et al., 1993: 31). If the former insist on the need to restrict the free development of the market as little as possible, the latter emphasize the need to preserve nature at the expense of production development.

Currently, there are different types of economic evaluation and methods for determining the efficiency of using the reserves of individual deposits. In accordance with the formulated goal and purpose, various criteria are adopted when evaluating the reserves of individual deposits. The need for a differentiated approach to the economic evaluation of individual deposits depending on the stage of study and development has been repeatedly noted by scientists in our previous works. The validity of this provision has been confirmed by practice.

Table 2. Classification of the main types and methods of the economic evaluation of mineral resources

No.	Main types of evaluation	Evaluation purpose	Proposed criteria	Acceptable methods
1	2	3	4	5
a) Isolated evaluation				
1	Geological-economic	Determination of expediency to transit to the next stage of exploration	Defective design parameters, natural indicators	Analogy methods
2	Pre-project	Determination of expediency to develop deposits	The cost price of extraction and enrichment, temporary design parameters	Methods of integrated technical and economic calculations
3	Project	Determination of the effect of industrial use of the deposit	Max effect Project design parameters	Design methods
4	Exploitation	Determination of the effect of	The system of	Design methods,

		further industrial use Determination of the effect of mining of individual sections and blocks	technical and economic indicators, design parameters	methods of block evaluation
5	Cadastral	Creation of the scientific information base for the establishment of a possible range of deposits that meet the needs of the national economy	All design parameters	Generalization methods, methods of technical and economic calculations, design methods
b) Group evaluation				
6	Evaluation of mineral resources	Determination of general enlarged expediency to use mineral resources of the region	Max effect	Regional economic-geographical methods, methods of economic-mathematical modeling, design methods
7	Evaluation of mineral resources as part of territorial combinations of natural resources	Determination of general enlarged expediency to use mineral resources of the region	Max effect	Regional economic-geographical methods, methods of economic-mathematical modeling, design methods

The features of the industrial use of certain types of natural resources are taken into account when determining the economic efficiency of their development. The methods of determination of economic efficiency vary in accordance with the specific purpose of development and the degree of study of certain types of natural resources. In view of the large number of economic evaluations of natural, in particular mineral, resources, generating various methodological techniques, we attempted to classify [8, 256] the economic evaluations of mineral resources (Table 2).

The need for the economic evaluation of certain deposits occurs at all stages of their development, beginning with preliminary exploration and ending with the completion of their development. This need is due to the decision on the expediency to carry out the next stage of geological exploration and development activities.

Before analyzing the characteristics of the economic evaluation of complex raw materials, one should dwell on the main provisions of the economic evaluation of raw materials.

The improvement and development of theoretical and methodological provisions of the economic evaluation of the use of multicomponent deposits. The economic evaluation of raw materials is carried out at all stages of geological study, design and operation of deposits. The purpose of evaluation at all these stages is to determine whether the raw material of a given deposit or simply a deposit is industrial or not, i.e. whether to invest in subsequent stages of its preparation for industrial development. Since the purpose is exclusive, the ways of achieving it should be uniform, i.e. at all stages of deposit development a unified methodology for its economic evaluation should be used. This method is based on the selection of the main

indicator – the criterion of economic efficiency and the identity of the method of its determination. This is necessary for the results of economic evaluation to have a certain continuity, consistency and unambiguity, when observing all other equal conditions. This does not mean that there should not be other, auxiliary, evaluation indicators, but there should be one single indicator characterizing the economic significance of the deposit and the decisive question of its industrial use at a given time (Hotelling, 1931: 152).

Currently, the following indicators of the value of the ore are generally recognized: potential, recoverable and industrial value. The potential value of the ore is determined by the sum of the products of the quantities of components contained in it for their price in the finished product, i.e. the potential value of the ore is the maximum possible volume of commodity products that could be obtained under perfect conditions when the extraction of components obtained at all stages of ore extraction and processing would be 100%. The recoverable value of the ore is defined as the sum of the products of the quantities of useful components contained in it for the end-to-end coefficients of their extraction into the finished product and their prices in the finished product. The recoverable value in economic terminology is understood as a commodity product derived from the ore (Humpreus, 1983: 169-176).

As it was emphasized above, mining rent is taken as the most justified criterion for the evaluation of deposit reserves. A number of studies, including our previous works, have been devoted to the method of determination of the latter.

$$R_i = \sum_{t=1}^{T} \frac{Zt - St}{(1+E_{sb})^t}, \qquad (1)$$

where T is the estimated period of deposit evaluation, calculated from the year with respect to which evaluation is performed up to the year of the mining of reserves;

Zt is the value of annual output (including all the components that can be extracted at the same time), calculated at wholesale prices or marginal costs of the t-th year;

St is the sum of upcoming capital and operational (without deductions for depreciation in renovation) costs in the t-th year of operation (development);

Esb is the standard for bringing various costs and results.

After determining the value of monetary evaluation for each option, the optimal option with a maximum value Ri is chosen, which is taken as an indicator of deposit evaluation. Thus, the methodological basis of economic evaluation based on the "rental" concept is designed to determine in monetary terms the value of natural resources in order to fully characterize (together with other indicators) their national economic importance. Along with the positive values of the theoretical-methodological and methodical foundations for the economic evaluation of individual deposits, it is necessary to point out some of its shortcomings.

When identifying the effect, the value of annual output (Zt) is recommended to be determined with regard to all the components that are taken in the process. It should be noted that not all such components can be effective, since the content of many associated components of non-ferrous metal ores is low, measured in grams per ton of ore, and they are technologically difficult to extract. Therefore, we propose extracting a technologically possible and economically justified list of components from associated components, i.e. only the established list of effectively extracted components.

Finally, there can be no rational use of natural, in particular mineral, resources, if, at their optimal integrated use, the natural environment protection is not ensured at the proper level on a regional and global scale, and an ecological balance is not guaranteed in the same scale. Therefore, taking into account the associated use of useful and “harmful” (sulfur, phosphorus, arsenic, etc.) components, refinement tailings and overburden rocks, slags and sludges as

factors contributing to the improvement of the environment, it is necessary to bring them in the procedure, as an arising concomitant effect of environmental protection. The foregoing allows us to recommend carrying out an economic evaluation of non-ferrous metal deposits by the following formula:

$$R_i = \sum_{t=1}^{T} \frac{(Z_{t\ est.} - S_t) + E_t}{(1+E_{sb})t} \qquad (2)$$

where Zt est. is the value of annual output (according to the established list of effectively extracted components), calculated in the realization prices of the t-th year;

Et is the effect of prevented environmental damage, received in the t-th year.

In conditions of multicomponent complex deposits, the effect (mining rent) of their industrial use directly depends on the level of the integrated use of raw materials and reserves. Therefore, it becomes necessary to establish a list of effectively extracted components (with regard to minerals that are mined at the same time), which ensure the maximum utilization of the reserves of such deposits.

Currently, the list of components to be extracted and proposed for future extraction is established when drafting design parameters and is specified when developing projects for the mining of the reserves of such multicomponent deposits.

The present article is devoted to the improvement and development of the theoretical and methodological provisions of economic evaluation, based on the specifics of the use of multicomponent deposit reserves and their comprehensive economic evaluation.

The results of the study make it possible to draw the following conclusions:

- the most important issue of the transition to a sustainable type of economic development is the issue of mechanisms to realize the environmentally-oriented development of nature management. In modern conditions, the main directions for implementing an effective concept of the economic mechanism of nature management were identified and developed;

- the economic mechanism of nature management should be an organic part of the "global" economic mechanism, it cannot be local and cover only nature-exploiting complexes and industries;

- the economic evaluation of natural, in particular mineral, resources is one of the main tools – elements of their rational use and, consequently, one of the main elements of the market economic mechanism of subsoil use.

Particular attention was paid to the choice of the criterion of economic evaluation. The most common and acceptable indicator as a criterion for evaluation, as recognized in this paper, is the differential mining rent, defined as the difference between the total recoverable value of the mineral product, calculated by the marginal and individual costs of obtaining the final product with regard to the time factor.

Practical significance of the research results. The developed basic principles and methods of the economic evaluation of non-ferrous metal ore deposits with regard to the time factor make it possible to use multicomponent mineral raw materials in the Republic of Kazakhstan with the greatest economic efficiency, not only at the present stage, but also in the long term.

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