State Management of Mineral Resource Potential Based on Geological and Economic Monitoring

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Abstract. The relevance of the study is to develop a geological and economic model for calculating the exploration work volume for reproducing mineral resource base of non-ferrous metals, covering the base levels and management functions of the subsoil Fund, all stages of the exploration process. The subjects of the study are methodological approaches to calculating reserve shortage by types of metal minerals, substantiating optimal production and reproduction volume of the mineral resource base. The geological and economic model for calculating the exploration volume for reproducing mineral resource base, developed in the framework of the study, has been tested and used in the Central Federal district (in the Federal budget institution “Territorial Fund of geological information for the Central Federal district” (Moscow); in the Department of subsoil use in the Central Federal district (Moscow) and the far Eastern Federal district in the Republic of Sakha (Yakutia) in the geological information funds, at the enterprise JSC "Polyus Aldan" and others. As the result of the research, a four-stage geological and economic model of the mineral resource base reproduction process was developed, on the basis of which methodological justification of geological and economic zoning of the Republic of Sakha (Yakutia) was prepared on the level of mineral resource potential of reserves of non-ferrous metals and forecast resources, the geological exploration volume for reproducing the mineral resource base of non-ferrous metals.

1. Introduction

In the context of the planned economy, working out geological and economic models for developing the mineral resource base (MRB) was carried out on the basis of their current state, taking into account the present and future demand for mineral raw materials and products of its processing, the potential of mineral resources, advanced tools and work operations. The results of geological and economic modelling were reflected in the exploration programs and the main results are expected after their im-
plementation. The total cost of national programmes was determined by minimizing the amount of private expenditures for individual territories, which were estimated at the regional level.

In modern economic conditions, the proportions between reserves and production, as well as between the reserves and forecast resources are formed largely spontaneously with a significant role of self-development (Tretyak, 2009). The consequences of small and medium-sized enterprise (SMEs) unregulated development are expressed in the emergence of excess reserves and resources, i.e. in the long-term freezing of funds spent on their detection. The elements of the latter, at the same time, were also evident in the size and in the context of the centralized planning.

2. Problem statement
The procedure of forming geological-economic model for calculating volumes of geological exploration work for reproducing mineral resource base of non-ferrous metals was dwelt upon in the works [2,5,7,8,10,12,15,19].

However, applying multivariate mathematical models for solving the problem is currently insufficiently investigated and requires its scientific justification [11,13,14,16].

To describe the system of using and reproducing SMEs a set of interrelated indicators was proposed, among which the leading role is played by these characteristics:

- consumption levels per capita [17,18];
- average annual consumption growth rate;
- average annual production growth rates [1];
- average annual population growth rate [6,9,20].

However, these indicators are applicable only for sufficiently long periods of developing SMEs in most countries of the world [3,4,11].

In a number of the developed countries having market economies, the bulk of work on reproducing SMEs is carried out at the expense of mining enterprises. Since the cost of geological exploration work (GEW) constitutes a portion of the enterprise profit, this model is limited to the capacity of SMEs reproduction, even by high-yield companies. Therefore, in many cases, especially in the early stages funds are attracted for GEW not only from the mining sector, but also from other sectors of the economy and finance.

3. Research questions
In modern Russia in the period of forming large mining business the basis of pre-reform geological and economic models of developing the country's mineral resource base, namely, cause and effect chain "need for mineral raw materials\rightarrow extraction (repayment) \rightarrow increase in reserves \rightarrow increase in forecast resources \rightarrow volumes of exploration \rightarrow centralized costs of geological exploration" does not meet modern conditions. After eliminating the centralized management of the industries which are mineral raw material consumers, the state cannot directly manage the processes determining the levels of mineral raw material consumption, capital investment in mining, increase in reserves on deposits, etc. Economic methods influencing the development of specific mineral types, meeting the country's interests are put to the forefront.

4. Research methods
Security of mining enterprises, subjects of the Russian Federation and regions (Federal districts) is defined as the private quotient of dividing the volume of the explored ("licensed", active, profitable, etc.) reserves by the level of repayment accepted for calculation (including extraction and losses at extraction).

Depending on this, three estimates of security can be obtained:

- by project level of repayment;
- by the highest achieved level of repayment;
- by the actual level of repayment in the year of settlement.
The difference between these estimates and the security standard obtained with a minus sign is the so-called security deficit (1-3).

\[ S_{d1} = S_{\text{max}} - S \]  
\[ S_{d2} = S_p - S_n \]  
\[ S_{d3} = S_f - S_n \]  

where \( S_{d1} \) has a physical meaning subject to \( S_n > S_{\text{max}} > S_p > S_f \).

In applying to the types of mineral raw materials being in very short supply, it should be taken into account that even achieving regulatory or excess security (at the enterprises, in the regions or even in the whole country) does not indicate a favorable situation in SMEs, since the levels of repayment in the remaining deposits of these minerals in the country are disproportionately lower than the levels of demand.

When calculating the reserve deficit, there are three options:
- at the maximum repayment level achieved (4).
- at the project repayment level (5)
- at the actual repayment level (6)

\[ D_1 = S_{d1} R_{\text{max}} \]  
\[ D_2 = S_{d2} R_p \]  
\[ D_3 = S_{d3} R_f \]  

where \( R_{\text{max}} \), \( R_p \) and \( R_f \) are, respectively, the maximum achieved, project and actual repayment level of the reserves. As the practice shows, at least the project indicators must be met.

It follows from the above that, in the end, the necessary need for mining is currently determined by the project capacity of existing enterprises, and the actual security consists of the developed reserves and active reserves of the spare deposits.

At the first stage of forming the specified model there is carried out the calculation of:
- the security of mining enterprises, industrial and raw material nodes, mining zones, subjects of the Russian Federation, Federal districts, etc.;
- the deficit of active reserves of the industrial categories, formed as the result of providing with the explored reserves below the accepted standard.

Control actions here are the values of security standards of:
- a particular enterprise – PSD (production structural division) (in terms of paying back the funds invested in it is of interest to the subsoil user);
- mining zone, based on the developed and reserve deposits (in the aspect of preventing social and demographic cataclysms that may be caused by the closure of mining enterprises);
  - Russian Federation subject;
  - Federal district of the Russian Federation (in terms of economic and defense security).

The regulatory period of security for regions with a developed mining industry can be considered 30 years, and for individual mining enterprises - terms of 10, 15, 20, 30 or more years, depending on the scale of deposits and industrial and raw material nodes.

The block under consideration can make the model universal, as an indicator of "the deficit of explored (active) reserves", calculated for the region or the country as a whole. The considered block can serve as a basis for the expanded reproduction of mineral resource base.

In the second stage - "Analysis of options for filling the deficit of active reserves" the choice of source (sources) of filling the deficit and the economic justification of the selected option is carried out. As sources of filling the deficit can be considered the following:
- inactive reserves of the distributed subsoil Fund,
- explored reserves of the undistributed subsoil Fund, represented in the majority by inactive reserves,
- off-balance sheet stocks,
- pre-estimated reserves and forecast resources of the identified and prospective fields,
- mining waste and man-made resources.
At each of the stages (blocks) of geological and economic monitoring it is necessary to control the indicators used in forming geological and economic model of SMEs reproduction.

In general, reserves and resources of deposits and projected mineral resources of the undistributed subsoil Fund will long be the most realistic alternative to the developed reserves for industrial and raw material nodes, mining zones, subjects of Russia.

The amount of reserves to compensate for the reserve shortage of the existing enterprise, which can be obtained from the above-mentioned reserve fields, is calculated by the formula (7):

\[ A \rightarrow Q_{A+B+D} = D + P_{pr}, (T_{pr} + T_{cons}) \]  

(7)

where \( Q_{A+B+D} \) is the number of reserves required to fill the deficit; \( D \) is the "regional" deficit of active reserves; \( P_{pr} \) is the project (or highest achieved) performance; \( T_{pr} \) is the project time of the mining enterprise(s) at the reserve field(s); \( T_{cons} \) is the construction time.

The amount of reserves to compensate for the deficit of the existing enterprise, which can be obtained from the explored fields, is calculated by the formula (8):

\[ B \rightarrow Q_{cl+B+D} = D + P_{pr}, (T_{pr} + T_{cons} + T_{exp}) \]  

(8)

where \( Q_{cl+B+D} \) is the amount of explored deposit reserves required to fill the deficit; \( T_{exp} \) is the exploration time (before designing and constructing a mining enterprise).

The amount of reserves to compensate for the deficit of the existing enterprise, which can be obtained from off-balance sheet deposits, is calculated by the formula (9):

\[ C \rightarrow Q_{c2} = D + P_{pr}, (T_{pr} + T_{cons}) \]  

(9)

where \( Q_{c2} \) is the number of off-balance deposit reserves required to fill the shortage.

The quantity of reserves to compensate for deficiency of the operating enterprise which can be received at the expense of positively estimated objects, is calculated by the formula (10):

\[ D \rightarrow Q_{c2+D} = D + P_{pr}, (T_{pr} + T_{cons} + T_{ass} + T_{ass}) \]  

(10)

where \( T_{ass} \) is the time from assessment completion to prospection.

The quantity of reserves to compensate for the deficiency of the operating enterprise which can be received at the expense of the perspective forecast sites offered for the subsequent stage work is calculated by the formula (11):

\[ E \rightarrow Q_{c2+D} = D + P_{pr}, (T_{pr} + T_{ass} + T_{ass} + T_{s} + T_{exp}) \]  

(11)

where \( T_{s} \) and \( T_{exp} \), respectively, is the time for carrying out search and evaluation work; the measurement units of \( Q \) and \( D \) are in thousand tons of minerals (metal, oxide, etc.); \( T \) - years.

5. Findings

The analysis of the reserve shortage must be carried out in the following sequence: the supply of existing enterprise (PSD) \( \rightarrow \) filling the deficit at the expense of reserve deposits with active reserves and positively evaluated objects according to the estimated data (Geopathic Zone). If the above-mentioned sources of replenishment do not meet the regulatory period of security, based on the existing productivity, the possibility of attracting reserves of off-balance deposits and determining the conditions under which their development will meet an acceptable level of profitability, etc. is analyzed.

If the economic calculations show the preference for prospecting, the next step (IV) is to calculate the amount needed to fill the deficit of active reserves. The expediency of carrying out prospecting operations can also be determined in the absence of active reserve shortage, but with such depletion of the "prospecting reserve", when geological exploration work (GEW) at the facilities of this "prospecting reserve" will not lead to forming the fields that can become equivalent (in the quantity and quality of reserves) to be replaced by workable reserves.

6. Conclusion

As the result of the research the authors have prepared the methodological substantiation of geological and economic zoning of the Republic of Sakha (Yakutia) on the level of the mineral and raw material potential of non-ferrous metals and forecast resources, the volume of geological exploration work for reproducing mineral resource base of non-ferrous metals. The calculation of the mineral resource po-
tential and forecast resources of the main mineral types of the Republic of Sakha (Yakutia) has been carried out, foregrounding tabular and graphical data for preparing an updated geological and economic map of the Republic of Sakha (Yakutia) has been fulfilled. The gross value of the balance reserves of non-ferrous metals in the subsoil as of 2017 is estimated at 1560.1 billion US dollars, of which the potential recoverable value is 1111.6 billion $ USA. On the territory of the Republic of Sakha (Yakutia) 9 geological and economic areas are allocated that are the part of the ore-bearing territory, which has certain features of the geological structure, the mineral potential of which is of industrial importance.

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