Methods of Calculating the Necessary Reserves Increment in Managing the Reproduction of Raw Material Base

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Abstract. In modern economic conditions, when state financing of geological exploration is limited, it is very important to make optimal management decisions on the choice of priority development targets, which give the maximum social and economic effect. The primary task in this context is to determine the level of providing enterprises with mineral reserves and inferred resources. Provision of enterprises with geological exploration products, reserves and inferred resources largely determines their investment attractiveness, directly affects their market value at the stock market. The quality and structural composition of mineral and raw materials potential define the amount of investments into geological exploration and reproduction of raw materials potential, as well as the possibility of its expansion through additional exploration of deposit flanks (up to 5 km from the boundaries of the subsoil license area). Some problems are still relevant, namely, competitiveness of deposits at the regional, Russian and international levels, taking into account the assessment of the demand for raw materials in accordance with market conditions, the geography of production facilities, the dynamics of production and product consumption, trends in international and domestic trade, the current level of prices for mineral raw materials and the forecast of their changes in the conditions of international division of labor, cooperation and collaboration. The aim of this paper is to form the methods of calculating the necessary reserves increment in managing the reproduction of raw material base. The authors developed the method of calculating the availability of reserves and inferred resources in managing the reproduction of raw material base that has 3 possible scenarios: extended reproduction, in which the increment of discovered reserves exceeds the depletion volume; simple reproduction, in which the volumes of increment and depletion are equal; maintenance of mining enterprises in the design mode.
1. Introduction
The model of reproduction of raw material base is determined by the interaction of mining operations, reducing reserves of deposits, and geological exploration, which discovers new deposits (reserves). Consumption of mineral products generates demand for appropriate mining operations [1,2].

The main current objective is to form investment-attractive mineral resources that will allow enterprises to solve the problem of reproduction of raw material base and increase their capitalization at stock markets.

2. Problem statement
Nowadays, in the field of reproduction of mineral resources, the main part of work is carried out by subsoil user companies. At the same time, funding from subsoil users is more than 90% of the total financing of exploration in both federal and regional aspects [5]. However, most of exploration on the reproduction of the mineral resource base is carried out for hydrocarbon raw materials, including offshore, rare earth and precious metals, while for a number of solid minerals, where there is already a shortage of reserves, work on their reproduction is practically not performed. The reason for this situation is due to the limited investment opportunities of enterprises in the development of their own raw material base, in improvement of its qualitative composition, since the most profitable areas of deposits have already been mined. Involving third-party investors in the development of its own raw material base will allow the company to solve this problem, but investors should see a clear interconnection between investing in the development of raw material base of the enterprise and increasing its mineral potential and, as a result, capitalization at stock markets. This determined research task, namely the formation of methods for calculating the necessary reserves increment in managing the reproduction of raw material base.

3. Research questions
Determination of exploration scope for the reproduction of raw material base (RMB) can also be carried out in several stages. In general, the scope of advanced exploration, ensuring the replacement of discovered (actual) reserves in the required amount and by the required date, is determined on the basis of the state of inferred reserves and resources of C2 + P1, P2, P3 categories at the time of forecasting [4].

At the first stage, it is necessary to calculate the amount of inferred reserves and resources that must be realized in the reproduction of RMB to supply the shortage of actual reserves. This procedure starts with the analysis of inferred resources to evaluate the possibility of creating adequate discovered reserves on its basis. For further calculations, it is necessary to have the ratio of objects for evaluation and search close to the optimum ratios theoretically obtained in [5, 6]. They should be adjusted taking into account the ratios that have been obtained in the regions with the most successful exploration results for similar types of minerals in the previous period.

Depending on the sources of supplying the shortage of discovered (active) reserves, the amount of shortage can be adjusted for actual or expected supplying at certain fields (mining companies, mineral and raw complexes), geological and economic regions, subjects of the Russian Federation and Federal districts for the period during which the preparation of discovered reserves will be made to supply the shortage [17,18,19].

According to calculations [5] this period can last from 1 year to 10 years:
- exploration, during which C3 reserves will be transferred to higher categories, will be carried out within 1-2 years [7,10,12];
- realization of industrial reserves at establishments with resources of P1 category will require about 2-5 years,
- the same at establishments with resources of P2 category will require not less than 5 years [12,16,20];
- the same applied to inferred fields with resources P3 category - minimum 10 years.

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Taking into account the design and construction of new enterprises in the discovered and explored fields, the terms from the beginning of exploration to the beginning of development can be about 5 years for inferred resources of P$_1$ category, 7 years - for P$_2$ and 10 years - for P$_3$ [13,21].

In new, and even more undeveloped areas, deposits of raw materials in very short supply can be of interest, or deposits of premium or strategic minerals unique in reserves and quality [3,8,9].

The need for exploration for RMB reproduction may arise in the absence of “absolute” shortage, but with a significant depletion of exploration reserves that is formations with inferred resources of C$_2$ + P$_1$, P$_1$ and P$_2$ categories. Apparently, we should consider depletion significant, when exploration and evaluation works on formations of depleted exploration reserves cannot a priori lead to localization (formation as a result of exploration) of deposits, which discovered reserves are able to supply fully or substantially recovered reserves [11,14,15].

4. Research methods
The calculation of the balance $B^0$ is carried out in our equation (1):

$$B^0 = \frac{C^0_{\text{r}} + K^0_{\text{d}} \cdot K^0_{\text{c}} + C^0_{\text{i}} \cdot \alpha^0 + C^0_{\text{u}}}{N^0}$$

where: the initial state of the raw material base $C^0_{\text{r}}$; the need of the country, region, geological and economic region, mining complex, enterprises in this type of mineral ($N^0$); extraction of minerals in mining $K^0_{\text{d}}$, processing $K^0_{\text{c}}$, reserves of recoverable materials $C^0_{\text{i}}$; and its resettling ratio into the national economy $\alpha^0$; the amount of this type of mineral in other sources of raw materials, profitable for processing (dumps, slugs, processing tailings, etc.).

The dynamics of state changes of the discovered reserves can be traced for each of the known deposits, as well as for areas, regions and the country. The change in the raw material base due to mining operations is revealed by the direct calculation of discovered reserves depletion and depending on the planned levels of mining and depreciation. The state of reserves for each field is calculated by the equation (2).

$$Q_i = Q_0 - \sum_{i=1}^{t} Y_i A_i = Q_0 - \sum_{i=1}^{t} \frac{1 - P_i}{1 - r_i} \cdot A_i$$

where: $Q_0$ is the state of ore reserves at the beginning of the first year of the forecast period; $Q_i$ is the state of ore reserves at the end of $t$-year of the forecast period; $A_i$ is the annual enterprise productivity for ore operating the deposit during $i$ - year; $Y_i$ is the depletion factor in $i$ - year, $r_i$ is the dilution factor in $i$ - year, $P_i$ is the loss factor in $i$ - year.

The loss of reserves in geological and economic areas, regions and the country consists of the amount of reserves, individual deposits located within these territories.

The minimum operation term of underground mines is recommended to be the following: 10 years - with ore production capacity per year up to 300 thousand tons, 15 years - 300-1000 thousand tons, 20 years - 1000-2000 thousand tons, 30 years - more than 2000 thousand tons; in the case of strip mining: 15-20 years - up to 2000 thousand, 20-25 years - 2000-5000 thousand tons, 30 years - more than 5000 thousand tons[3,5].

5. Conclusion
According to the calculations of the developed methods, reserves exploration of C2 and higher categories will take up to 1-2 years. The implementation of forecast resources of P$_1$ category will require about 2-5 years. P$_2$ resources can be implemented in the discovered reserves during 5-7 years, and P$_3$ category during about 7-10 years, because it takes time to discover, evaluate and explore. If we take into account that the design and construction of new enterprises for mining minerals will require another 5-10 years, then the time from the beginning of exploration to the beginning of operation for
P1 resources will be 3-7 years more, for P2 category – 5-10 years and for P3 category – more than 10 years. The given methods of calculating the development of reserves and forecast resources in managing the reproduction of raw material base may include:

- expanded reproduction, in which the increase in discovered reserves (especially resources) exceeds the volume of supplying;
- simple reproduction, in which the volumes of growth and supplying are equal;
- maintenance of mining enterprises in the design conditions.

The following conditions were taken into account while developing the methodology:

- in the market conditions a significant part of the discovered reserves was transferred into an inactive category, including: copper – 31%, lead – 27%, zinc – 39%, aluminum – 40%, molybdenum – 50%, tungsten – 55%, tin – 67% [2];
- the most part (65-100%) of active reserves of these minerals is concentrated near the existing mining enterprises and actually makes up their raw material base, while recovered reserves are only partially supplied;
- in other developed areas, a scanty share of active reserves is localized (at the beginning of the century, there were practically no active reserves of lead, tin, molybdenum, bauxite, 1% copper, 6% manganese, 8% tungsten), which does not give reason to expect the creation of any powerful production there.

6. References

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