

Assessment of the Mineral and Raw Material Potential of the Region Through the Geological and Economic Zoning Methodology on the Example of the Republic of Sakha (Yakutia)

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Abstract— In the mineral and raw material balance of the country and the Far Eastern Federal District, the Republic of Sakha (Yakutia) occupies a leading position in the reserves and extraction of a number of strategic types of minerals. To develop an effective policy of rational use and development of the mineral resource base of the Republic, to solve strategic and operational tasks in the sphere of subsoil use, it is necessary to provide the state bodies of the subsoil fund with economic and analytical materials in the current time and forecast mode. The basic element of these materials is the economic evaluation of mineral and raw materials potential on the basis of the analysis of the situation in the markets for mineral raw materials, taking into account the geological and economic zoning of the territory and the derivation of general information on an electronic cartographic basis. The creation of a system of geological and economic monitoring is possible as a result of stage-by-stage studies of its individual blocks and components, the basis of which is the assessment of mineral resources and geological and economic mapping. The main purpose of this study is to formulate a methodology for geological and economic regionalization to assess the mineral and raw material potential of the region on the example of the Republic of Sakha (Yakutia). The research method involves the development of a system of indicators characterizing the state of the mineral and raw materials base by types of raw materials and specific subsoil use facilities. The main results of the research are: the improvement of the geological and economic geological information methodology and estimation of the cost of geological exploration work to translate the forecast potential of minerals into explored reserves; calculation of the mineral and raw materials potential of reserves and forecasted resources of the main types of minerals on the territory of the Republic of Sakha (Yakutia).

Keywords— *geological and economic monitoring, mineral resources, regional economy, reserve classification, investment potential*

I. INTRODUCTION

Natural resources and phenomena in their various forms, being a prerequisite for the development of society, have a

direct impact on the development of productive forces and production relations, they are the source of the labor objects and production instruments. Society and the environment are inseparable from the territory - a space that includes all elements of nature and human life. The allocation of regions as economic categories formed in the process of territorial division of labor must take into account the continuity of development and the dynamics of the distribution of productive forces. This is especially important for regions with a predominant development of mineral and raw materials economy sector, which is undoubtedly the Republic of Sakha (Yakutia), since the location of mining and mineral resource centers is more related to natural and geographical factors than processing.

In the current situation, the problem of increasing the economic efficiency of exploration works (geological exploration) aimed at identifying and exploring mineral deposits, as well as developing the discovered deposits, remains acute. One of the ways to solve this complex problem was regional geological and economic mapping.

The cartographic method allows to determine the actual and potential value of the aggregate of mineral resources in specific natural and geographical conditions as a possible sphere for the application of capital assets.

II. LITERATURE REVIEW

L.V. Gromov and K.P. Kavun suggested that in calculating the mineral resource potential (MRP), resources according to the existing system of categorization of mineral resources (A + B + C1 + C2) [1,2,3,4, 5] should be taken into account. At the same time, forecasted reserves of minerals should be considered separately as a reserve for the mineral and raw material potential of the region, which is realized with further exploration work [6,7,8,9,10,11].

V. P. Vasilenko, V.A. Aliskerov, M.N. Denisov, and others considered the following options for calculating the value of the mineral-raw potential:

MRP as the gross potential value of all minerals in the subsoil, taking into account the value of all the explored and assessed subsoil use objects (deposits) of A + B + C1 + C2 category, as well as the value of the forecast resources in the subsoil of category P1 + P2 + P3 (C3 + D1 for oil and gas) without taking into account losses during extraction, enrichment and redistribution [12,13,14,15]. This option reflects not so much the value of MRP as the mineral saturation of the territory, which can be used primarily to assess the prospects of high-order mineragenic and oil and gas bearing structures [16, 17, 18].

MRP - as the value of a part of recovered minerals, accounted for in explored, preliminarily estimated reserves and forecasted resources of subsoil use objects (deposits); while taking into account losses during extraction, enrichment and redistribution. This option obviously significantly overstates the MRP estimate, since the forecast resources of various reliability categories are equated with the explored reserves.

MRP - as the value of active explored and valued reserves (cat. A + B + C1 + C2) extracted from the bowels, and the forecast resources of subsoil use objects (deposits). The latter are reduced to the conditional category C2 by means of the coefficients of confirmation (transfer of resources), statistically calculated on the basis of a retrospective analysis of the results of prospecting works in the region. The specified variant of calculations has certain difficulties connected with reliability of allocation of an active part of stocks, and also definition of decreasing (to predictive resources) factors [19,20,21,22].

A. Ya. Katz, S.A. Kimelman, N.K. Nikitina suggest to calculate the value of the total mineral and raw material potential, which includes the valuation of the balance reserves of cat. A + B + C1 + C2 and forecasted resources of subsoil use objects (deposits and forecast sites) of various degrees of perspective [23]. At the same time, the forecast resources of cat. P1, P2, and P3 (C3 and D1 for oil and gas) should first be brought to reserves (reliability of reserves) of category C2 by applying the appropriate coefficients.

III. PROBLEM STATEMENT

For the purposes set before the geological and economic map, the most suitable variant is a variant of the general mineral and raw material potential, covering the resources identified and tested at all stages of the geological study of the subsoil.

To characterize the most studied part of mineral resources - the recoverable part of the explored reserves - the following indicators are used:

subsoil wealth (SW) (as part of national wealth - NW) - the valuation of the recoverable part of the explored reserves, accounted for by the state balance;

The industrial value (IV) is the recoverable value of reserves (cat. A + B + C1 + C2) and the forecasted resources (category P1) of explored and valued mineral resources that can be exploited at an acceptable level of profitability.

There are, at least, two approaches to determining the value of the subsoil wealth indicator: 1) it is defined as the total value of the recoverable part of the explored reserves of minerals included in the State Balance; 2) the wealth of the subsoil is a valuation of the approved reserves of the GKZ or CKZ of A + B + C + C2 cat., which can be implemented in a relatively limited time (up to 50 years); and this assessment is carried out according to the income method as the difference between the annual cost of production and the annual operating costs for extraction and enrichment, including depreciation, excluding taxes and other deductions that are part of operating costs.

Being an approximate estimate of the cost of the entire complex of mineral resources, MRP can be used to assess the excess or shortage of geological "reserve" for short, medium or long-term prospects and the rate of development of the mineral resource base for each type of minerals.

The ratio of the values of MRP, NW and IV characterizes the degree of geological exploration of the mineral resources of the territory, and also determines the share of the cost of resources that can be actually mastered in the foreseeable future.

The use of cost indicators characterizing the mineral resource potential of the territory (MRP, NW and IV) allows to get a clear picture of the state and prospects of development of individual regions, federal districts, subjects of the Russian Federation and their fragments (economic, mining and administrative areas) for zoning.

Pointing out the parameters of group III is due to the fact that in conditions of market economy and paid subsoil use priority is given to integrated cost parameters. The essence of them is to get an answer to the question: what economic result is obtained when the mineral resources of the region are developed?

For the state customer this result will be refracted into an integrated indicator (a system of indicators) of social and economic development. An indicator of the effectiveness of investing in the development of the region's mineral and raw materials base is more important for an investor.

From this point of view, the geological and economic map compiled by order of the administration of the Russian federation subject should show as the final result the amount of revenue of the consolidated budget or only the budget of the region (the subject of the Russian Federation) that directly and indirectly measures the development of mineral resources, and subsoil use, not related to the extraction of minerals. Depending on the needs of the customer, the period for obtaining the specified income may be limited by the time frame of a short, medium or long-term perspective. At the same time, the possibilities of the map make it possible to show the distribution of budget revenues in administrative regions, mining and mining areas, territorial industrial complexes, etc. Since the budget revenue is provided by the receipt of taxes from currently operating enterprises (subsoil users) or from enterprises (subsoil users) whose operation (development) is planned in the periods stipulated by the customer, the value of tax potential (TP). The map makes it

possible to attribute this indicator to individual subsoil use objects, as well as to mining, mining areas, administrative units or territorial industrial complexes.

IV. THEORETICAL PART

Valuation of the mineral and raw materials potential is produced both for a separate deposit, and for a group of deposits, ore areas, etc.

For its calculation, formula (1) is used.

$$MRP = (Q_{res} + Q_{forec} \times K_e)P \quad (1)$$

Q_{res} - reserves of minerals in the bowels in units of measurement adopted in the State Balance of Reserves (categories A + B + C1 + C2);

Q_{forec} - predicted resources of solid minerals (P1 + P2 + P3 cat.) or perspective hydrocarbon resources (category D), common minerals and groundwater in volumes that can be sold in a relatively limited time (up to 50 years);

K_e - a coefficient of confirmability of forecast resources.

P - a purchase price of the final commodity unit operating on the world market.

To calculate underground MRP, operational reserves are used for each type of groundwater located on the State Balance of Mineral Reserves (thousand cubic meters per day), and the forecast resources for prospective areas, areas, deposits and sites assessed by the results of regional hydrogeological studies, as well as the selling price of m^3 , thermal and mineral waters and tons of steam (2).

$$MRP_{UWR} = (Q_{res} + Q_{forc} \times K_e) \times T \times P \quad (2)$$

where T - term of operation of a deposit of underground waters in days.

Forecast resources of fresh groundwater used for domestic and drinking water supply are estimated as a whole for the region.

The mineral resource potential of the mining zone, as well as of the region as a whole, is defined as the sum of the mineral and raw materials potentials of all types of mineral deposits located in the respective territory.

Under the mineral and raw material potential of balance reserves as a component of the mineral and raw material potential of the subsoil the valuation of the recoverable part of the explored reserves is understood.

To calculate the mineral resource potential of the balance reserves of ore deposits (mln. P), the formula (3) is used.

$$MCP_{balr} = \frac{Q_{res} \times (1-n)}{1-r} \times P \times M \times K_r \times K_{extr} \quad (3)$$

Q_{res} - balance reserves of ore in the bowels, million tons;

n - loss of ore during extraction, share of a unit;

r - dilution (clogging) of ore during extraction, the fraction of a unit;

P - the price of metal, operating on the world market, P / t , P / g - depending on the dimension "M";

M - the content of metal in the ore in the interior, t / t , g / t , kg / t ;

K_r - dilution factor during production (quality change factor) (4);

$$K_r = \frac{M(1-r) + M_z \times r}{M} \quad (4)$$

M_z - metal content in admixtures during mining, t / t , g / t , kg / t ;

K_{extr} - through extraction of metal in the final (commodity) product in the enrichment and metallurgical transformation.

Due to the fact that it is difficult to obtain reliable mixing indicators for the whole range of balance fields (especially reserve deposits), it is possible to simplify the calculation formula. Deviations of the results of calculations in practice do not exceed 2% (5, 6).

$$MRP_{bal} = Q \times P \times I_0 \quad (5)$$

$$I_0 = I_{extr} \times I_{ben} \times I_{conv} = I \times (1 - n) \quad (6)$$

Where I_{extr} - extraction at mining, unit share;

I_{benef} - extraction at beneficiation, unit share;

I_{conv} - extraction at metallurgical conversion, unit share

V. PRACTICAL RESULTS

The potential gross value of the balance reserves of the main types of minerals as of early 2017 is \$ 1,560.13 billion, the cost of potentially recoverable balance reserves is \$ 1111.63 billion. The "active" reserves of minerals amount to 1164.99 billion US dollars, while the "active" reserves are 825.95 billion US dollars. When implementing the forecasted resources, the gross value of the subsoil may increase to \$ 1,0003.2 billion. Mineral and raw materials potential of the main types of minerals of the Republic of Sakha (Yakutia) is given in Table 1.

TABLE 1. Mineral and raw material potential of the Republic of Sakha (Yakutia)

| Minerals | Mineral and raw material potential, billion \$ USA | | |
|--|--|--|---|
| | Mineral reserves on the balance ABC1 + C2 | The recoverable balance reserves of categories ABC1 + C2 | Recoverable active reserves of ABC1 + C2 categories |
| Natural gas | 312,00 | 296,4 | 276,55 |
| Oil and condensate | 344,71 | 96,55 | 86,40 |
| Coal | 577,86 | 491,18 | 335,75 |
| Diamonds and precious metals (gold, silver, platinum) | 95,49 | 85,00 | 85,00 |
| Iron Ore | 92,03 | 41,57 | 2,73 |
| Colored and rare metals (zinc, lead, tungsten, uranium, ed., Mercury, tin) | 58,33 | 35,58 | 30,62 |
| Apatity | 3,85 | 2,89 | 2,89 |
| Graphite | 0,15 | 0,12 | 0,12 |
| Antimony | 0,65 | 0,27 | 0,27 |
| Phlogopite and piezoquartz | 1,52 | 0,75 | - |
| Salt | 60,61 | 54,55 | - |
| Gypsum and anhydrite | | 0,44 | 0,27 |
| Other (facing stones, metallurgical dolomites) | 12,44 | 6,32 | 5,36 |
| Total | 1560,13 | 1111,63 | 825,95 |

The reserves and forecast resources of coal, oil, natural gas, diamonds, precious metals (gold, silver, platinum), non-ferrous and rare metals (tin, rare earths, polymetals) and iron ores are of the greatest importance in MRP in Yakutia.

VI. CONCLUSIONS

In the territory of the Republic of Sakha (Yakutia), 9 geological and economic regions have been identified. They unite several uluses and do not always coincide with the boundaries of the latter, which is explained by the difference between the criteria for administrative and geological zoning.

The geological and economic regions of the Republic are conditionally divided into groups: the most exploited are the South Yakutia and Mirninsky GER, the exploitation of high-value and highly liquid mineral deposits (diamonds and gold) made it possible to identify and successfully develop much-needed fuel and energy resources, as well as such important types of mineral raw materials as iron ore, the extraction of which makes it possible to bring the economy of the Republic to a new quality level and creates conditions for geological exploration, aimed at identifying and exploring the types of minerals needed for the needs of the construction industry and agriculture, as well as exports to other regions; to this group adjoins the economically equipped Central Geological and Economic Region, the identified and developed fuel and energy resources of which have allowed to successfully develop the energy industries of the economy, industry, agriculture, transport construction and create a social infrastructure;

The next group includes the East (Yansky) and the South-Eastern GER, rich in deposits and highly prospective objects of noble and valuable non-ferrous metals; considerable distance from the developed regions of the Republic and a very weak transport infrastructure make it possible to develop mainly the extraction of precious metals; the expansion of tin and antimony mining, as well as the beginning of the development of copper, tungsten and polymetallic deposits, depends to a large extent on the market situation of these metals and on the coordination of efforts of the subjects of the Far Eastern FD (Magadan Region and Khabarovsk Territory) in geological exploration and industrial development adjacent territories rich in mineral resources; a group of areas including the North-East, Kolyma and North-West GER is characterized by their very poor economic development in the near-Arctic zone, which allows them to exploit mainly a few rich placer deposits of diamonds and gold, as well as coal deposits for their own needs;

The economic potential created on this basis does not yet contribute to the maintenance of more active geological exploration work to expand the mineral resource base.

Taking into account the current degree of exploration of the territory of Yakutia, the average specific value of the subsoil of the Republic with balance reserves is 503 thousand

US dollars per 1 km², the specific value of the extracted "active" reserves is 266 thousand dollars per 1 km². In the context of administrative districts, the specific value of the subsoil varies from a wide range of 0.07 thousand dollars per 1 km² (balance reserves) in the Srednekolymsky region to 4898 (Neryungri) and 5078 thousand dollars per 1 km² in the Lensk district. Considering the vast territory of Yakutia, the various degrees of its development, the natural and climatic features and the socio-economic conditions of the economy, the following major economic regions are distinguished within the Republic: South Yakutia, West Yakutia, North-Western, Central Yakutia, East Yakutia and North -Oriental.

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