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The Methodology to Calculate the Investment Potential of Mineral Resource Base in the Areas of New Development

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***Abstract* — In the current situation, the problem of economic efficiency increase of geological exploration aimed to identify and to explore mineral deposits, as well as to develop discovered deposits, remains acute. One way to solve this complex problem is to conduct geological and economic monitoring in regions and at the national level. However, in the context of limited funding for geological exploration programs and the reproduction of mineral resource base, the issue of priority areas identification for the development of regional mineral resource base that could become catalysts for the growth of region's economy is becoming topical. This is especially important for regions rich in mineral and raw materials resources, for which the natural and geographical factor is crucial for the specialization of regional industry, but at the same time that are poorly developed and covered, primarily in the infrastructural plan. The purpose of this article is to develop a methodology to calculate the investment potential of mineral resource base in the areas of new development. The method to achieve this goal is the development and use of an integral indicator of subsoil investment potential, adjusted by indicators of infrastructure coverage of the territory with the use of scoring expert assessments. As a result, a methodology was developed to calculate investment potential, taking into account a set of indicators for the expert assessment of infrastructure coverage, which was tested in the most difficult region in terms of assessment – the Republic of Sakha (Yakutia).**

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

I. Introduction

The assessment of geological prospecting costs (geological exploration) to transfer predicted resources into explored reserves is one of the most important tasks that must be dealt with when developing the country's mineral resource base. Measuring the future costs of geological exploration and the expected results allows to determine their effectiveness and to substantiate priority objects to transfer forecast resources into explored reserves. With the adoption of the Law “On Subsoil” and the transition of the industry to market relations, it became necessary to significantly revise the provisions on tasks and methods for determining the economic efficiency of geological exploration, the main element of which is the assessment of the cost of their implementation. In particular, the role of the exploratory and evaluation stage significantly increases, the task of which is to transfer the forecast resources P2 and P1 into explored reserves, and to conduct a geological and economic assessment of industrial value of the field identified as a result of exploration.

When translating the forecast resources into explored reserves, the boundaries of the deposit should be established in terms of plan, the main ore bodies should be identified, their size and spatial position should be determined, data on the material composition and content of useful components should be obtained, natural varieties and industrial (technological) types of mineral should be determined. The degree of geological study of the deposit, the quality and quantity of minerals should provide an estimate of reserves in categories C1 and C2. The ratio of deposits number of these categories is determined depending on geological structure complexity of the deposit, the constancy of the composition, its scale. Of many factors that determine the volume of geological exploration when transferring the forecast resources into reserves, the defining is the idea of the geological-industrial type of the deposit.

II. Literature review

The exploration cost assessment of geological exploration to transfer the forecast potential of minerals into explored reserves was considered in terms of calculating the investment potential of the subsoil in the following works:

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 should be taken into account (A + B + C1 + C2) [1, 2, 3, 4, 5]. At that, forecasted reserves of minerals were to be considered separately as a reserve for the investment potential of region subsoil, 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 investment potential of the subsoil as the gross potential value of all minerals in the subsoil, taking into account the value of all the explored and assessed subsoil objects (deposits) in category A + B + C1 + C2, as well as the value of the forecast resources in the subsoil for category P1 + P2 + P3 (C3 + Д1 for oil and gas) without taking into account losses during extraction, enrichment and redistribution [12, 13, 14, 15]. A. Ya. Kats, S. A. Kimelman, N. K. Nikitina suggest calculating the value of total investment potential of the subsoil, which includes the valuation of the balance reserves of cat. A + B + C1 + C2 and forecasted resources of subsoil objects (deposits and forecast sites) of various degrees of perspective [16, 17, 18, 19, 20].

At that, 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. FORMULATION OF THE PROBLEM

Information on the manifestation of minerals discovered as a result of prospecting works is extremely limited, and therefore it is possible to use information on the geological and industrial type of the deposit from numerous factors that determine the methodology of prospecting and evaluation works and their reliability at this stage of exploration. The determination of the geological-industrial type of the revealed manifestation of a mineral and its estimated sizes allows us to roughly outline reserves (large, medium or small) and the average content of useful components.

Geological and industrial types of deposits are subdivided into stockwork, plastoid, lenticular and veined. Within the allocated types deposits are also significant different in the complexity of the geological structure. Based on the complexity of the structure and distribution of useful components, as well as costs for prospecting and evaluation, the deposits of solid minerals are divided into 4 groups.

The first group includes deposits of a simple geological structure with a uniform distribution of main valuable components in them. A characteristic morphological feature of ore bodies is their continuity or insignificant discontinuity in plan.

The second group includes deposits of complex geological structure with variable capacity and internal structure, uneven and very uneven distribution of main useful components. However, many deposits with a complex geological structure have a low variability in the content of useful components. In deposits of this group, the discontinuity of mineralization differs significantly by a factor of 1.5-2. In a number of cases, deposits are represented by dozens of ore bodies, which are usually located in groups separated by large sections of practically country rocks. However, main reserves of useful component are concentrated, as a rule, in single largest and continuous ore bodies.

Deposits of the third group are characterized by a very complex geological structure, a sharp variability in power and internal structure, as well as noncontinuous quality and a very uneven distribution of main useful components. Deposits are represented by tens, sometimes hundreds of ore bodies. However, main reserves are concentrated in 3-8 of them.

The fourth group includes mainly small deposits. Deposits are represented mainly by bodies of vein, lenticular, less often plastiform and irregular in shape.

However, reserves of small, medium and large deposits of the same industrial type differ in 3-5, and in some cases in 6-8 times. Thus, stocks of small, medium and large stockwork copper deposits can differ, respectively, in 4-6 times, molybdenum deposits in 4-5 times, vein tin deposits in 2-6 times, and so on. Moreover, the content of useful components significantly fluctuates. As a rule, the content of useful components varies: in small deposits in 5 and more times, for medium - in 3-4 times and for large - in 2-3 times.

As exploration and evaluation work is carried out, information on the deposit is accumulated, which allows us to refine the methodology for their conduct, to evaluate the reliability of the results obtained and to carry out an appropriate adjustment of the scope of work to assess its industrial significance.

The classification of deposits takes into account the data limitation on features of the geological structure and, accordingly, the variability of ore bodies, which the geologist possesses after the completion of prospecting works.

IV. THEORETICAL PART

Among the parameters (indicators) of Group I, which give a presentation of economic and territorial conditions, indicators characterizing the territory of the region that is part of the geological and economic region are used:

transport and energy infrastructure:

- length of railways,
- length of highways,
- length of ground and improved roads,
- length of oil and gas pipelines,

length of power transmission lines,

- length of navigable sections of rivers,

social infrastructure:

- population;
- number of settlements (cities, towns and rural settlements).

For all administrative units, specific indicators are calculated: the length of communication lines / km^2 of district area or persons / $km^2$of district area, the number of units of settlements / $km^2$of district area.

Later, these indicators were scored:

1. for indicators of social infrastructure:

population: < 0.1 people / km^2 – 1 point; 0.11-0.5 – 2 points; 0.51-1.0 – 3 points; 1.01-10.0 – 4 points and > 10 people / km^2 – 5 points;

number of settlements:

- cities: < 0.01 – 0 points; 0.01-0.1 – 3 points and > 0.1 – 6 points;
- towns: < 0.01 – 0 points; 0.01-0.1 – 2 points; 0.11-1.0 – 4 points and > 1.0 – 8 points;

rural settlements: 0.01-0.1 – 1 point; 0.11-0.5 – 2 points; 0.51-1.0 - 3 points and > 1.0 – 4 points;

2. for indicators of transport and energy infrastructure:

- railways: 1-2 km/ km^2– 10 points, > 2.1 km / km^2 – 20 points;

- highways: 0 km / km^2 – 0 points, up to 0.5 km / km^2 – 0.5 points; 0.51-1.5 km/ km^2 – 1 point; 1.51-2.5 km / km^2 – 2 points; 2.51-3.5 km / km^2 – 3 points; 3.51-4.5 km / km^2 – 4 points, etc., > 20 km / km^2 – 20 points;
- ground and improved roads: up to 0.5 km / km^2 – 0 points, 0.5-1.5 km / km^2 – 0.5 points; 1.51-2.5 km/ km^2 – 1 point; 2.51-3.5 km / km^2 – 1.5 points; 3.51-4.5 km / km^2 – 2 points, etc., > 40 km / km^2 – 20 points;
- oil and gas pipelines: 0 km / km^2 – 0 points, up to 2 km / km^2 – 1 point; 2.1-4 km / km^2 – 2 points; 4.1-6 km / km^2 – 3 points, etc.,
- power lines: 0 km / km^2 – 0 points, up to 1 km / km^2 – 0.5 points; 1.01-2.5 km / km^2 – 1 point; 2.51-3.5 km / km^2 – 1.5 points; 3.51-4.5 km / km^2 – 2 points; 4.51-5.5 km / km^2 – 2.5 points, etc.
- navigable rivers: 0 km / km^2 – 0 points, up to 2.5 km / km^2 – 1 point; 2.51-4.5 km / km^2 – 2 points; 4.51-6.5 km / km^2 – 3 points, etc.

When assessing the transport and energy infrastructure by score, the priority is given to the availability of railway communication, since even with a relatively small length of railways, they account more than a half of all traffic, followed by roads (20%), rivers (slightly more than 15%) and oil and gas pipelines (about 10%).

When scoring the social infrastructure, the priority is given to a factor that takes into account the population density, especially in conjunction with the presence of cities or town settlements. The population of cities and towns, in our opinion, is much more than the inhabitants of rural settlements can be considered as a reserve workforce that can be used in the mineral and raw materials sector of the economy. In addition, the social and production (including transport) infrastructure of cities and towns is more adapted to the perception and development of capacities of extractive and processing (mineral raw materials) industries.

Further, proceeding from the specific length of communication routes, energy and product pipelines, population density and settlements of various types, each district received points corresponding to grades of the above scales. Points are summed up by geological and economic areas, separately for transport and energy infrastructure and for social infrastructure. Then the average (specific) score is calculated as the quotient from dividing the sum of points by geological and economic area into its area.

On the basis of a score, the correction factor is applied to the specific value of recoverable balance reserves, taking into account the impact of the transport, energy and social infrastructure on the possibility of realizing this value. It is conventionally accepted that the correction factor is equal to 1, provided that the above infrastructure is absent. The presence of infrastructure, respectively, increases this coefficient by some amount. It is calculated as a quotient from the division of the average score assigned to a specific geological and economic area for the presence of a transport, energy or social infrastructure there, to the corresponding average score calculated for the geological and economic region adopted as the base (usually the most covered). Since the sum of scores that take into account the social infrastructure is approximately 10% lower than the sum of scores that take into account the transport and energy infrastructure, the correction value to the original coefficient (equal to 1) in the part reflecting the amendments for the presence of social infrastructure, respectively, is also reduced.

The final correction factor is calculated as the product of coefficients that take into account different groups of infrastructure factors. The given specific value, taking into account the influence of transport and energy and social infrastructure, is the product of the specific value of extracted balance reserves for the final correction factor.

Thus, the formula (1) is used to calculate the value of total amount of reserves and forecast resources reduced to explored reserves.

$$Q^{sum}_{zap_{pr}} = Q^{b}_{ABC1} + Q^{b}_{C2}K^{C2}_{per} + Q^{z}K^{zab}_{per} + Pr_{P_1}K_{per} + +Pr_{P_2}K_{per} + Pr_{P_3}K_{per} \quad (1)$$

Where Q^{b}_{ABC1} are balance reserves of cat. A + B + C1, tons (m3), Q^{b}_{C2} are balance reserves of mineral (M) of cat. C2, tons (m3), K^{C2}_{per} is the transition coefficient from reserves of cat. C2 to explored reserves (fractions of unit), K_{per} are transition coefficients from the forecast reserves to explored reserves (fractions of unit), Pr_{Pi} are forecast reserves of the i-th category.

To calculate the investment potential of the subsoil (IP), depending on the ratio of total amount of reserves and forecasted resources reduced to explored reserves, the formula (2) is used.

$$Inv = Q^{sum}_{zap_{pr}} \times K_z \times P_{ed} \times K_0^{izvl} + Z_{grr} \quad (2)$$

Where $Q^{sum}_{zap_{pr}}$ is the total amount of reserves and forecasted resources reduced to explored reserves (unit of measurement), K_z is the coefficient of accounting for current and capital costs in the price of the first commercial product, %, P_{ed} is the unit price of the first commercial product, K_0^{izvl} is the coefficient of end-to-end PI extraction for the initial year of forecasting, %, Z_{grr} are exploration costs (search, evaluation, exploration).

The investment potential of the subsoil as a sum of capital investments necessary for the development of deposits or the reconstruction of mining enterprises is determined based on the results of the valuation only for those facilities that are scheduled for commissioning during the forecasting period, taking into account amendment to the infrastructure provision of the territory.

V. Practical Results

The methodology for calculating the investment potential of the mineral and raw materials base in new development areas is applicable for the territory of the Republic of Sakha (Yakutia). Most of Yakutia's mineral reserves have a significant reserve of their increase due to exploration of forecast resources.

In terms of administration, the highest mineral resource potential belongs to: Lensky, Mirninsky, Neryungrinsky, Aldan, Yakutsk, Tomponsky, Suntarsky, Oleneksky, Olekminsky, Nyurbinsky, Vilyui, Kobiai, Megino-Kangalassky, Verkhoyansky, Verkhnekolymsky, Anabarsky, and Oymyakonsky districts. A weak mineral resource base in the Even-Bytantaisk, Khangalassky, Churapchinsk, Ust-Aldansky, Namsky, Zhigansky, Gorny and Verkhnevilyui districts. The indicators of the IP of administrative districts of the Republic of Sakha (Yakutia) are shown in Table 1.

TABLE 1. Calculation of the IP of administrative districts of the Republic

Administrative Districts	Specific investment potential (thousands of US $ / km^2)		
	Balance reserves	Extractable balance reserves	Extractable active reserves
Abyisky	21.99	18.39	14.01
Aldan	113.58	73.47	46.53
Allaihovsky	0.10	0.08	0.05
Amginsky	0.20	0.15	0.15
Anabar	58.24	53.91	53.60
Bulunsky	14.67	12.40	3.57
Verkhnevilyuysky	0.00	0.00	0.00
Verkhnekolymsky	164.38	139.12	105.20
Verkhoyansky	28.31	20.58	13.95
Viluysky	819.68	772.26	735.57
Gorny	0.00	0.00	0.00
Zhiganskiy	0.00	0.00	0.00
Kobiaisky	201.59	188.26	172.65
Lenskiy	5077.89	3023.83	2935.88
Megino-Kangalassky	1675.21	1427.35	355.56
Myrninsky	1312.56	776.64	728.69
Momsky	2.34	2.01	1.73
Namsky	0.00	0.00	0.00
Nizhnekolymskiy	0.52	0.37	0.37
Nyurbinsky	554.30	487.92	263.05
Oymyakonsky	21.94	14.93	14.74
Olekminsky	785.36	531.39	3.14
Oleneksky	127.70	75.26	77.55
Srednekolymsky	0.07	0.05	0.05
Suntarsky	772.03	467.11	300.76
Tattinsky	5.58	4.70	0.75
Tomponsky	238.03	196.26	158.41
Ust-Aldansky	0.00	0.00	0.00
Ust-Maysky	10.05	6.07	4.29
Churapchinsky	0.00	0.00	0.00
Ust-Yanskiy	68.42	50.73	43.95
Even-Bytantaisky	0.08	0.06	0.06
Yakutsk city	15250.00	12961.11	3227.78
Neryungri city	4898.18	4001.29	3011.19
TOTAL	502.91	358.33	266.25

of Sakha (Yakutia) (taking into account the amendment to infrastructure provision)

VI. Conclusions

The introduction of amendments to the presence of infrastructure factors did not lead to a fundamental change in the ranking of geological and economic areas, did only on mineral and raw materials potential, more precisely – by the value of balance reserves of main types of minerals. The fact is that recognition of deposits already implies the possibility of their effective development, which is unthinkable in the absence of even a minimum of infrastructure coverage. In the Republic of Sakha (Yakutia) there are known unique objects in terms of reserves or quality of mineral resources (Sardana, Tomtor, etc.), development of which is still very problematic due to the lack of proper infrastructure, and a number of them for this reason is not recognized in the state balance.

In connection with this, it seems that the introduction of adjustments that take into account the infrastructure coverage will be more visually and effectively when characterizing the mineral and raw potential of geological and economic areas with the involvement of estimates of reserves of off-balance deposits and forecast resources, at least at the level of categories P_1 and P_2.

At the same time, it is necessary to note a higher contrast of the given values of specific value. In our opinion, taking into account the nature of the ranking of regions in terms of the “specific value” index (taking into account “infrastructure factors”) would allow a more objective assessment of the investment attractiveness and investment potential of particular territories, in particular within the Republic of Sakha (Yakutia).

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