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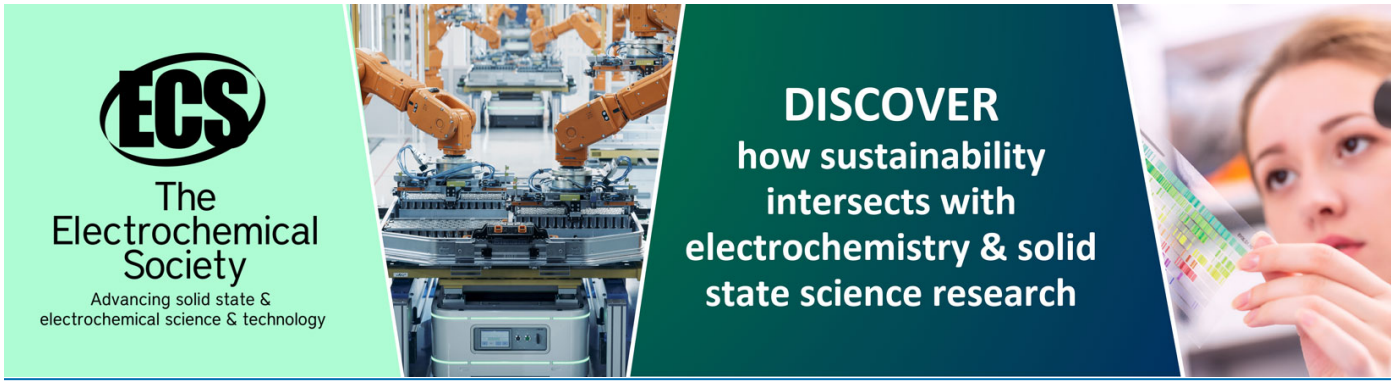

Geological and Economic Monitoring and Assessing the Prospective Expansion of Graphite Deposits in New Development Areas

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Abstract. This article discusses the results of the geological and economic monitoring of graphite and apatite deposits in the south of the Republic of Sakha (Yakutia) conducted by the authors. These deposits differ in initial technical and economic indicators and development conditions, therefore, calculating the aggregated geological and economic indicators is required. The estimator results will allow, on the one hand, determining the investment attractiveness of each mineral resource facility, on the other hand, evaluating the sequence of their operational commissioning. In the development prospect of the southern Yakutia mining regions, exploiting the Birikeen apatite deposit is seen, which also needs a geological and economic evaluation. As a tool for assessing the technical and economic indicators of these deposits, it is recommended to use the methodology for assessing the mineral potential while conducting geological and economic monitoring. This work was financially supported by the grant of the President of the Russian Federation No. MD-2409.2020.5.

1. Introduction

Currently, there is a steady trend in developing the digital economy in the Russian Federation, which certainly affects a number of related industries, including those that ensure creating and functioning the necessary infrastructure. In particular, the question of developing the mineral resource base of graphite deposits is becoming relevant. As it is known, today graphite is considered to be in demand in the field of electronics, clean energy, medicine, mining, and military industry.

2. Theoretical part

Transiting the national economy to new technological production and the emerging tendency to provide its own resources allows us to optimistically consider the possibility of exploiting graphite deposits in the south of the Sakha Republic (Yakutia) [1-20].

These are the following deposits: the Nadezhdinskoye, the Chebere, the Levo-Nimerganskoye, the Kerakskoye (table 1). The close location of the deposits predestinates the construction of one mining and processing plant while exploiting deposits, and also allows determining the sequence of their operational commissioning as the area develops.

Table 1. The list of deposits for which the aggregated economic estimations were carried out in the Republic of Sakha (Yakutia).

Object, type of natural resources	Name of the deposit	Estimated operational reserves, thousand tons	Annual production, thousand tons	The period of provision with stocks, years	Payback period, years
1. Graphites	The Nadezhdinskoe (plots 1, 2)	6970,9	349,0	19,4	7,52
2. Graphites	The Chebere (Central plot)	3950,0	133,0	25,7	3,45
3. Graphites	The Levo The Nimgerkanskoye	15495,5	287,2	54,0	4,31
4. Graphites	The Kerakskoye	2786,0	239,3	11,6	4,05
5. Apatities	The Biriken	534713,5	11743,4	45,6	5,32

For each deposit, it is necessary to clarify technical and economic indicators (operational reserves, estimated content of the useful component, annual quarry productivity, guaranteed term of the reserve development, payback period for capital investments) to determine their investment attractiveness and the order of commissioning for commercial operation. As a tool for assessing the technical and economic indicators of these deposits, it is recommended to use the methodology for evaluating the mineral resource potential during geological and economic monitoring [5].

3. Practical part

Let us consider the results of large-scale economic calculations on the example of the Nadezhdinskoye graphite deposit. The source data are presented in table 2.

Table 2. The initial data for the aggregated economic estimations of the Nadezhdinskoye graphite deposit.

Indicator	Value
Proven reserves in the mining circuit	6,82 million tons;
The average content of the useful component	4,7%;
Estimated annual output of marketable products	13,9 thousand tons;
Estimated construction time	2 years

The results of the aggregated economic estimations of the Nadezhdinskoye graphite deposit are presented in table 3.

Table 3. The results of the aggregated economic estimations for the Nadezhdinskoye graphite deposit.

Indicator	Value
Operating reserves	6,77 million tons;
Estimated content of the useful component	4,385%;
Annual quarry productivity	349,0 thousand tons;
Guaranteed term of the reserve development	19,4;
Payback period for capital investments	7,52 years

Cost effectiveness indicators confirm the development feasibility and investment attractiveness of the deposit. This field can be recommended for licensing and searching investors.

Given the specifics of the region, it should be noted that one of the important issues is infrastructure security. In many respects, solving the problem of the deposit development will depend on distributing the responsibilities and shared costs for constructing infrastructure:

- constructing 42 km of external power lines from the village Maly Nemnyr to the industrial site of the processing plant;
- constructing 50 km of paved roads from the processing plant to the nearest Amur-Yakutsk highway.

The 19.4-year supply life of the enrichment plant while operating the Nadezhdinskoye deposit indicates the necessity for preparing and commissioning the Levo-Nimerkanskoye graphite deposit.

The source data are presented in table 4.

Table 4. The initial data for the aggregated economic estimations of the Levo-Nimerkanskoye graphite deposit.

Indicator	Value
Proven reserves in the mining circuit	15,5 million tons;
The average content of the useful component	5,79 %;
Estimated annual output of marketable products	13,9 thousand tons;
Estimated construction time	2 years

The results of the aggregated economic estimations of the Levo-Nimerkanskoye graphite deposit are presented in table 5.

Table 5. The results of the aggregated economic estimations for the Levo-Nimerkanskoye graphite deposit.

Indicator	Value
Operating reserves	15,5 million tons;
Estimated content of the useful component	5,39%;
Annual quarry productivity	287,2 thousand tons;
Guaranteed term of the reserve development	53,9 years;
The payback period for capital investments	4,31 years

Cost effectiveness indicators confirm the development feasibility and investment attractiveness of the deposit. Improved technical and economic indicators of the Levo-Nimgerkanskoye deposit relative to the Nadezhdinskoye one are explained by the fact that the content of the useful component in the Levo-Nimgerkanskoye deposit is higher than in the Nadezhdinskoye one; therefore, upon receiving a fixed final product of 13.9 thousand tons, the annual productivity of the quarry is marked by a decrease in ore production per year. The calculations for the Levo-Nimgerkanskoye deposit were carried out taking into account the existing mining and processing plant and, accordingly, lower capital costs for putting it into operation. Therefore, the payback period differs by almost 3 years.

The Chebere deposit is attractive for exploitation.

The content of the useful component is 12.5%, the accepted content for calculations is 11.64%.

With this content and fixed annual production of marketable products (corresponding to the Nadezhdinskoye deposit which equals 13.9 thousand tons), it will be necessary to significantly reduce the production of natural resources and, accordingly, treating at the mining and processing enterprise. This provision is reflected in the technical and economic calculations.

The source data are presented in table 6.

Table 6. The initial data for the aggregated economic estimations of the Chebere graphite deposit.

Indicator	Value
Proven reserves in the mining circuit	3983,5 million tons;
The average content of the useful component	12,5 %;
Estimated annual output of marketable products	14,25 thousand tons;
Estimated construction time	2 years

The results of the aggregated economic estimations of the Chebere graphite deposit are presented in table 7.

Table 7. The results of the aggregated economic estimations for the Chebere graphite deposit.

Indicator	Value
Operating reserves	3950,0 thousand tons;
Estimated content of the useful component	11,64 %;
Annual quarry productivity	133,0 thousand tons;
Guaranteed term of the reserve development	25,7 years;
Payback period for capital investments	3,45 years

The obtained technical and economic indicators demonstrate that if 349.0 thousand tons of ore are supplied annually to the mining and processing plant (initial data from the Nadezhdinskoye deposit), the plant productivity will increase almost threefold.

Considering the complex of graphite deposits of the Aldan shield, the aggregated economic estimations were also carried out for the Kerakskoye graphite manifestation.

The source data are presented in table 8.

Table 8. The initial data for the aggregated economic estimations of the Kerakskoye graphite manifestation.

Indicator	Value
Proven reserves in the mining circuit	2805,7 thousand tons;
The average content of the useful component	6,95 %;
Estimated annual output of marketable products	13,9 thousand tons;
Estimated construction time	2 years

The results of the aggregated economic estimations for the Kerakskoye graphite manifestation are presented in table 9.

Table 9. The results of the aggregated economic estimations for the Kerakskoye graphite manifestation.

Indicator	Value
Operating reserves	2786,0 thousand tons;
The estimated content of the useful component	6,47 %;
Annual quarry productivity	239,3 thousand tons;
Guaranteed term of the reserve development	11,6 years;
Payback period for capital investments	4,05 years

Based on analyzing technical and economic indicators and the state of the natural reserve complex of graphite deposits of the Aldan shield, it is recommended to prepare the Nadezhdinskoye deposit for licensing. But to attract investors, proposals should be arranged to address the issues of providing infrastructure for the licensed field.

In the Levo-Nimgerkanskoye, the Cheber and the Kerakskoye deposits, geological exploration is required to transfer copyright reserves to balance reserves with additional detailed work. The aggregated

economic estimations determined the following sequence of operational commissioning: at first the Nadezhdinskoye, then the Levo-Nimgerkanskoye, then Keraskoye and Cheber deposits should be commissioned.

In the development prospect of the mining regions of southern Yakutia, exploiting the Birikeen apatite deposit is visible. The performed aggregated technical and economic estimations on exploiting this field using the initial data are presented in table 10.

Table 10. The initial data for the aggregated economic estimations of the Birikeen apatite deposit.

Indicator	Value
Proven reserves in the mining circuit	535,3 million tons;
The average content of the useful component	7,79 %;
Estimated annual output of marketable products	2,0 million tons;
Estimated construction time	2 years

The results of the geological and economic evaluation of the Birikeen apatite deposit are presented in table 11.

Table 11. The results of the geological and economic evaluation for the Birikeen apatite deposit.

Indicator	Value
Operating reserves	534,7 million tons;
The estimated content of the useful component	7,79 %;
Annual quarry productivity	11,7 million tons;
Guaranteed term of the reserve development	45,6 years;
Payback period for capital investments	5,32 years

Cost effectiveness indicators confirm the development feasibility and investment attractiveness of the field, the parameters of which are determined in the source data. To prepare the Birikeen deposit for operation, it will be necessary to conduct geological exploration transferring its reserves to industrial ones.

4. Conclusions

Thus, as a result of geological and economic monitoring and assessing the prospects for expanding graphite deposits in the areas of new development in the Republic of Sakha (Yakutia), the initial data for aggregated economic estimations were determined for the Nadezhdinskoye, the Cheber, the Levo-Nimerganskoye, the Kerakskoye and the Birikeen apatite deposits. As a result of the aggregated economic estimations, the geological and economic characteristics of these deposits were specified, which made it possible to determine the sequence of operational commissioning and investment attractiveness. The development of each deposit is also a major investment project, and in many respects solving the issue of the deposit development will depend on distributing the responsibilities and shared costs for constructing the corresponding infrastructure. So, for example, to begin the Birikeen apatite deposit development, it will require the construction of 28 km of external power lines, a grader road, a railway, a medium-pressure gas pipeline to the industrial site of the plant, and a gas distribution station.

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