SPATIAL ORGANIZATION OF ARCTIC MINERAL RESOURCE CENTERS

Introduction
Spatial development becomes increasingly more topical in the Russian Arctic and in adjacent countries to stimulate their social and economic advance. Russia has authorized some legal documents to support the regional development in the Arctic zone, including such strategic enactments as the: 2025 Spatial Development of Mineral Resources and Mineral Reserves of Russia; 2035 Energy Strategy of Russia; 2035 Transport Strategy of Russia, etc.

The term of spatial development was introduced in the early 21st century, in the framework of spatial economy theory, and the term assumed a national economy to a multiregional integration of social, economic and corporate scales.

The issues of the spatial development and selection of effective stimulation tools for the regional development are the most debatable points in the community of national economy theory, and the term assumed a national economy to a multiregional integration of social, economic and corporate scales.

Conclusions
The proposed procedures for re-evaluation of an object of management with concentration of studies into control objects represented by natural characteristics of mineral deposits allow effect in short terms, at minimal cost and minor modifications of a system of management.

The expert research of an object of management enable subsequent adjustment of subjects and objects of management depending on the obtained results of research and commissioning, which allows transition to the program control of business processes [7]. The authenticity and reliability of geological assessment of mineralization, which permits reducing variability of the object characteristics, enhances efficiency and improves predictability of business processes.

The real economic effect achieved at an insignificant cost of material encouragement of the outsourcing research allows predicting further increase in production and economic factors of mining projects.

References
Theoretical practitioners and advisors. A solid background for the spatial development in the regions is the national wealth which can maintain economic diversity in the regions, including establishment of the mineral resource centers (MRC). This term is mentioned in the 2025 Spatial Development Strategy of Russia as a driver of the regional economic growth.

The trends related with MRC are widely discussed by foreign scientists. However, the Arctic countries demonstrate various definitions of the term, e.g., mineral clusters, resource territories, resource centers, mining areas, natural resources cities etc.

Most foreign researchers consider MRC as a tool of economic management alongside with the environment and engineering aspects [1].

For instance, Susan Kinnear and Ian Ogden [2] discussed the theoretical role of a resource center in the social, environmental and economic spheres. The research subject was Central Queensland as one of the key resource centers in Australia. This MRC is effective and beneficial thanks to the well-managed mining, processing and transport industries, but there exist some unfavorable social and ecological consequences which call for a due care to be taken.

Researchers Yang Chen and Danning Zhang [3] discussed the issues of the urban development based on mineral mining and production. In the rating of correlated technological capability and economic advancement in resource regions, the comparison of the influential factors showed a great spatial nonuniformity of each indicator; and the indicators of technological capabilities in the aggregate had a stronger determinant than the indicators of economic advancement.

Some foreign researchers such as Kjartan Eliasson, Gudmundur F. Ulfarsson, Trausti Valsson, Sigururd M. Gardarsson, Ronald E. Doel and Suzanne Zeller [4, 5] reflect the urgency of the mineral resource centers to be organized in the Arctic areas. The most promising regions are the Barents Sea, the Beaufort Sea and the Kara Sea, and the eastern and western coasts of Greenland in the Northern Atlantic. These regions possess the highest capabilities in terms of mineral mining and infrastructural development but are environmentally vulnerable.

Such scientists as Stanislav Martinit, Bohumil Frantal, Petr Dvorek and others [2, 6, 7] disclose the importance of the urban development in towns grown in the areas of heavy industry or mineral mining. The results display the expediency of the large-scale and economically efficient resource-related projects in remote areas far from agglomerations, with a view to developing these areas through creation of new infrastructure, allied industries and new jobs.

Foreign researchers mostly think such mineral resource centers are directly connected with the trends on the global market of mineral resources and with the energy prices governed by unstable regional development [4, 8].

Russian researchers collate the terms mineral resource centers and regional industrial clusters with the territorial industrial packages of the Soviet period of the country. The latter term was popular in the Post-War time and characterized development of the administrative-territorial facilities, layouts and scenarios of production units in the new regions of economic management. Having switched to the market economy, Russia started a novel regional philosophy. An extensive research was initiated to delineate regional clusters in the federal districts of Russia, including the regions accommodating the Soviet-era purpose-oriented territorial clusters of industry and transportation. For this reason, the notions of the regional industrial clusters and mineral resource centers contain the features of different stages of technological development of the national economy (Fig. 1) [9, 10].

The terminology of MRC is indissoluble with the theory of regional economy [11]. The many-sidedness of the latter allowed Academician Granberg to revise the definition of the regional science and to formulate it as a spatial economy. The present study systematizes the theoretical framework for the development of the regional economy and its types, including MRC.

A fundamental unit of the spatial organization of a regional economy is a locality or a spatially localized economic system with a subject specialization which governs the type of the locality. The spatially organized package of localities makes a specific type of regional economy—MRC.

In the present study, MRC means an area of one or a few municipal formations and/or an aquatic area holding a set of mineral deposits which are or to be mined, and intends (1) production and product finishing; (2) formation of traffic of marketable mineral products; (3) common loading point and communications; (4) single operator to control development of energy resources.

The scope of this study encompasses the main constraints for the development of MRC in the Arctic countries. For instance, in the United States, the oil reserves mostly occur nearby Alaska, the national oil resources are huge but underexplored and underappraised. Furthermore, development of energy resources is complicated as operations are run in the ecologically sensitive areas far from the developed infrastructure. Norway, which has been producing hydrocarbons on the shelf of the North and Norway Seas for a long time, currently faces deficiency of discovered mineral deposits in the Barents Sea. The infrastructural development needs new mineral resources. Sweden features strategic development of the mining sector (iron ore and nonferrous metals) and infrastructure for production of goods of higher added value.

The international experience of the MRC organization identifies the related obstacles. The main obstacle is the low evaluation of the commercial efficiency of the projects, affected by the market environment, competitive prices of energy resources, higher costs of mineral mining and transport, national taxation policy in terms of concessionality in subsol use and management, as well as by the transport infrastructure availability. The aspect of the environment in organization of MRC is critical in all countries mentioned.

An important part of MRC is formation of an infrastructure, in particular, transport. Global warming which causes deglaciation in the Arctic gives rise to climatic changes, and that opens new ways and opportunities for transportation of hydrocarbons [12, 13]. Such routes include the Northern Sea Route (Russia) and the Northwest Passage (Canada).

The Russian and international experience of the MRC organization enables the authors to define the feature of the Arctic MRC as a complex integrity of activities:

- Localized centers of resources being explored and mined;
Materials and methods

Materials

The test subject is the Arctic MRC in the north of the Krasnoyarsk Krai — the area which holds mineral deposits which are or to be mined in the geologically adjacency to the Yenisei–Khatanga oil and gas province. The center includes three clusters of mineral deposits, namely:

1. The Vankor cluster — Suzun (oil and gas), Lodochnoe (oil and gas), Vankor (oil and gas), Tagul (oil and gas) and Ichemminskoe (oil) reservoirs;
2. The Paiyakha cluster — Piyakha (oil), Baikal (oil and gas), Kazantsevo (gas) and West Irkino, Turki, Deryabinskoe and North Gorchinskaya license areas;
3. East Tamyr cluster — Balakhinskoe reserve (gas).

Oil and natural gas resources of the Arctic MRC, according to the estimates obtained at the Institute of Petroleum Geology and Geophysics, by the beginning of 2021 totaled 2.43 Mt and 517 Bm³, respectively. The recoverable oil and gas reserves make 1.94 Mt and 359 Bm³, respectively.

An obstruction of the oil and gas production at this MRC is the absence of a transport infrastructure, including pipelines, trucks and ships.

A new scenario of oil and gas export from the MRC deposits via the Northern Sea Route is now under consideration. This alternative also needs pipelines to connect the reservoirs in different clusters, a new sea port to be constructed on the east coast of the Yenisei Bay in the Krasnoyarsk Krai, and an oil pipeline to connect the sea port and the reservoirs. The shipment via the Northern Sea Route to the Asia–Pacific countries can also involve transit sea ports in Russia.

Methods

The research uses a set of methods including the system analysis, economic geology modeling and prediction, and evaluation of the investment attractiveness of the MRC.

For the efficient oil and gas reserves management at the MRC, the authors have developed a procedure of the integrated assessment of the Arctic development effects, which consists of three blocks:

Block I: Prediction algorithm of hydrocarbon production at the MRC reservoirs, to determine the long-term availability of hydrocarbons for the internal and external markets;

Block II: Evaluation of investment efficiency of the Arctic MRC organization, including the cost estimate of the communication, production and processing infrastructures;

Block III: Validation of multiplier effects of the Arctic MRC organization on the national, regional and corporate scales.


The capital investment prediction is grouped into investments in geological exploration, drilling, reservoir field arrangement and development, and creation of transportation and processing infrastructure, and uses consolidated norms.

The estimates include all taxes and charges due and payable at all levels (federal, regional and local budgets) as per the Tax Code of the Russian Federation, and their allocation in accordance with the Budget Code of Russia. The integrated evaluation of the Arctic MRC efficiency uses the characteristic values of the commercial and budget efficiency in accordance with the Investment Project Efficiency Evaluation Guide mentioned above.

The hydrocarbon production forecast for the reservoir fields of the Arctic MRC takes into account the structural features of the oil and gas resources and reserves, and the dynamics of their increase subject to the extent of their exploration.

The prediction algorithm consists of a few stages [9, 14]:

1. Prediction of oil and gas resources at reservoirs under mining ($Q^{f}(t)$).
2. Prediction of oil and gas resources at reservoirs being explored ($Q^{d}(t)$) and to be actuated ($Q^{s}(t)$).
3. Summary prediction of oil and gas production at the MRC ($Q^{p}(t)$).

The oil production dynamics is described by a $\alpha$-curve or by a trapezoid. This empirical pattern uses the actual data on oil production per individual reservoirs. The level of oil and gas production at the MRC is found from the formula:

$$Q^{p}(t) = Q^{f}(t) + Q^{d}(t) + Q^{s}(t).$$

The production profile takes into account the time taken to reach the design capacity per reservoir to maintain stable production thanks to the serial input of ready-to-function reservoirs in operation.

Results and inferences

Spatial organization chart of the Arctic Mineral Resource Center (compiled by the authors)

The key weight belongs to the system of communications to supply hydrocarbons to the internal and external markets. The spatial organization of the Arctic MRC includes creation of an infrastructure for production and transportation. The system of communications includes pipelining, construction of a new sea port and formation of a tanker fleet to export raw materials along the Northern Sea Route to the countries of the Asia–Pacific region. The gas potential availability conditions construction of LNG plant (Fig. 2).

Algorithm of calculating economic efficiency of spatial organization of the Arctic Mineral Resource Center

A feature of mineral resources at the Arctic MRC is the low extent of exploration, which governs high investments in geological exploration to ensure desired increase in reserves. The high resource potential enables planning the oil production at the level of up to 115 Mt as consistent with prospects of subsoil using companies. Such production level requires high capital investments which can total USD 2.139 billion over the period to 2050, by the authors’ estimates, and include expenses connected with geological exploration, arrangement of field works, drilling, as well as transport and processing infrastructure for the integrated development of the resource potential of the Arctic MRC.

The revenue comes mostly from the returns of oil export along the Northern Sea Route to the Asia–Pacific countries, and from the returns of LNG export. The revenue of the MRC project implementation over the period of 2021–2050 will be USD 1517 billion.

The investment in transportation routes will be USD 92 billion, including USD 2.3 billion spent for the construction of the sea port and USD 4.1 billion for the construction of two airdromes. Such transport infrastructure assumes enlargement of the ice-class tanker fleet at the total cost of USD 2.1 billion.
The capital investments in the system of communication include 3.5 thousand kilometers of electrical grid facilities, 2 thousand MW of power generation, 15 mining towns (200 people), intra-field and extra-field road construction 4.5 thousand kilometers in total length, as well as 3 reservoir parks.

The number of producing wells depends on the area of a promising field and on the well density. The total number of oil producing and injection wells is 5130 and 3422, respectively. It is planned to perform drilling uniformly within 2021–2050. The total number of gas producing wells is 1650 subject to the drilling experience gained at the similar objects.

The economic geology modeling produces characteristic indicators of the Arctic MRC efficiency, including enlargement of resources and communications for the sustainable functioning of all processes connected with production and transport (Table 1).

Organization of the Arctic MRC can ensure high budget efficiency. The collected taxes and charges due and payable at all levels of budgeting over the period of 2021–2050 can total USD 696 billion. At the same time, the values of the investment attractiveness criteria of the Arctic MRC organization point at the economic inefficiency of the project over the test horizon period.

The project has a high multiplier effect on the allied industries and on the spatial development in the northern areas of the Krasnoyarsk Krai. The system of communications created in organization of the Arctic MRC assumes participation of allied companies in power engineering and transport, and involvement of many specialists of various qualifications. For this reason, the authors systematize the effects achieved on the national and corporate scales in qualitative terms (see Table 1) and in qualitative terms (Table 2).

Table 1. Summary financial and economic indicators for 2021–2050 period of development

<table>
<thead>
<tr>
<th>Indicator</th>
<th>MRC</th>
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<tbody>
<tr>
<td>Oil production up to 2050, Mt</td>
<td>2631.0</td>
</tr>
<tr>
<td>Design rate of oil exploration, Mt/yr</td>
<td>115.0</td>
</tr>
<tr>
<td>Gas production up to 2050, Bm³/y</td>
<td>1109.0</td>
</tr>
<tr>
<td>Design level of gas exploration, Bm³/y</td>
<td>48.0</td>
</tr>
<tr>
<td>Rate of return, USD billion</td>
<td>1517.4</td>
</tr>
<tr>
<td>Capital costs, USD billion</td>
<td>213.9</td>
</tr>
<tr>
<td>Including (USD billion)</td>
<td></td>
</tr>
<tr>
<td>Geological exploration</td>
<td>14.3</td>
</tr>
<tr>
<td>Drilling</td>
<td>57.0</td>
</tr>
<tr>
<td>Field arrangement</td>
<td>50.3</td>
</tr>
<tr>
<td>Communications and infrastructure</td>
<td>92.1</td>
</tr>
<tr>
<td>Operating costs, USD billion</td>
<td>980.4</td>
</tr>
<tr>
<td>Taxes, USD billion</td>
<td>696.4</td>
</tr>
<tr>
<td>Before-tax income, USD billion</td>
<td>315.9</td>
</tr>
<tr>
<td>Profit tax, USD billion</td>
<td>63.1</td>
</tr>
<tr>
<td>Net profit, USD billion</td>
<td>252.7</td>
</tr>
<tr>
<td>CF, USD billion</td>
<td>252.7</td>
</tr>
<tr>
<td>NPV, USD billion</td>
<td>–43.0</td>
</tr>
<tr>
<td>IRR, %</td>
<td>6.5</td>
</tr>
<tr>
<td>Profitability index, units</td>
<td>0.7</td>
</tr>
<tr>
<td>Payback period unadjusted for discounting, years</td>
<td>17.0</td>
</tr>
<tr>
<td>Payback period adjusted for 10% discounting, years</td>
<td>30.0</td>
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The construction and workload of the shipbuilding facilities will promote formation of an inhouse tanker fleet. Shipment of 115 Mt of oil by 2030 will take around 39 Arc 7 tankers, and shipment of 35 Mt of LNG (48 Bm³) needs 11 Arc 7 tankers of the same capacity. This stimulates construction of the appropriate infrastructure and development of the allied industries. For instance, arrangement of a system of communications aimed to maintain sustainable production infrastructure in the area of the MRC will promote creation of new jobs and employment of local population, lowering of migration from population centers and shrinkage of unemployment.

One of the major multiplier effects on the national scale is the growth of population and improvement of the quality of life in the regions having low social and demographic indicators. Russia has a similar experience in development of the oil and gas industry by means of formation of the West Siberian Petroleum MRC in the Khanty Mansi Autonomous Okrug. That large-scale project was supported by the state and resulted in the growth of population, foundation of new cities, townships and plants, and in creation of a transport system integrated in the international streams of traffic. The population also grew thanks to the national policy aimed to ensure establishment of people in the area.

Finally, the tools of the governmental promotion of the MRC development are defined primarily by the effects of the projects on the national scale, as well as by the performance of the companies that implement these

Table 2. Indicators of multiplier effect due to spatial organization of the Arctic Mineral Resource Center

<table>
<thead>
<tr>
<th>National scale</th>
<th>Corporate scale</th>
</tr>
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<tbody>
<tr>
<td>Increased tax revenues in federal budget (VAT, export duty).</td>
<td>Increased capitalization.</td>
</tr>
<tr>
<td>Increased national revenue (state participation income, international reserves, National Wealth Fund).</td>
<td>Attraction of foreign investors.</td>
</tr>
<tr>
<td>Increased macroeconomic indicators (GDP).</td>
<td>Public–private partnership.</td>
</tr>
<tr>
<td>National security enhancement in the Arctic region and in the whole country.</td>
<td>Growth of permanent assets.</td>
</tr>
<tr>
<td>Territorial integrity, national boundary protection.</td>
<td>Potential tax remissions.</td>
</tr>
<tr>
<td>Trade workload of the Northern Sea Route.</td>
<td>Advance through horizontal and vertical integration of process flows and assets.</td>
</tr>
<tr>
<td>Increased personal income etc.</td>
<td>Leadership of oil and gas supplier on internal and external markets.</td>
</tr>
<tr>
<td></td>
<td>Entrance to promising market of LNG.</td>
</tr>
<tr>
<td></td>
<td>Enhanced labor efficiency etc.</td>
</tr>
</tbody>
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projects as their performance simulates the social, economic and technological advancement and solves the problems of the national significance.

Conclusions

Organization of mineral resource centers has a strategic value for the integrated territorial development either in Russia or in other countries (Canada, Norway, Finland, Sweden) in terms of advancement of their Arctic zones, workload of the Northern Sea Route, as well as creation of social and engineering facilities in remote areas far from the main regional communications. Implementation of such large-scale projects involves the conventional risks connected with changes in national rates of exchange and in prices of hydrocarbons on the global market, and also the risks of sanctions against the business and the country in the spheres of technologies and finance. Irrespective of the high risks and the scale of investments required, the Arctic MRC is a source of a high multiplier effect on all allied industries and is a driver of the spatial development. The MRC project is of strategic importance for the advancement in the Arctic zone, and can enhance the social and economic significance of the Arctic and improve the spatial organization in this area.

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References


