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.

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SPATIAL ORGANIZATION OF ARCTIC MINERAL RESOURCE CENTERS

In modern conditions of geopolitical instability, the problem of developing regional space to strengthen territorial integrity and ensure energy security is becoming increasingly important. The organization of mineral resource centers (MRC) is one of the effective forms of spatial development, especially for the regions of the Arctic zone. MRC contribute to solving the problems of integrated development of energy resources and the formation of a transport and logistics framework for poorly studied territories, which governs the effective advancement of the regional economy. The article systematizes the theoretical foundations for the development of MRC and updates the prerequisites for their formation in the Arctic. A conceptual scheme of territorial development is proposed with the allocation of the Arctic MRC in the north of the Krasnoyarsk Krai, a financial and economic model is built, an assessment of the main production and technical indicators is made, and the criteria for investment attractiveness are calculated. It is shown that the expediency of organizing the Arctic MRC is defined primarily by the strategic goals and objectives of the development of the Arctic zone at the federal level, and economic efficiency – by the development of a multi-level transport and logistics infrastructure. At the same time, despite large-scale capital investments and their long payback, the authors substantiate feasibility of developing the Arctic MRC through a high multiplier effect and propose a system for its assessment on the national, regional and corporate scales.

Keywords: *Arctic region, mineral resource center, transport system, spatial organization, oil export, Northern Sea Route, social and economic development*
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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 Strategy of Russia; 2035 Energy Strategy of Russia; Regional Social and Economic Development with Regard to Infrastructure; 2035 Strategy of Development of Mineral Resources and Mineral Reserves of Russia; 2030 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 as a multiregional integration of social, economic and social factors on a regional and international scale.

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

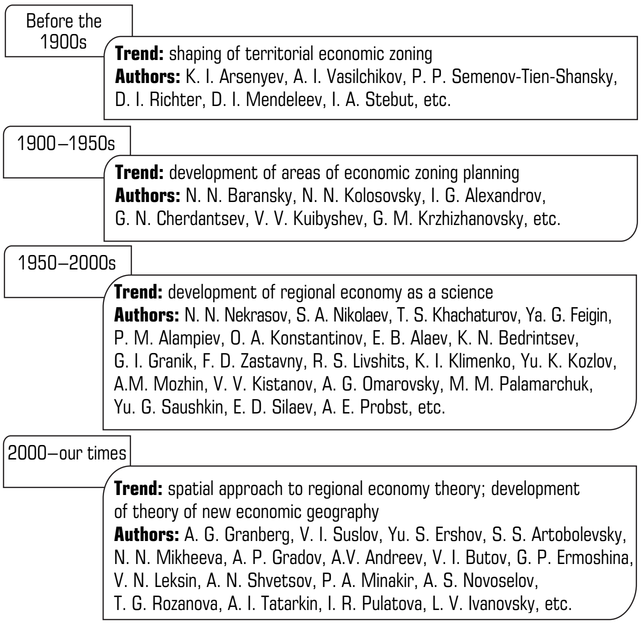

Fig. 1. Regional economy theory

theoreticians and practitioners. A solid background for the spatial development in the regions is the natural 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 technological 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, Sigurdur 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 Martinat, Bohumil Frantal, Petr Dvorak 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 manysidedness 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 strategical 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 subsoil 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;

• Adjacent distribution network to ensure integrated development and processing of strategic raw materials, and diversification of supplies of energy resources to premium markets, which is supported by the presence of the equipped sea ports with exits to the Arctic and Pacific Oceans.

In this manner, the present study aims to assess the investment efficiency in the spatial development of MRC in the Russian Arctic.

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 — Paiyakha (oil), Baikal (oil and gas), Kazantsevo (gas) and West Irkino, Turki, Deryabinskoe and North Gorchinskaya license areas;
3. East Taimyr cluster — Balakhninskoe reservoir (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 Bm^3, respectively. The recoverable oil and gas reserves make 1.94 Mt and 359 Bm^3, 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 investment efficiency evaluation procedure complied with the Investment Project Efficiency Evaluation Guide (approved by the Ministry of Economic Development, Ministry of Finance and the Ministry of Construction, Housing and Utilities of Russia, Order no VK 477 as of 21 June 1999). 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

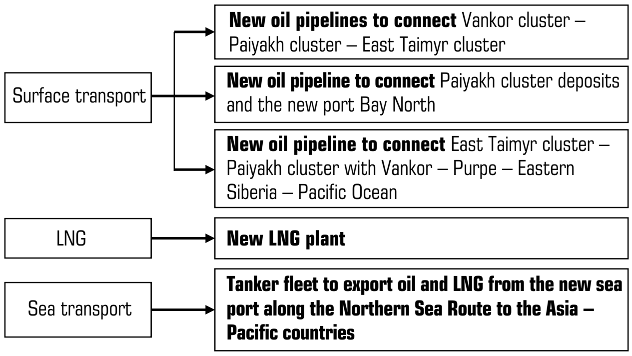

Fig. 2. Spatial organization chart for the Arctic Mineral Resource Center (compiled by the authors)

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

The oil production dynamics is described by a ϖ-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:

$$Q^*(t) = Q^d(t) + Q^s(t) + Q^f(t).$$

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

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 million 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.

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

Indicator	MRC
Oil production up to 2050, Mt	2631.0
Design rate of oil exploration, Mt/yr	115.0
Gas production up to 2050, Bm^3	1109.0
Design level of gas exploration, Bm^3/yr	48.0
Rate of return, USD billion	1517.4
Capital costs, USD billion	213.9
Including (USD billion)	
Geological exploration	14.3
Drilling	57.0
Field arrangement	50.3
Communications and infrastructure	92.1
Operating costs, USD billion	980.4
Taxes, USD billion	696.4
Before-tax income, USD billion	315.9
Profit tax, USD billion	63.1
Net profit, USD billion	252.7
CF, USD billion	252.7
NPV, USD billion	–43.0
IRR,%	6.5
Profitability index, units	0.7
Payback period unadjusted for discounting, years	17.0
Payback period adjusted for 10% discounting, years	30.0

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 quantitative terms (see Table 1) and in qualitative terms (**Table 2**).

The quantitative analysis of the indicators can involve the investment modeling. For instance, tax revenues can be calculated as a sum of all taxes and charges planned to replenish the budgets, with scale-wise differentiation, which allows tracing the project effect on the federal, regional and local scales. For similar oil and gas projects, the national scale effect can show up as oil and gas ROS (VAT, export duty) in the federal budget, estimated in the investment project. Alongside the principal sources of the federal budget income, the hydrocarbon production revenues is an important component in the balance of trade, as well as the basis of international reserves and funds.

The returns are also expected as a part of the project implementation profit, and this value can be calculated with regard to the dividend policy of a company–subsoil user.

Development of the Russian Arctic against the background of import substitution and constrained international cooperation calls for the new advanced production facilities to meet requirements of the industry. The extremely severe nature and climate of the Arctic demand new technologies to be evolved. For another thing, the MRC and its infrastructure can become a principal consumer of the domestic industry, and can spur the domestic demand for the products of various industries at an increment equivalent to 2% GPD yearly.

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 Bm^3) 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

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

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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