SOCIAL AND ECONOMIC DEVELOPMENT

Arctic and North. 2023. No. 50. Pp. 5–18
Original article
UDC [553.3/.9:33](985)(045)
doi: 10.37482/issn2221-2698.2023.50.5

Spatial Organization of the National Economy in the Development of Non-Ferrous Metal Deposits in the Western Part of the Russian Arctic

Sergey V. Belov [1]✉, Intern
Vladimir A. Skripnichenko [2], Dr. Sci. (Econ.), Cand. Sci. (Geol. and Mineral.), Professor

[1] Luzin Institute for Economic Studies — Subdivision of the Federal Research Centre "Kola Science Centre of the Russian Academy of Sciences", ul. Fersmana, 24a, Apatity, 184209, Russia
[2] Northern (Arctic) Federal University named after M.V. Lomonosov, Naberezhnaya Severnoy Dviny, 17, Arkhangelsk, 163002, Russia
[1] belov.sergeiy@gmail.com ✉, ORCID: https://orcid.org/0000-0001-9118-4439
[2] v.skripnichenko@narfu.ru, ORCID: https://orcid.org/0000-0002-4108-842X

Abstract. The article analyzes the possibilities of studying the issues of the interterritorial distribution of the economy, taking into account maritime communications in the development of solid minerals in the western sector of the Russian Arctic on the basis of interaction of national and corporate interests at the regional level. Relatively large deposits of solid minerals are located in this region. The development of non-ferrous metal deposits, taking into account the requirements of rational nature management, is the engine of economic development in the western Arctic regions of Russia. An urgent task is the scientific substantiation of favorable conditions for the comprehensive development of marine activities, necessary technological and human potential, economic benefits from the use of domestic marine potential, mineral resources and spaces of the western part of the Russian Arctic in the interests of national security, economic development and improving the welfare of citizens of the Russian Federation. The information framework is based on the experience of developing lead-zinc ore deposits in the Arctic. The topic under study is consistent with the provisions of regional and sectoral economics, as well as spatial economics. This scientific basis makes it possible to substantiate the spatial organization of the national economy in the development of solid minerals in the western part of the Russian Arctic.
Keywords: *spatial organization, national economy, solid minerals, marine communication*

Acknowledgments and funding

The authors express their sincere gratitude to Doctors of Economic Sciences Kozmenko S.Yu. and Ivanova M.V. for their consultations.

Introduction

The relevance of the research topic is confirmed by the theory of new economic geography in the study of inter-territorial distribution of the economy, taking into account maritime communications and the development of theoretical foundations of the Russian scientific school in the issue of the spatial organization of the national economy in the development of solid minerals in the western sector of the Russian Arctic. The development of non-ferrous metal deposits in this

For citation: Belov S.V., Skripnichenko V.A. Spatial Organization of the National Economy in the Development of Non-Ferrous Metal Deposits in the Western Part of the Russian Arctic. *Arktika i Sever* [Arctic and North], 2023, no. 50, pp. 5–22. DOI: 10.37482/issn2221-2698.2023.50.5

region is of great importance for the national economy. In the western part of the Russian Arctic, along with oil and gas deposits, reserves of non-ferrous metal ores have been discovered, some of which are mined, and new deposits should be included in development. Geological mapping, prospecting, evaluation, exploration and extraction of non-ferrous metal ores should be accompanied by their processing and transportation by container ships to consumers, mainly by sea. The problem of the spatial organization of the national economy in the development of solid minerals in the western part of the Russian Arctic is relevant, its solution is necessary for the development of mineral resources in the economic activity of Russia. Modernization of maritime transport communications, which are of strategic importance for the economic and national security of the country, is urgent. In accordance with the state program for the development of the Arctic [1] and the Marine Doctrine of Russia [2], a significant activation of productive forces is required within the Arctic territories of the country, including the development of new deposits of solid minerals.

The urgent task is to provide scientific substantiation of favorable conditions for comprehensive development of maritime activity, necessary technological and human resources, obtaining economic benefits from the use of domestic maritime potential, mineral resources and spaces of the western part of the Russian Arctic in the interests of national security, economic development, and welfare of citizens of the Russian Federation.

Problem statement

The information framework is based on the experience of developing lead-zinc ore deposits in the Arctic. The topic under study is consistent with the provisions of regional, sectoral and spatial economics, the theory of which was promoted by foreign [1, Lesh A.], [2, Krugman P.] and domestic [3, Granberg A.G.], [4, Minakir P.A.], [5, Tatarkin A.I., Litovskiy V.V.] scientists. This scientific base allows substantiating the spatial organization of the national economy in the development of solid minerals in the western part of the Russian Arctic. The paper shows the impact of the marine communication networks in order to transport ores and concentrates from mining enterprises to consumers, as well as in the integrated development of the natural resources of the Arctic in the unity of spatial development.

This scientific framework provides a rationale for the spatial organization of the national economy in the development of solid minerals in the western part of the Russian Arctic.

[1] Gosudarstvennaya programma Rossiyskoy Federatsii "Sotsial'no-ekonomicheskoe razvitie Arkticheskoy zony Rossiyskoy Federatsii". Utverzhdena postanovleniem Pravitel'stva Rossiyskoy Federatsii ot 30 marta 2021 g. № 484 [State program of the Russian Federation "Socio-economic development of the Arctic zone of the Russian Federation". Approved by Decree of the Government of the Russian Federation of March 30, 2021 No. 484]. URL: https://base.garant.ru/400534977/ (accessed 20 July 2022).

[2] Morskaya doktrina Rossiyskoy Federatsii Utverzhdena Ukazom Prezidenta Rossiyskoy Federatsii 31.07.2022 g. № 512 [Maritime Doctrine of the Russian Federation Approved by Decree of the President of the Russian Federation on July 31, 2022 No. 512]. URL: http://www.kremlin.ru/acts/bank/48215 (accessed 20 July 2022).

Methodology

The aim of the study is to solve the task of developing the spatial organization of sea communications for solid minerals deposits exploitation in the Western Arctic. In order to achieve the goal, the following tasks are solved:

- to substantiate the addition of the theory of spatial and regional economics in terms of the development of non-ferrous metal deposits by adjusting the interests of the regional and sectoral economy in the western part of the Arctic;
- to determine the spatial organization of the national economy, the spatial distribution of economic resources in the western part of the Arctic zone of Russia, taking into account domestic and foreign experience in the development of solid minerals in the Arctic;
- to analyze regional economic development and factors of state of mineral resource base of the Western Arctic to diagnose the constraints for the effective development of non-ferrous metal ores and the spatial organization of the national economy;
- to assess the level of balance between the spatial organization of the development of non-ferrous metal deposits in the western part of the Arctic zone of Russia and the pricing environment and demand in world markets;
- to propose directions for modernization of spatial organization in the development of solid minerals deposits on the basis of balanced communications in the Western Arctic for the extraction, processing and transportation of mineral resources;
- to identify the impact of spatial organization in the development of lead-zinc ore deposits in the western part of the Arctic zone of Russia in order to assess the region's role in the national economy, its contribution to the economic development of the country.

Discussion

The spatial organization of the national economy and distribution of economic resources as a scientific and methodological basis are used in the study of socio-economic mechanisms in the Arctic [6, Kudryashova E.V., Sorokin S.E.], [7, Selin V.S., Larichkin F.D., Tsukerman V.A., Goryachevskaya E.S.]. Regional economic development and its factors are also considered, the problems of balancing regional socio-economic complexes, including the organization of maritime communication network, routes and water areas of the Northern Sea Route in the development of mineral resources (oil, gas, solid minerals) are evaluated [8, Ivanova M.V., Kozmenko A.S.], [9, Kozmenko S.Yu.], [10, Kondratyev V.B.].

Scientific problems of studying the socio-economic mechanism of development of non-ferrous metal deposits in the Arctic are most fully addressed in the works [11, Dodin D.A., Ivanov V.L.], [12, Dodin D.A., Ivanov V.L., Kaminskiy V.D.], [13, Mikhailov B.K., Vorobyov Yu.Yu., Kimelman S.A.], [14, Skripnichenko V.A.], [15, Cherepovitsyn A.E., Lipina S. A., Evseeva O.O.].

The development of the Arctic is strategically included in the Russia's system of interests, and the exploitation of non-ferrous metal deposits is one of the national security sectors of the state in ac-

cordance with the Constitution of the Russian Federation and the Law of the Russian Federation "On Subsoil". The western part of the Arctic zone of Russia is bounded by the eastern border of the Vilkitskiy Strait (meridian 105°54'E). The region under study is distinguished from the territory of the Russian Arctic zone by the criterion of localization of mineral reserves, allowing for the extraction of non-ferrous metals (copper, nickel, zinc and lead). According to the specified criterion, it is necessary to single out a region that includes mineral resource centers for the extraction of solid minerals within the Western Arctic supporting zones. The state program "Reproduction and use of natural resources" contains the terms "priority territories", which include the Russian Arctic. The implementation of the Program will provide conditions for the stable development of the Arctic, mining and manufacturing industries in priority areas through the exploitation of non-ferrous metal ores. The most promising deposits are the Pavlovskoe lead-zinc ore deposit on the Novaya Zemlya archipelago, as well as similar deposits on Vaygach Island and in the Polar Urals. These deposits are located within the western sector of the Russian Arctic. Transportation of ores and concentrates of non-ferrous metals is done mainly by sea. In the Arctic, along with hydrocarbons, apatite and barite ore, platinoids and gold, nickel, copper and cobalt are mined. The development of zinc and lead deposits is planned.

Development of the economy of the western part of the Russian Arctic on the basis of domestic and foreign experience of solid minerals exploitation

Freight traffic along the Arctic Sea routes is almost entirely represented by cargos that need to be delivered during the extraction of minerals. The authors have only touched upon the issues of transportation of copper-nickel ores, lead-zinc ores, rare and precious metals ores. Russian and foreign experience of spatial organization in the development of non-ferrous metal deposits in the western part of the Russian Arctic shows that the development of the region has great growth prospects (twofold). Prospects for the discovery of non-ferrous metal deposits take place in the Arctic territories of Russia, the USA, Canada and Greenland [3].

Analysis of the table 1 shows that the Russian Arctic territory has the richest variety of non-ferrous metal ores in comparison with foreign countries. Geologists predict the greatest growth in the production of non-ferrous metals in the western part of the Russian Arctic on the Kola Peninsula, in Karelia, in the Arkhangelsk Oblast, in the Nenets and Yamalo-Nenets Autonomous okrugs.

The spatial organization of the national economy in the western part of the Arctic zone of Russia involves the connection of mines, quarries, pits with seaports and sea routes of the Arctic Ocean.

The development of spatial organization is determined by the following factors:

- increased international attention to the Arctic, including numerous research projects;
- balance of the Arctic socio-economic complexes in Russia and in the foreign Arctic based on the mineral resource potential;

[3] Poleznye iskopaemye v Arktike. Oznakomlenie [Minerals in the Arctic. Acquaintance]. NGU. Geological Survey of Norway. Skipnes Communication AS. 1st edition 2016. URL: https://www.ngu.no/sites/default/files/Mineral_Resources_Artic_Russian_screen.pdf (accessed 20 July 2022).

- assessment of the role of the Western Arctic in the national economy, its contribution to the economic development of the country on the basis of new large deposits of non-ferrous metals;
- monitoring of the socio-economic development of the western part of the Russian Arctic, analysis of the dynamics of the strategic minerals exploitation;
- achieving access through the long-term opening of Arctic shipping lanes, combined with wide access to ice-class container ships and nuclear-powered icebreakers.

Preparation of non-ferrous metal deposits for development and construction of the infrastructure necessary for the extraction and transportation of ores is the result of the search, evaluation and exploration of deposit reserves, which prove the profitability of the development of mineral resources in the Arctic. Non-ferrous metal deposits in areas with logistical challenges must have high grades of the useful component in the ore or large reserves in order to attract significant investment from domestic and foreign investors.

Table 1

Solid mineral resources of the Arctic [10, Kondratiev V.B.] [4]

Country	Resorces
Denmark (Greenland)	Gold, molybdenum, nickel, platinum group elements, rare earth metals (tantalum, niobium)
Canada	Diamonds, gold, gypsum, iron ore, lead, uranium, zinc
USA (Alaska)	Zinc (67 Mt), Lead (67.6 Mt)
Sweden	Iron ore (2413 Mt)
Norway	Iron ore (1000 Mt)
Russia	Apatite, ceramic raw materials, coal, cobalt, copper, diamonds, gold, gypsum, iron ore, molybdenum, nickel, palladium, platinum, silver, precious stones, rare earth metals, tin, titanium, zinc. The total value of reserves is 1.5–2 trillion dollars.

Figure 1 shows the scheme of spatial organization of lead-zinc deposits development in the western part of the Arctic zone of Russia.

Regional space	Deposits oF Novaya Zemlya and Polar Urals
Maritime territories Arkhangelsk Oblast, Nenets Autonomous Okrug, Yamalo-Nenets Autonomous Okrug	Existing and planned infrastructure (marine communications)
Water areas Barents Sea, Pechora Sea, Kara Sea	Shipping points Offshore transshipment complexes of the Barents Sea Fleet Container ships, bulk carriers, auxiliary vessels, icebreakers Port complexes Murmansk, Arkhangelsk, Amderma, “Port on Novaya Zemlya” and “Indiga” under construction

Fig. 1. Scheme of spatial organization of lead-zinc deposits development in the western part of the Arctic zone of Russia.

[4] Source: URL: https://mining-media.ru/ru/article/newtech/15541-mineralnye-resursy-i-budushchee-arktiki (accessed 20 July 2022).

Prerequisites and constraints for effective development of non-ferrous metal ores and spatial organization of the national economy in the western part of the Arctic zone of Russia

In recent years, Russia has restored the system of strategic planning, defined plans for spatial and economic development of the state, including the Arctic territories with deposits of non-ferrous metals. Development of the Arctic territories is envisaged by state documents that determine the intensification of the development of the Northern Sea Route as an international maritime communication and transit corridor to the countries of the Asia-Pacific region. The Northern Sea Route is of great importance for coastal areas that have access to the Arctic shoreline with a long coastline and poorly developed land communications. The role of sea routes connection to river waterways and railways for transportation of ores and ore concentrates of non-ferrous metals is significant. The problems of spatial development of sea communications for the extraction of non-ferrous metal ores consist in the necessity of building new sea ports and reconstruction of the existing ones, construction of ice-resistant container ships, installation of modern navigation equipment along the Northern Sea Route [17, Belov S.V., Skripnichenko V.A.].

The main problems of creating the Arctic marine communications are the following:

- negative temperatures prevail throughout the year, the sea level changes in the tidal zone, sea ice and icebergs on the routes complicate the situation; when carrying out prospecting and exploration work, developing deposits and transporting ores, hydrometeorological monitoring of the water areas is required;
- monitoring of ore transportation should be established to avoid oil spills from transport vessels, which may cause damage to the environment;
- necessity of construction and development of winter roads in coastal areas from mining enterprises to port complexes during winter seasons;
- use of surface communications to transport ores by rail is cost-effective in the long-term development of deposits, as the construction of railways also takes a large amount of time.

Environmental risks and risks to the profitability of non-ferrous metal deposits should be taken into account.

When transporting copper-nickel ores and concentrates, the leading position is occupied by the Arctic ports, which provide year-round navigation support along the Murmansk — Dudinka route to ensure the operation of the PJSC MMC Norilsk Nickel. These actions encourage companies developing non-ferrous metal deposits to invest in the creation of a specialized fleet (Arc7 class or higher) and icebreakers [16]. The consumption of high-tech metals in the world is planned to increase several times by 2035. Huge geological reserves of non-ferrous, rare, rare-earth and precious metals, which are used in Russia or can be sold abroad, have been discovered and estimated in the Arctic. The extraction of “battery” metals is carried out at the Arctic deposits in the Murmansk Oblast, the Krasnoyarsk Krai and Yakutia [16, Belov S.V., Skripnichenko V.A.].

The prospects for the development of non-ferrous metal deposits are related to the distance to the Arctic Ocean coast and navigable rivers, which allows using water transport for cargo delivery. The spatial organization of communications in the extraction of non-ferrous metals is a combination of water, land and air routes. Efficient operation of these routes will require the construction of new port complexes, stations and airports in the Arctic region.

Copper-nickel ores with associated extraction of rare elements and platinum group metals have been mined in the Norilsk district of the Krasnoyarsk Krai for decades. Transport communications include the Dudinka port complex, sea and river vessels, railway lines, Alykel airport, airplanes and helicopters. Concentrates of non-ferrous metal ores are delivered by container ships to the port of Murmansk and to consumers in Europe, Asia and America [16]. PJSC Norilsk Nickel is one of the world's largest producers of nickel, palladium, platinum and copper. The company has a Polar branch in the Krasnoyarsk Krai, the Kola Mining and Metallurgical Company on the Kola Peninsula and assets abroad. The Polar branch includes six mines (Zapolyarnyy, Mayak, Komsomolskiy, Oktyabrskiy, Skalistyy, Taymyrskiy), one open pit (Medvezhiy Ruchey), three processing plants (Norilskaya, Talnakhskaya, Aglomeratsionnaya), three metallurgical plants (Mednyy, Nikelevyy, Nadezhda), one refinery (Krasnoyarsk), three gas fields (Pelyatka, Solenoe, Messoyakha), one HPP (Khantayskaya). The Kola Mining and Metallurgical Company unites three mines (Tsentralnyy, Severnyy-Glubokiy, Kaula-Kotselvaara), the Zapolyarnaya processing plant, a roasting plant in Pechenga, a refinery in Monchegorsk, and a smelter in Nikel. Dudinka is the largest port in Siberia; it has received the status of an international port. The port is year-round connected by sea with the ports in Murmansk and Arkhangelsk; in the summer, there is a river connection with the ports of Krasnoyarsk and Dikson. Year-round railway and road communication are established between the port of Dudinka and the city of Norilsk, as well as the Alykel airport [17, Tarkhov S.A.].

The Pavlovskoe lead-zinc deposit was discovered on the Novaya Zemlya archipelago in the Arkhangelsk Oblast. Ore reserves at the deposit are protected by the State Reserves Commission, and a business plan for the mining and processing plant has been approved. The port complex is planned to be built in the bay of the Bezymyannaya River, which flows into the Barents Sea. It is planned to transport zinc and lead concentrates by sea to Europe in the west and to Asia-Pacific in the east. In the Yamal-Nenets Autonomous Okrug in the Polar Urals, the Saureyskoe lead-zinc deposit [18, Kontar E.S.], the Ray-Iz chromite deposit [19, Markov V.E., Karelina E.V., Emsigarrell D.Sh.], the Novogodnee-Monto gold deposit [20, Kuznetsov V.I., Pryamonosov A.P., Grigoriev V.V.] are known. The listed deposits are located away from the sea coast and navigable rivers. In order to develop the Saureyskoe deposit, a motorway to the railway should be provided. In the Soviet period, lead-zinc ores were mined underground on Vaygach Island, the deposits of which have been mothballed. The port of Varnek is in the southern part of Vaygach Island, near the Yugorskiy Shar Strait.

In the western part of the Arctic, the Pizhemskoe placer titanium deposit in the north of the Komi Republic [21, Ponaryadov A.V.], chromite deposits of the Polar Urals, Karelia and the Kola

Peninsula are promising for development. Over the past 12 years, from 2008 to 2020, the following achievements have been made in the development of the Arctic zone [22, Zhuravel V.P.]:

- maritime transport along the Northern Sea Route has increased substantially in volume, from 1.9 million tons in 2006 to 26 million tons in 2019;
- the reason for the increase in the number of sea transportations is active development of mineral deposits: liquefied natural gas, oil, copper-nickel ores and coal. An insignificant volume of shipping is accounted for by Northern Delivery and international transit traffic;
- new domestic icebreakers are being built;
- the natural environment of the Arctic is being protected and the ecological consequences of economic activity in the USSR are being eliminated. Since 2012, more than 80.000 tons of hazardous waste have been removed from the Russian Arctic. In 2009, the Russian Arctic National Park started functioning on Novaya Zemlya, which is visited by tourists and students;
- development of the Arctic zone of Russia implies the national security of the northern borders of the country. Since 2012, 475 military facilities, 9 new military bases have been built in the Arctic, 16 deep-water ports have been reconstructed and 13 airfields have been restored;
- in 2019, S-400 air defense missile systems were deployed on Novaya Zemlya, and a continuous field with Container radar stations along the country's Arctic borders is planned to be created;
- in 2035, the volume of traffic along the Northern Sea Route should reach 160 million tons. The development of sea, river, land and air transport communications, the modernization of telecommunications infrastructure should ensure a high level of well-being in the Arctic [16].

The economic development of solid minerals depends on current (traditional) and prospective (new) trends (Table 2).

Table 2

Trends in the development of mineral resources in the Arctic region

Traditional	New
Increasing the production costs of non-ferrous metal ores of Arctic deposits	Start of development of new lead-zinc deposits in the Paykhoy-Novozemelsk region
Demand stagnation of traditional consumers of non-ferrous metal ores in Europe	Significant growth in demand for non-ferrous metal ores in the Asia-Pacific region

There is an increase in the cost of mining non-ferrous metal ores in the Arctic deposits and a decline in demand among consumers of non-ferrous metal ores in Europe. It is necessary to plan production at new lead-zinc deposits in the Paykhoy–Novozemelsk region in the context of global warming with a significant increase in demand for non-ferrous metal ores in the countries of the Asia-Pacific region.

Degree of dependence of the spatial organization of solid minerals development in the western part of the Arctic zone of Russia on pricing environment and demand

Transport remoteness of the Arctic deposits of non-ferrous metals from consumers is the main obstacle to strengthening the competitive economic position of Russia in the non-ferrous metal markets in Europe and the Asia-Pacific region. International flows of ore and concentrates to China, Korea and Japan have increased due to growing demand for solid minerals from Asian countries.

Between 2000 and 2019, the growth of transported volumes amounted to 109%: from 50.0 million tons to 104.3 million tons. There was a significant increase in demand for raw materials for batteries that use non-ferrous and rare metals. Production of lithium, gallium and cobalt increased several times between 2000 and 2018. China ranks first in imports of zinc ore, as the construction of infrastructure facilities increases demand for galvanized steel. South Korea is a large consumer of zinc with ore imports of 2.07 million tonnes in 2019, accounting for 16.7% of the global share. Japan is one of the leading importers of zinc concentrate [23, Rastyannikova E.V.].

Lead is needed in the manufacture of batteries, in radiation protection devices at X-ray facilities, in the protection system of nuclear reactors, and for containers during the transportation of radioactive materials. Russian exports of lead concentrate to China in 2019 increased by 30% compared to the previous year, 368 thousand tons were sold to China, which is the world leader in the production of refined lead, accounting for about 50% of the produced metal. The Republic of Korea is increasing imports of lead ores and concentrates, with raw material purchases increasing by 8% in 2015–2019. In Japan, the import of lead ore temporarily decreased by 1% per year, dropping to 132 thousand tons, or 3.9 % of the world import [23, Rastyannikova E.V.].

The system of maritime transport communications in the Western Arctic is currently poorly developed. Of the nine ports in the Western Arctic, only Murmansk, Sabetta and Dudinka have access to large-tonnage tankers with deadweight over 45.000 tons. Rapidly developing countries (China, the Republic of Korea, Japan) are interested in importing non-ferrous metal ores, which can be mined in the Russian Arctic and delivered via the Northern Sea Route to the Asia-Pacific countries [23, Rastyannikova E.V.].

Directions of modernization of spatial organization in the development of solid mineral deposits on the basis of conjugation of communications in the western part of the Arctic zone of Russia

There are seventeen seaports in the Polar region of the country. Ports are divided into four groups according to their importance. The first group includes ports with railway communications: Murmansk, Vitino, Kandalaksha, Onega and Arkhangelsk. The second group is represented by ports served by specific mining companies. The port of Varandey operates for the Lukoil oil company, and the port of Dudinka serves the Norilsk Nickel company. The third group of ports has no railway lines: Mezen, Naryan-Mar, Amderma, Sabetta, Dikson, Khatanga, Tiksi, Anadyr, Pevek, Egvekinot, Beringovskiy, Provideniya. The fourth group includes the projected port on Novaya Zemlya in the Bezymyannaya Bay near the Pavlovskoe lead-zinc deposit and the projected port of

Indiga on the Northern Timan in the Nenets Autonomous Okrug [24, Botnaryuk M.V.].

The deep-sea port of Indiga, which is under construction, is promising, provided that a railway is built through the Nenets Autonomous Okrug and the Komi Republic. The location of this port near numerous non-ferrous metal ore fields in the Northern Timan may provide an opportunity for their additional exploration and development. Coal and oil terminals, a liquefied natural gas terminal, a transshipment complex and specialized berths are planned in the port. The construction of the Indiga–Sosnogorsk railway line, 612 km long, will connect the port with the Vorkuta–Moscow Northern Railway. The Pechora coal basin has significant potential due to its favorable geographical location and competitive advantages. The railway from Konosha to Vorkuta was built at the beginning of the Great Patriotic War in record time using the labor of Gulag prisoners. The railway has been used to transport high-quality Vorkuta coal since the 1940s to the present. The projected railroad Vorkuta–Ust-Kara (Ust-Kara is a small seaport on the Kara Sea) is important for the development of coal deposits in the Vorkutinskoe, Khalmeryuskoe, Korotaikhinskoe and Karskoe coal fields.

The seaport under construction on Novaya Zemlya is linked to the Pavlovskoe field development project, signed by the government of the Arkhangelsk Oblast and enterprises of the State Corporation Rosatom – Atomredmetzoloto and JSC First Mining Company in 2019. More than 800 jobs will be created in the Arkhangelsk Oblast to recruit workers for the mining company and the port complex, an additional “front of work” will be created for many enterprises in the region. Tax revenues to the Arkhangelsk Oblast budget will be at least 1 billion rubles a year.

It is planned to deliver the necessary building materials, mining equipment, mining mechanisms for the construction of a mining plant, a processing plant and a port complex, as well as to transport the finished products of the mining and processing plant: silver-containing lead and zinc concentrates. It is necessary to organize rotational shifts for the mining and processing plant; delivery of materials to support the plant's operations at the deposit as well as fuel and vehicles is envisaged; food delivery is planned.

The construction of the port complex is determined by the depths of the water area for the means of cargo delivery and technological safety requirements. The port terminal will be built at a distance of 15–18 km from the mining and processing plant [25, Belov S.V., Skripnichenko V.A.].

The port complex includes an approach fairway and water area with the necessary navigational equipment; a berth for a transshipment complex for ore concentrates is provided; transshipment of heterogeneous cargoes is planned; power lines, water treatment system, conduit; roads, road bridge across the Britvinka River. The coastline in the area of the planned port complex is difficult for the placement of onshore transport communications. The Novaya Zemlya archipelago is characterized by harsh conditions with long winters, winds and snowstorms. The port complex is to be built in an undeveloped area of the archipelago. The construction conditions are very difficult, characterized by the presence of permafrost. Care must be taken with the technology impact on highly sensitive tundra surfaces.

The process of modernization of the Arctic transport system is a complex technological task, the main focus of which is the profitable development of deposits and transportation of non-ferrous metal ores.

Impact of spatial organization in the development of lead-zinc ore deposits on national economic development in the western part of the Arctic zone of Russia

The Pavlovskoe lead-zinc deposit has been prepared for development by the JSC First Mining Company. Design of the mining company started in 2019; lead and zinc were not mined within the Arctic zone of Russia.

The Saureyskoe deposit of lead and zinc is located in the Polar Urals within the Yamalo-Nenets Autonomous Okrug. The development of the deposit is not carried out yet.

The Amderminskoe lead-zinc-fluorite deposit is located on the coast of the Kara Sea in the Northern Pay-Khoy near the village of Amderma within the Nenets Autonomous Okrug. Fluorite was mined from 1932 to 1951 and is currently mothballed. The ores are represented by fluorite, sphalerite, galena and pyrite. The zinc content in the ores ranges from 0.33 to 1.11%, the lead content is 0.2%. At a depth of 100 m, the concentration of lead and zinc in the ore increases in total to 1.5%. Lead-zinc resources have not been determined.

Lead-zinc deposits were discovered on Vaygach Island, where ore was mined from 1931 to 1934. Ore fields of lead and zinc have been discovered in the Northern Timan. Additional exploration is required in the above areas. These ore fields will be of interest to industry in case of construction of railways and highways in the ports of Indiga, Amderma and Ust-Kara, which are being designed and reconstructed.

The development of lead and zinc ore deposits in the Arctic territories is a new direction for the Russian extractive industries. Transportation of cargoes and mined ore from the Pavlovskoe deposit in Novaya Zemlya, Saureyskoe and Amderminskoe deposits in the Polar Urals has not been started. One of the problems is to ensure the regional security of Russia in the struggle for control over the mineral resources of the Arctic.

The Pavlovskoe deposit is located on Novaya Zemlya, Arkhangelsk Oblast, in the northwest of the Yuzhnyy Island of the archipelago, 16–17 km to the east of the mouth of the Bezymyannaya River within the Bezymyanskiy polymetallic minerogenic cluster. In 2020, exploration work was carried out to assess mineral resources in accordance with the JORC code and engineering surveys were carried out as part of the Pre-Feasibility study. Repeated public hearings on the environmental impact assessment were carried out. In 2021, the Pavlovskoe project was included in the list of projects planned for implementation in the Arctic zone of Russia. The conclusion of the ecological expertise for the construction of the mining and processing plant and the port complex was received.

As of February 2021, the resources of Pavlovskoe are estimated at 55 million tons with average zinc content of 4%, metal resources: zinc — 2 million tons, lead — 430 thousand tons, silver — 30.3 million ounces. Such an assessment of mineral resources confirms the status of Pavlovskoe

as the country's largest zinc deposit among new projects [17]. The drilling program has provided a sufficient degree of confidence in the mineral resource estimate in the open pit area. Geotechnical drilling with core orientation was carried out. The resource estimate for the Pavlovskoe deposit is based on open pit contour optimization with a forecast price of $3145/t for zinc, $2176/t for lead, and $30/oz for silver. Zinc recovery is planned at 90%, lead extraction — at 53%, silver recovery into lead concentrate — 33%. The average content of zinc is 6.32%, lead — 1.26%, silver — 42.57 g/t, with a cut-off content of conventional zinc of 2%.

The Pavlovskoe investment project is aimed at the efficient development of a lead-zinc deposit. A mining enterprise will be created at the deposit to extract and process 3.5 million tons of ore per year. Products are two types of concentrate: 1) lead concentrate with silver content; 2) zinc concentrate. The annual production of concentrates on average will be the following: zinc — 260 thousand tons per year, lead concentrate with silver content — 67 thousand tons per year. It is planned to build berthing facilities 20 km from the processing plant to load containers with concentrates on container ships. The mining enterprise includes an open pit, a processing plant, a tailing dump, a 30 MW liquefied natural gas power plant, a shift camp, storage infrastructure and other facilities. The deposit is supposed to be developed on a rotational basis all the year round. The number of personnel is 436 employees. The development period is up to 14 years.

The project implementation strategy envisages construction works at the field facilities. Design and survey works include research and development of the project for construction of the mining and processing plant, necessary approvals and examinations of project documentation; development of working documentation for the construction of the MPP. Currently, as a result of unfriendly relations between Russia and the countries of Northern Europe, it is necessary to consider options for planning priority directions for the delivery of lead-zinc ores of the Pavlovskoe deposit to the countries of the Asia-Pacific region. Competitive sales of lead-zinc ores can be achieved on these routes using a combination of supply and demand options from potential buyers.

Conclusion

The spatial organization of communications during the development of solid minerals of the resource base in the western part of the Arctic zone of Russia has been determined. Numerous deposits of solid minerals are located in the Western Arctic. The development of non-ferrous metal deposits, taking into account the requirements of rational nature management, is the basis for the creation of mineral resource centers. An important task is to substantiate the necessary conditions for the development of water, land and air communications, technological and human potential, obtaining economic benefits from the use of communications, mineral resources and spaces of the western part of the Russian Arctic in the interests of ensuring national security, developing the economy, improving the welfare of citizens of the Russian Federation. The information framework is based on the experience of developing lead-zinc ore deposits in the Arctic.

References

1. Lesh A. *Geograficheskoe razmeshchenie khozyaystva* [Geographical Location of the Economy]. Moscow, 1959, 216 p. (In Russ.)
2. Krugman P. Prostranstvo: posledniy rubezh [Space: The Final Frontier]. *Prostranstvennaya ekonomika* [Spatial Economics], 2005, no. 3, pp. 121–136.
3. Granberg A.G. *Osnovy regional'noy ekonomiki* [Fundamentals of Regional Economy]. Moscow, SU HSE Publ., 2004, 495 p. (In Russ.)
4. Minakir P.A., Demyanenko A.N. Prostranstvennaya ekonomika: evolyutsiya podkhodov i metodologiya [Spatial Economics: The Evolution of Approaches and Methodology]. *Prostranstvennaya ekonomika* [Spatial Economics], 2010, no. 2, pp. 6–32.
5. Tatarkin A.I., Litovsky V.V. Rossiya v Arktike: strategicheskie prioritety kompleksnogo osvoeniya i infrastrukturnoy politiki [Russia in Arctic: Strategic Priorities of Integrated Development and Infrastructure Policy]. *Vestnik MGTU* [Vestnik of MSTU], 2014, vol. 17, no. 3, pp. 573–587.
6. Kudryashova E.V., Sorokin S.E. "The third mission" in the Arctic universities' development strategies. *Arktika i Sever* [Arctic and North], 2019, no. 34, pp. 20–43. DOI: 10.17238/issn2221-2698.2019.34.20
7. Selin V.S., Larichkin F.D., Tsukerman V.A., Goryachevskaya E.S. Problemy natsional'noy industrializatsii i promyshlennaya politika resursno-syr'evykh kompaniy Arkticheskoy zony rossiyskoy Federatsii [Problems of National Industrialization and Industrial Policy of Resource Companies in the Arctic Zone of the Russian Federation]. *Gornyy zhurnal* [Mining Journal], 2016, no. 10, pp. 25–30. DOI: 10.17580/gzh.2016.10.04
8. Ivanova M.V., Kozmenko A.S. Prostranstvennaya organizatsiya morskikh kommunikatsiy Rossiyskoy Arktiki [Spatial Management of the Shipping Routes in the Russian Arctic]. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz* [Economic and Social Changes: Facts, Trends, Forecast], 2021, vol. 14, no. 2, pp. 92–104. DOI: 10.15838/esc.2021.2.74.6
9. Kozmenko S.Yu. *Prognozirovanie i regulirovanie razvitiya territorial'nykh sotsial'no-ekonomicheskikh sistem v usloviyakh konversii: dis. dok. ekon. nauk* [Forecasting and Regulation of the Development of Territorial Socio-Economic Systems in the Context of Conversion: Dr. Econ. Sci. Diss.]. Saint. Petersburg, 1995, 292 p. (In Russ.)
10. Kondratiev V.B. Mineral'nye resursy i budushchee Arktiki [Mineral Resources and Future of the Arctic]. *Gornaya promyshlennost'* [Mining Industry Journal], 2020, no. 1, pp. 87–96. DOI: 10.30686/1609-9192-2020-1-87-96
11. Dodin D.A., Ivanov V.L. Mineral'no-syr'evoy potentsial rossiyskoy Arktiki i ego rol' v razvitii ekonomiki [Mineral Resource Potential of the Russian Arctic and Its Role in the Development of the Economy]. *Razvedka i okhrana nedr* [Prospect and Protection of Mineral Resources], 2000, no. 12, pp. 17–23.
12. Dodin D.A., Ivanov V.L., Kaminsky V.D. Rossiyskaya Arktika — krupnaya mineral'no-syr'evaya baza strany (k 60-letiyu VNIIOkeangeologiya) [Russian Arctic Sector is the Great Mineral-Resources Base of this Country (To the Sixtieth Anniversary of VNIIOkeangeologiya). *Litosfera*, 2008, no. 4, pp. 76–92.
13. Mikhaylov B.K., Vorobyev Yu.Yu., Kimelman S.A. Znachenie mineral'no-syr'evoy bazy tverdykh poleznykh iskopaemykh v ekonomike Rossii [The Value of the Mineral Resource Base of Solid Minerals in the Russian Economy]. *Mineral'nye resursy Rossii: Ekonomika i upravlenie* [Mineral Resources of Russia. Economics and Management], 2008, no. 3, pp. 18–25.
14. Skripnichenko V.A. *Sotsial'no-ekonomicheskiy mekhanizm formirovaniya proizvodstvennykh kompleksov: Na primere almaznogo kompleksa: dis. dok. ekon. nauk* [Socio-Economic Mechanism for the Formation of Industrial Complexes: On the Example of the Diamond Complex: Dr. Econ. Sci. Diss.]. Moscow, 2000, 291 p. (In Russ.)
15. Cherepovitsyn A.E., Lipina S.A., Evseeva O.O. Innovatsionnyy podkhod k osvoeniyu mineral'no-syr'evogo potentsiala Arkticheskoy zony RF [Innovative Approach to the Development of Mineral Raw Materials of the Arctic Zone of the Russian Federation]. *Zapiski Gornogo instituta* [Journal of Mining Institute], 2018, vol. 232, pp. 438–444. DOI: 10.31897/PMI.2018.4.438

16. Belov S.V., Skripnichenko V.A. Problemy prostranstvennogo razvitiya vodnykh i nazemnykh kommunikatsiy v rossiyskoy Arktike dlya dobychi rud vysokotekhnologichnykh metallov [Problems of Spatial Development of Aquatic and Terrestrial Communications in the Russian Arctic for High-Tech Metals Extraction]. *Mezhdunarodnyy nauchno-issledovatel'skiy zhurnal* [International Research Journal], 2022, no. 6–5 (120), pp. 104–108. DOI: 10.23670/IRJ.2022.120.6.111
17. Tarkhov S.A. Noril'skiy promyshlennyy rayon [Norilsk Industrial Region]. *Geografiya* [Geography], 2000, no. 23, pp. 16–23.
18. Kontar' E.S. *Geologo-promyshlennye tipy mestorozhdeniy, medi, tsinka, svintsa na Urale (geologicheskie usloviya razmeshcheniya, istoriya formirovaniya, perspektivy): nauchnaya monografiya* [Geological and Industrial Types of Deposits, Copper, Zinc, Lead in the Urals (Geological Conditions of Location, History of Formation, Prospects)]. Yekaterinburg, USGU Publ., 2013, 199 p. (In Russ.)
19. Markov V.E., Karelina E.V., McGarrell D.Sh. Strukturnaya pozitsiya khromitovogo orudeneniya na mestorozhdenii Tsentral'noe (polyarnyy Ural) [Structural Position of Chromite Mineralization at the Deposit Central (Polar Urals)]. *Vestnik Rossiyskogo universiteta druzhby narodov. Seriya: Inzhenernye issledovaniya* [RUDN Journal of Engineering Research], 2016, no. 3, pp. 41–50.
20. Kuznetsov V.I., Pryamonosov A.P., Grigoryev A.V. Zolotorudnoe mestorozhdenie Novogodnee-Monto (Polyarnyy Ural). Istoriya izucheniya [Gold Deposit Novogodnee-Monto (Polar Urals). History of Study]. *Ural'skiy geologicheskiy zhurnal* [Uralian Geological Journal], 2002, no. 6 (30), pp. 125–130.
21. Ponaryadov A.V. Mineralogo-tekhnologicheskie osobennosti il'menit-leykoksenovykh rud Pizhemskogo mestorozhdeniya, sredniy Timan [Minerals and Processing Features of Ilmenite-Leucoxene Ores of Pizhemskoe Deposit, Middle Timan]. *Vestnik instituta geologii Komi nauchnogo tsentra Ural'skogo otdeleniya RAN* [Vestnik IG Komi SC UB RAS], 2017, no. 1 (265), pp. 29–35. DOI: 10.19110/2221-1381-2017-1-29-36
22. Zhuravel V.P. Rossiya v Arktike: itogi 2020 goda i perspektivy razvitiya [Russia in the Arctic: The Results of 2020 and Development Prospects]. *Nauchno-analiticheskiy vestnik IE RAN* [Scientific and Analytical Herald of IE RAS], 2021, no. 1, pp. 89–95. DOI: 10.15211/vestnikieran120218995
23. Rastyannikova E.V. Mirovoy rynok resursov tsvetnoy metallurgii [Global Non-Ferrous Metallurgy Resources Market]. *Vostochnaya analitika* [Eastern Analytics], 2020, no. 3, pp. 109–130. DOI: 10.31696/2227-5568-2020-03-109-130
24. Botnaryuk M.V. Analiz sostoyaniya i perspektivy razvitiya Severnogo morskogo puti [Analysis of the State and Prospects for the Development of the Northern Sea Route]. *Vestnik gosudarstvennogo universiteta morskogo i rechnogo flota imeni admirala S.O. Makarova*, 2013, no. 1 (20), pp. 186–194.
25. Belov S.V., Skripnichenko V.A. Otechestvennyy i zarubezhnyy opyt prostranstvennoy organizatsii proizvodstvennykh kompleksov mineral'no-syr'evoy bazy tverdykh poleznykh iskopaemykh v Arktike [Domestic and Foreign Experience of Spatial Organization of Mineral Raw Materials Manufacturing Complex Base of Solid Minerals in the Arctic]. *Mezhdunarodnyy nauchno-issledovatel'skiy zhurnal* [International Research Journal], 2022, no. 6 (120), vol. 5, pp. 100–103. DOI: 10.23670/IRJ.2022.120.6.110

The article was submitted 22.08.2022; approved after reviewing 01.10.2022; accepted for publication 12.10.2022.

Contribution of the authors: the authors contributed equally to this article.

The authors declare no conflicts of interests.