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EXPLORABLE AND ECONOMICALLY ATTRACTIVE MINERAL DEPOSITS IN THE SIBERIAN AND FAR EASTERN FEDERAL DISTRICTS OF RUSSIA

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ABSTRACT

Purpose. Selection of the most explorable mineral deposits in the Siberian and Far Eastern Federal Districts of the Russian Federation as investment projects.

Methods. System rank analysis of minimizing the risks of investment projects for their provision with transport and energy infrastructure.

Findings. There were selected the most attractive mineral deposits in the Siberian and Far Eastern Federal Districts, which had not been developed before due to lack of investment.

Originality. Ranking of mineral deposits is carried out not by geological and economic indicators, but according the degree of these objects availability.

Practical implications. It is presented an additional possibility of the Siberian and Far Eastern Federal Districts territories development by changing the attractiveness of investment programs for the mineral resources exploitation.

Keywords: *mineral deposits, investments, projects, Siberia, the Far East*

1. INTRODUCTION

Availability of mineral resources is one of the major determinates of mineral deposit development. It implies reliable transport infrastructure (auto roads and railways, navigable waterways, and sea ports), which would allow transporting huge amount of extracted mineral resources.

In addition, available energy sources such as transmission lines and the possibility to attract local labor force are additional favorable conditions. In the Siberian and Far Eastern Federal Districts, the developed energy infrastructure is commonly within the densely populated regions with good transport infrastructure, i.e. basically in the southern part of the districts.

Mineral deposits found in the Chukotka Autonomous Region, the Kamchatka Region, Magadan Region, the Republic of Altay, northern part of the Republic of Sakha (Yakutia) and Krasnoyarsk Region are not economically attractive due to poorly developed transport infrastructure. In these areas, it is only possible to develop so-called low-tonnage deposits (gold, gem stones, and a number of rare metals) of superior quality. A striking example of such problems is the development of the Tomtorsk field, the richest in niobium-rare-earth-mineral, in the north of the Republic of Sakha (Yakutia), which is still at its initial stages.

In the Siberian and Far Eastern Federal Districts, there are a great number of ready-to-develop mineral deposits, which were abandoned in the time of transitional period crisis and newly-discovered deposits, development of which was stopped at the stage of reserve estimation due to the reduction of state geo-exploration budget. Most of these deposits have become economically unattractive because of surges in the cost of energy resources and transport services, decrease in prices for minerals. However, the number of deposits which are still attractive destination for investments is rather sufficient.

2. MAIN PART

Which mineral deposits discovered in the Siberian and Far Eastern Federal Districts have more attractive investment potential?

First of all, it concerns minerals which are imported into Russia and represent a large proportion of total consumption (Khat'kov & Boyarko, 2005). Among these are manganese and chromite ores, tin, ilmenite, rutile and zircon concentrates, niobium, fluorspar, graphite, barite, bentonite, kaolin, and bauxite. The Government conducts

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many activities to facilitate import replacement in iron and steel industry (the order of the Ministry of Industry and Trade of the RF dated 31 March 2015 No. 652) and non-ferrous (the order of the Ministry of Industry and Trade of the RF dated 31 March 2015 No. 651) industry, as well as chemicals sector (the order of the Ministry of Industry and Trade of the RF dated 31 March 2015 No. 646).

Secondly, the development of mineral resources for export could also be rather attractive for investments. This includes hard coking coal, power-station coal, non-ferrous metals, agro-raw materials (phosphate and potassic raw materials), etc.

However, there are a number of restrictions on foreign investors' participation in mineral extraction sector of Russia. Thus, uranium reserves, as well as large oil and gas deposits (in fact, any of them) can be developed only by domestic companies. A particular challenge is competition with the investors in the regions where major mining companies operate. It is almost impossible to establish independent diamond-mining company in the Republic of Sakha (Yakutia) where mineral deposits are developed as a monopoly by the Alrosa Group. Similarly, the development of new copper-nickel deposits in the Krasnoyarsk Region faces competition from the side of Norilsk Nickel, Mining and Metallurgical Company. The arrival of new contractors in coal mining within Kuznetsk coal basin (Kemerovo Region) and Kansko-Achinsk coal basin (Krasnoyarsk Region, the Republic of Khakassia) is rather problematic.

Despite the above-mentioned factors, the number of mineral deposits in the Siberian and Far Eastern Federal Districts, which could become attractive destination for investment, is rather significant. It concerns both the deposits which have been already explored, but being stored, and those which have been prepared for mining by organizations experiencing financial difficulties with the involvement of funds for their development. In addition, new mineral deposits have been recently discovered, which are under beginning geological exploration work.

Listed below are those mineral deposits which are available and most economically attractive in the Siberian and Far Eastern Federal Districts. The deposits which face various problems of their development (technological, economical), as well as deposits which are developed by monopoly-companies are not listed. Figure 1 illustrates the location of available mineral deposits.

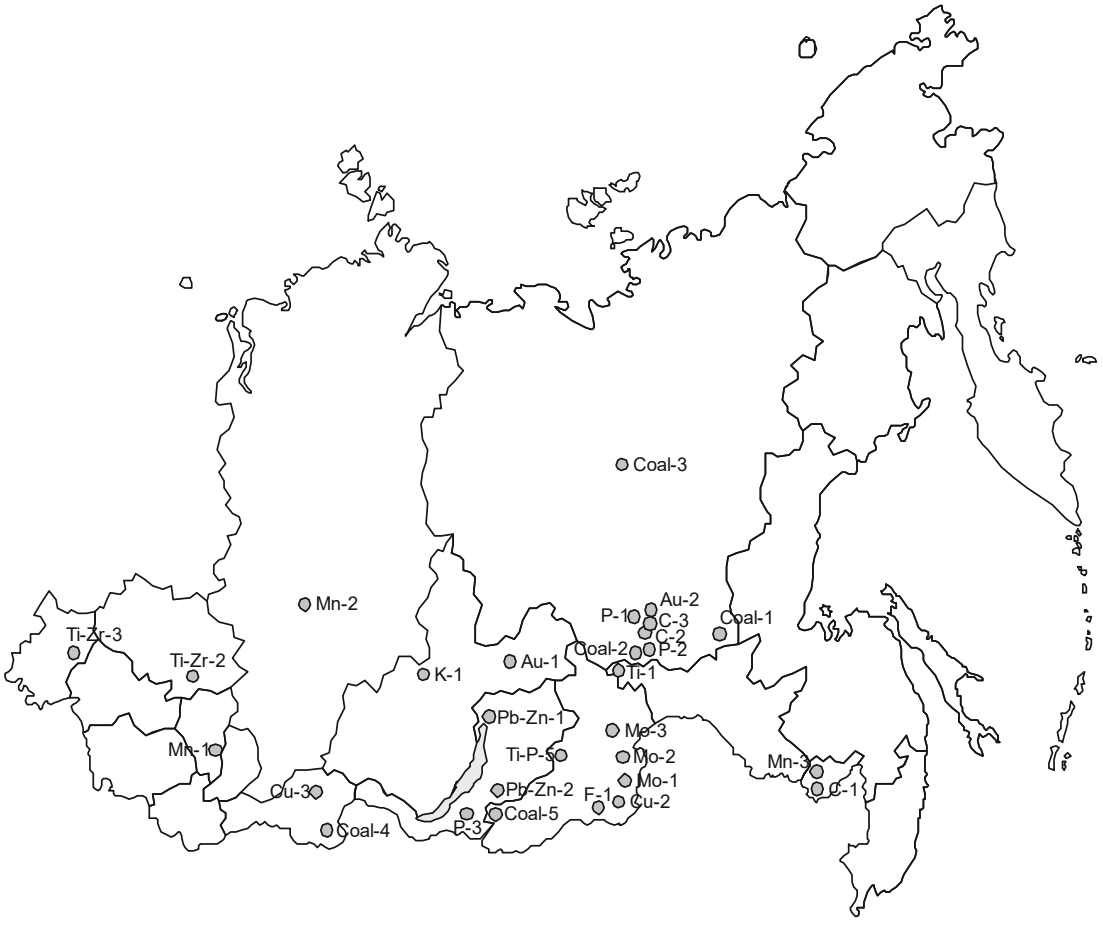

Figure 1. Location of explorable mineral deposits in the territory of the Siberian and Far Eastern Federal Districts: coal: 1 – Elginsk; 2 – Southern-Yakutsk (Kabaktinsk, Nizhne-Taluminsk, Burpalinsk and Naldinsk); 3 – Megino-Kangalassk coal region; 4 – Ulug-Khemsk coal basin; 5 – Zalashansk coal basin; Manganise (Mn): 1 – Usinsk; 2 – Porozhinsk; 3 – Yuzhno-Khingansk and Bidzhansk Titanium Ti (and Zirconium Ti – Zr) (and Apatite Ti – P): 1 – Kuranahsk and Bolshoy Seim; 2 – Tugansk and Georgievsk; 3 – Tarsk and Samsonovsk; 4 – Kruchininsk; Gold (Au): 1 – Sukhoy Log; 2 – Bolshoy Kuranah; Copper (Cu): 1 – Udokansk; 2 – Bystrinsk; 3 – Ak-Sugsk; Lead and Zinc (Pb – Zn): 1 – Kholodninsk; 2 – Ozernyi; Molybdenum (Mo): 1 – Bukdrainsk; 2 – Orekitsk; Potassium salt (K): 1 – Nepsk Phosphate (P): 1 – Seligdarsk; 2 – Birikeensk; 3 – Oshurkovsk; Graphite (C): 1 – Soyuznyi; 2 – Nadezhdinsk; 3 – Chebere; Fluorspar (F): 1 – Urtuysk

Coal. The global coal market faces pressure due to the crises. Therefore, only hard coking coal and power-station coal which meet the increasingly stringent environmental standards for toxic impurities (sulfur, etc.) are globally in demand (Logvinov, Faydov, & Starokozheva, 2013; Gosudarstvennyy doklad…, 2015; Logvinov, Gordeev, Mikerova, & Starokozheva, 2017; Skryl', 2017).

El'konsk coking coal deposit in Neryungrinsk Ulus, the Republic of Sakha (Yakutia). There, it is estimated to be more than 2 billion tons of coal. The deposit is developed by Yakutugol, Holding company. The railway line with a length of 320 km was built. The mine was commissioned in 2011. For six months of 2016, 2 million tons of coal were produced. Coal mine output is expected to increase up to 27 million tons per year.

Coal deposits in South-Yakutsk coal basin. In addition to Neryungrinsk, Verkhne-Taluminsk and Chul'makansk coal deposits which are currently being operated in this region, it is also possible to start developing Kabaktinsk, Nizhne-Taluminsk, Burpalinsk, and Naldinsk coal deposits located in close proximity to the railway lines. Total reserves of coking coal are estimated to be more than 1 billion tons.

Megino-Kangalassk coal region in Lena coal basin. Up to 0.6 million ton of power-station coal was produced by underground coal mines until 1990. When the Amur-Yakutsk railway line is built, it would be possible to renew a coal mining activity within the region. Besides, coking coal which has not been produced here can also be mined. However, additional exploration is required. The closed mining companies have corresponding qualified workforce.

Ulug-Khemsk coal basin is located in the Republic of Tyva. There is estimated to be 3.7 billion tons of coal, with high-quality coking coal making up the largest portion of the total reserves. The biggest Elegestsk coal deposit is estimated to contain 855 million tons of coking coal. It is operated by Energy and industry corporation of Tuvinsk. The enterprise capacity is estimated as 15 million tons of coking coal produced annually. In neighboring Mezhegeisk (investor – Mezhegeiskugol) and Tsentral'nyi (investor – Severstal') mines, it is planned to produce 6 – 9 million tons of coal annually. These projects are rather promising due to the construction of the Elegest – Kyzyl – Kuragino railway line 410 km in length. In addition, this railway can be extended to China.

Zalashansk coal deposit located in the Transbaikal Region is currently being prepared for development by Razrezugol, Russian-Chinese company. The company will export coal to China.

Manganese. Today, Russia receives by import up to 1020 thousand tons of manganese a year. Therefore, the Government promotes establishment of manganese-producing companies. The discovered manganese deposits are of various quality and should be developed differently (Dashevskiy, Yusfin, Podgorodetskiy, & Baeva, 2013; Pechenkin, Zublyuk, & Alikberov, 2013; Gosudarstvennyy doklad…, 2015).

Usinsk manganese ore deposit in Kemerovo Region. The estimated reserves of the deposit contain 5.8 million tons of oxide ore (25.6% Mn) and 163 million tons of carbonate ore (19.7% Mn). One of the major challenges in developing this ore deposit is the prevalence of carbonate manganese ores that are not used in ferroalloys production. The exploitation is prepared by Chek-su. The planned annual output of metal manganese is up to 80 thousand tons (Dashevskiy, Yusfin, Podgorodetskiy, & Baeva, 2013).

Porozhinsk ore deposit in Krasnoyarsk Region. The estimated oxide ore reserves are 30 million tons, with average Mn concentration to 18.8%. The mine's annual output is estimated up to 70 million tons. The main challenge in developing this ore deposit is the remoteness of the mine from the railway line. Being highly dependent on river transport, ore is transported only in summer. The exploitation is prepared by Turukhanskiy meridian.

Yuzhno-Khingansk ore deposit in Jewish Autonomous Region. It is estimated to contain 9 million tons of oxide and oxidized ore with average concentration of Mn to 20.9%. The mine is operated by Khemen – Dal'niy Vostok, Chinese company. The designed annual output of manganese is 90 thousand tons. A neighboring Bidzhansk manganese ore deposit containing 6 million tons of reserves could be also considered.

Titanium (and zirconium). Now 100% of ilmenite, rutile and zircon concentrate is imported to Russia. Whereas there are many potential mineral fields to substitute the import of these products, including those in the Siberian and Far-Eastern Federal Districts (Sporykhina, Orlova, & Bykhovskiy, 2013; Gosudarstvennyy doklad…, 2015).

Kuranakhsk ilmenite-titanium-magnetite deposit in Amur Region is located in immediate vicinity to Baikal – Amur railway line. The reserves of ore material amount 21 million tons of TiO_2 with the average content 9.1% of TiO_2. Titanium-magnetite of this deposit is up to 1% of V_2O_5. In 2014, by Olekminsky rudnik, Enrichment Plant of Petropavlovsk, 178000 tons of ilmenite concentrate was extracted and exported to China. There is one more ilmenite-titanium-magnetite deposit near the plant – Bolshoy Seim, which is prepared to exploitation by Ural-Mining, Petropavlovsk. Its reserves are 23 million tons of TiO_2 with the average content 7.67% of TiO_2.

Tugansk titanium-zirconium placer deposit in Tomsk Region. The ore sand reserves amount 120 million m^3 with the average sand content of ilmenite 30.5 kg/m^3, rutile 4.8 kg/m^3 and zirconium 12.8 kg/m^3. It is developed by Tugansk mining and processing plant "Ilmenite". Not far from it, there is Georgievsk field with the reserves of ore sand about 27 million m^3, with the average sand content (kg/m^3) of ilmenite (31.6), rutile (4.5) and zirconium (12.4).

Tarsk titanium-zirconium placer deposit in Tomsk Region. The salable ore sand reserves amount 24 million m^3 with the average content of ilmenite in sands to 48.5 kg/m^3, rutile to 6.0 kg/m^3 and zirconium to 8.0 kg/m^3. The deposit is developed by Tarsk mining and processing plant. Another new Samsonovsk titanium-zirconium deposit has been located in vicinity of it.

Kruchininsk apatite-titanium-magnetite deposit in Transbaikal Region (70 km from Chita city). The ore reserves of the deposit are 617 million tons with the average content 22.5% of iron, 3.66% of P_2O_5, 8.39% of TiO_2, 0.09% of V_2O_5. With the mine capacity of 10 mil-

lion tons per year, it is possible to produce 1.6 million tons of titanium-magnetite concentrate, 0.7 million ton of ilmenite, and 0.5 million ton of apatite concentrates.

Gold. Gold deposits are of significant interest regardless their size and location. The bulk of known gold deposits are being developed or prepared for development (Gosudarstvennyy doklad…, 2015). In this work the authors showed the deposits that were overlooked by investors basically owing to suggested irrational mining and operating conditions.

Sukhoy Log gold-sulfide ore deposit in Irkutsk Region with the reserves of 2000 tons, the average content 2.1 g/t and calculated reserves in the flanks. The ores are well processed; traditional methods can be used to abstract metal. The deposit is located 357 km from the Taksimo railway station of Baikal – Amur railway line.

Bolshoy Kuranakh gold deep-lead in Aldan Ulus of the Republic of Sakha (Yakutia) is located in immediate vicinity of Amur-Yakutsk railway line. The distinguishing feature of this placer in Bolshoy Kuranakh valley is great thickness of sand (up to 40 m), the reserves and resources of the placer are 162 tons. In the upper part the placer is developed with dredgers, but there is also an experimental selective production zone of total placer section thickness by bucket wheel and washing at the coastal beneficiation plant. The deposit is developed by Aldgold mining company. Similar gold deep-leads as forecasted are located in the neighboring valleys of the Seligdar and Yaklkit Rivers.

Copper. In the territory of the Siberian and Far-Eastern Federal Districts there is the largest in Russia Udokansk cupriferous sandstone deposit, newly discovered copper deposits in Krasnoyarsk Region and the Republic of Tyva (Sporykhina, Orlova, & Bykhovskiy, 2013; Gosudarstvennyy doklad…, 2015).

Udokansk cupriferous shale deposit in Transbaikal Region is 30 km from the Novaya Chara railway station of Baikal – Amur railway line. The deposit reserves are 20 million tons of copper with the average copper content in ore to 1.56%. The deposit is developed by Baikal'skaya gornaya kompaniya. The development project forecasts the production of up to 36 million tons of ore per year (up to 500000 tons of copper).

Bystrinsk skarn gold-copper deposit in Transbaikal Region is located in the immediate vicinity of the railway road. The deposit reserves are 2.1 million tons of copper (with the average copper content in ore to 0.78%), 406 tons of gold, 2468 tons of silver and 103 million tons of iron ore. The development of deposit is performed by Bystrinsk mining plant. The development project intends to produce up to 10 million tons per year (up to 75000 tons of copper).

Ak-Sugsk porphyry copper deposit (the Republic of Tyva) may soon become explorable due to construction of the railway road. The deposit reserves are 3.6 million tons of copper and 38000 tons of molybdenum with the average content of copper in ore 0.67%. Exploration and development of the deposit is performed by Golevsk mining plant.

Lead and zinc. The resources of zinc are particularly great in the Republic of Buryatia where two large pyrite-polymetalic deposits were explored: Kholodninsk and Ozernyi (Sporykhina, Orlova, & Bykhovskiy, 2013; Gosudarstvennyy doklad…, 2015).

Kholodninsk deposit is near Baikal – Amur railway line. 21.2 million tons of zinc and 3.1 million tons of lead with the average content 3.99% of zinc in ore and 0.6% of lead. The deposit is developed by InvestEvroCompany. A significant constrain of its development is high standards of Lake Baikal environmental protection.

Ozernyi deposit in vicinity of Trans – Siberian railway road. 8.3 million tons of zinc and 1.5 million tons of lead with the average content 6.16% of zinc in ore and 1.13% of lead. The deposit is developed by Techprominvest. Like Kholodninsk deposit Ozernyi is located in the Lake Baikal basin and is a subject of high requirements on environmental protection.

Molybdenum. All newly discovered deposits of molybdenum (Bukdrainsk, Zherekensk, and Orekitkansk) are located in Transbaikal Region. The richest among them, Zherekensk deposit has already been developed by Zherekensk mining and processing plant (Sporykhina, Orlova, & Bykhovskiy, 2013; Gosudarstvennyy doklad…, 2015).

Bukdrainsk molybdenum-porphyry deposit. The reserves of this deposit are estimated at 600000 tons of molybdenum (with the average 0.08% Mo content), as well as 11.2 tons of gold and 193.5 tons of silver. The deposit development is performed by Bukdrainsk Rudnik.

Orekitkansk deposit. Its reserves amount 360000 tons of molybdenum with the average 0.099% Mo content. The right to develop the deposit belongs to Orekitkansk mining and processing plant. The development project intends to produce up to 9 million tons per year (up to 1000 tons of molybdenum).

Potassium salt. The center of potassium salt production in Russia is located in Perm Territory and specialized in deliveries to agricultural plants in the European part of the country and for export. In the Eastern part of the country, in the north of Irkutsk Region the large Nepsk deposit of high-grade sylvinite ore (22% of K_2O), including 504 million tons of K_2O was explored. It could become a source of potassium fertilizer for Siberia and Far East, as well as for the export to the East (Aksenov, Vafin, Sadykov, & Senatorov, 2013; Gosudarstvennyy doklad…, 2015).

Phosphates. Similar to potassium salt deposits for phosphate-bearing raw material the centers of apatite ore production are located in Murmansk Region and the Republic of Karelia and specialized for provision of the European part of Russia with phosphate fertilizer and for export. Similarly, it is necessary to provide agricultural plants of Siberia and Far East with phosphates as well as potential export to the East (Aksenov, Vafin, Sadykov, & Senatorov, 2013; Gosudarstvennyy doklad…, 2015).

Seligdarsk apatite deposit in Aldan Ulus of the Republic of Sakha (Yakutia) is located 12 km from Amur – Yakutsk railway line. Its reserves amount 85.6 million tons of P_2O_5 (the average content of P_2O_5 is 6.7%) as well as 4.4 million tons of rare-earth elements (the average content is 0.35% $\sum$TR). The unconventional composition of apatite-carbonaceous ores of this deposit has long been a subject of engineering research, one of which has suggested a nitric-acid scheme of phosphorous acid

treatment to extract rare-earth and fluorine. 250 km from it, to the South Birikeensk deposit was discovered, which was a weathering crust of apatite-carbonaceous ores of Seligdar type. And, as a result of which the apatite-francolite deposit was formed with the average content of P_2O_5 up to 19%. The deposit exploration was stopped at the estimation stage.

Oshurkovsk apatite deposit in the Republic of Buryatia is presented by lean, but easy apatite-silicate ores. Oshurkovsk deposit has already been developed, but the production was stopped after sewage volley from the enrichment plant to the Selenga River (the Lake Baikal basin). At present the recovery of mine productive capacity is performed by Daxy Ltd.

Graphite. Annually, Russia imports up to 30000 tons of flake graphite, whereas there are graphite deposits in the Far East (Soyuznyi, Nadezhdinsk, Chebere) (Luzin, Kuznetsov, Luzina, & Kuznetsova, 2012; Aksenov, Vafin, Sadykov, & Senatorov, 2013).

Soyuznyi deposit in Jewish Autonomous Region. Its reserves are 385000 tons of graphite (with the average content of graphite to 15.5%). The deposit development is performed by Dal'graphite. The production project provides production of 40000 tons of graphite per a year.

Nadezhdinsk and Chebere deposits in Aldan Ulus of the Republic of Sakha (Yakutia) is located 65 km from the railway station. The reserves and resources of these deposits amount 1.8 million tons of graphite. The average graphite content of Nadezhdinsk deposit is 14.6%, that of Chebere – 35.7%. At the moment, the geological exploration of the deposits has been resumed.

Fluorspar. The most part of large metallurgic fluorspar is imported to Russia, but in Transbaikal Region, 25 km from Krasnokamensk town there is Urtuysk fluorspar deposit perspective for development. Its resources and reserves are 3.4 million tons with the average fluorite content in ores to 28.8% (Gosudarstvennyy doklad…, 2015).

3. CONCLUSIONS

In the territories of Siberia and Far East reachable for transport there are more than 30 investment-attractive mineral deposits producing import-substituting (manganese ores, ilmenite, rutile, zirconium concentrates, fluorspar and graphite), marketable (gold) and export-oriented (coking and power station coal, copper, molybdenum, zinc, lead, potassium salts, phosphate minerals) commercial products.

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ДОСТУПНІ ДЛЯ ОСВОЄННЯ ПРИВАБЛИВІ МІНЕРАЛЬНО-СИРОВИННІ ОБ'ЄКТИ СИБІРСЬКОГО ТА ДАЛЕКОСХІДНОГО ФЕДЕРАЛЬНИХ ОКРУГІВ РОСІЇ

Г. Боярко

Мета. Оцінка найбільш доступних і привабливих для розробки родовищ корисних копалин у Сибірському та Далекосхідному федеральних округах Російської Федерації в якості інвестиційних проектів.

Методика. Для оцінки доступності родовищ корисних копалин виконано комплексний аналіз їх запасів і цінності по відношенню до внутрішнього й зовнішнього ринків, а також наявності транспортної інфраструктури (автомобільних і залізних доріг, судноплавних річок, морських портів), що дозволяє здійснювати достатнє вивезення великих обсягів видобутих мінеральних ресурсів.

Результати. Обрані 30 найбільш привабливих в інвестиційному відношенні родовищ корисних копалин у Сибірському та Далекосхідному федеральних округах, які раніше не освоювались через нестачу інвестицій та мають пріоритет щодо імпортозаміщення (марганцеві руди, ільменіт, рутиловий і цирконовий концентрати,

плавиковий шпат і графіт), високоліквідності (золото) та експортноорієнтованості (коксівне й енергетичне вугілля, мідь, молібден, цинк, свинець, калійні солі, фосфатна сировина).

Наукова новизна. Запропоновано здійснювати ранжування родовищ корисних копалин не тільки з урахуванням геолого-економічних показників, а також з урахуванням їх доступності (наявність транспортної та енергетичної інфраструктур).

Практична значимість. Складено схематичну карту розташування доступних для освоєння родовищ затребуваних корисних копалин на території Сибірського та Далекосхідного федеральних округів, що дає додаткову можливість більш ефективного розвитку даних територій.

Ключові слова: *родовища корисних копалин, інвестиції, проекти, Сибір, Далекий Схід*

ДОСТУПНЫЕ ДЛЯ ОСВОЕНИЯ ПРИВЛЕКАТЕЛЬНЫЕ МИНЕРАЛЬНО-СЫРЬЕВЫЕ ОБЪЕКТЫ СИБИРСКОГО И ДАЛЬНЕВОСТОЧНОГО ФЕДЕРАЛЬНЫХ ОКРУГОВ РОССИИ

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Цель. Оценка наиболее доступных и привлекательных для разработки месторождений полезных ископаемых в Сибирском и Дальневосточном федеральных округах Российской Федерации в качестве инвестиционных проектов.

Методика. Для оценки доступности месторождений полезных ископаемых выполнен комплексный анализ их запасов и ценности по отношению к внутреннему и внешнему рынкам, а также наличия транспортной инфраструктуры (автомобильных и железных дорог, судоходных рек, морских портов), позволяющих осуществлять достаточный вывоз крупных объемов добытых минеральных ресурсов.

Результаты. Выбраны 30 наиболее привлекательных в инвестиционном отношении месторождений полезных ископаемых в Сибирском и Дальневосточном федеральных округах, ранее не осваиваемых по факту недостатка инвестиций, имеющих приоритет по импортозамещению (марганцевые руды, ильменитовый, рутиловый и цирконовый концентраты, плавиковый шпат и графит), высоколиквидности (золото) и экспортноориентированности (коксующийся и энергетический угли, медь, молибден, цинк, свинец, калийные соли, фосфатное сырье).

Научная новизна. Предложено осуществлять ранжирование месторождений полезных ископаемых не только с учетом геолого-экономических показателей, а также с учетом их доступности (наличие транспортной и энергетической инфраструктур).

Практическая значимость. Составлена схематическая карта месторасположения доступных для освоения месторождений востребованных полезных ископаемых на территории Сибирского и Дальневосточного федеральных округов, что дает дополнительную возможность более эффективного развития этих территорий.

Ключевые слова: *месторождения полезных ископаемых, инвестиции, проекты, Сибирь, Дальний Восток*

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