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Possibilities of Russian hi-tech rare earth products to meet industrial needs of BRICS countries

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The prospects of the creation in Russia of a new scientific and technological sector of production from rare earth materials from the unique niobium rare earth Tomtor deposit (Russia, Yakutia) are discussed in this article. The authors show that an effective innovative technological chain 'ore processing – getting highly liquid REM-products' could be created. This could make it possible in the near future to begin the integration of Russian products into the global market of highly liquid rare and rare earth metals where today two BRICS countries – China and Brazil – are in the leading positions.

Keywords: BRICS, rare metals, rare earth metals, the Tomtor deposit, the State Corporation 'Rosatom', innovations, technologies, oxides of rare earth metals, pure rare earth metals, hi-tech industries, value added

Introduction

In modern economies, innovations are the vital source of competitiveness and economic development. One of the ways to promote innovative development is the stimulation of hi-tech industries, which is not possible without development of hi-tech materials and a country's own domestic resource base. In this article, we discuss perspectives of Russian innovative materials to meet the needs of hi-tech industries in the BRICS countries.

Statement of the problem

The global rare elements market is controlled by just two BRICS countries (Brazil and China). About 90% of the world's niobium is produced in Brazil based on Araxá carbonatite deposits and about 90% of the rare earth elements (REE) are produced in China from the giant field Bayan-Obo deposit.

The Tomtor niobium rare earth deposit, which is located in the Arctic zone in the north-west of Yakutia (Russia), is a virtually inexhaustible source of highly liquid minerals that will be used in the hi-tech sectors of industrial production, military industrial complexes and the nuclear industry for the foreseeable decades. For example, at least 40% of the critical technologies which are required for innovative dominance in developed and developing countries (such as the BRICS countries) – from the development of advanced weapons and nuclear energy to the melting of special steels and alloys, and the creation of major structural nanomaterials – is not realizable without the rare earth metals (REM) and related hi-tech materials and products based on them (Tolstov et al. 2014).

There are many applications of REM and the corresponding final products based on them. Rare metals and rare earths are included in the technological chains of weapons and military equipment production for the Russian Military forces and for export, as well as for a wide range of other products produced by the State Corporation 'Rosatom' enterprises, the State Corporation 'Rostech' and other companies and corporations strategic to the Russian economy (Pokhilenko et al. 2014).

Research questions and research objectives

The research question (hypothesis) of this article is the following: Is it possible to provide Russian industry with a wide range of rare earth products in the form of the entire lanthanides line of different purities for a long period of time with the development of the Tomtor deposit and consequent processing of its ore and obtaining collective REM carbonates (i.e. containing unseparated metals) from the ore? Moreover, is production of niobium, yttrium and scandium of high processing degrees (oxides of the individual metals, pure and high-pure metals and their compounds) ensured? Furthermore, is it possible to export the rare earth metals and hi-tech pig products for the needs of industries in the BRICS countries, especially China and India?

Literature review

The research subject is the economic and technological balance of rare earth products production, which allows for the optimization of obtaining of rare earth metals in quantity and value. This is a research paper, and its methodology is based on the analysis of the competence of possible manufacturer of final REM products, of the unique geological and industrial and technological features of rare earth raw materials and of the special economic and geographic characteristics of the deposit location, as well as of the prospective routes of the ore transportation to the place of processing. Methods of analysis are based on estimated economic models of evaluation of investment projects of solid minerals exploitation. Economic, product and technological data used for calculations rely on projected production plans and the price situation on the REM market. We also use system and industrial economic analysis.

In the first part of the paper we demonstrate the possible development of a wide range of competences in rare earth products production in Russia. The second part deals with the characteristics of Russian REE deposits as well as the problems of technological cycle of the Tomtor deposit development and peculiarities of processing of its ore. In the third part, calculations showing real perspectives of Russian hi-tech rare earth products to meet industrial needs of the BRICS countries are given.

In the literature on the economy of REM, the question of the optimization of REM distribution between the consumers and the problem of the Chinese and Brazilian monopoly in the market (REM and niobium correspondingly) are discussed (Dadwal 2011; Manceheri, Sundaresan, and Chandrashekar 2013; He 2014). Another important issue is the search for and implementation of new technologies for the reproduction of REM or technologies that could make it possible to use 'excess' REM (e.g. cerium, samarium, gadolinium, etc.) instead of scarce metals on the market (neodymium, dysprosium, terbium), (Gscheider 2014; Nicoletopoulos 2014; Rare Earths … 2014). At the centre of these problems and solutions is the analysis of the role of the government in the market and its influence on the demand dynamics as the main mechanism for the development of the REM industry (European Commission … 2011; Binnemans 2014; Cassard et al. 2014; Endl and Berger 2014).

Object of the research

The State Corporation 'Rosatom' (SC 'Rosatom') can play a significant role in the formation and revival of the Russian rare earth industry, and help take it to the world market. In this regard, it is worth mentioning what the State Corporation is and what its current spheres of competence are, as well as its technological and economic activities. The State Nuclear Energy Corporation 'Rosatom' ensures the implementation of governmental policy and the effective coordination of the use of nuclear energy, the stable operation of nuclear power and nuclear weapons sectors, nuclear and radiation safety.

'Rosatom' unites about 400 enterprises and scientific organizations, including all civil companies in the Russian nuclear industry, enterprises of the nuclear weapons complex, research organizations and the only nuclear icebreaker fleet in the world. The Corporation holds a leading position in the world nuclear technologies market, ranked first in the world in the number of simultaneously constructed nuclear power plants abroad, second in uranium reserves and the third in its production. It is also ranked the second in the world in terms of nuclear electricity generation, providing 36% of the world market for uranium enrichment services and 17% of the nuclear fuel market.

The goal of this paper is to show the possibilities and mechanisms of including SC 'Rosatom' enterprises into the production chain of REE of different purities and the final product based on them, as well as the resulting economic effect.

The data for the analysis (such as ore reserves, the content of valuable components, degrees of extraction, production and processing volumes) are given by the geological reports on the Tomtor deposit (the Blizzard site) and the parameters of the preliminary feasibility study of its development.

Combining the competencies of several Siberian divisions and enterprises of the SC 'Rosatom' referred to below, allows for the creation of an effective technological chain: REM processing – obtaining REM carbonate – obtaining pure REM – obtaining innovative products of deep processing – producing products based on REM and, thus, to provide:

1. Formation of the segment, which is new for the SC 'Rosatom', of highly liquid innovative REM products (oxides and high-purity metals, and, in the future, the final rare earth products based on them, for example, for nuclear power) to fully meet the needs of the Russian hi-tech industry and for export, including to the other BRICS countries.
2. Development, concentration and accumulation of scientific and technological competencies in the sphere of innovative processing technologies of the unique Tomtor ores and subsequently obtaining individual rare earth metals from them.
3. Increase of scientific and technological competencies in decontamination of radioactive ores and products of chemical and metallurgical processing (thorium, uranium and their decay products).
4. Effective utilization of production and technological capabilities in the disposal of radioactive waste produced during processing, including the modernization of existing facilities and the creation of new REM complexes.
5. Creation and application of the production and economic model for the processing cycle regulation, storage and selective production of high-purity rare earth products subject to changes of the conditions in metal markets (optional balancing model of ore processing and producing REM-components) in the REM business (Binnemans 2014).
6. Training of highly qualified specialists in the REM ore processing and obtaining rare earth products.

Results and discussion

Currently, an effective research and industrial technology has been developed. It is adapted for one of the SC 'Rosatom' enterprises, Zheleznogorsk Mining and Chemical Combine located in the Krasnoyrsk region. The technology allows for the transformation of more than 75% of Tomtor ores into market products and the obtaining of products from both the first process stage (carbonates of rare earth elements) and the second process stage (the individual oxides), as well as high-purity products (pure REM, including heavy and the most expensive lanthanides, and their compounds). This technology was developed by the Institute of Chemistry and Chemical Technology SB RAS in Krasnoyarsk (by V. I. Kuzmin) and was used as the basic technology in the entering of the Tomtor deposit Blizzard site reserves on the State balance in 2000 (Tolstov, Konoplev, and Kuzmin 2011; Pokhilenko et al. 2014).

The proposed technology provides enormous economic effectiveness in terms of product processing degrees. Each subsequent stage of the technological chain significantly increases the value added – from 1.5 to 10 times. Scandium, europium, terbium, dysprosium, praseodymium and neodymium constantly hold the first places in the value and liquidity among the REM in the world market. Unique natural concentrations of the

Tomtor ores allow obtaining up to 1.0 kg of scandium, 0.8 kg of europium, 0.2 kg of terbium, 1.5 kg of dysprosium, 6 kg of praseodymium and more than 20 kg of neodymium from one ton of the ore. These are currently the scarcest, most expensive and highly liquid metals on the world's rare earth metals markets and will be so in the future as well (Kryukov et al. 2016).

Further, new alternative pyrometallurgical technology – liquation melting (Joint Institute for High Temperatures, Moscow, CJSC 'Lanthanum', Novosibirsk region) – has a serious potential. This technology allows for the obtaining of easily separable phosphate saline alloy with rare earths (slag) and, separately, alloy with niobium, significantly cheaper compared with the accepted alkaline hydrometallurgical method (up to 25–30%) (Delitsyn et al. 2015). With the use of the liquation technology, a set of laboratory tests has already been carried out and the corresponding products of the electroslag casting have been obtained from the Tomtor ores transferred by the Institute of Geology and Mineralogy SB RAS (Novosibirsk) to the organizations mentioned here.

Extraction and processing from 10 thousand tons of the Tomtor ore per year, with a gradual increase to 100 thousand tons, will be required to meet fully the REM needs of Russian industry.

The remoteness of the deposit and the complete lack of infrastructure, as well as the extraction volumes of the Tomtor ore arising from the needs of the economy (10 to 100 thousand tons), suggest the creation of a compact mining enterprise with the transportation of raw materials (transportation costs will amount to 3–5% of operating costs) into two possible centres of its primary processing. Options for the ore transportation are presented in Figure 1.

1. Zheleznogorsk MCC (SC 'Rosatom', Krasnoyarsk region). During winter, prepared ore in big-bags is delivered by trucks by winter snow road to the Anabar River mouth, stored on the ore site and then, during navigation season, transported by water on the Yenisei to the MCC pier.
2. Krasnokamensk Hydrometallurgical Combine (private enterprise), uses territory and radioactivity removal technology of Priargunsk Industrial Mining and Chemical Combine (SC 'Rosatom', Zabaykalsky region). Similarly, the ore is delivered to the river mouth, then with trans-shipment on the Lena to Yakutsk (see Figure 2) and then by the railroad to the combine.

Table 1 presents the initial ore processing obtaining volumes of collective carbonate, dependent on increasing processing capabilities with access to full capacity (11.4 thousand tons) within five years, which is possible on the Zheleznogorsk MCC industrial site or on the Krasnokamensk MCC-Priargunsk MCC.

Further, it is advisable to organize separation and extraction of individual rare earth oxides, material purification, transformation of oxides into the high-purity metal alloys on the SC 'Rosatom' regional Siberian enterprises and (or) partly on the capacities of independent companies which have competencies in the production of rare metal and rare earth products:

- Novosibirsk Chemical Concentrates Plant (Novosibirsk);
- Siberian Integrated Chemical Plant (Seversk, Tomsk region);
- Manufacturing group 'Electrochemical plant' (Zelenogorsk, Krasnoyarsk region);
- Electrolytic chemical combine (Angarsk, Irkutsk region);
- CJSC 'Lanthanum' (Berdsk, Novosibirsk region);
- CJSC 'Rare metals plant' (Baryshevo, Novosibirsk region).

Table 1 represents possible volumes of primary REM products and ferroniobium and secondary raw materials (aluminum, phosphates, etc.) production when processing

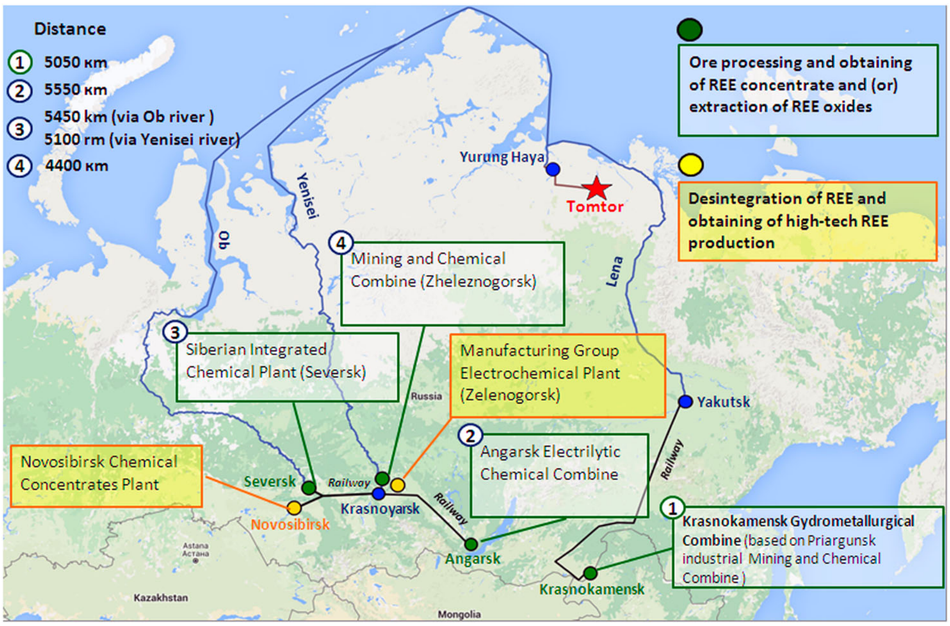

Figure 1: Options for the transportation of the ore and collective carbonates to the processing and enrichment enterprises.
Source: Kryukov et al. 2016

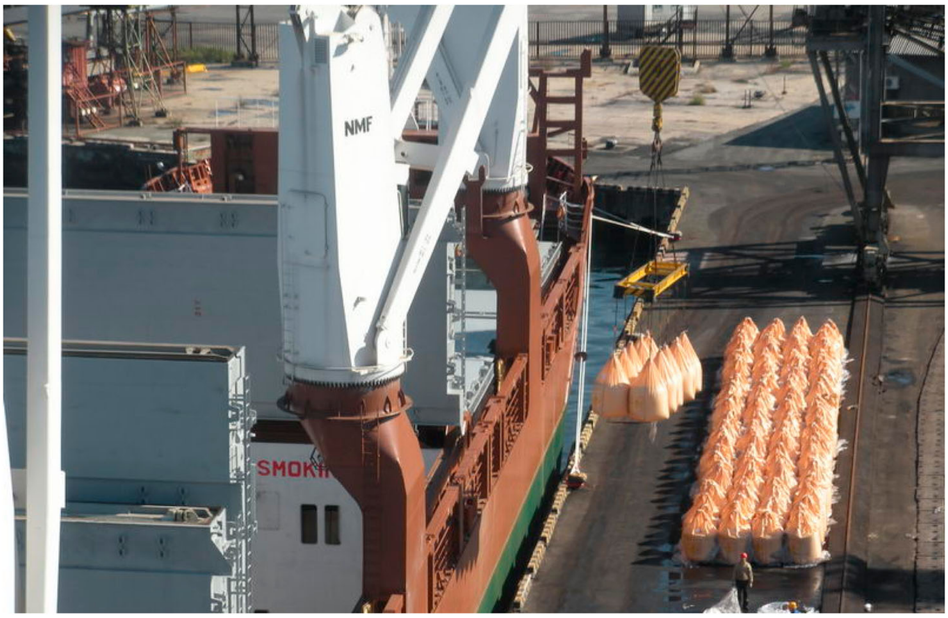

Figure 2: Loading of the raw material in the big-bags onto the bulk carrier.
Source: Kryukov et al. 2016

capacities are between 10 to 100 thousand tons of the Tomtor ore per year.

The intermediate industrial products supplied to the SC 'Rosatom' enterprises for separation, extraction of individual rare earth oxides and transformation of the oxides into metal alloys are:

1. REM carbonate, including yttrium oxide (from 1.14 to 11.4 thousand tons per year);
2. Scandium oxide concentrate (0.02–0.2 thousand tons per year).

By-products (titanium powder, alumina, trisodium phosphate, ferroniobium) are secondary for the rare earth industry and are either sold to consumers by the owner of the initial raw material after the primary stage of ore processing or stored.

The possibilities for the SC 'Rosatom' to produce the corresponding nomenclature and volumes of REM oxides (including yttrium and scandium) on the basis of carbonates are presented in Table 2. At the first stage, processing of 1.14 thousand tons of carbonates allows for production of up to 582 tons of REM oxides (including yttrium and scandium) per year. Thus, a tenfold capacity increase (full capacity) will allow for production of up to 5.82 thousand tons of oxides.

At the first stage, US$21.4 million[1] per year total revenue from oxides sales is guaranteed and, at full capacity, US$214.4 million (see Table 3). It is not difficult to calculate that if SC 'Rosatom's' total revenue is US$9 billion (about 600 billion rubles in 2015), the share of the new prospective REM production segment could be between 0.3 and 2.3%.

This approach should be called a gradual rare earth products market launch, a launch without high expectations and illusions. Moreover, the cost of enrichment of some (up to 30%) of produced oxides to create innovative products – pure and high-purity metals – will be significantly higher.

The unique composition of the ores, the tremendous deposit resources and the flexible deposit ore processing technological scheme allow for the obtaining of a wider range of highly liquid and innovative products, including high-purity and the scarcest heavy REM, and consumer products on their basis, after full transformation of the ores. It should be mentioned here that the market

Table 1: Volumes of primary REM products and secondary components obtained in Tomtor ore processing.

Components, thousand tons	Period of development, year							Total
	Year 1*	Year 2*	Year 3	Year 4	Year 5	Year 6	Year 7–15	
Ore processing	0	0	10.0	30.0	52.0	77.0	100.0	**1069.0**
REM carbonates, including yttrium oxide (composite product of the 1st stage of processing)	0	0	1.14	3.42	5.92	8.78	11.4	**121.86**
Ferroniobium	0	0	0.51	1.52	2.64	3.91	5.08	**54.3**
Trisodium phosphate	0	0	7.7	23.1	40.04	59.29	77	**823.13**
Alumina	0	0	1.5	4.5	7.8	11.55	15	**160.35**
Scandium oxide concentrate	0	0	0.02	0.06	0.1	0.15	0.2	**2.13**
Titanium powder	0	0	0.28	0.84	1.45	2.15	2.8	**29.92**

*The investment period for the enterprise construction.
Source: Authors' calculations; Kryukov et al. 2016; Pokhilenko et al. 2016

Table 2: REM oxides produced on the basis of REM carbonates (sales plan).

	Period of development, year							
Components	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7–15	Total
Ore, ths. tons	0	0	10.0	30.0	52.0	77.0	100.0	**1069.0**
REM oxides, tons								
Lanthanum	0	0	120.0	360.0	624.0	924.0	1 200.0	**12 828.0**
Cerium	0	0	246.0	738.0	1 279.2	1 894.2	2 460.0	**26 297.4**
Praseodymium	0	0	25.0	75.0	130.0	192.5	250.0	**2 672.5**
Neodymium	0	0	98.0	294.0	509.6	754.6	980.0	**10 476.2**
Samarium	0	0	12.3	36.9	64.0	94.7	123.0	**1 314.9**
Europium	0	0	3.9	11.7	20.3	30.0	39.0	**416.9**
Gadolinium	0	0	12.0	36.0	62.4	92.4	120.0	**1 282.8**
Terbium	0	0	0.9	2.8	4.9	7.2	9.4	**100.5**
Dysprosium	0	0	7.3	21.9	38.0	56.2	73.0	**780.4**
Holmium	0	0	0.9	2.8	4.9	7.2	9.4	**100.5**
Erbium	0	0	1.9	5.7	9.9	14.6	19.0	**203.1**
Thullium	0	0	0.5	1.5	2.5	3.8	4.9	**52.4**
Ytterbium	0	0	1.9	5.7	9.9	14.6	19.0	**203.1**
Lutecium	0	0	0.5	1.4	2.4	3.6	4.7	**50.2**
Yttrium	0	0	30.7	92.1	159.6	236.4	307.0	**3 281.8**
Scandium oxide concentrate	0	0	20.0	60.0	104.0	154.0	200.0	**2 138.0**

Source: Authors' calculations; Kryukov et al. 2016; Pokhilenko et al. 2016.

situation for rare earth products – oxides and high-purity metals – with China controlling the prices, makes the question of developing and using the Russian REM business production and economic model for the processing cycle regulation, storage and selective production of high-purity rare earth products urgent. Moreover, Brazil has a significant impact on the global REM market, operating the Araxá high-quality pyrochlore deposit which contains niobium and rare earths as the secondary components.

The Tomtor ore field is located in Russia, in the north-western part of the Republic of Sakha (Yakutia) in the territory of Olenek ulus (locality) 400 km from the coast of the Laptev Sea (see Figure 3) and is associated with the unique size carbonatite massif of alkaline ultrabasic rocks and carbonatites of the same name (Entin et al. 1990; Tolstov et al. 2014).

On an area of 30 square kilometres, there are three isolated sites (North, Blizzard and South), within which there is the ore bed of redeposited and epigenetically altered weathering crust (see Figure 4).

The Blizzard site has been explored; its resources of the first stage are entered on the State balance. Geological reserves and average components content of the Blizzard site are shown in Table 4. The content of harmful additions and radioactivity causing low environmental risks are the following: uranium – 0.0092%, thorium – 0.11%, radium – 0.157%.

The North and the South sites have been explored to a much lesser extent; exploration works are complete and prospecting works are being performed. Projected measured reserves were tested and evaluated as 1.1 million ton of ore with 1% niobium pentoxide, 5% total rare earth oxides and 0.04% scandium oxide concentrations (Tolstov et al. 2014).

High concentrations of rare and, in most importantly, the scarcest and the most expensive yttrium-earth metals in the Tomtor ores together with real possibilities of

Table 3: Sales of REM oxides, including yttrium and scandium (excluding related products), in US$ millions.

	Period of development, year							
Indicator	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7–15	Total
REM oxides sales, US$ millions								
Lanthanum	0	0	0.6	1.7	3.0	4.4	5.8	61.9
Cerium	0	0	1.1	3.2	5.6	8.3	10.8	115.4
Praseodymium	0	0	2.6	7.9	13.7	20.2	26.3	281.1
Neodymium	0	0	5.8	17.3	30.1	44.5	57.8	617.9
Samarium	0	0	0.1	0.4	0.6	0.9	1.2	12.8
Europium	0	0	2.7	8	13.8	20.4	26.5	283.4
Gadolinium	0	0	0.5	1.4	2.4	3.6	4.7	50.2
Terbium	0	0	0.6	1.7	2.9	4.3	5.6	59.9
Dysprosium	0	0	2.5	7.4	12.9	19.1	24.8	265.1
Holmium	0	0	0.5	1.4	2.4	3.6	4.7	50.2
Erbium	0	0	0.1	0.4	0.8	1.1	1.5	15.9
Thullium	0	0	0.7	2.2	3.8	5.7	7.4	79.0
Ytterbium	0	0	0.6	1.7	3.0	4.4	5.7	61.0
Lutecium	0	0	0.7	2.1	3.7	5.4	7.1	75.8
Yttrium	0	0	0.5	1.4	2.4	3.5	4.6	49.2
Scandium oxide concentrate	0	0	2	6	10.4	15.4	20.0	213.8
Total	**0**	**0**	**21.4**	**64.3**	**111.5**	**165.1**	**214.4**	**2291.9**

Source: Authors' calculations; Kryukov et al. 2016; Pokhilenko et al. 2016

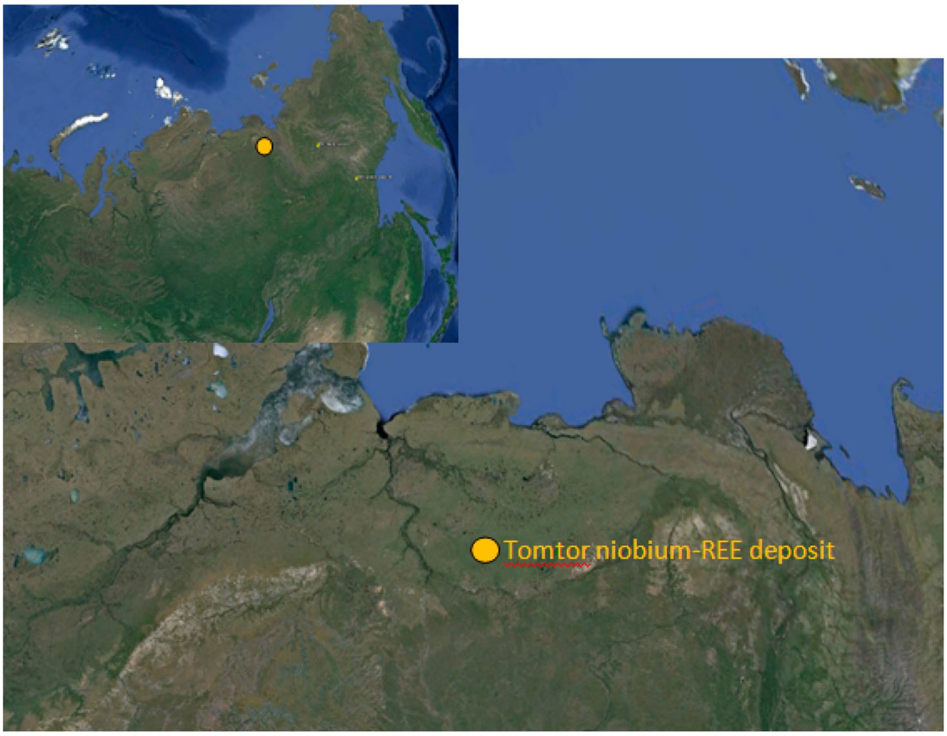

Figure 3: The location of the Tomtor ore field. Coordinates: NL 71°03′; HP 116°30′.
Source: Authors' calculations

infrastructural support (resource, energy, transport and logistics), despite the location in a remote area of north-west Yakutia, make it possible to recommend the deposit as a new and priority source of raw material for full range production of REM, ferroniobium, yttrium, scandium, alumino phosphates and other liquid products (Delitsyn et al. 2015). The geological reserves of the Blizzard site of the Tomtor deposit are given in Table 4 and the structure and the absolute content of the REM oxides in the Blizzard site ores are shown in Table 5.

The project of the deposit development and production of REM products from a high degree of processing of the Tomtor raw materials is a part of the State Programme 'Development of Russian industry and increase its competitiveness 2020', into which it has been included as a number one priority.

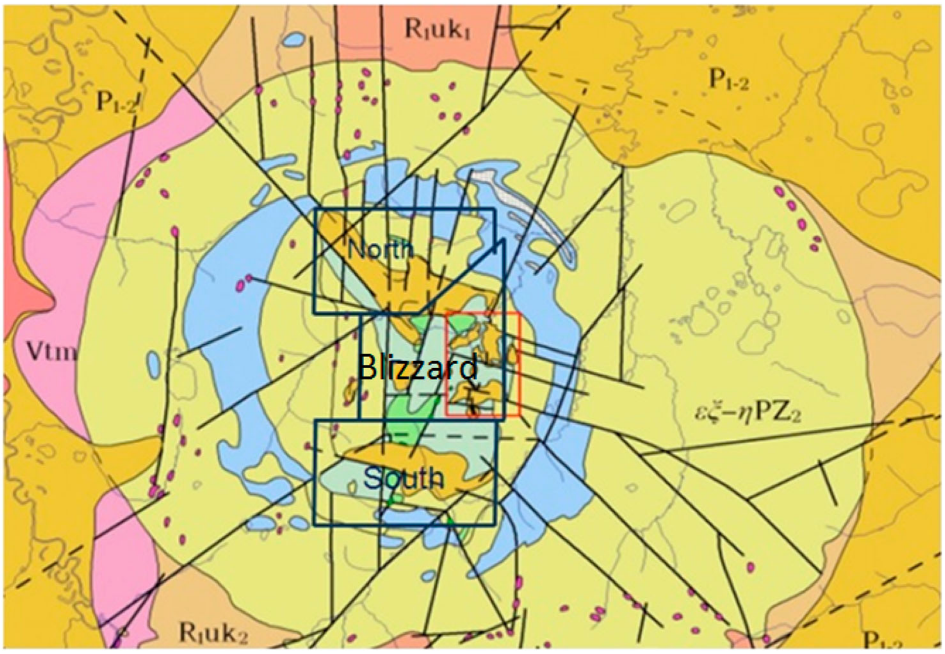

Figure 4: A fragment of the geological map of the Tomtor ore field.
Source: Entin et al. 1990; Kravchenko et al. 1990; Tolstov 2005; Lapin and Tolstov 1993; Tolstov and Samsonov 2014

Table 4. Geological reserves of the Blizzard site of the Tomtor deposit (proved and probable).

Ore (dry)		897.63 ths. tons
	Average oxide content, %	Oxides reserves, ths. tons
Niobium	6.06	54.36
Yttrium	0.50	4.27
Scandium	0.05	0.32
Rare earth elements	8.19	73.47

Source: Entin et al. 1990; Kravchenko et al. 1990; Tolstov 2005; Lapin and Tolstov 1993; Tolstov and Samsonov 2014

Table 5. The structure and the absolute content of the REM oxides in the Blizzard site ores, %.

Oxides	Relative content in the 100% amount of lanthanide oxides	Absolute content in the ore
Lanthanum	23.52	1.96
Cerium	47.7	3.97
Praseodymium	4.51	0.38
Neodymium	14.3	1.19
Samarium	1.63	0.14
Europium	0.57	0.05
Gadolinium	1.42	0.12
Terbium	0.22	0.02
Dysprosium	1.01	0.08
Holmium	0.18	0.01
Erbium	0.38	0.03
Thullium	0.07	0.01
Ytterbium	0.23	0.02
Lutecium	0.06	0.005
Total	100	7.98
Yttrium	–	0.50
Scandium	–	0.05

Source: Entin et al. 1990; Kravchenko et al. 1990; Tolstov 2005; Lapin and Tolstov 1993; Tolstov and Samsonov 2014

The Blizzard site of the Tomtor ore field was licensed in 2014. The owner of the license is 'Vostokengineering' LLC which is a subsidiary company of the 'ThreeArc Mining' (the joint company of the SC 'Rostech' and 'ICT group'). The technological chain of the project implies obtaining of the REM carbonate from one of the Russian enterprises and placing it on the market for further production of the oxides and high-purity metals.

Conclusion and recommendations

At present, global consumption of REM is 130 thousand tons of oxides per year, with demand predicted to increase to 180 thousand tons by 2020. This increase in consumption is reasonable, since the 'big' technological economies of the USA, China, the EU, Japan, Canada and South Korea continue to expand the scope of the REM use and increase their consumption, even with lower rates of GDP growth.

At the same time, in the consumption of rare earths (up to 3 to 5 thousand tons of rare earth oxides per year, mostly imported from China), Russia lags far behind the developed countries, although it is assumed that by 2025 the needs of the Russian economy will reach 15 thousand tons of rare earth oxides.

Obtaining the REM products from the Russian enterprises of the SC 'Rosatom' on the basis of domestic sources of raw material, unique in the mineralization scale (reserves and resources) and in the content of the rare earth components, allows Russia to avoid dependence on the current structure of global monopoly-producing countries and suppliers (China, Brazil) and the risk of unfair competition in the global REM market, as well as being subjected to global price fluctuations of the rare elements.

The research hypothesis, whether rare earth products including niobium, yttrium, scandium could meet the needs of Russian industry, is confirmed. With consumption volumes of Russian industry being about 2 thousand tons of rare earth oxides, the development of the Tomtor deposit guarantees REM deliveries to the domestic market. The surplus capacity makes it possible to export Russian REM to world market, including the other BRICS countries, primarily China and India.

Our estimations show that the value of highly liquid REM products made using concentrates from the ore of the Tomtor deposit reaches US$215 million per year. It is found out that this value enables the development of the scientific and technological competences in innovative ore processing technologies of the unique ores like Tomtor and the subsequent obtaining of individual rare earth metals from them. It is shown that combining competences within SC 'Rosatom' enable the creation of an effective technological chain to obtain highly liquid REM-products that could meet the industrial needs of the other BRICS countries as well.

As a result, BRICS could strengthen its role as a tool of competitive confrontation between countries that are focused on the development of basic and classic industries, mining and processing, and countries that are more or less focused on the collection of rent from the processes of globalization.

In conclusion, we would like to mention that Russia may hop on the last carriage of technologies and hi-tech products producers, even if in the form of primary goods. That is to say, it still has the opportunity to board the carriage of those who contribute to the development to the global economy, rather than receiving it in the form of ready-made products, especially products invented and manufactured elsewhere.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Note

1. 2015 prices for metal oxides were used in calculations.

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