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Geological and Economic Characteristics of the Russian Mineral-Resource Base

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Abstract–Characteristics of the Russian mineral-resource base and its development under the current market conditions are given on the basis of the analysis of deposits accounting for 90% of reserves and extraction of 65 types of mineral resources. Statistical data on reserves of the deposits included into the State Register and the demanded component of the mineral-resource base are presented. The defining role of major deposits in the mineral-resource base development is demonstrated. The group of highly liquid minerals forming the domestic mineral-resource base is described. The reserves of these mineral raw materials are essential and sufficient to satisfy both the domestic needs and a considerable export component.

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INTRODUCTION

The reason for writing this article was the publication of "Atlas of Major Deposits of the Russian Federation" and the monograph "Subsoil Wealth of Russia: Mineral-Resource and Cost Analysis" [1, 2]. The Atlas covers the deposits of the most important types of mineral resources (more than 60) that are included into the Russian State Register of Reserves. The Atlas depicts the most significant objects, i.e. deposits accounting for 70 and 90% of the total amount of reserves and/or extraction of mineral raw materials, for each type of these resources. The national subsoil wealth of all mineral resources, i.e. their recoverable value, is calculated. The Atlas establishes an information basis for analysis of the Russian proved mineral-resource base and its data on the global reserves, extraction, and consumption of mineral raw materials makes it possible to perform detailed analysis taking into account the global market conditions.

The Atlas clearly distinguishes a part of the Russian mineral-resource base that is profitable under the existing market conditions. This part consists of deposits that are involved in development within the Russian mineral-resource complex. At the same time, technically and economically unfeasible deposits that are included into the State Register of Reserves are also evidently seen.

Methodological Bases for Calculation of the Russian Subsoil Wealth

The problem of sustainable and balanced development of Russia under conditions of globalizetion of the world economy and the market of mineral raw materials can be largely solved through systematic and regular appraisal of the country's mineral-resource base, which is particularly important for Russia where almost 50% of the budget revenues comes from the mineral-resource sector.

In other countries valuations of subsoil mineral resources have been performed since the post-war years. Often the magnitude of mineral deposits or ore-bearing areas and administrative units (especially with complex mineralization) has been shown on maps in monetary terms. In Canada, the United States, and France such maps have been compiled since the 1960s. For example, according to the Geological Survey of Canada, a deposit is considered minimally economic when it can ensure a profit of at least $20 million with annual investments that do not exceed $6 million. On the basis of statistical analysis of deposits magnitude in monetary terms for various developed countries (which made it possible to compare deposits with different mineralization) M. Allais [3] elaborated recommendations on prospecting and appraisal works under the conditions of Algerian Sahara. F. Blondel [4] provided data on "mineralization density," i.e. specific ore content per 1 square km, reflected in the value of mineral raw materials. The specific ore content proved to be inversely proportional to the size of the territory (e.g. for Luxemburg it is higher than for the United States). J. Griffits [5] indicated absolute and relative (per 1 square mile) values of "mineral commercial products" of the US states. Due to their oil and coal deposits the richest states are Pennsylvania, West Virginia, and Louisiana. Griffits writes about desirability to use all resources during territorial exploration and not only the most profitable of them, as after such resources are mined out, the remaining can become unprofitable (this warning correlates with a warning against predatory exploitation of deposits for extraction of rich ores only).

Such task became topical in Russia from the 1990s, a period of economic transition to commodity relationships under free market conditions. One of the first works in this field was published by V.L. Zavertkin et al. [6]. The applied evaluation methodology was simple: the total volumes of reserves and resources were multiplied by their prices.

Later I.A. Nezhenskii and I.G. Pavlova proposed a methodology [7–10] and performed an appraisal [11, 12] of "commodity" value of the Russian subsoil reserves and forecast resources, which differed from the above-mentioned "potential" value by taking into account a share of the reserves and resources value in the price of the primary marketable product.

At the beginning of the 2000s researchers from the All-Russian Research Institute of Economy and Exploration of Mineral Resources (VIEMS) published several works, containing a clearer interpretation of the "subsoil wealth" concept itself and a new approach to assessment of other economic characteristics [13–15]. Later this methodology was used in development of a general algorithm for assessment of subsoil wealth and such economic characteristics as the expected income, the revenues of the investor, the state revenues, and the investment, tax, and socioeconomic potential [16, 17].

Subsoil wealth of a certain territory is a complicated geological and economic category. The result of geological prospecting works is discovery of deposits of mineral resources. However, not all objects discovered and investigated by geologists are subsoil wealth. Mineral raw materials can be considered subsoil wealth only in case their exploration and extraction is, firstly, profitable (i.e. covering the costs and generating the profit margin in the amount not less than planned) and, secondly, liquid (i.e. required both for the domestic consumption and for export at the moment of the assessment and for a certain future period). It is these fundamental provisions which we took into account when we were developing our methodology for subsoil wealth evaluation in the context of the Russian realias.

Brief Characteristics of the Russian Existing Mineral-Resource Base

There is quite a large group of mineral resources, the mineral-resource base of which is characterized by well-balanced development and reproduction. A relatively satisfactory component of the Russian mineral-resource base includes such types of raw materials, essential for the economy of country, as oil and gas, coal, uranium, iron ores, copper, precious metals, diamonds, potassium salts, apatites etc. The reserves of these resources are quite abundant and on the whole their extraction volumes satisfy the domestic needs (not only for today but also in the long term) and a considerable export component. Thus, Russia is ranked fourth in the world by oil reserves and second by oil extraction, following the Saudi Arabia. The domestic consumption accounts for a half of the oil extraction volume; the remaining amount is exported by the country. With regard to gas reserves Russia is the richest country in the world and it is ranked second by gas extraction (after the United States). About one-third of the extracted gas is exported. Russia is among the five leading countries by coal reserves and production. Approximately 30% of the extracted Russian coal is exported. All these factors have determined the position of Russia as a large exporter of energy resources in the global subsoil management structure.

Prices for fossil fuels are increasing steadily; at the same time, the energy resources consumption rates are also growing due to the overall increase in energy consumption. At present this process is particularly intensive in rapidly developing countries of the Asian-Pacific region, such as China, India etc. In such situation the position of exporters of energy raw materials is becoming more and more economically advantageous.

A significant share of the Russian export is formed by metallic minerals. Russia is among the five leading countries by reserves and extraction of iron ores, copper, gold, silver, platinum metals, tungsten, molybdenum, cobalt, and nickel; the country fully satisfies the needs of the domestic market and exports large volumes of these raw materials. Moreover, the Russian export component of some of these raw materials and metallic mineral products accounts for 50–70% of their total extracted volume (tungsten, cobalt, nickel, cooper, gold, and silver) or more (platinum and palladium). Russia also plays a significant role as a world producer and exporter of diamonds, apatites, potassium salts, chrysotile asbestos, and boron.

Development of the Russian mineral-resource base of zinc, lead, tin, antimony, barite, fluorite, and graphite is not so successful. Although by reserves of these raw materials Russia is among the world leaders, their extraction volumes cannot satisfy even the modest domestic needs. The present consumption level already requires imported raw materials.

The third component of the Russian mineral-resource base is formed by highly-scarce raw materials, including bauxites, titanium, zirconium, chrome, and manganese ores, which are essential for industrial production. For this group of mineral resources consumption is rigidly connected with import, as their extraction volumes can cover only a minor share of the required amount of these raw materials. At the same time, Russia exports products of their processing (aluminum, titanium, titanium sponge, and ferrochrome), which are manufactured mostly from imported raw materials.

For all types of mineral resources under consideration the Atlas provides data (regarding their recoverable value in monetary terms) with a breakdown of the national subsoil wealth into the following four categories: the demanded national subsoil wealth (DNSW); the national subsoil wealth consisting of objects included into the State Register of Reserves (NSW); the potential national subsoil wealth taking into account P_1 (C_3) resources (PNSW); and the subsoil wealth mineral-resource potential taking into account P_2 (D_1) resources (SWMRP). The national subsoil wealth is calculated taking into account 25-year demand for mineral resources. The national subsoil wealth indicators for the above-listed groups of mineral resources are given in Table 1.

The first group of mineral resources forms a very significant share of the national subsoil wealth. This group includes mineral resources with the highest recoverable value indicators, taking almost all the highest positions both in DNSW and SWMRP ranks.

Therefore, this relatively satisfactory component of the Russian mineral-resource base contains highly-liquid mineral resources in the highest demand, defining the national subsoil wealth. In principle, problems of the other components of the mineral-resource base can be solved at the expense of this group of mineral resources both in terms of development and exploration of the mineral-resource base and in terms of import of the required raw materials.

As can be seen from Table 1, the share of non-demanded reserves, the recoverable value of which is included into the national subsoil wealth, amounts to 219 trillion rubles or 42% of the national subsoil wealth. It is a kind of reserve for involvement of the proved part of the State undistributed subsoil resource fund into commercialization.

The indicator of the subsoil wealth mineral-resource potential (SWMRP), which includes the potential recoverable value of P_1 (C_3) and P_2 (D_1) resources, is very important for innovative development of the Russian economy. In principle, the extraction volumes of the mineral resources included in Table 1 can be increased more than thrice if the resources are transferred to reserves and explored. Such growth is possible for oil, gas, gold, silver, uranium, and other types of highly-liquid mineral-resource products.

In case of favorable global market conditions and commissioning of high-tech manufacturing and processing complexes, the situation with the problematic component of the Russian mineral-resource base can be significantly improved due to forecast resources. Thus, in terms of SWMRP and DNSW the annual production of tantalum, lead, and zinc can be increased 8–10-fold, of niobium 7-fold, of kaolin 6-fold, and of

Table 1. Categories of the Russian national subsoil wealth with regard to major mineral resources. Prices as of the beginning of 2008

Mineral resource	National subsoil wealth, billion rubles				Ranking position	
	DNSW	NSW	PNSW	SWMRP	in DNSW	in SWMRP
Relatively satisfactory component of the Russian mineral-resource base						
Oil, condensate	155971	227808	317071	476203	1	1
Gas	88768	185784	236422	325568	2	2
Coal	19829	28385	31155	37530	3	3
Iron ores	9717	17776	19956	19984	4	4
Nickel	9017	14514	16286	17353	5	5
Copper	4459	9070	9580	9783	6	6
Platinum metals	3544	4192	4203	4307	7	10
Potassium salts	1550	1550	2007	2007	8	13
Gold	1473	4827	6088	7320	9	8
Diamonds	730	1247	1632	1644	10	14
Cobalt	643	1268	1369	1369	11	17
Vanadium	617	1217	1443	1443	12	16
Silver	367	749	798	813	13	21
Rare-earth metals	318	2033	2035	2035	14	12
Apatites	220	387	390	390	17	28
Tungsten	191	334	365	373	19	29
Uranium	173	240	317	446	20	25
Chrysotile asbestos	167	913	917	918	21	19
Molybdenum	143	203	233	233	22	32
Beryllium	79	419	425	425	25	26
Talc	54	1125	1125	1125	28	18
Boron ores	46	100	100	100	30	37
Vermiculite	35	544	544	544	33	24
Total	298111	504685	654461	911913		
Problematic component of the Russian mineral-resource base						
Zinc	282	1781	1986	2309	16	11
Niobium	218	1455	1492	1492	18	15
Magnesite and brucite	116	868	888	903	23	20
Tin	86	320	344	353	24	30
Bentonite clay	65	123	129	129	27	36
Kaolin	50	290	296	306	29	31
Tantalum	42	407	407	407	31	27
Fluorspar	42	80	118	135	32	35
Lead	12	588	610	655	35	23
Baryte	11	15	18	22	36	40
Antimony	10	26	26	26	37	39
Graphite	7	91	91	91	39	38
Laminar muscovite	1	17	17	17	41	41
Total	942	6061	6422	6845		
Highly-scarce component of the Russian mineral-resource base						
Manganese ores	4	172	200	225	40	33
Chrome ores	8	52	173	184	38	34
Titanium	34	4969	8317	8909	34	7
Zirconium	291	1824	4862	6439	15	9
Bauxites	66	747	748	748	26	22
Total	403	7764	14300	16505		
Total for all groups	299456	518510	675183	935263		

tin 4-fold. It is also extremely important that in the long term SWMRP can solve the problem of providing the Russian industry with currently highly-scarce mineral resources, as application of innovative technologies can increase the extraction volumes of these mineral resources by dozens of times.

The fundamental characteristics of the Russian mineral-resource base are as follows: uneven distribution of reserves and production of the majority of mineral resources on the territory of the country; confinement of the mineral-resource base objects to infrastructure; dependence of deposits operation on market relations; dominating importance of large and super-large unique deposits for development of production of many mineral resources; absence of demand for a number of deposits with abundant reserves; remoteness of the majority of production sites from processing and consumption facilities.

Uneven Distribution of Reserves and Production

Uneven distribution of reserves and production on the territory of the country is typical for the majority of mineral resources. Deposits of almost all types of raw materials are concentrated in several areas of distribution which are often isolated. Thus, oil reserves are mostly concentrated in Western Siberia, in the Khanty-Mansi and Yamal-Nenets Autonomous Districts (two-thirds of the Russian reserves), and partly in the Ural–Volga region. These territories also account for 90% of the Russian oil extraction. The Yamalo-Nenets Autonomous District accounts for more than two-thirds of the proved reserves of natural gas and for more than 90% of its production. Thus, the major part of raw hydrocarbons is produced in remote regions with difficult natural conditions. Hydrocarbon reserves of European Russia, where the need for energy resources is the highest, are depleted and limited.

Russia possesses a rich mineral-resource base of coals; however, the proved reserves of high-quality coking coals are localized only in the Kuznetsk, Pechora, and South Yakutsk basins. Such large objects as the Tunguska, Lena, and Zyryansk coal basins, located in regions with poor infrastructure, remain non-demanded. The Kuznetsk and Kansk-Achinsk coal basins account for 70% of the Russian coal production. For regions of the Central Russia and the Urals coal is a scarce raw material.

Despite their uneven distribution, oil-and-gas and coal basins are characterized by a great areal extent, while deposits of solid mineral resources and even accumulations of deposits of individual resources occupy incomparably smaller areas. Reserves of many types of solid mineral resources are concentrated only in several federal districts and subjects of the Russian Federation.

The Central Federal District, more specifically Belgorod and Kursk oblasts, account for two-thirds of the Russian iron ore reserves.

The Volga Federal District accounts for more than 16% of the total copper reserves (Orenburg oblast and the Republic of Bashkortostan) and possesses major reserves of potassium and magnesium salts (Perm region).

The Southern Federal District accounts for about 40% of the Russian tungsten reserves (mostly concentrated in the Kabardino-Balkarian Republic).

The Northwestern Federal District possesses two-thirds of the total chrome ore reserves (the Republic of Karelia and Murmansk oblast), two-thirds of the titanium reserves (the Komi Republic), major reserves of bauxites (the Komi Republic and Arkhangelsk oblast), 70% of apatite reserves and three-fourths of the Russian nepheline reserves (Murmansk oblast), major reserves of highly-aluminous raw materials (Murmansk oblast) and amber (Kaliningrad oblast), and 20% of the total diamond reserves (Arkhangelsk oblast).

The Urals Federal District accounts for more than 20% of the total manganese ore reserves, two-thirds of the vanadium reserves, and about 30% of the Russian apatite reserves (Sverdlovsk oblast).

The Siberian Federal District possesses 70% of the Russian reserves of manganese ores (Kemerovo oblast and Krasnoyarsk region), one-fourth of the titanium reserves and one-third of the vanadium reserves (Zabaykalye region), about 90% of the zirconium reserves (Zabaykalye region and Tomsk oblast, the Tyva Republic), 70% of the Russian copper reserves and more than 80% of the lead reserves (Krasnoyarsk region, the Republic of Buryatia, and Zabaykalye region), about 70% of the zinc reserves, 40% of the tungsten reserves and two-thirds of the total fluorspar reserves, more than 80% of the molybdenum reserves (the Republic of Buryatia, the Republic of Khakassia, and Zabaykalye region), three-fourths of the nickel reserves and almost all reserves of platinum-group metals (Krasnoyarsk region), 80% of the Russian muscovite reserves (Irkutsk oblast), and all reserves of Iceland spar (mostly concentrated in Krasnoyarsk region, in Evenkia).

The Far Eastern Federal District accounts for more than 90% of the Russian tin reserves (the Sakha Republic, Primorye and Khabarovsk region, the Chukotka Autonomous District, and the Jewish Autonomous Oblast), 80% of the diamond reserves (the Sakha Republic), and almost all boron reserves (Primorye and the Sakha Republic).

About 95% of the Russian uranium deposits are concentrated in the Siberian and the Far Eastern Federal Districts (Zabaykalye, Buryatia, and Southern Yakutia).

Confinement of the Mineral-Resource Base Objects to Infrastructure

The uneven distribution of deposits of mineral resources on the territory of Russia is directly related to degree of geological exploration of the mineral-resource base and poor infrastructure of many Russian regions. The regions of the European part of Russia and industrially-developed Urals with their high social and economic potential and well-developed infrastructure are rather well-explored in terms of geology. The possibility to discover new significant deposits of mineral resources in these regions may exist only for the Nenets Autonomous District, the Polar Urals, the Kola Peninsula, Karelia, and shelf areas.

In remote Russian regions the mineral-resource base is characterized by uneven development; moreover, there is a connection between the level of geological exploration and demand for deposits and the degree of territorial development and availability of infrastructural elements. Thus, in the southern part of Siberia and the Far East there is a whole belt of deposits of many mineral resources, forming the basis for development of a mineral-resource complex with numerous mining and processing enterprises. This belt is associated with the Trans-Siberian and the Baikal-Amur Railway Mainlines; the majority of the population of the Siberian and Far Eastern Federal Districts is also concentrated in this area. In poorly developed northern areas the degree of geological exploration is unsatisfactory and often even well-explored deposits, competitive in terms of geology, are not in operation.

It is necessary to emphasize once more that exploration of the mineral-resource base starts only after establishment of the auxiliary (transport, energy, and socioeconomic) infrastructure. At the same time, significant geological discoveries can become the starting point and form the basis for establishment of the infrastructure required for their exploration. During the Soviet era objects of the mineral-resource complex emerged not only in well-developed regions; often great geological discoveries gave an impetus to exploration of new regions. The state built roads, oil pipelines, towns, and cities (Surgut, Norilsk, Magadan, and Nizhnevartovsk) to satisfy the needs of the mining industry. Thus, an oil mineral-resource complex was created in Western Siberia; a polymetallic complex appeared in Norilsk oblast, a diamond complex was formed in Yakutia, and a gold-mining complex was created in northeastern Russia. As a result of this approach the Soviet Union possessed a powerful and competitive mineral-resource complex, determining the economy and social development of many remote subjects of the Federation. At present, in order to attract investments for extraction and processing of raw materials in the region it is still necessary to make advance budget investments into establishment of the regional infrastructure.

Dependence of Deposits Operation on Market Relations

Specific features and patterns in development of the Russian mineral-resource base are in many respects determined by market relations. The market sets up the priorities: only profitable deposits of mineral resources are in demand today. And now it is evident that the country is not so rich. As described above, many deposits containing significant amounts of balance reserves are not in operation because due to some reasons the production of mineral resources at these objects is considered economically unfeasible. Thus, Russia imports highly-scarce manganese ores because the domestic raw materials are mostly represented by hard-to-process carbonate ores. Apart from that, the Russian largest manganese deposit (the Usinskoye in Kemerovo oblast) is hard to develop and the second largest deposit of manganese reserves (the Porozhinskoye) is located in a district of Krasnoyarsk Region with poor infrastructure.

Russia is the world leader in tin reserves. Tin deposits are rather numerous (the State Register of Reserves includes 270 deposits). However, in Russia tin is considered a scarce raw material. Almost all tin reserves are localized in deposits of the Far East (mostly in the Sakha Republic), in remote areas with poor infrastructure. Large tin deposits located on the territory of the Chukotka Autonomous District are non-demanded as well. Volumes of tin production decrease every year and fail to satisfy the domestic needs.

Moreover, it is necessary to note that Russian and foreign investors focus only on exploration of highly-liquid deposits of oil, gas, coal, gold, platinum metals, and diamonds, while numerous deposits of other mineral resources, which are rather economically viable, are not developed unless they ensure short-term super-profits and do not require significant financial investments.

A list of similar problems in exploration of the Russian mineral-resource base can be continued. It should be noted that in recent years investments into mining enterprises have become more attractive due to the growth in global prices. Granting of financial preferences to holders of licenses for subsoil use for the period of prospecting and start of exploration can also contribute to this trend.

However, in order to avoid the market spontaneity and ensure well-balanced development of the Russian mineral-resource base on the ground of the public-private partnership, it is important to strengthen the role of the state in creation of the necessary infrastructural elements. At present, a number of large-scale projects are implemented within the framework of the strategic program on regional development. These projects include construction of the Eastern Siberia–Pacific Ocean export oil pipeline, construction of the Amur federal highway (Chita–Khabarovsk and Primorye) and a highway linking the Chukotka Autonomous District to Magadan oblast and Yakutia, and finalization of construction of the Berkakit–Tommot–Yakutsk railroad line.

At present, exploration and development of the regional mineral-resource bases, first of all in the eastern part of Russia, is entering a new phase. Ideologically it is based on concentration of private and state investments for establishment of effective complex mining-and-metallurgical innovation-technological centers of socioeconomic growth in order to create self-sufficient regions with competitive industry both on the domestic and international market. The market has predetermined division of the state fund of subsoil sites into the distributed and the undistributed components and, like it or not, it regulates the sequence of involvement of subsoil sites from the undistributed fund into commercialization. In this respect the Atlas also reflects the market relations within the Russian mineral-resource base.

Significance of Large and Super-Large Unique Deposits

A large share of reserves and production of many mineral resources is concentrated in several deposits and is characterized by various “saturation” rates (proximity to 100%) of their ordered ranks.

For many types of raw materials there are one or two large deposits accounting for up to 70% of the total amount of reserves. Thus, there is a single deposit accounting for 70% of the Russian reserves of potassium and magnesium salts (Verkhnekamskoye), a deposit containing 70% of all boron reserves (Dal’negorskoye), a deposit accounting for 70% of the graphite reserves (Kureiskoye) etc. (Table 2). For vanadium, titanium, zirconium, platinum-group metals, chrysotile asbestos, talc, and zeolite, there are two deposits accounting for 70% of the total reserves of the respective minerals. There is quite a large group of mineral resources, 3–10 deposits of which account for 70% of the total Russian reserves. A much lower number of mineral resources are characterized by more than 10 deposits accounting for 70% of the total reserves, including iron (11 deposits), tin (13), gas (17), and silver (20). Oil and gold distinctly stand out among the total number of registered deposits and deposits accounting for 70% of the total reserves. The total number of oil deposits exceeds 2500, 110 of them account for 70% of the reserves. About 6000 primary and placer gold deposits are registered, including 14 large-scale deposits (more than 100 t) accounting for 55% of the total reserves and 26 medium-scale deposits (25–100 t), the other deposits are small-scale (less than 25 t). Seventy percent of the total gold reserves are localized in 43 deposits.

Therefore, for the majority of mineral resources 70% “saturation” of ranks by reserves is provided by large deposits, often by one or several. Many of the latter are complex deposits which occupy the leading positions in the ranks for several types of mineral resources at once; for instance, the Oktyabr’skoye deposit (Krasnoyarsk region) is the leader in nickel, copper, cobalt, and platinum metals.

As of today, there are more than 12 000 deposits in the Russian State Register, including 7500 deposits of major solid mineral resources (without coal). At the

Table 2. Characteristics of the Russian mineral-resource base with regard to major mineral resources

Number of deposits	Mineral resource	Number of deposits: included in the state register of reserves	accounting for 70% of reserves	accounting for 90% of reserves	Share of the largest deposit, %
1–5	Amber	2	1	1	98.1 (Primorskoye)
	Boron salts	3	1	2	88.4 (Dal’negorskoye)
	Potassium salts	4	1	1	95.1 (Verkhnekamskoye)
	Native sulfur	4	1	2	81.0 (Syreisko-Kamennodol’skoye)
	Vermiculite	5	1	2	88.4 (Kovdorskoye)
6–20	Magnesium salts	9	1	1	98.6 (Verkhnekamskoye)
	Zirconium	9	2	5	14.3 (Katuginskoye)
	Antimony	9	2	5	38.1 (Sentachanskoye)
	Bentonite clay	9	3	5	31.6 (Biklyanskoye)
	Perlitic materials	10	3	5	43.0 (Mukhor-Talinskoye)
	Strontium	10	4	6	29.1 (Koashvinskoye)
	Graphite	12	1	1	90.3 (Kureiskoye)
	Chrysotile asbestos	12	2	4	52.8 (Bazhenovskoye)
	Nepheline ores	12	6	9	16.7 (Partomchorrskoye)
	Titanium	13	2	5	52.9 (Yaregskoye)
	Molybdenum	13	4	7	26.0 (Bugdainskoye)
	Chrome ores	14	3	5	54.3 (Aganozerskoye)
	Zeolites	15	2	4	55.0 (Shivyrtuiskoye)
	Rare earths	15	6	10	25.9 (Lovozerskoye)
	Vanadium	16	2	2	54.5 (Gusevogorskoye)
	Talc	16	2	6	57.1 (Shabrovskoye)
	Magnesite and brucite	17	2	5	68.9 (Savinskoye)
	Arsenic	17	5	8	18.4 (Oktyabr’skoye)
	Apatite ores	19	7	11	16.4 (Koashvinskoye)
	Baryte	20	5	10	25.9 (Kvartsitovaya Sopka)
21–50	Oil shale	21	3	5	39.6 (Kashpirskoye)
	Manganese ores	22	3	8	52.4 (Usinskoye)
	Diamonds	23	7	12	24.2 (Trubka Udachnaya)
	Kaolin	25	9	17	15.5 (Chalganskoye)
	Mercury	27	4	10	33.1 (Tamvatneiskoye)
	Uranium	30	6	11	24.0 (Strel’tsovskoye)
	Phosphorite ores	32	3	6	60.1 (Vyatsko-Kamskoye)
	Fluorspar	41	6	10	21.2 (Voznesenskoye)
	Cooking salt	41	7	14	27.0 (Nepskoye)
	Bismuth	44	6	16	22.4 (Tyrnyauzskoye)
	Quartz, quartzite	47	9	18	22.6 (Sopka 248)
	Tungsten	50	5	12	33.9 (Tyrnyauzskoye)
51–100	Bauxites	59	7	12	17.6 (Iksinskoye)
	Laminar muscovite	65	10	17	12.8 (Sogdiondonskoye)
	Molding materials	89	10	25	36.0 (Igirminskoye)
	Cadmium	96	12	33	22.2 (Kholodninskoye)
	Platinum-group metals	99	2	3	46.4 (Oktyabr’skoye)
	Lead	99	6	25	39.2 (Gorevskoye)

Table 2. (Contd.)

Number of deposits	Mineral resource	Number of deposits			Share of the largest deposit, %
		included in the state register of reserves	accounting for 70% of reserves	accounting for 90% of reserves	
101–500	Pyrite sulfur	101	10	27	18.7 (Gaiskoye)
	Glass raw materials	102	11	28	16.2 (Bosninskoye)
	Tin	120	13	30	12.5 (Deputatskoye)
	Copper	135	4	21	27.3 (Oktyabr'skoye)
	Zinc	145	9	34	34.5 (Kholodninskoye)
	Helium	169	3	8	40.4 (Chayandinskoye)
	Anthracite (sections)	188	42	81	3.9 (Mirnyi, Glubokii)
	Iron ores	193	11	31	13.3 (Mikhailovskoye)
	Silver	274	20	57	12.4 (Dukatskoye)
	Coking coal (sections)	420	85	177	3.3 (El'ginskoye, Severo-Zapadnyi)
	Brown coal (sections)	473	24	62	8.9 (Uryupskii, Vostochnyi, gor. 0)
501–1000	Power coal (sections)	721	78	202	9.2 (Karantsaiskoye)
	Non-associated gas	830	17	47	12.2 (Urengoiskoye)
More than 1000	Oil	2541	110	≈400	Samotlorskoye
	Gold	5861	43	≈400	15.8 (Natalkinskoye)

same time, 70% of the total reserves of mineral resources are contained in less than 5% of deposits and for solid mineral resources this benchmark is as low as 3%. One thousand six hundred and twenty-three (13%) deposits account for 90% of the reserves and for less than 10% of deposits of solid mineral resources this figure is less than 10%. It should be noted that among solid mineral resources precious metals are characterized by the largest number of deposits. If we exclude coal, gold, and silver from consideration, we will see that reserves of major solid mineral resources are localized in only 1290 deposits; 254 (19.7%) of them account for 90% and 157 (12.2%), for 70% of the total amount of reserves. As we can see, the total number of deposits of the major group of solid mineral resources, which consists of about 60 mineral species, is not too large at all.

Statistical data on demanded deposits demonstrate (Table 3) that for the overwhelming majority of mineral resources 70% of the total production is provided by not more than five deposits. For many minerals (titanium, zirconium, antimony, molybdenum, platinum, vanadium, tungsten, boron, potassium and magnesium salts, chrysotile asbestos, barite, and fluorite) the majority of raw materials (70% and more) is produced at a single deposit. With regard to the total number of developed deposits and deposits accounting for 70% of the production, oil (about 1500 developed deposits; about 250 deposits accounting for 70% of the production) and gold (about 1600 developed deposits; 19 deposits accounting for 70% of the production) differ from the other types of mineral resources.

Out of 4000 developed deposits about 1100 objects in all (30% of all deposits in operation) account for 90% of the total production. A little more than a half of the developed objects are fossil fuel deposits (oil, gas, and coal). With regard to solid mineral resources (without coal) there are 1910 demanded deposits and only 9% of the developed deposits (about 180 objects) account for 90% of the production. Gold and silver deposits drastically predominate among the developed deposits of solid mineral resources, accounting for more than 90% of the total number of deposits. With regard to the other rather numerous raw materials (about 60 types of solid mineral resources) only 125 deposits are developed. Thus, for solid mineral resources (without coal, gold, and silver) the number of demanded deposits is less than 10% of their total amount. Even if we take into account that there are

Table 3. Characteristics of the demanded component of the Russian mineral-resource base with regard to major mineral resources

Number of demanded deposits	Mineral resource	Number of deposits			Share of the largest deposit in production, %
		total number of deposits involved in production	accounting for 70% of production	accounting for 90% of production	
1–3	Zirconium	1	1	1	99.2 (Kovdorskoye)
	Antimony	1	1	1	100 (Sarylakhskoye)
	Boron ores	1	1	1	100 (Dal’negorskoye)
	Phosphorite ores	1	1	1	100 (Kingiseppskoye)
	Potassium salts	1	1	1	100 (Verkhnekamskoye)
	Graphite	1	1	1	100 (Taiginskoye)
	Perlitic materials	1	1	1	100 (Mukhor-Talinskoye)
	Mercury	2	1	2	84.2 (Saf’yanovskoye)
	Arsenic	2	1	2	80.7 (Festival’noye)
	Amber	2	1	2	78.8 (Pal’mnikenskoye)
	Helium	3	1	1	91.2 (Orenburgskoye)
	Vanadium	3	1	1	95.1 (Gusevogorskoye)
	Magnesium salts	3	1	1	96.8 (Verkhnekamskoye)
	Laminar muscovite	3	1	1	96.4 (Chuiskoye)
	Titanium	3	1	2	72.6 (Kukisvumchorrskoye)
	Molybdenum	3	1	2	71.8 (Sorskoye)
	Chrysotile asbestos	3	1	2	62.5 (Bazhenovskoye)
	Vermiculite	3	2	2	59.2 (Kovdorskoye)
	Talc and talc stone	3	2	2	51.0 (Syrostanskoye)
	Manganese ores	3	2	3	48.3 (Durnovskoye)
	Bentonite clay	3	2	3	62.2 (Desyatyi Khutor)
4–10	Chrome ores	4	2	3	57.2 (Tsentral’noye)
	Magnesite and brucite	5	1	1	95.4 (Satkinskoye)
	Baryte	5	1	3	77.5 (Kvartsitovaya Sopka)
	Uranium	5	2	3	42.7 (Strel’tsovskoye)
	Zeolites	5	2	4	41.7 (Yagodninskoye)
	Kaolin	6	2	4	45.9 (Eleninskoye)
	Tin	6	3	5	27.1 (Festival’noye)
	Strontium	7	3	5	34.3 (Plato Rasvumchorr)
	Rare earths	7	3	5	34.6 (Plato Rasvumchorr)
	Nepheline ores	7	4	6	32.1 (Plato Rasvumchorr)
	Tungsten	8	1	3	75.3 (Vostok 2)

Table 3. (Contd.)

Number of demanded deposits	Mineral resource	Number of deposits			Number of deposits
		total number of deposits involved in production	total number of deposits involved in production	accounting for 70% of production	
4–10	Diamonds	8	3	8	43.4 (Trubka Udachnaya)
	Fluorspar	9	1	3	81.3 (Pogranichnoye)
	Quartz, quartzite	9	2	4	46.0 (Sopka 248)
	Nickel	9	2	5	67.4 (Oktyabr'skoye)
	Bauxites	9	3	6	27.7 (Vezhayu-Vorykvinskoye)
	Apatite ores	9	4	6	27.4 (Plato Rasvumchorr)
	Cooking salt	10	3	7	45.0 (Yar-Bishkadakskoye)
11–20	Bismuth	12	4	8	34.9 (Festival'noye)
	Cobalt	13	3	7	61.7 (Oktyabr'skoye)
	Lead	15	4	8	29.1 (Gorevskoye)
	Glass raw materials	19	5	10	31.6 (Tashlinskoye)
	Cadmium	20	6	15	22.5 (Uchalinskoye)
	Anthracite	20	7	11	15.9 (Almaznaya)
21–50	Platinum-group metals	25	1	3	73.4 (Oktyabr'skoye)
	Pyrite sulfur	26	4	9	32.6 (Oktyabr'skoye)
	Zinc	28	6	11	30.7 (Uchalinskoye)
	Molding materials	32	5	12	40.6 (Lebedinskoye)
	Copper	36	4	11	54.8 (Oktyabr'skoye)
	Iron ores	46	5	12	29.0 (Mikhailovskoye)
51–100	Brown coal	70	10	21	24.2 (Borodinskii no. 1)
	Coking coal	84	21	42	9.6 (Bachatskii, gor, 20)
101–500	Power coal	163	37	76	6.7 (Taldinskii, gor, 260)
	Silver	~175	7	19	35.7 (Dukatskoye)
	Non-associated gas	369	5	13	24.0 (Yamburgskoye)
More than 500	Oil	1416	246	~800	Samotlorskoye
	Gold	1610	19	43	27.3 (Olimpiadinskoye)

many complex objects among the deposits of precious metals excluded from our consideration and these complex deposits are developed for production of other components as well, these figures indicate a rather low demand for the proved component of the Russian mineral-resource base.

These data demonstrate that large and super-large objects (the leading positions in the ordered ranks) usually play a crucial, often decisive, role in the formation of the mineral-resource base (reserves of mineral resources), but not always in operation of its objects (production of mineral raw materials). This specific feature is not so evident when we look at more wide-spread mineral resources localized in a large number of deposits. Among the mineral raw materials under consideration it is most typical for gold, in the reserves and production of which the role of medium- and small-scale deposits is relatively important.

Therefore, the demanded component of the Russian mineral-resource base (without fossil fuels and precious metals) includes a little more than one hundred deposits accounting for more than 90% of the production of 60 types of major mineral resources.

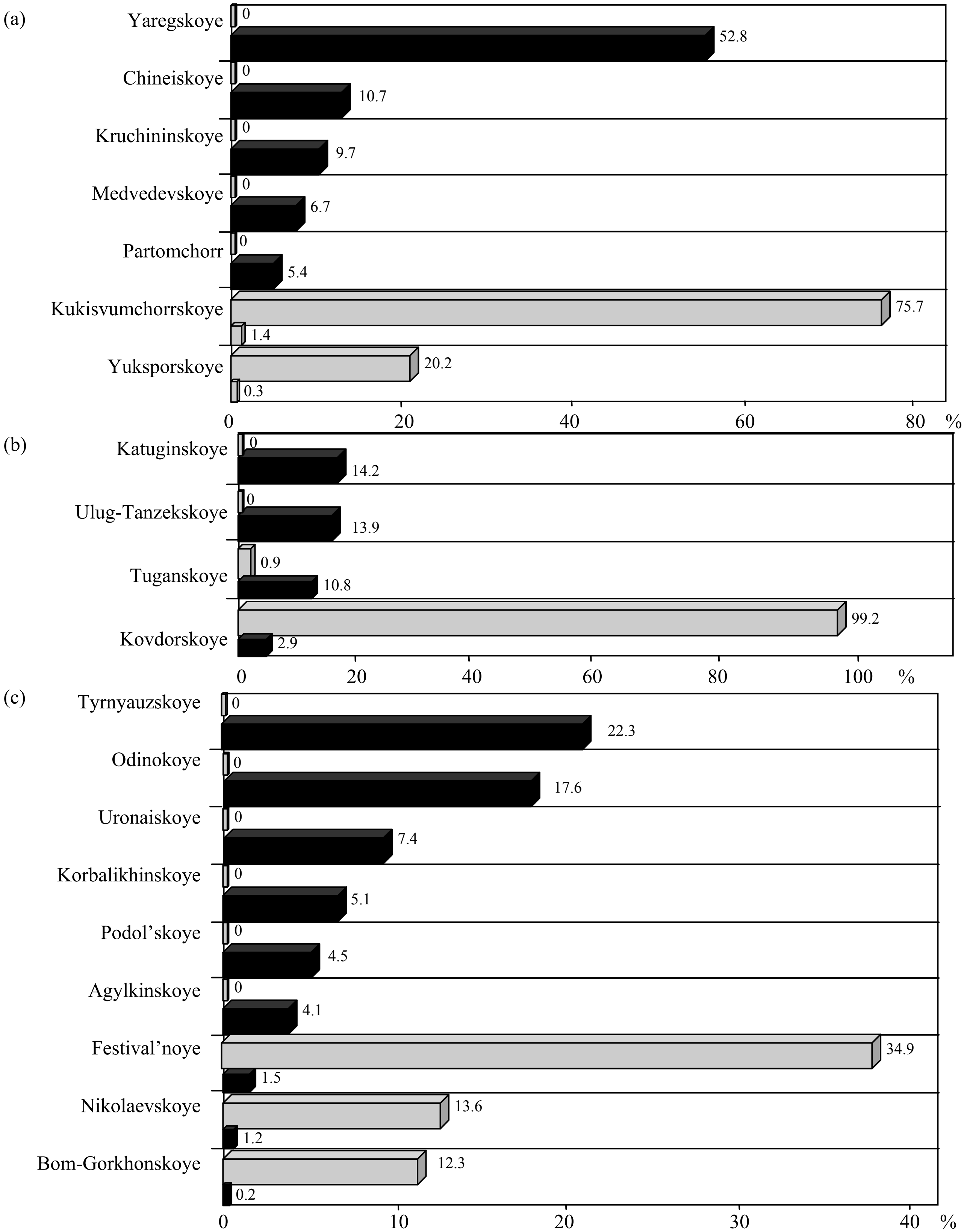
Unfortunately, very often published works mention dozens of thousands of developed deposits in Russia, thus misleading both the geological community and the federal government. Such data create a wrong impression of "grandiosity", high availability, and even inexhaustibility of the Russian mineral-resource potential. The factual material of the Atlas shows the actual state of the Russian mineral-resource base, which is as follows: only large and unique deposits that are confined to the functional infrastructure determine the value of the mineral-resource base, while small- and medium-scale deposits, remote objects and deposits that are not supported with auxiliary infrastructure are not more than a background, a makeweight to the large deposits involved in development. At present, this component of the mineral-resource base is ignored by the market and under the existing economic conditions it will remain non-demanded for a long time.

Absence of Demand for a Number of Deposits with Abundant Reserves

Deposits of many solid mineral resources (titanium, zirconium, manganese, tin, zinc, lead, gold, tungsten, molybdenum, bismuth, kaolin, phosphorites, zeolites etc.) that are involved into operation do not contain great reserves, while the richest deposits are not developed (see the figure). Probably, this specific feature should not be considered as a trend as it can be caused by various reasons: e.g. deposits containing great volumes of reserves can be characterized by low concentrations of commercial components in the ores or low-quality ores that are too hard and expensive to process. As mentioned above, often large deposits are non-demanded if they are located in regions with poor infrastructure.

About one-fourth of non-demanded iron ore reserves are concentrated in three large deposits of the Kursk Magnetic Anomaly. The Usinskoye and Porozhinskoye deposits possess more than 70% of the total reserves of manganese ores; the Aganoozerskoye deposit accounts for more than 50% of chrome ores; the Gusevogorskoye and Chineiskoye deposits possess more than 70% of the Russian vanadium reserves; and the Katuginskoye and Ulug-Tanzekskoye deposits account for more than 70% of the zirconium reserves. About a half of bauxite production comes from medium- and small-scale deposits; a half of zinc reserves are contained in two objects in Buryatia that have been recently licensed (the Ozernoye and Kholodninskoye deposits). The largest deposits of tin, tungsten, molybdenum, bismuth, rare earths, and uranium are not developed. Reserves of three world-class gold objects, namely the Sukhoy Log, Natalkinskoye, and Nezhdaninskoye deposits, also remain almost intact.

Let us consider potential reasons for this situation. Difficult geographical and economic conditions of the deposits location, technological properties of the ores, and high market occupancy, when it is easier to enter the market with small- or medium-scale deposits, are not the only deterrent to involvement of these objects into development. A historical reason is also evident. In the Soviet Union almost all large and super-large deposits that are not developed today had alternatives in the USSR republics. These alternative objects were usually located in more favorable infrastructural, natural, climatic, social, and environmental conditions or they contained more high-grade easy-to-process ores or the development of these deposits were in better compliance with the current or future economic, political, and/or social preferences. For instance, the alternative to the Russian large gold deposits of the Northeast (gold-quartz formation located in Irkutsk oblast and the Sukhoy Log deposit of gold black-shale formation) was the Muruntau deposit of gold black-shale formation located in Uzbekistan and others; the alternative to the Kursk Magnetic Anomaly ferruginous quartzite deposits of metamorphogenic formation was similar deposits in Krivoi Rog, Ukraine. The alternative to titanium deposits (of titanomagnetite, copper-titanium-vanadium, apatite-titanium-iron ore and other formations, including placer deposits) and zirconium deposits (including baddeleyite objects in nepheline syenits and placer deposits) was Ukrainian placer deposits. The alternative to lead-zinc objects (pyrite-polymetallic



Reserves of major deposits and Production of (a) titanium, (b) zirconium, and (c) bismuth in 2007. (■) Reserves, % of the total Russian reserves and (■) production, % of the total Russian production.

deposits in flyshoid black-shale formations, e.g. the Kholodninskoye deposit and others) was stratiform lead-zinc deposits in carbonate formations (the Mirgalimsaiskoye and Shalgiya deposits in Kazakhstan and the Uchkulach in Uzbekistan), pyrite deposits in carbonate-quartz formations (the Zhairemskoye and Karagailinskoye deposits in Kazakhstan), and skarn deposits (the Altyn-Topkan in Uzbekistan). The alternative to Uralian and Karelian platinum-bearing chromite objects was the Kempirsai deposit in Kazakhstan. The alternative to vein and stockwork deposits in argillisites and alkaline metasomatites of Zabaykalye and to other types of uranium objects was Kazakh and Ukrainian deposits of similar or different types. The alternative to oxide manganese objects and carbonate manganese deposits mostly containing rebellious ores was deposits of high-grade oxide and carbonate ores associated with Oligocene arenaceous-argillaceous formation (the Nikopol basin in Ukraine and the Chiatura basin in Georgia). The alternative to the Udokanskoye deposit of cuprous sandstones in Chita oblast was a similar Kazakh deposit, the Dzhezkazganskoye. There are examples of termination of production at the largest deposit in the sector (e.g. at the Tyrnyauzskoye molybdenum-tungsten deposit, at the tin-tungsten objects of the Chukotka Autonomous District, and at the Deputatskoye tin deposit in Yakutia) during the infancy of the already Russian mineral-resource base.

Remoteness of Production Sites from Processing and Consumption Facilities

A spatial disconnection of production sites on the one side and processing and consumption facilities on the other side is observed for a number of mineral resources. For instance, the main iron-ore base of Russia (the Kursk Magnetic Anomaly) is associated with its central part, containing sufficient reserves for many decades. For the metallurgical plants of the Southern Urals, the own mineral base of which is almost depleted, not to mention the eastern regions of the country, the ores imported from Kazakhstan are apparently more economically advantageous than the ores transported from the Kursk Magnetic Anomaly. Each case of such disconnection of objects of the mineral-resource complexes requires an economically justified choice: what is more economically feasible, to transport raw materials inside the country, to establish processing enterprises near production sites, or to import raw materials from abroad.

CONCLUSIONS

For a number of mineral resources, the production volumes of which do not satisfy the Russian needs (titanium, zirconium, chrome, manganese, and bauxites), it is necessary to economically justify the choice of one of the two alternatives (or their combination at a certain ratio): whether to establish own mineral-resource base of this raw material or to cover the shortfall in the raw material through import. For many types of mineral resources such economic assessment has never been performed in Russia. Thus, the Yaregskoye oil-titanium deposit (the Komi republic) accounts for more than a half of the Russian total titanium reserves. However, instead of developing a technology of titanium recovery from this type of ores (this possibility has been already proved by experimental works), Russia imports titanium. The country has similar “technological” problems with zirconium, manganese, and some other types of strategic mineral raw materials.

Economic and technological problems result in incomplete recovery of associated mineral resources at multi-component deposits. Thus, for example, 2500 tons of rubidium and 130 tons of cesium that are extracted as part of complex ores every year are completely lost in the concentration process (the recovery ratio is equal to zero), and the necessary amount of these extremely expensive raw materials is obtained from pollucite concentrates, which are imported from Canada, at the only Russian Redmet plant in Novosibirsk. Such “redemption” of reserves is quite typical for Russia. With regard to many types of mineral raw materials Russia can be considered well-stocked only due to almost no demand for them (a typical example is molybdenum or trace and rare elements).

Let us pay attention to another important economic and political aspect of development of the Russian mineral-resource base. For historical reasons the Soviet Union, first, completely satisfied its needs for almost all types of mineral raw materials and, second, exported certain types of raw materials (mostly, oil and gas) to European countries. Therefore, the mineral-resource base of the country became a part of the global subsoil management system, covering a certain share of the global consumption of mineral resources. Today Russia has become an importer of many mineral raw materials, the production of which has proved to be unprofitable under the emerging market conditions in Russia. In this context the federal government should take decisions on the types and volumes of imported mineral raw materials, which in turn predetermines further development of the Russian mineral-resource base with regard to these types of resources.

Finally, it should be noted that although under the current conditions the amount of developed small-scale deposits of some mineral resources is higher due to their profitability, in the long term only large and unique deposits will become determinative for the Russian mineral-resource base. These deposits “make” the state and the business create the infrastructure necessary for their exploration. The analysis of the Russian mineral-resource base presented in the Atlas demonstrates that there will be new discoveries of large and unique deposits. It is clearly indicated by the existing geological prerequisites in geologically understudied Russian regions. And in the coming years the entire complex of geological prospecting works on reproduction of the mineral-resource base should be aimed at achieving this goal.

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