HIGH-Mg RAW MATERIALS: MINERAL PRODUCTS OF THE KARELIAN-KOLA REGION, RUSSIA

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ABSTRACT

Geodynamic regimes at an early stage in the formation of the earth crust are essential for the formation of high-Mg rocks. The komatiite-basalt series of Archean greenstone belts (high-Mg volcanics) and boninite-like assemblages in the supracrustal units of the same belts, with which talc, magnesite and serpentine of two stages (Meso- and Neoarchean), newly-formed after high-Mg rocks, are associated, are the earliest units productive for industrial minerals. Siliceous high-Mg series represented by formed large lava flows with gabbronorite dyke swarms and the formation of layered mafic-ultramafic intrusives. Large magnetite units were formed in serpentine ultra-alkaline rock which has suffered hydrothermal leaching of magnesium from serpentinite. A third class of high-Mg rocks in this region is associated with the dolomites of the Paleoproterozoic sedimentary-volcanic units of the Karelian-Kola region.

The Kola Peninsula has many high-Mg-silicate rock deposits that meet the requirements for the production of refractory, building and technical materials on their basis such as Kovdor and Khabozero olivinites, Sopcheozero and Pados-tundra dunites, etc. Sungulitic and iddingsitic concentrates are suitable for the production of the pigments and fillers of varnishes, paints and polymeric materials, technical rubber and high-Mg meliorants.

Karelia has two types of talc-bearing rocks. Deposits and occurrences of type I (apoultramafic type) are common in ultramafic rocks of peridotite-picrite or dunite-peridotite composition. Occurrences of type II (apocarbonate type) are confined solely to the dolomites of the Jatulian superhorizon of the Proterozoic. Low-iron talc to talcite occurrences are associated with these complexes.
The Karelia-Kola region, located on the Fennoscandian Shield, is promising for high-Mg raw materials.

Keywords: high-Mg complex, industrial minerals, Precambrian, Fennoscandian Shield, Karelian-Kola region

INTRODUCTION

Magnesium as an element is in position 8 in terms of its amount in the solar system. It makes up about 2% of the earth crust [1]. Magnesium is a third element in terms of its abundance in sea water solution. Its concentration is about 1300 ppm. Major high-Mg minerals are shown in Table 1. Over 60 minerals that contain magnesium are known to occur in nature.

Table 1. Major high-Mg minerals

	Mineral formula	Mg, %	MgO, %
Brucite	$Mg(OH)_2$	41.68	61.0
Forsterite	Mg_2SiO_4	34.5	57.3
Olivine (Mg-Fe)	$(Mg,Fe)_2SiO_4$	30.0	49.7
Magnesite	$MgCO_3$	28.8	47.8
Serpentine	$(Mg, Fe)O\ 2SiO_2\ 2H_2O$	26.3	43.6

Source: [2].

Various applications of magnesium depend on the technical requirements to be met. Magnesia is a general term for magnesium oxide, which can be produced from natural magnesite, breunnerite, brucite and salt water. There are certain requirements to be met by industrial high-Mg raw materials in terms of their major oxide content, e.g. refractory production in nonferrous metallurgy, foundry, industry (MgO content is at least 12 %, total Al_2O_3 + Fe_2O_3 + Mn_3O_4 is 3-6%, the sizes for kilning and charging Martin furnaces are 5-25 and 25-80 mm and those for furnace thresholds are 35-100 мм); as flux and for high-Mg agglomerate production; in the glass industry (MgO at least 18 %, CaO no more than 34 %, SiO_2 and Al_2O_3 1.5 and 2.0, respectively, Fe_2O_3 0.1-0.4); ceramics and porcelain-glazed pottery production (MgO is at least 19 %, total Al_2O_3 + Fe_2O_3 is 0.05 %, SiO_2 is 3.0 % and Al_2O_3 is 0.5%) and the chemical industry (MgO is at least 17 %, SiO_2 is no more than 2.5 %), etc.

Raw magnesite is used as dominantly in prepared form. Dressing technology consists of the crushing of original ore, dressing in heavy media, radiometric separation, washing, flotation and deep dressing by hydrometallurgical technology.

Global reserves from which Mg-bearing compounds can be extracted are widespread. They are estimated at about 12 billion tons of magnesite and several million tons of brucite. Dolomite, forsterite, Mg-bearing evaporate mineral and Mg-bearing brine reserves are estimated at several billion tons. Mg-bearing hydroxides can be extracted from seawater.

In addition to magnesite and brucite, Mg-bearing ultramafic rocks (olivinite, dunite, peridotite and serpentinite) which contain Mg-bearing silicates, e.g. diopside $CaMg(Si_2O_6)$, enstatite $Mg_2(Si_2O_6)$, tremolite $Ca_2Mg_5(Si_4O_{11})(OH)_2$, olivine-forsterite Mg_2SiO_4 and some others, are in demand on the world market. Iron-free varieties are also of interest.

GEOLOGICAL CHARACTERISTICS AND POTENTIAL OF HIGH-Mg RAW MATERIALS FROM THE KARELIAN-KOLA REGION

Of great geological importance in rock formation is the relation and dependence of tectono-magmatic episodes on the characteristics of geodynamic regimes in the general magmatism-tectonics-earth geodynamics chain. High-Mg rocks in the eastern Fennoscandian Shield display distinctive geochemical features from the Meso- and Neoarchean to the Paleozoic (Caledonian epoch). These complexes dominated at an early stage in earth crust formation. The earliest rocks productive for high-Mg industrial minerals are a komatiite-basalt series of Archean greenstone belts (high-Mg volcanics) and boninite-like assemblages in the supracrustal units of the same belts associated with talc, magnesite and serpentine newly-formed after high-Mg rocks at two stages (the Meso- and Neoarchean): 3.06 – 2.9 (Vedlozero-Segozero, Sumozero-Kenozero and South Vygozero belts) and 2.85 – 2.8 Ga (Kostomuksha structure, where MgO concentrations in komatiite lava vary from 24-31 % to 33-39 %) [3]. Siliceous high-Mg series (picrite, basalt, andesite), which formed large lava flows with tremendous gabbronorite dyke swarms, dominated later at a cratonic stage. Layered mafic-ultramafic intrusives formed at this stage. For example, the big layered mafic-ultramafic Burakovian intrusive unit was formed in a rift structure in Karelia during a 2.45-2.43 tectonic episode in the Paleoproterozoic [4]. It contained such high-Mg industrial minerals as olivine and serpentine. The Pados-Tundra massif, located in the so-called "serpentinite" belt zone in the southwestern Kola Peninsula, displays a mineralogenic specialization for talc, serpentinite and dunite. Pre-carbonatitic olivinite and dunite (Gremyakha-Vyrmes and Tiksheozero massifs) were formed in the Paleoproterozoic (Fig.1).

talc (1): 1 Pados Tundra; 2 Svetloozerskoe; 3 Ignoila; 4 Povenchanka; 5 Pindushi;

soapstone (2): 6 Turgan Koyvan-Allusta; 7 Kalievo-Murennenvaara; 8 Osterozero; 9 Urosozero; 10 Vozhemskoe; 11 Ozerky;

olivine (3): 12 Shapkozerskoe; 13 Aganozersky; 14 Kovdorskoye; 15 Lesnaya Varaka;

dunites (4): 16 Sopcheozerskoe;

serpentinite (5): 17 Hautavaara; 18 Hankus; 19 Taloveys;

carbonate rocks (6): 20 Pyalozerskoe; 21 Vidanskoe

Figure 1 High Mg raw materials of Karelian-Kola region

There are two types of talc-bearing rocks in Karelia [4]. Deposits and occurrences of type 1 are an apoultramafic type. In Karelia, such deposits were commonly produced by the hydrothermal reworking of peridotite komatiite and serpentinite formed in the Lopian metallogenic epoch. Svetloozero (Fig.2), Rybozero and Ignoila are the best-studied talc deposits and occurrences of type 1. All of these deposits share some common features such as sheet-type serpentinized dunite and harzburgite intrusions that comprise steeply dipping talc-enriched ore bodies up to 200 m thick. Serpentinite and chlorite schist are most common host rocks. By now, about 20 soapstone occurrences and deposits have been revealed in Central Karelia and in the Kostomuksha Administrative District.

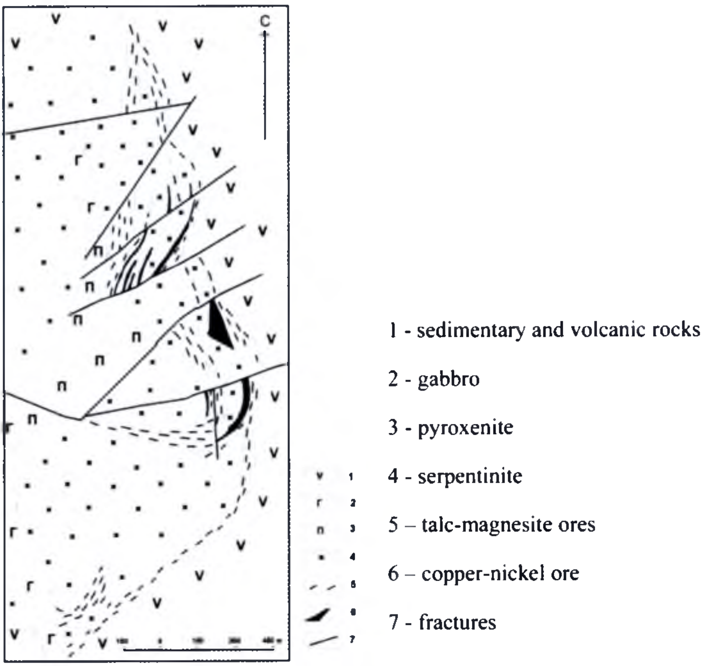

Figure 2. Schematic geological map of West Svetlozergo ultramafic massif

Occurrences of type 2 (apocarbonate type) are confined solely to the dolomite of the Jatulian superhorizon of the Proterozoic. Low-iron talc to talcite occurrences are associated with these complexes.

The largest magnesite and talc clusters were formed in the serpentinite portion of the Svetloozero deposit, the biggest one in Northwest Russia, by hydrothermal leaching of magnesium from serpentinite. The morphology of the ore bodies is commonly represented by lens-shaped bodies and nests, varying in size from tens to hundreds of metres, and depends on the original size of the rock and metasomatic grade.

There is another group of Precambrian rocks associated with dolomites that build up the Paleoproterozoic sedimentary-volcanic unit of the Karelian Craton and the Svecofennian Fold Region. According to official data [5], dolomites of state reserves class 1 are represented by the explored Raiguba-Pyalozero deposit. Its reserves are estimated at 12 millions tons. The state reserves also comprise the Pyalozero, Olenyostrov, Kuzaranda and Vidany deposits and six dolomite occurrences. Kuzaranda dolomite is not contaminated by impurities (quartz). The dolomite meets chemical composition requirements for the production of building and hydraulic lime. Pyalozero dolomite meets chemical composition requirements for refractory raw material of class 1.

The big resources in the Kola Peninsula are associated with many Paleozoic Mg-bearing-silicate deposits, primarily Kovdor (Fig.3) and Khabozero, which can well be used for the production of refractory building and technical materials. High-Mg refractory materials, refractory and chemically resistant ceramics and building materials are in demand in Russia's market.

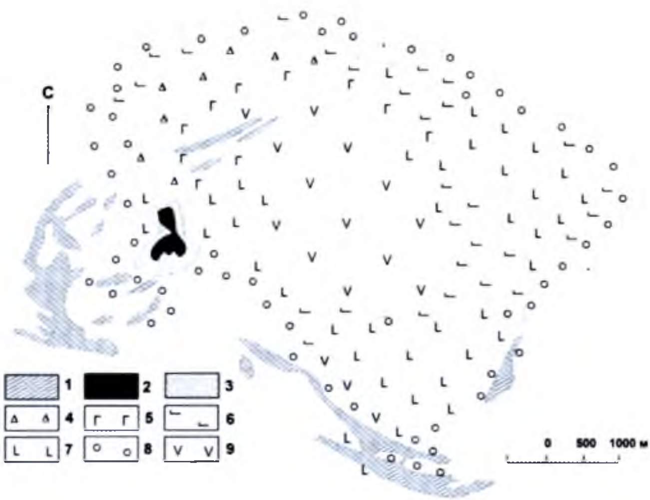

Figure 3. Geological scheme of Kovdor, composed by B.I.Sulimov et al. (1997)

1- carbonatites; 2 - magnetite ores; 3 - apatite-forsterite; 4 - melilite rocks; 5 - phlogopite-diopside; 6- turyaity; 7 - pyroxenite; 8 - ijolites; 9 - olivinites; 10 - fenitized gneisses; 11 - iron ore deposit; 12 - phlogopite deposit

In the Kola Peninsula, relatively big magnesium-silicate reserves are located in the Khabozero olivinite deposit. It is confined to the Lesnaya Varakka ultramafic rock intrusion of Hercynian orogeny. The intrusion covers an area of about 9 km^2. Olivinites make up 85-90% of the massif. Two groups of rocks: fine- to medium-grained ore-bearing and pegmatoid olivinite and coarse-grained ore-free olivinite [5]. Olivinites constitute the central portion of the massif and are surrounded by a pyroxenite band which is in contact with host rocks. The massif is cross-cut by many ijolite, tinguaite and cancrinitic syenite dykes and veins, etc.

The olivinite reserves of the Lesnaya Varakka massif (Khabozero deposit) are estimated at 9.7 million tons. The average MgO content of the olivinite is 43.6 % (fayalite makes up no more than 13%). The olivinite reserves of the Kovdor massif as raw materials for the production of refractory materials are estimated at 290 M t. Experimental batches of Kovdor olivinite have also been tested at ferrous and nonferrous metallurgical plants.

TECHNOLOGICAL FORECAST

The study of the thermal resistance of the rocks has shown that it depends on the composition and structure of the rocks whose indices increase as their thermal physical parameters rise and decrease as the grain size of the mineral constituents of the rocks increase.

Karelian serpentinites as an industrial rock type have not yet been thoroughly studied, but available geological data suggest that they are widespread and could, therefore, be studied mineralogically and technologically, like tremolite and diopside. These are industrial minerals unknown earlier in the region. Two varieties of serpentinite have been identified at the Aganozero chromium ore deposit: serpentinite after high-Fe dunite and serpentinite after high-Mg dunite. Their thicknesses are 540 and 410 m, respectively. Serpentinites are rich in magnesium (36-38%) and contain small quantities of Al_2O_3 (0.1-0.5%) and CaO (0.24-0.5%) impurities. At the Svetloozero talc-magnesite deposit the average MgO content is 34% and the quantities of Al_2O_3 (0.2-3%) and CaO (0-2%) impurities are small. At other localities, such as Hautavaara, Vozhemsky, Taloveis, Hankus, Kropotnavolok, etc., MgO concentrations are lower (25.7-32.35%), while Al_2O_3 (3-6%) and CaO (2.9-5.8%) concentrations are much higher. Considering the chemical composition of Svetloozero and Aganozero serpentinites, they can be used for the biological protection of nuclear reactors. The preliminary study of Hautavaara serpentinite has shown that it can be used in welding operations.

The experimental-industrial tests and the study of the composition and properties of olivinites conducted by the Mining Institute, KSC, RAS, have revealed their application fields (Table 3). These high-quality olivine concentrates can be used for the production of forsteritic refractories, chemically resistance ceramics and the constituents of lubricants for welding electrodes. Sungulitic and iddingsitic concentrates can be used for the production of pigments and fillers of paints and varnishes, rubber articles and magnesium meliorants [6].

Table 2. Chemical composition of original Mg-bearing materials

Material	MgO	SiO_2	Fe_2O_3	FeO	CaO	TiO_2	Al_2O_3	$Na_2O + K_2O$
Olivinite (Khabozero)	40.29	37.55	14.64	10.1	0.56	3.52	0.25	0.32
Olivinite (Kovdor)	39.4	38.7	9.9	6.6	1.0	0.1	0.7	0.3
Dunite (Sopcheozero)	38.49	40.76	2.70	7.45	2.08	-	2.18	0.1
Serpentinite (Pentisuo)	40.42	33.39	6.31	3.51	0.01	0.2	0.22	0.03

CONCLUSIONS

The Karelian-Kola region of the Fennoscandian Shield is the most promising region for high-Mg raw materials because it is here that the lower portion of the earth crust consists of Mg-bearing rocks.

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