RAW MATERIALS

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OLIVINE ROCKS OF THE TOPCHULSKOE DEPOSIT IN KUZNETSK ALA TAU

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A brief mineralogical and petrographic characterization of ultrabasic mainly olivine rocks of the hyperbasic massif of Mount Konchik (Kuznetsk Ala Tau), collectively called the Topchulskoe Deposit of olivinites is presented. The mean chemical compositions of the main kinds of the serocks are calculated on the basis of more than 300 tests. It is shown that their composition completely corresponds to the industrial requirements on high-magnesia silicate raw materials. It is established experimentally that not only fresh olivinites and dunites but also their serpentinous variants, widely developed in the massif, can be used as a refractory magnesia material after an appropriate heat treatment. General information on some application domains for olivine raw materials in ferrous metallurgy and other industries is presented.

Olivine rock is a magnesia silicate raw material widely used in the metallurgical industry. In West Siberia the problem of supplying this raw material is very urgent because of the presence of such giants of ferrous metallurgy as the West Siberian and Kuznetsk Combines and is mainly solved by shipments from the Ural Deposits (the Kytlymsk group of massifs). At the same time, ultrabasic rocks are developed rather widely in the hyperbasic formation in the territory of Kuznetsk Ala Tau and Salair near these industrial entities of Kuzbass [1]. Taking this into account, a Tom-Usinsk expedition headed by M. E. Karev has investigated the local olivine raw materials in 1975 – 1977 to determine their applicability for the production of heat-insulating inserts. The object of the geological prospecting was the hyperbasic massif of Mount Konchik, which is situated south of Kuznetsk Ala Tau 140 km from Novokuznetsk in the vicinity of the Novokuznetsk – Abakan railroad.

A number of outcrops of fresh substantially olivine rocks was discovered on an area of 5 km^2 known as the Topchulskoe Deposit (see Fig. 1). The rocks are mainly represented by olivinites, olivinous harzburgites, and smaller amounts of dunites, occurring as fields stretched in the northeast direction in accordance with the position of the massif. The total area of the outcrops of olivine rocks is about 1 km^2.

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Olivine rocks lie among serpentinites and serpentinous dunites and peridotites and have both well defined and smeared boundaries with the latter. Depending on the boundary, the outcrop has either a rectilinear or a curvilinear shape on the surface with many protrusions that give a strange configuration to the plan of the body morphology. Against the

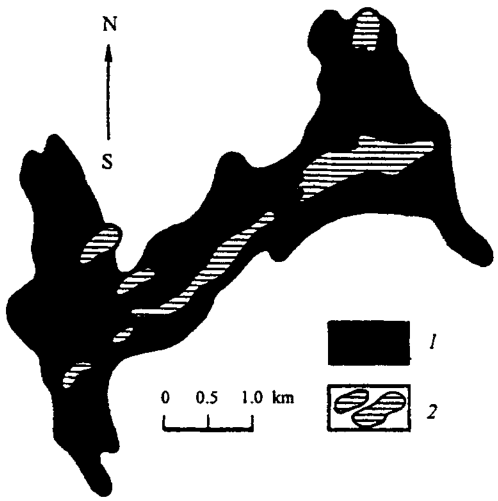

Fig. 1. View of the hyperbasic massif of Mount Konchik: *1*) serpentinites and substantially serpentinous dunites and peridotites; *2*) high-quality olivine rocks of the Topchulskoe Deposit.

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TABLE 1. Mean Chemical Composition of Ultrabasic Rocks of the Hyperbasic Massif of Mount Konchik, % (mass fractions)*

Components	Olivinites Δm_{calc} < 2.0% (n = 25)	Olivinites Δm_{calc} > 2.0% (n = 25)	Dunites (n = 16)	Harzburgites (n = 25)	Serpentinites (n = 25)	Composition of serpentinites per "dry" residue (n = 25)
SiO_2	42.72	42.38	43.85	43.96	39.16	44.47
TiO_2	0.04	0.03	0.07	0.13	0.04	0.05
Al_2O_3	0.87	1.10	1.04	2.11	1.18	1.34
Cr_2O_3	0.44	0.42	0.41	0.42	0.39	0.44
Fe_2O_3	3.40	4.08	2.55	2.75	5.04	5.72
FeO	4.29	4.44	5.53	5.54	2.27	2.58
MgO	44.90	43.88	43.21	40.34	39.14	44.45
CaO	0.02	0.07	0.19	0.71	0.73	0.83
K_2O	0.01	0.01	0.01	0.02	0.02	0.02
Na_2O	0.04	0.03	0.06	0.07	0.09	0.10
Δm_{calc}	1.71	2.98	2.63	3.37	11.77	Not determ.
Ni	0.25	0.24		Not determ.		
Co	0.014	0.02		" "		
Cu	0.003	0.004		" "		
Total	98.71	99.68	99.55	99.42	99.83	100.00

* The table has been composed from the data of analyses made in the chemical laboratory of the West Siberian Geological Administration (Novokuznetsk) in 1978; n is the number of analyses.

background of mother rocks, which have a dark color with a greenish tint, the olivine rocks have a light color, which makes it possible to distinguish them under the field conditions. In addition, they are easily identified by a high density and a clinking when struck. We give a brief petrographic characterization of the rocks below.

Dunites are dark-green dense rocks with a panidiomorphic granular texture complicated by intense serpentinization, which leads to the formation of looplike, latticed, and parallel-fiber microstructures. The mineral composition of the rocks (in mass fractions) is 75 – 95% olivine and 5 – 15% serpentine and accessory minerals, namely, chrome spinel and magnetite. Insignificant amounts (2 – 3%) of enstatite are often encountered.

The main mass of these rocks, usually strongly serpentinous up to apodunitic serpentines, is encountered near olivinites and also inside olivinite outcrops in the form of small irregular spots. In the latter case the degree of serpentinization of the rocks is markedly lower, and new formations of olivines over serpentine can be clearly seen under a microscope. The mean chemical composition of ultrabasic rocks of the massif is presented in Table 1. It can be seen from the table that dunites are characterized by a high content of MgO and a low content of SiO_2 in proportions close to the stoichiometry of natural olivines and small amounts of impurities such as CaO, Al_2O_3, and alkali and of iron.

Olivinites. Macroscopically, olivinites are dense ores clinking when struck. They have a bright-green color, often with a yellowish tint, and grains of nonuniform size, often with a porphyritic structure. The panidiomorphic granular structure typical for dunites is usually not observed in olivinites. The mineral composition of the rocks consists of virtually monomineral formations (96 – 98%) of olivine. The impurity minerals are enstatite, strongly magnetitized chrome spinel and magnetite, and serpentine is a secondary impurity.

In the rock, olivine forms two well-defined generations arbitrarily called primary and secondary ones. Olivines of the primary generation are encountered in the form of individual rare grains of idiomorphic habitus, whereas the secondary-generation olivines are represented by segregations of various sizes and shapes, which sometimes contain relics of primary olivines in the form of poikilitic ingrowths. Sometimes, they are crystals of elongated prismatic "amphibolic" shape. Secondary-generation olivines often have a well-defined or perfect cleavage in one or, more rarely, two directions at an angle of 90°. Optical data indicate that olivines of the primary generation contain 8 – 10% fayalite component, and those of the secondary generation contain 6 – 7% (mole fractions) fayalite.

Rhombic pyroxene (enstatite) in olivinites is encountered in the form of rare flakes commonly of irregular shape in spaces between olivine grains, and in coarse species it has a characteristic wavelike extinction (a result of deformations). In some places the mineral is olivinized, which is manifested by the formation of olivine over the periphery of enstatite flakes and inside them over a cleavage or fracture cracks. The degree of olivinization differs up to complete pseudomorphic replacement of pyroxene by olivine. In the latter case the inherited nature of the new olivine grains is observed over fine-grained magnetite aggregates arranged in parallel chains reflecting the shadow structure of the pyroxene grains.

Ore minerals in olivinites are represented by chrome picotite and magnetite. Chrome spinel forms subidiomorphic and xenomorphic grains and, as a rule, is almost completely replaced by magnetite, being preserved as separate fine "eyes" in the central part of it. In addition, apochrome spinel grains of magnetite are often surrounded by a thin border of chlorite of the kümmererite group. Thin brucite veins are encountered in this region. In addition to apochrome spinel magnetite the ore accessories in olivinite are rather widely represented by magnetite proper, which forms fine grains of various habitus (from perfect crystals to elaborate irregular shapes) and aggregations of a dust-like material. The latter also fills breakthroughs in serpentine cords and loops and sometimes impregnates olivine grains together with iron hydroxides and leucoxene.

The mean chemical composition of olivinites is presented in Table 1. Olivinites are only slightly different from dunites. The differences mostly concern the content of MgO, which is somewhat elevated in olivinites reaching 45 and even 47% is some samples. Another special feature of oli-vinite is a negligible concentration of impurity components such as TiO_2, CaO, and alkali.

Harzburgite and apoharzburgite serpentinites occur in large amounts in the massif of Mount Konchik and have a complex interrelation with olivinites and dunites. A characteristic feature of them is a low content of rhombic pyroxene and a marked enrichment in olivine. On the average the amount of pyroxene in them does not exceed 5 – 7%.

Macroscopically these are dark-green medium-grained massive rocks with well-defined enstatite prisms against a dense background. The degree of serpentinization of harzburgites varies within a wide range up to formation of pure serpentinites. The least serpentinized rocks are positioned close to the outcrops of dunites and olivinites. In addition to serpentine, which is the main product of secondary changes in the rocks, they contain insignificant amounts of talc, carbonates, chlorite, and amphibole; accessory minerals are represented by chrome spinel and magnetite. However, the main distinguishing feature of the rocks is the manifestation of olivinization processes in them, which are especially noticeable near the regions where olivinites are exposed (see Fig. 1). At these places polished sections clearly exhibit new formations of olivine over serpentine and pyroxene. On the serpentine, olivine forms fine- and small-grained aggregates with mosaic extinction, and on the enstatite it forms either full pseudomorphoses or regions of isometric shape with a granoblastic structure. These olivinized harzburgites have a chemical composition close to dunites but contain somewhat smaller amounts of MgO and larger amounts of Al_2O_3 and CaO, and have higher losses in calcination (see Table 1).

The rocks described occur among dark serpentinites with a greenish tint, which have dominant inclusions of a mixed chrysotile-lisardite-antigorite composition or much more rarely of a purely antigorite composition.

The chemical composition of serpentinites is very close to that of harzburgites and, as recalculated per "dry" residue, to that of olivinites, differing from the latter by a somewhat higher content of SiO_2, Al_2O_3, and CaO (see Table 1).

The rocks considered have been subjected to weathering. By drilling data the thickness of the changed zone is 1 – 2 m in massive blocks and 10 – 15 m in regions of crushing along tectonic disturbances. The process of surface changes is mainly manifested by the entrainment of magnesium-containing rocks, which affects the quality of the rocks as a refractory raw material (Table 2). It can be seen from the table that the olivine rocks of the investigated deposit have a chemical composition that on the whole meets the requirements imposed by industry and they can be used in ferrous metallurgy.

Ferrous metallurgy mainly uses olivine rocks (1) in the production of heat-insulating inserts for casting killed steel, (2) in the production of forsterite refractories, and (3) for molding boxes in steel casting in machine building. Preliminary estimates [2] show that the use of heat-insulating inserts increases the output of quality steel by 2 – 7% from each ton of ingots, which has been confirmed by the practice of the Magnitogorsk, Nizhni Tagil, Cherepovets, Chelyabinsk, and Krivoi Rog Metallurgical Plants [3].

TABLE 2. Content of the Main Components Specified by Industry in Olivinites of Mount Konchik, % (mass fractions)*1

Components	$\Delta m_{calc} < 2.0\%$ *2	$\Delta m_{calc} > 2.0\%$ *2	Weathering zone	Zone of fresh rocks (in prospecting hole)	Industrial requirements on olivine raw material
MgO	$\frac{42.64-47.39}{44.90}$	$\frac{41.33-46.00}{43.88}$	42.8	45.10	45.0 – 47.0
SiO_2	$\frac{41.26-44.89}{42.72}$	$\frac{41.18-43.57}{42.38}$	42.9	42.12	Unspecified
SiO_2 + MgO	87.62	86.26	85.7	87.22	≥ 86.0
FeO + Fe_2O_3	7.69	8.52	8.6	8.30	≤ 10.0
CaO	$\frac{\text{Tr.}-0.28}{0.02}$	$\frac{\text{Tr.}-0.42}{0.07}$	0.5	0.2	≤ 1.0
Δm_{calc}	$\frac{1.09-2.00}{1.71}$	$\frac{2.02-5.82}{2.98}$	2.8	2.00	≤ 2.0

*1 By the results of over 300 analyses. Free silica is absent in the olivinites.

*2 In the numerator – extreme values, in the denominator – mean values.

Forsterite refractories are used in wall linings of open-hearth furnaces, especially in edge walls, but are even more efficient in regenerator checkerwork [4]. In the latter case it becomes possible to increase the temperature of the air and gas supplied to the furnace and thus intensify steel melting substantially. This occurs because the stability of forsterite regenerator checkerwork is much higher than that of dinas and chamotte ones. For this reason forsterite refractories can be used successfully in glass furnaces instead of dinas and chamotte refractories.

The range of application of olivine rocks in industry makes them a valuable raw material, and this fully refers to the olivine rocks of the Topchulskoe Deposit. However, olivine rocks often contain serpentinized regions, which lowers the quality of the raw material. This requires selective mining of the rock and increases its cost.

At the same time it is well known that serpentine is easily dehydrated at temperatures above 500°C with the formation of olivine (forsterite) with a high magnesia content [5].

The reaction of dehydration (olivinization) occurs as follows:

$$\underset{\text{Apodunitic serpentinite}}{Mg_3Si_2O_5(OH)_4} + Mg(OH)_2 \rightarrow \underset{\text{Forsterite}}{2Mg_2SiO_4} + 3H_2O,$$

$$\underset{\text{Apoharzburgitic serpentinite}}{2Mg_3Si_2O_5(OH)_4} \rightarrow \underset{\text{Forsterite}}{2Mg_2SiO_4} + \underset{\text{Orthopyroxene}}{Mg_2Si_2O_6} + 4H_2O.$$

Proceeding from this, the Kuznetsk Metallurgical Plant conducted an experiment on firing serpentinized harzburgites, dunites, and serpentinites. The test mixture was heated gradually to 1380°C at atmospheric pressure and then slowly cooled. In all cases the pouring mixture consisted almost en-

TABLE 3. Experimental Data on Calcining Various Rocks of the Massif of Mount Konchik, % (mass fractions)*

Components	Serpentinous and thermolytic dunite	Serpentinized harzburgite
SiO_2	42.49/44.42	42.27/46.85
TiO_2	0.02/0.03	0.03/0.005
Al_2O_3	2.06/0.70	1.52/0.58
FeO	5.03/0.37	3.26/3.40
Fe_2O_3	2.27/7.93	3.91/3.92
MgO	42.00/45.34	37.40/44.20
CaO	0.14/0.70	0.70/0.42
P_2O_5	0.13/0.06	0.09/0.06
K_2O	0.005/0.005	0.055/0.005
Na_2O	0.03/0.01	0.14/0.01
Δm_{calc}	4.31/0.00	8.80/0.00
NiO	0.19/0.15	0.25/0.25
CoO	0.014/0.014	0.02/0.02
Cr_2O_3	0.30/0.28	0.28/0.34
Total	98.98/100.00	98.67/100.15

* In the numerator – before calcining; in the denominator – after calcining.

tirely of olivine of the forsterite series with individual grains of rhombic pyroxene (Table 3).

Calcination of the rock is accompanied by a marked increase in the MgO content in it relative to the primary material; the amount of SiO_2 + MgO reaches 90%. In this parameter the calcined specimens completely correspond to the industrial requirements imposed on olivine raw materials (see Table 2).

It has been established that the serpentine – olivine phase transition in air occurs at 790 – 830°C [6, 7]. This temperature can be decreased (to 550°C) by increasing the heating time and decreasing the dimensions of the material [8].

The data presented show the prospects of not only selectively mined fresh olivinites and dunites but also their hydrated variants, which makes their mining economically efficient.

The present investigations of ultrabasic rocks of the Topchulskoe Deposit and the calculated resources of olivine raw materials in it place this deposit among industrial ones with high quality of the material. The resources of the Topchulskoe Deposit can completely satisfy the needs of the enterprises of ferrous metallurgy of Kuzbass, which will make it possible to cut shipments of raw materials from other regions and substantially reduce the cost of products.

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