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The Chuktukon niobium-rare earth metals deposit: Geology and investigation into the processing options of the ores

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ABSTRACT

The Chuktukon niobium-rare earth elements ore deposit is located in Siberia (Russia). Weathered carbonatite crusts are the basis of the ore deposit. The deposit itself is 3.5 km in length, about 800 to 1400 m in width and up to 200–300 m in thickness. The ores are composed of iron-manganese oxides (hydrogoethite, hematite, psilomelane, pyrolusite) and contain 3–7 wt.% of rare-earth phosphates (florencite, monazite) and 0.5–1 wt.% of niobium oxide (pyrochlore). The ore is completely finely dispersed and consists of oxide particles formed of compact, dense aggregates which makes ore dressing as well as leaching of the rare and radioactive elements very difficult. Several options for processing of these ores have been considered: 1) reduction of the iron oxides to magnetite followed by beneficiation with magnetic separation to produce a rare metal concentrate; 2) processing of the rare earth elements (REE) containing minerals by direct alkaline-acid treatment; 3) processing of the ores using nitric acid leaching in an autoclave.

1. Introduction

The Chuktukon niobium-rare earth metal ore deposit is located in Siberia, in the Krasnoyarsk region, 110 km from the Boguchan hydroelectric power station which has recently been commissioned (Fig. 1). This mineral raw materials is capable of providing impetus for the modernization of the Russian rare metal industry because of its qualitative and quantitative characteristics. The deposit is located in a region of promising industrial development and is a part of the territoriy where the Russian Federation's Program "Complex Development of the Lower Angara Region" is currenly being realized. The main program directions are creation and development of industrial activities in sectors such as power, metallurgy, oil and gas, gold, rare-metals, and timber. The program will aid the development of the niobium and rare-metal resources of the Lower Angara and neighbouring regions as well as increase the national production of REE and therefore import substitution (Lapin, 1997; Lomaev and Kuzmin, 2003; Lomaev and Serdyuk, 2011; Serdyuk et al., 2000).

In this paper, we present general information about the Chuktukon deposit, including geology, as well as the results of our studies aimed at selecting the most efficient practical flowsheets for processing of the ores. In order to obtain a better understanding of this ore site, both earlier published data (Kuzmin et al., 2006; Kuzmin et al., 2012; Shabanov et al., 2012) and the results of new research were used in the paper.

2. Geological background

The Chuktukon deposit corresponds to the eponymous dome of the Chadobetsk uplift of the Siberian platform. This deposit belongs to the REE weathered carbonatite type ore formation. The Nb-REE bearing mineral is a finely dispersed pyrochlore-monazite in lateritic weathered crusts. The geological structure of the Chuktukon deposit is composed of terrigenous slightly metamorphosed carbonatite sediments of the Upper Proterozoic age, broken by intrusive rocks of the Chadobetsk complex and covered by loose formations of Cretaceous-Neogene and Quaternary ages.

Sediments of dolomite and dolomitic limestone (composing an arch of the Chuktukon uplift), aleuro-clay shales, silty shales with sandstones and dolomites, sandstones (composing the uplift wings) were revealed by core drilling within the deposit. The geochronological age of the rocks, defined by the potassium-argon method by glauconite, is about

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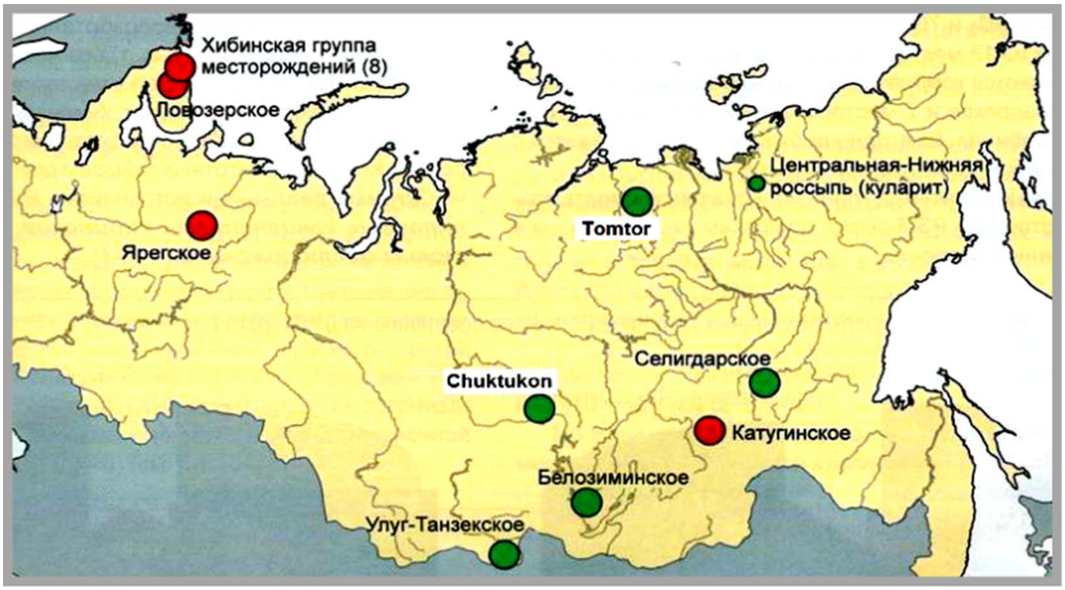

Fig. 1. Location of the Chuktukon deposit: Siberia, Krasnoyarsk region.

1290–1250 million years. The total thickness of the Upper Proterozoic deposits is 830–1150 m.

The ultrabasic alkaline rocks, represented by alkaline picrites and breccias of alkaline picrites (εδ T1), and carbonatites (x T1) of the Chadobetsk complex, whose bodies are concentrated in the crest of the Chuktukon brachyanticline, play the main role in the structure of the Chuktukon deposit. The age of the alkaline picrites ranges from 299.0 ± 9.0 to 255.1 ± 7.7 Ma; for explosion breccias it is 219.7 ± 6.6 Ma; for carbonatites it is 260.1 ± 7.8–183. 3 ± 5.3 Ma. All massifs, both facing the surface and overlapped by a sedimentary cover, are recycled by hypergenesis processes, making it difficult to define the morphology and size of the bodies.

Two large rod-like carbonatite bodies (the South and Central ones) are located in the apical part of the Chuktukon dome. Carbonatites, unlike alkaline picrites, are almost non-magnetic, but, because of the low thickness of the roof strata, the products of their weathering, accumulating thorium, rare metals, phosphorus and other elements, are clearly registered by radiometry by an increase in the gamma field over 8–10 mR/h.

The central body of carbonatites has an irregular rod-like shape with sinuous contours, slightly elongated in the meridional direction, with a size of 2.5 × 1.8 km. The south carbonatite body (1.9 × 0.9 km) has an irregular rod-like shape elongated in the latitudinal direction; its contours are also sinuous.

Three structural-mineralogical types of carbonatites are distinguished in this deposit by the mineral composition, textural-structural features and on the basis of chemical analysis: niobium – rare-earth – essentially calcite, rare-earth – essentially dolomite and less common dolomite – siderite – calcite.

The area of the ore zone is relatively small (about 16 km^2) and its thickness reaches 300 m, increasing up to the top of the dome structure. The lower and top borders of the weathered crusts are very irregular. The profile of carbonatite weathering is specific. There are three zones in the structure (from bottom to top): a) a disintegration zone, b) a zone of leaching and hydrogene cementation, and c) a zone of hematites and ochres (final products).

Rare earth metal ores of the weathered carbonatite crusts, with regard to composition and structure, are present in the three main species: hematites (about 14 wt.%), ochres (clay, friable, loose yellow–brown color, black fine rocks, about 42 wt.%) and ochre clays, friable or lumpy, yellow or yellow–brown in color, differing from the ochre by a lower content of Fe and Mn oxides and hydroxides (about 44 wt.%).

The prevailing mineral components of the ores are goethite, hydrogoethite, hematite, psilomelane and pyrolusite. They are characterized by a particular set of rare metal minerals, such as barium pyrochlore, strontium pyrochlore and cerium pyrochlore. At some locations, there is also primary pyrochlore, to some extent altered, but of a common composition. Rare earth metals are present in the secondary mineral species – florencite, monazite and cerianite.

The ore zone of the Chuktukon deposit resembles a powerful crustal shield-like formation. The ore zone, contoured by a 3.0 wt.% boundary value of REE in rare-earth ores and 0.8 wt.% content of niobium oxide in niobium ores, is about 3.5 km long in the north–south direction and its maximum width is 1600 m.

The REE ores reserves, as proved by the State Commission for Mineral Reserves of Russia in 2007, are 6.6 million tonnes (by category C2, accepted in Russia), with an average content of Nb_2O_5 – 0.60 wt.%, rare earth oxides (REO) – 7.32 wt.%, MnO_2 – 15.5 wt.%, Fe – 34.3 wt. %. The resources forecast by the authors for the niobium and rare earth ores are based on the results of the drilling operations and with regard to the quality characteristics, they are commensurate with the reserves proved by the State Commission for Mineral Reserves (Table 1).

According to the results of many chemical analyses conducted on the samples, iron and manganese in the rare earth ores are 28.6 wt.% and 6.9 wt.% respectively. Iron content in the niobium ores is 31.0 wt. %, manganese at 4.6 wt.% and the vanadium pentoxide content is 0.28 wt.%.

Table 1
Reserves and resources of the niobium and REM ores.

Ores	Category	Ore reserves (resources), thousand tonnes	Content,%		Metal oxide reserves (resources), tonnes	
			Nb_2O_5	Rare earth oxides	Nb_2O_5	Rare earth oxides
REE	C_2	6639	0.60	7.32	39834	485975
REE	Resources	61629	0.34	6.18	209951	3809735
Niobium	Resources	101092	1.18	2.96	1197150	2997142