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Technology opportunities to develop large-volume platinum ore deposits in dunite of zoned mafic–ultramafic complexes

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ABSTRACT

The results of mineralogical and technological studies of PGM mineralization in zoned mafic – ultramafic complexes of the Ural–Alaskan type are given. Technological properties, grain size, and good opening of PGM ore in grain size class +80 μm make it possible to concentrate ore using gravity methods with stadial comminution and between cycle separation of relatively large grains and nuggets into high-grade concentrates at the early stage of disintegration. The elaborated technological flow chart approved under semi-industrial conditions allows recovery of as much as 94% Pt.

1. Introduction

For more than 200 years, concentrically zoned pyroxenite-dunite massifs (Alaskan–Ural-type zoned mafic–ultramafic complexes) have attracted the attention of researchers as a native source of unique platinum placers. The overall output of "pan" platinum from placers of Columbia, Ural and Alaska has exceeded 800 tonnes, and platinum placers are still mined in the Aldan Shield and Kamchatka. The latest analysis shows that the metallogenic potential of zoned complexes within the Ural Platinum Belt alone is estimated at 19 000 tonnes of native and 1300 tonnes of placer platinum (Dodin et al., 2010).

Platiniferous mineralization within the boundaries of zoned mafic–ultramafic complexes for the first time was found in the Urals in 1830 by Shvetsov (Shvetsov, 1830), and at a later time it was studied by numerous researchers (Inostrantsev, 1893;Vysotsky, 1925; Zavaritsky, 1928; Betekhtin, 1935; Razin, 2008;Yuzhko-Zakharova, 1975; Volchenko, 1999; Ivanov, 1997). Initially, the payable platiniferous mineralization was associated only with chromite veins and schlieren, which quantity within the boundaries of the Nizhny Tagil massif exceeded 1600 (Ivanov, 1997; Razin, 2008). Minor platinum deposits, where platiniferous mineralization is concentrated in chromitite ore bodies among dunites of zoned complexes are included in the current classifications as a dunite-chromitite-platinoid ore formation, with the Soloviev Mountain deposits as a typical case (Petrov et al., 2001). In the Nizhny Tagil massif high concentrations of platinum were discovered directly in coarse-grained dunites without any presence of metallogenic chromitite inclusions. This geological-commercial type of platinum deposits is included in the classification as dunite-pegmatite-platinum ore formation, with Avrorinskoe as a typical deposit (Lazarenkov et al., 2002).

In the early 20th century, based on the idea of high platinum concentration in most dunites and the presence of platinum-enriched areas in chromite ores and pegmatite dunite, N.K. Vysotsky and A.V. Zavaritsky, prominent researchers of the Ural Platinum Belt, investigated an opportunity of localization and development of a large-volume platiniferous mineralization in zoned mafic–ultramafic complexes. In line with this scientific theory "…in general, all dunite massifs must be viewed as platinum ore bodies", and their commercial development will depend solely on the "technological feasibility (one may also add profitability) of the noble metal extraction" (Vysotsky, 1925; Zavaritsky, 1928).

Until recently, technological feasibility of large-scale processing of igneous rocks with low concentration of platinum has not been speculated even on a theoretical basis. Nowadays, however, when the world practice proves the efficient development of ore deposits with an average noble metal concentration of less than 1 g/t we have scrutinized the proposed theory both in terms of technological feasibility and in terms of economic viability of platinum extraction from dunite. A package approach to the problem included the acquisition of exhaustive and reliable data on the composition, structure and processibility characteristics of this type of platiniferous materials due to the integration of methods for investigation of the composition and properties of ore-

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hosting rocks with mineralogical and processibility research into payable mineralization, and laboratory and pilot-scale processibility tests with potentially metalliferous bodies.

2. Research subject and methods

2.1. Research subject and characteristics

The main subject matter of the study is platiniferous dunites of ore zones identified in the late 20th century within the boundaries of the Gal'moenan massif in the northern part of Kamchatka (Kozlov, 2007; Kozlov and Chanturia, 2009; Chanturia et al., 2011). The identified areas of platiniferous dunites with their proved 1300 m length, 130–160 m thickness and 0.7–3.2 g/t average platinum content are promising from a standpoint of commercial development. In recent years, large-volume platiniferous ore zones have been identified also in dunites of the Svetloborsk massif in the Central Urals (Telegin et. al., 2009), and today quite a realistic background is available for the localization of such zones in the Nizhny Tagil massif (Ivanov, 1997; Razin, 2008).

For laboratory test work and pilot-scale tests a platiniferous dunite bulk sample (weight is equal 9750 kg) was taken with standard procedures. The sampling was performed by trenching of the surface of open-pit workings providing an access to ore zones of the Gal'moenan zoned massif (Tolstykh et al., 2004; Kozlov et al., 2011). The bulk sample characterizes adequate platiniferous dunites of the Western ore zone at the step of the research woks (Fig. 1).

The ore material (bulk sample) was coarse-size dunite of varying serpentinization degree containing minor quantities of disseminated chromitites (less than 2%). In terms of mean content of the main petrochemical components the ore composition correlates with that of dunite having low concentrations of chromite (%wt): SiO_2–42.3; MgO–41.0; Fe_3O_4–10.1; Cr_2O_3–0.86; Al_2O_3–0.54; MnO–0.25; TiO_2 –0.03; CaO–0.28.

The scheme of the sampling from the bulk sample ***for the laboratory test work*** consisted of the next steps: ore sample (9750 kg) was crushed with jaw crusher SMD – 116 until – 50 mm fully, then all mass of crushed sample was charged in receiving bunker and by feeder, it was given to the conveyor for the representational sampling. The sampling was carried out in the dumping place during all time of the sample passing. The weight of the sample for the laboratory work was 750 kg. The results of the sample screen analysis are represented in Table 1.

Seven samples (m = 100 kg) with size of −50 mm were formed from the laboratory sample (750 kg). The one on that samples was crushed until −10 mm and five samples were crushed till −2 mm with roll breaker for the further test work.

For the pilot-scale tests the rest part of the bulk sample (~8200 kg) was processed through the proposed technological scheme (Fig. 6).

2.2. Methods

Research of the mineral composition, grain-size distribution of platinum-group metal minerals (PGM) in samples were performed with scanning electron microscopy (SEM) using a CAMSCAN-4VD microscope, light microscopy and laser microscopy using Colour 3d laser microscope VK-9700 k (Keyence).

For the evaluation of platinum content in samples, three methods were used: ICP-MS (VG Elemental Plazmaquad), assay tests (AAS with Shimadzu AA 6200) and balance calculations, as weighted mean value (with due account for product recovery) of three assay tests of products resulting from gravity separation of the sample material. ICP-MS and AAS were used for determination of the samples chemical composition.

Laboratory test work To identify the parameters of the flowsheet for platiniferous ores of zoned mafic–ultramafic complexes laboratory researches and pilot-scale tests were performed. A set of physical methods of platiniferous ore separation tested with platiniferous ores at a broad laboratory scale included the following: dense-media separation; X-ray radiometric separation; separation in magnetic fields of

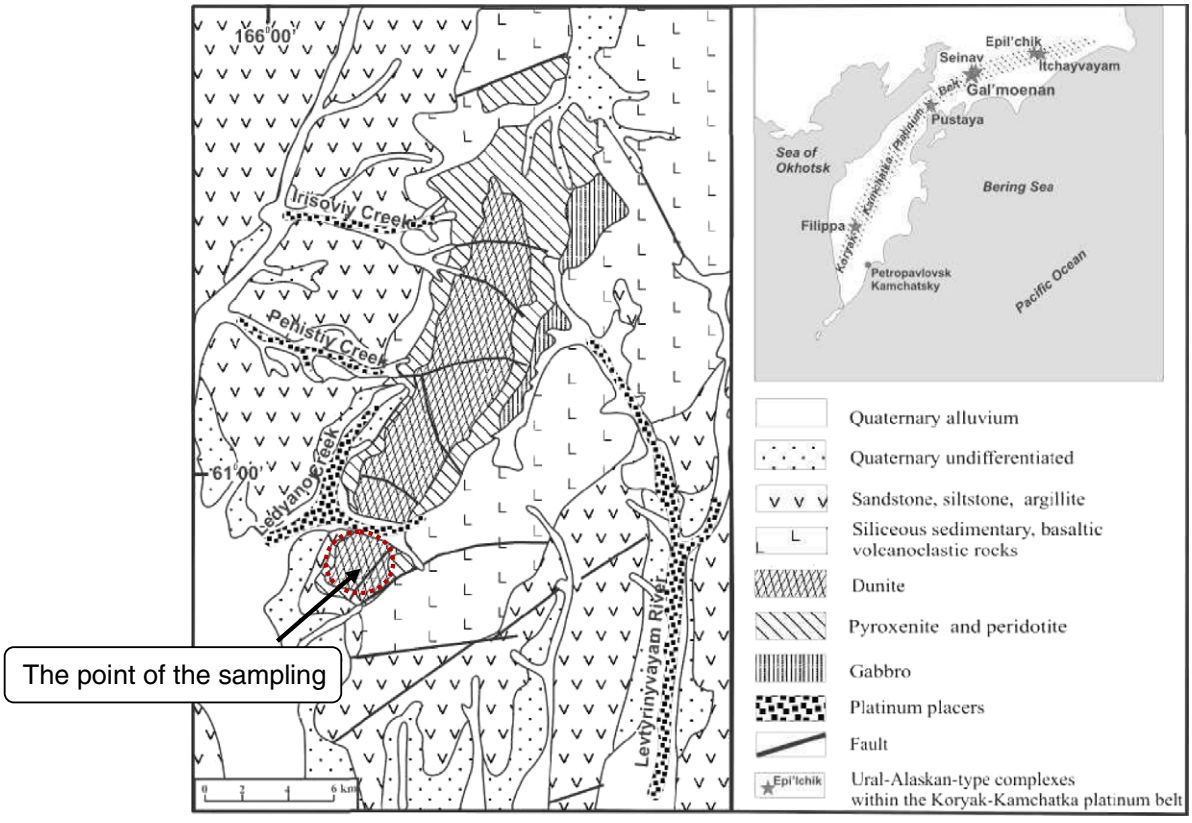

Fig. 1. Location map of Gal'moenan complex and surrounding placers.