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Primary Platinum Mineralization in the Nizhny Tagil and Kachkanar Ultramafic Complexes, Urals, Russia: A Genetic Model for PGE Concentration in Chromite-Rich Zones

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Abstract

The Nizhny Tagil Uralian-(Alaskan)-type Ultramafic Complex is composed of a dunite core with a rim of wehrlite and pyroxenite. The dunite unit, which has a uniform mineral composition (olivine $Fo_{89.8–92.1}$, avg 0.25 wt % CaO), represents an accumulation of olivine and minor chromite from a mafic magma in an open-system magma chamber. After solidification of the dunite, differentiation began with the formation of the wehrlite (olivine $Fo_{77.9–88.8}$) and pyroxenite, corresponding to the closure of the magmatic system. Two main types of chromitite occurrence are observed in the dunite body: small (100 × 5 cm) scattered schlieren of chromite crystals within the ultramafic unit and much larger (up to 100 × 5 m) concentrations. The chromite composition in both types is similar and uniform [$Cr/(Cr + Al + Fe^{3+}) = 66.02$, $Mg/(Mg + Fe^{2+}) = 49.05$ and $Cr/(Cr + Al + Fe^{3+}) = 69.14$, $Mg/(Mg + Fe^{2+}) = 49.81$, respectively]. The larger concentrations of chromite include brecciated and net-textured ore or massive veins that reflect the dynamic accumulation of chromite crystals in cavities along magma conduits inside the dunite body. These cavities are analogous to small magma chambers within the consolidated part of the dunite body and, similar to podiform chromitites in ophiolites, were created by continuous feeding of magma to the system.

The platinum-group element (PGE) content of the chromite-free facies of the dunite is relatively low, Pt being the only significant PGE (typically between 0.3–35 ppb but as much as 98 ppb in one sample). In contrast, both types of chromite occurrence are enriched in PGE. Two PGE mineralizing episodes are distinguished: an Ir-Ru-(Rh ± Os)-rich, Pt-Pd-poor episode in which the platinum-group minerals (PGM) are mainly Ir alloys, and a Pt-(Pd)-rich episode in which the PGM are mainly Pt alloys (i.e., $Pt_2(Fe,Ni,Cu)$, $PtFeNi_2$, and tetraferroplatinum- and tulameenite-like compositions, along with rare hollingworthite and an unidentified RhNiAs mineral). The primary PGM have been affected locally by a serpentinization-related low-temperature alteration that is characterized by addition of copper, with alteration to complex Pt-(Fe,Ni,Cu) alloys of varied stoichiometry, including tulameenite and platinian copper. Placer concentrations derived from the Nizhny Tagil Complex have a slightly different assemblage of PGM, with abundant isoferroplatinum, the presence of gold commonly aggregating the PGM, and unusual Au-Sn and Au-Pb alloys.

The Kachkanar Complex, situated 120 km north of the Nizhny Tagil Complex, has essentially the same characteristics, apart from a slightly different composition of the ultramafic cumulates suggesting that they were derived from a magma of different composition. The PGM distribution also differs in that it contains more abundant isoferroplatinum than other PGM.

The high Pt concentrations are the result of the affinity of platinum minerals for chromite and the mode of chromite deposit formation. In the cavities in which chromite crystallized, PGM tended to be incorporated in chromite or remained attached to chromite crystals. To explain the very high concentrations of chromite-associated PGM we define a CR factor, which is the ratio of the mass of silicate magma to the mass of chromite in contact with the ascending magma. Where the CR is high (i.e., a relatively low proportion of chromite in contact with a large amount of magma crystallizing the Pt minerals), the efficiency of the mechanical collection of Pt minerals is at a maximum, and the Pt concentration (i.e., amount of Pt minerals) will be high. Possible variations due to the collection of PGE by a sulfide liquid have not been established. A model is proposed whereby the observed chromite and associated Pt mineralization can result from the normal magmatic evolution of the complex, provided that a structural (hydrodynamic) trap is available to concentrate the chromite.

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