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## GEOLOGY

# Platinum Group Minerals in Alluvium of the Northern Urals and Timan: The Key to Primary Sources of Platinum

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Prospecting searches for platinum-group minerals (PGM) in alluvial deposits throughout the western slope of the northern Urals and Timan have been conducted for many years. Data have been accumulated regarding PGM finds at several tens of localities that are very diverse in terms of their geographical position: from the Polar Urals (on the Longot-Yugan, Elets, Esto-Shor, Grubeyu, Voravozh, Kharuta, and Nyan'vorgavozh rivers), through the Subpolar Urals (on the Kozhim, Balban'yu, Kos'yu, Berezovka, Peribor, Syv'yu, Bol'shoi Patok, and Shchugor rivers), to the North Urals (Ilych, Pechora, and Un'ya rivers) and Timan (Chernaya, Kyv-Vozh, and other rivers). Very rare fine grains of PGM have been found in alluvium of many of the mentioned streams by geologists of the PGO Polyarnouralgeologiya in the course of panning surveys. These particles are from 40 to 300 μm in size; rarely, they are larger. A significant amount—many tens or even hundreds—of such grains were obtained both by concentration of the ultraheavy fractions of large-volume samples with the use of the blowing method, and as a result of experimental extraction from gold-bearing alluvial placers of the Syv'yu and Kozhim rivers in the Subpolar Urals and of the Kyv-Vozh Creek in Timan. At these sites, the PGM contents amount to as much as 1.0–2.5% of the weight content in gold. The average size of the rounded, flattened grains of PGM is 500–600 μm, but some of them reach 2 mm in diameter.

The PGM identification was conducted using the X-ray diffraction method with phase determination and with calculation of the crystal lattice parameters. In addition, visual morphological signs of minerals were used, as well as their reflectivity, density, and hardness. The PGM chemical compositions were determined by N.N. Kononkova with the use of a Camebax SX50 microprobe at MGU (experiment conditions: $U = 20$ kV, $I = 30$ nA, $t = 10$–$12$°C; analytical lines: $L_\alpha$ for PGE and $K_\alpha$ for Fe, Ni, and Cu; pure metals and PGE and NiO alloys were used as standards). About 170 complete chemical analyses of PGM were obtained using the microprobe. The surface of the PGM grains was studied with a scanning electron microscope, while their intergrowths and inclusions were investigated under the PGE characteristic X-rays.

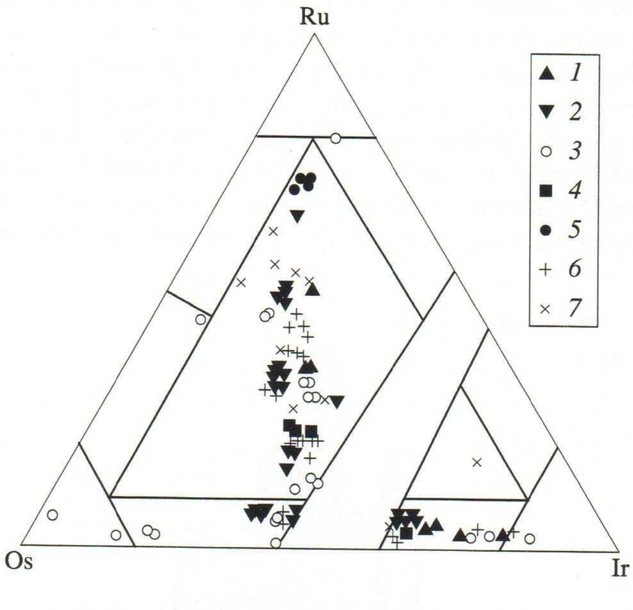


**Fig. 1.** The PGM compositions in the Os–Ir–Ru system on Cabri's ternary diagram. Mineral grains derived from alluvium: (*1*) Esto-Shor Creek; (*2*) Elets and Longot-Yugan rivers (Polar Urals); (*3*) Kozhim River (Subpolar Urals); (*4* and *5*) Un'ya River (North Urals): (*4*) rutheniridosmines and iridosmines, (*5*) laurites; (*6*) Kyv-Vozh Creek; and (*7*) Chernaya River (Timan).

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**Table 1.** Chemical compositions of PGM from alluvial deposits of the northern Urals and Timan (in wt %)

| Mineral | Os | Ir | Pt | Rh | Ru | Pd | Fe | Ni | Cu | S | As | Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fe-platinum | 0.62 | 1.94 | 90.15 | 1.50 | 0.10 | 1.55 | 5.43 | 0.12 | 0.63 | 0 | 0 | 102.04 |
| Ru–Fe-platinum | 3.69 | 2.11 | 82.45 | 2.05 | 3.01 | 1.28 | 4.06 | 0.22 | 0.50 | 0 | 0 | 99.37 |
| Ir–Fe-platinum | 2.33 | 4.47 | 87.11 | 0.35 | 0.14 | 0.47 | 5.43 | 0.06 | 1.06 | 0 | 0 | 101.42 |
| Isoferroplatinum | 0.56 | 0.23 | 89.16 | 0.35 | 0.09 | 0.13 | 8.51 | 0.03 | 0.79 | 0 | 0 | 99.85 |
| $Pt_2Fe$ | 0.81 | 2.32 | 81.35 | 0.32 | 0.12 | 0.39 | 13.51 | 0.58 | 1.26 | 0 | 0 | 100.66 |
| Rh-isoferroplatinum | 0.54 | 0.38 | 89.03 | 3.00 | 0.35 | 1.08 | 6.53 | 0.29 | 0.63 | 0 | 0 | 101.83 |
| Ir-isoferroplatinum | 0.97 | 18.40 | 68.22 | 1.19 | 0.53 | 0.61 | 10.48 | 0.16 | 0.72 | 0 | 0 | 101.28 |
| Osmium | 92.79 | 2.86 | 1.95 | 0.98 | 3.38 | 0.55 | 0.03 | 0.05 | 0.13 | 0 | 0 | 102.72 |
| Ru-osmium | 57.14 | 11.17 | 0.33 | 0.38 | 28.42 | 0 | 2.12 | 0.03 | 0.15 | 0 | 0 | 99.74 |
| Iridosmine | 54.33 | 40.68 | 0.55 | 0.12 | 3.30 | 0.11 | 0.60 | 0.09 | 0.54 | 0 | 0 | 100.32 |
| Iridium | 20.19 | 76.47 | 0.82 | 0.30 | 1.14 | 0.22 | 0.54 | 0.06 | 0.76 | 0 | 0 | 100.50 |
| Pt-iridium | 15.36 | 70.82 | 10.26 | 3.01 | 1.04 | 0.84 | 0.30 | 0.03 | 0.66 | 0 | 0 | 102.32 |
| | 13.31 | 63.30 | 20.42 | 0.76 | 0.88 | 0.18 | 2.42 | 0.05 | 0.76 | 0 | 0 | 102.08 |
| Ruthenosmiridium | 15.40 | 67.80 | 8.40 | 0 | 7.80 | 0 | 0 | 0 | 0 | 0 | 0 | 99.40 |
| Osmiridium | 24.68 | 69.83 | 2.86 | 0.42 | 1.16 | 0 | 0.38 | 0.11 | 1.05 | 0 | 0 | 100.49 |
| Pt-osmiridium | 18.72 | 53.69 | 23.01 | 2.07 | 1.11 | 0.42 | 1.54 | 0.03 | 0.72 | 0 | 0 | 101.31 |
| Ruthenium | 6.19 | 10.05 | 0.45 | 1.31 | 78.98 | 0 | 2.10 | 0.02 | 0.08 | 0 | 0 | 99.18 |
| Rutheniridosmine | 46.63 | 43.76 | 0.86 | 0.15 | 7.45 | 0.46 | 0.58 | 0.09 | 0.46 | 0 | 0 | 100.44 |
| | 30.45 | 30.08 | 2.71 | 1.45 | 34.67 | 1.59 | 0.27 | 0.11 | 0.56 | 0 | 0 | 101.89 |
| rarsite | 1.45 | 59.00 | 3.16 | 0.48 | 4.05 | 0.15 | 0 | 0.03 | 0.50 | 10.45 | 20.25 | 99.52 |
| Os–Ir-laurite | 16.11 | 13.30 | 0.17 | 0.63 | 37.07 | 1.81 | 0.08 | 0.01 | 0.14 | 30.43 | 0 | 99.75 |

The following 19 mineral species and varieties have been identified in alluvium of the region: Fe-bearing platinum*, Fe- and Ir-bearing platinum*, Rh- and Fe-bearing platinum*, isoferroplatinum*, Ir-bearing isoferroplatinum*, Ru-bearing isoferroplatinum*, $Pt_2Fe$*, osmium*, iridosmine*, Ru-bearing osmium, iridium*, Pt-bearing iridium*, osmiridium*, Pt-bearing osmiridium*, ruthenosmiridium*, irarsite*, ruthenium, rutheniridosmine*, and Ir- and Os-bearing laurite*. Seventeen of them, marked by asterisks, were first discovered by us. The following assemblages are encountered as intergrowths or as inclusions: osmium + isoferroplatinum, Pt-bearing iridium + Ir-bearing isoferroplatinum, osmiridium + iridosmine, osmium + iridosmine + irarsite, Ir-bearing isoferroplatinum + Pt-bearing iridium + Pt osmiridium, Fe- and Ir-bearing platinum + Ir-bearing isoferroplatinum. Only rutheniridosmine and ruthenosmiridium do not form intergrowths with other PGM.

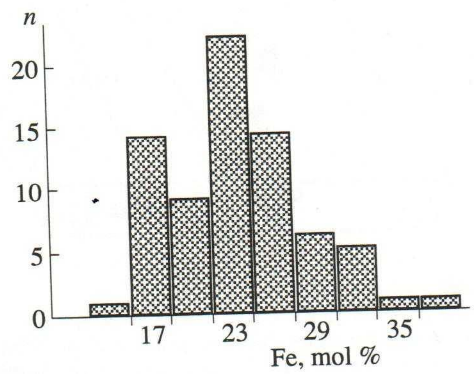


**Fig. 2.** Histogram of distribution of the isomorphous iron contents in Fe–Pt intermetallic compounds from the Kozhim River and Kyv-Shor Creek placers.

In Table 1, a portion of the results of the original analyses of PGM is presented, which characterizes all the mineral varieties. Data points, corresponding to the compositions of minerals of the Os–Ir–Ru system, are shown in Fig. 1. Eight mineral species and two varieties have been revealed in the Os–Ir–Ru system of natural alloys. A histogram of distribution of isomorphous iron in Fe–Pt alloys (Fig. 2) shows a three-modal pattern of Fe distribution and provides evidence of the presence of at least three minerals corresponding to this system: native platinum (with the Fe impurity content no more than 20 at. %), isoferroplatinum, and the $Pt_2Fe$ compound.

At present, the mineralogy of PGM of two placers from those mentioned above has been the most completely studied. In the Kozhim River alluvium (the Subpolar Urals), 300 PGM grains have been studied, 70 microprobe analyses have been done, and

**Table 2.** Statistical characteristics of the component contents in PGM from the Kozhim River (the Subpolar Urals) and from the Vym Range (Timan) (in wt %)

| Mineral | Statis | Os | Ir | Pt | Rh | Ru | Pd | Fe | Ni | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Kozhim River | | | | | |
| Isoferroplatinum, $n = 34$ | min | 0.22 | 0 | 85.26 | 0 | 0 | 0.11 | 5.43 | 0 | 0.23 |
| | max | 1.13 | 1.98 | 92.62 | 3.31 | 0.86 | 2.93 | 9.55 | 0.85 | 1.48 |
| | $x$ | 0.59 | 0.47 | 88.49 | 1.28 | 0.18 | 1.30 | 7.72 | 0.13 | 0.69 |
| | σ | 0.23 | 0.50 | 1.64 | 1.09 | 0.23 | 0.78 | 1.32 | 0.16 | 0.29 |
| Ir-isoferroplatinum, $n = 14$ | min | 0.50 | 2.32 | 68.22 | 0.19 | 0 | 0.04 | 5.36 | 0.04 | 0.50 |
| | max | 2.84 | 18.40 | 87.96 | 2.09 | 0.60 | 1.01 | 13.51 | 0.72 | 3.00 |
| | $x$ | 1.24 | 8.00 | 79.69 | 0.80 | 0.20 | 0.46 | 9.40 | 0.22 | 1.05 |
| | σ | 0.74 | 5.58 | 6.63 | 0.53 | 0.20 | 0.27 | 2.25 | 0.19 | 0.59 |
| Os–Ir alloys, $n = 9$ | min | 13.31 | 2.86 | 0.53 | 0.03 | 0.17 | 0 | 0.03 | 0.03 | 0.13 |
| | max | 92.79 | 73.46 | 20.42 | 0.98 | 3.66 | 0.55 | 2.42 | 0.83 | 1.05 |
| | $x$ | 52.82 | 40.92 | 3.53 | 0.34 | 1.93 | 0.17 | 0.57 | 0.16 | 0.59 |
| | σ | 26.45 | 23.43 | 6.05 | 0.31 | 1.17 | 0.15 | 0.68 | 0.24 | 0.28 |
| Rutheniridosmine, $n = 8$ | min | 36.87 | 24.14 | 0.86 | 0.15 | 7.09 | 0.38 | 0 | 0.03 | 0.30 |
| | max | 46.63 | 44.64 | 5.39 | 1.39 | 29.45 | 1.29 | 0.58 | 0.14 | 0.55 |
| | $x$ | 41.40 | 35.56 | 2.63 | 0.83 | 18.53 | 0.95 | 0.27 | 0.09 | 0.44 |
| | σ | 3.86 | 7.24 | 1.75 | 0.46 | 7.78 | 0.33 | 0.20 | 0.04 | 0.08 |
| | | | | Timan | | | | | | |
| Isoferroplatinum, $n = 16$ | min | 0.55 | 0 | 82.45 | 0.08 | 0 | 0.20 | 4.06 | 0 | 0.50 |
| | max | 3.69 | 2.11 | 91.20 | 2.05 | 3.01 | 2.18 | 8.28 | 0.22 | 2.32 |
| | $x$ | 1.02 | 0.85 | 87.77 | 0.79 | 0.23 | 1.02 | 6.79 | 0.06 | 1.18 |
| | σ | 0.72 | 0.65 | 1.87 | 0.53 | 0.72 | 0.55 | 1.09 | 0.06 | 0.42 |
| Ir-isoferroplatinum, $n = 9$ | min | 0.45 | 2.39 | 69.25 | 0.24 | 0 | 0.41 | 6.19 | 0.04 | 0.60 |
| | max | 4.44 | 18.36 | 87.16 | 1.94 | 0.80 | 1.04 | 12.29 | 0.24 | 1.53 |
| | $x$ | 1.21 | 6.59 | 80.54 | 0.76 | 0.16 | 0.68 | 9.25 | 0.12 | 1.06 |
| | σ | 1.19 | 5.38 | 6.72 | 0.54 | 0.26 | 0.18 | 2.11 | 0.08 | 0.32 |
| Os–Ir alloy, $n = 6$ | min | 15.36 | 40.86 | 0.81 | 0.14 | 0.68 | 0.02 | 0.17 | 0 | 0.56 |
| | max | 54.41 | 70.82 | 23.01 | 3.01 | 3.81 | 0.84 | 1.54 | 0.14 | 0.86 |
| | $x$ | 35.78 | 55.02 | 6.27 | 0.99 | 1.83 | 0.32 | 0.46 | 0.06 | 0.72 |
| | σ | 15.27 | 10.99 | 8.21 | 1.13 | 1.26 | 0.26 | 0.48 | 0.05 | 0.10 |
| Rutheniridosmine $n = 13$ | min | 32.74 | 27.74 | 0.41 | 0.33 | 10.22 | 0.59 | 0.11 | 0 | 0.34 |
| | max | 47.69 | 41.11 | 6.67 | 1.80 | 28.36 | 1.72 | 0.62 | 0.18 | 0.62 |
| | $x$ | 39.92 | 33.60 | 3.95 | 1.00 | 20.07 | 1.09 | 0.36 | 0.09 | 0.47 |
| | σ | 5.12 | 3.96 | 2.22 | 0.47 | 6.35 | 0.37 | 0.18 | 0.05 | 0.09 |

Note: $n$ is the number of analyses in a statistical sample, $x$ is average, σ is mean square deviation.

15 mineral species and varieties of PGM have been identified. On the Kyv-Vozh Creek (the Vym' Range, Timan), 96 grains have been studied, 44 microprobe analyses have been done, and 10 PGM have been identified. In Table 2, statistical characteristics are presented of the most widespread minerals of the two placers, namely, of Fe–Pt alloys, Os–Ir alloys, and rutheniridosmine. The proportions between percentages of these three mineral groups at each of the two localities agree closely with one another, amounting to 88, 6, and 6% for the Kozhim River and 73, 6, and 21% for the Kyv-Vozh Creek, respectively. Thus, Fe–Pt alloys

prevail at these placers. The calculation of the PGE content balance in the placers shows that the Pt : Ir : Os : Ru : Rh : Pd relations are 82 : 7.5 : 7 : 1.5 : 1 : 1 for the Kozhim River and 68 : 13 : 12 : 5 : 1 : 1 for the Kyv-Vozh Creek, respectively.

Both the compositional peculiarities of the mineral grains and the character of their intergrowths allow us to conclude that there are two PGM assemblages in the alluvial placers, which are related to different geological types of ultrabasic rocks: (1) Fe–Pt alloys and intermetallic compounds are associated with Os–Ir alloys, the origin of this assemblage being probably related to concentrically zoned pyroxenite–dunite massifs of the Ural–Alaskan type or to alkaline-ultrabasic massifs of the Konder type; (2) rutheniridosmine is associated with laurite, the primary source of this alluvial assemblage being most probably represented by "alpine type" ultrabasic rocks.

The superposition in recent alluvium of the two PGM assemblages related to the different rock associations may be caused by intricate processes of rewashing of intermediate collectors, such as ancient alluvial and beach placers, glacial deposits, and others. The alpine type ultrabasic-rock massifs, which can serve as a possible source of rutheniridosmine and laurite in alluvium, are known in the northern Urals [1, 2]; in contrast, the concentrically zoned massifs producing Fe–Pt alloys have not been recognized within this region up to the present.

The numerous finds of isoferroplatinum, Os–Ir alloys, and Ru-low rutheniridosmine, as well as a peculiar composition of chrome-spinels from panned heavy concentrates, suggest that the discovery of concentrically zoned ultrabasic massifs is possible in the Subpolar Urals and Timan and that the Pt bearing belt of the Urals may possibly extend further to the north [3]. It is likely that these massifs will be very small. Most probably, some of them have already been fully eroded. The way toward the discovery of primary sources of PGM in the northern Urals and Timan lies in the study of the composition of the heavy concentrate platinum and in generalization of all available geological and mineralogical data.

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## REFERENCES

1. Makeyev, A.B., *Mineralogiya al'pinotipnykh ul'trabazitov Urala* (The Mineralogy of Alpine Type Ultrabasic Rocks in the Urals), St. Petersburg: Nauka, 1992.
2. Makeyev, A.B., Kotov, A.A., Begizov, V.D., *et al.*, in *Mineralogicheskaya kristallografiya i svoistva mineralov* (Mineralogical Crystallography and Mineral Properties), Syktyvkar, 1984, pp. 95–103.
3. Makeyev, A.B., Abstracts of Papers, *VII Int. Platinum Symp.*, Moscow, 1994, pp. 69–70.