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PLATINUM OF THE UGOLNYI STREAM (NORILSK) FROM THE FERSMAN MINERALOGICAL MUSEUM COLLECTION

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Three specimens from the Mineralogical Museum, catalogued as «platinum» from placer of the Ugolnyi stream (Norilsk), appeared to be complicated mixture of zoned minerals. By chemical composition the following mineral phases were found: tetraferroplatinum, ferronickelplatinum, isoferroplatinum, minerals of the atokite-zvyagintsevite series, stannopalladinite.
It is supposed that formation of particular pseudomorphs of fine-grained aggregates, in which minerals of Pd-Sn-Pb-Cu system and isoferroplatinum prevail, after monocrystals of tetraferroplatinum is connected with local combination of different stages of formation of precious metal mineralization.
1 table, 5 figures, 7 references.

In funds of the Mineralogical Museum are three specimens registered as platinum from the Ugolnyi stream (Norilskii region). These are the first Museum specimens from the Norilsk deposits. Two of them (41647 and 46887) were received from professor Orest Evgenievich Zvyagintsev, researcher of chemistry of precious metals, one of organizers of industrial mining of platinoids in the USSR.

The samples were registered in collection of the Museum in 1938 and 1949. Judging by author's label appended to the specimen 41647 (Fig. 1), it was mined during panning out of placer of platinoids of the Ugolnyi stream in September, 1938. Pencil caption made in the Museum on this label runs: «From O.E. Zvyagintsev who has analogous Pt». That allows supposing that other samples keeping in the Museum were possibly mined at the same time. It is not excluded that also this find resulted in issue of joint decree of the Communist Party Central Committee and Soviet Government of April 7, 1939, «On forcing of building of Norilsk industrial complex».

In 1948, academician Vladimir Afanasievich Obruchev, the most well-known geologist, geographer, author of books «Plutoniya» and «Sannikov's Land» presented a platinum specimen from the Ugolnyi stream (45863) to the Fersman Museum.

It is difficult to expect accurate data about genealogy of specimens from the Norilsk deposits found in 30-40s of 20th century. Since 1935 till 1956 the Norilsk deposits were mined by Norillag (one of soviet concentration camps). First mines of the Ugolnyi Sream and Gora Rudnaya deposits, nickel, cobalt, and copper factories were built by prisoners, whose number had been continuously increased from 1200 in 1935 to nearly 60 000 in 1949 (Norilsk Calvary, 2002).

Evidences about that time can be picked up in diaries of former prisoner of Norillag, Efrosiniya Kersnovskaya, who was there in 1944 (Kersnovskaya, 2000-2004).

«*What an unsightly Norilsk appeared through rain shroud! Coal mines and places, where peoples, deprived all human rights, live, work and die, made this place even more ugly. We could quite enough «admire» Zero picket, i.e. geodesic point where counting of route Norilsk-Dudinka began.*

Black gorge, along which a black stream flows, and some black buildings cling along it, whistling wind, also black, black slush, on which they ordered us, frozen, hungry, and tired, to squat, — all that made our reflections by no means lighter than surrounding landscape...

The most part of mines and pits are in two mountains, between which the Ugolnyi stream flows. The Mt. Saint Helene is at its southeast bank. Ore bodies of huge thickness and intricate form are contained in it. It is mined very intensively: both open quarry, in the manner of Easter cake, and simultaneously cutting deep into the mountain. At another bank of the Ugolnyi stream to northwest is the Shmidt mountain, or plainly «Shmitikha», as a cake «Napoleon»: thick layers of coal are alternated with intercalations of barren rock...

Nickel was the main ore mined in Norilsk. Copper, cobalt, and molybdenum were mined too. Platinoids, i.e. platinum, gold, and silver, went in waste of concentrating factory, so-called «tails». By pipes they were transferred in tundra, and lakes were filled up by them: amount of platinoids in «tails» is insignificant and their mining was considered unprofitable...»

Now this Ugolnyi stream is at the south outlying districts of Norilsk. Its placers are not entirely worked till now (Geomarkinform, 2004).

Table 1. **Microprobe analyses of phases in grain of specimen 41467, wt.%**

	Pt	Pd	Fe	Ni	Cu	Sn	Pb	Rh	Ag	Au	S	Σ
1	75.29	0	18.14	3.99	2.34	0	0	0	0	0	n.d.	99.75
2	74.85	0	18.06	3.91	2.28	0	0	0	0	0	n.d.	99.09
3	74.96	0	18.02	3.79	2.31	0	0	0	0	0	n.d.	99.07
4	60.94	2.61	18.75	12.61	3.70	0	0	0	0	0	n.d.	98.60
5	66.76	2.17	17.68	8.20	3.66	0	0	0	0	0	n.d.	98.48
6	30.59	30.02	9.40	4.06	6.17	13.24	0	0	0	0	n.d.	93.48
7	84.24	0	9.74	0.51	0.62	0	0	1.83	0	0	n.d.	96.94
8	15.13	51.42	0.81	0	4.94	23.50	1.70	0	0	0	n.d.	97.5
9	0.24	59.29	0.11	0.00	0.47	0	39.84	0	0	0	n.d.	99.95
10	0	59.23	0.41	0	7.06	17.56	16.08	0	0	0	n.d.	100.34
11	0	57.90	0.46	0	8.76	16.22	17.72	0	0	0	n.d.	101.06
12	0.58	64.35	0.49	0.09	1.12	7.74	27.35	0	0	0	н.о	101.72
13	0	56.65	0.54	0	9.39	11.79	18.67	0	0	0	n.d.	99.16
14	0	57.09	0.51	0.10	9.66	12.59	20.62	0	0	2.33	n.d.	102.9
15	n.d.	0	37.18	17.61	0	n.d.	n.d.	n.d.	13.61	0	31.35	99.75

* *n.d. — not determinated*

They have alluvial origin and are genetically related to rocks of west branch of the Norilsk I intrusion.

Museum specimens mined during panning out of placer of the Ugolnyi stream are represented at Figure 2. Size of grains is 1-10 mm. Grains are cube-shaped, parallelepiped-like, flattened. Features of skeletal growth are visible on many of them. Surface of grains is dull, brownish-grey; edges are slightly rounded.

Initial diagnostics of them as «platinum», obviously, was checked with quantitative analysis of surfaces of faces in 1970-1980s. As a result of that on museum labels the mark (Pt_3Sn) and note «rustenburgite» in the box with sample 41647 have appeared. A perspective to have in the museum collection the large crystals of rustenburgite (Pt Sn) forced to study these samples in more details. Preliminary electron microprobe analysis of surfaces of crystals has confirmed the presence of tin in them (at predominance of Pt and presence of significant admixture of Pd). However, strong ferromagnetism of considerable part of grains is evidence of presence of iron-platinum intermetalids in them.

New data on mineralogical compositions of these grains was obtained by study of section of one of them, with size 2 mm and cube-like form. Only after polishing the zoning of the grain, the well-polishing central zone with the most high relief and dull periphery with smaller hardness than central zone according to its relief, have been found. Analyses of some phases of this grain are given in Table 1.

Analyses 1-3 by chemical composition match to copper-nickel variety of tetraferroplatinum, $Pt_{0.95}Fe_{0.80}Ni_{0.16}Cu_{0.09}$. They correspond to central part of the grain (zone A at Fig. 3), in which among associating phases the rounded inclusions 20-100 μm in size, determined as magnetite, are found.

Around central part of the grain is a zone 20-100 μm in size, with small inclusions, which obviously resulted from exsolution (zone B at Fig. 3). They form lamellae, reticulate ingrowths in matrix, round-drop-shaped grains. Size of grains is up to 10μm, thickness of lamellae is up to 5 μm. Analyses 4 and 5 in Table 1 reflect the chemical composition of this zone. Averaged formula in calculation on 4 atoms is as follows: $Pt_{1.44}Pd_{0.10}Cu_{0.26}Fe_{1.42}Ni_{0.78}$. Among mineral phases known so far only ferronickelplatinum closely matches these analyses. Enrichment of this zone by Ni and Pd is notable as compared to central zone. Analysis 6 shows the composition of one of the phases resulted from exsolution. Probably, some material of matrix is presented in this analysis, an exsolution results in formation of phases enriched by Pd, Sn, and Cu. Close to periphery, aggregate with lamella-shaped exsolutionary phases is changed by a zone of Pd-Cu-Sn-Pb phases, more dark in back-scattered electrons (Fig. 4).

Peripheral zone (zone C at Fig. 3), 100-500 μm in size, represents fine-grained aggregate, in which phases of the Pd-Cu-Sn-Pb system, 2-50 μm in size, and the Pt-Fe system, less than 5 μm in size, prevail (Fig. 5). Grains in this zone are often surrounded by grey in

Fig. 1. *Specimen 41647 from the Museum collection with labels:*
On the label the following is written with pen:
Coll. N. 2959,
large platinum
from placer
at the Ugolnyi stream,
Norilsk. September, 1938.
The following is written with pencil:
from O.E. Zvyagintsev
who has analogues Pt.

Fig. 2. *Specimens registered as platinum from the Ugolnyi stream from the Museum collection. a — 41647, b — 45863, c, d — 46887 (d — more detailed image of three grains). Diameter of a coin is 17 mm.*

reflected light phases, in which composition only Fe is detected. Probably, these are iron hydroxides, resulting in brown colour of «platinum» grains surfaces. The Pt-Fe phases of this zone are distinguished from matrix of central zone by increased content of Pt and insignificant amounts of Ni, Cu and also notable presence of Rh, which was not registered in other phases. Analysis 7 made for such grain allows to consider it as isoferroplatinum, ($Pt_{2.69}$ $Rh_{0.11}$ $Cu_{0.06}$ $Fe_{1.09}$ $Ni_{0.05}$).

Phases of the Pd-Cu-Sn-Pb system the most significant differ on ratios of Sn and Pb. Maximal content of tin is noted for phase 8, ($Pd_{2.25}Pt_{0.36}Cu_{0.36}$ $Fe_{0.07}Sn_{0.92}Pb_{0.04}$), which can be identified as stannopalladinite. Enriched by lead phase 9, ($Pd_{2.93}Pt_{0.01}Cu_{0.04}Fe_{0.01}Pb_{1.01}$), among known mineral phases, can be identified as zvyagintsevite. Phase at the periphery of grain, which has averaged chemical composition, $Pd_{2.43}Cu_{0.54}$ $Fe_{0.04}Sn_{0.63}$ $Pb_{0.36}$, (analyses 10, 11) can be presumably determined as lead stannopalladinite.

At the outside surface of studied grain are phases 12, $Pd_{2.91}Pt_{0.01}Cu_{0.08}Fe_{0.04}Sn_{0.31}Pb_{0.64}$, (tin-enriched atokite), 13 and 14 with almost similar atomic content of Sn and Pb, $Pd_{2.42}$ $Cu_{0.67}Fe_{0.04}Sn_{0.45}Pb_{0.41}$ and $Pd_{2.34}Cu_{0.66}$ $Au_{0.05}Fe_{0.04}Ni_{0.01}Sn_{0.46}Pb_{0.43}$ respectively. In phase 14, admixture of gold is noted, which was not detected in other analysed phases. Sulphide phase (analysis 15) identified as argentopentlandite, $Ag_{1.04}Fe_{5.47}Ni_{2.46}S_{8.03}$, intergrows with it. Silver and gold are present also in chemical composition of electrum, forming inclusions to 10 μm in size in the outside zone of the «platinum» grain.

Smoothed, winding borders between zones in this grain do not correlate with its facing and, obviously, are not connected with grain growth, but resulted from secondary processes. Heterogeneity of peripheral zones is another evidence of that.

One can suppose that here we deal with local superposition of two stages of precious metal mineral formation. Earlier formed crystals of copper-nickel tetraferroplatinum were exposed to influence of fluids, forming assemblage of minerals of the Pd-Cu-Sn-Pb chemical composition typical for the Norilsk deposits (Questions..., 1973; Minerals..., 1986; Sulphide Copper-Nickel Ores..., 1981). Some components of these mediums (in particular, Pd and Sn, transported in fluid phase (Spiridonov, 2003)), obviously, diffuse in crystals of tetraferroplatinum, forming the zone of Pt-Pd-Sn solid solutions, which are disintegrated when temperature decreases. Further influence of these

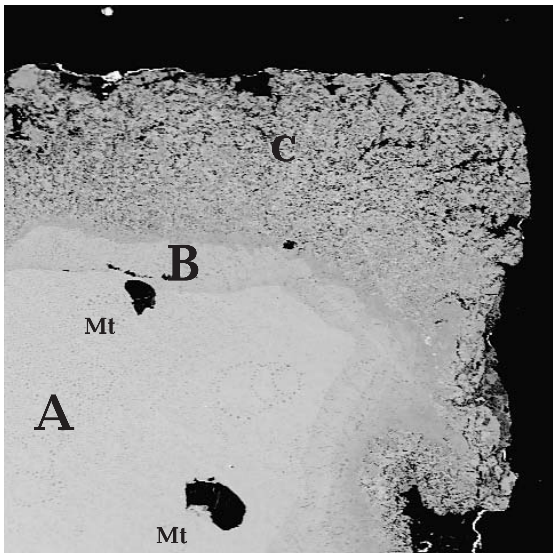

Fig. 3. *Image of a grain from the specimen 41647 in back-scattered electrons. Image size is 1500 μm Mt — magnetite.*

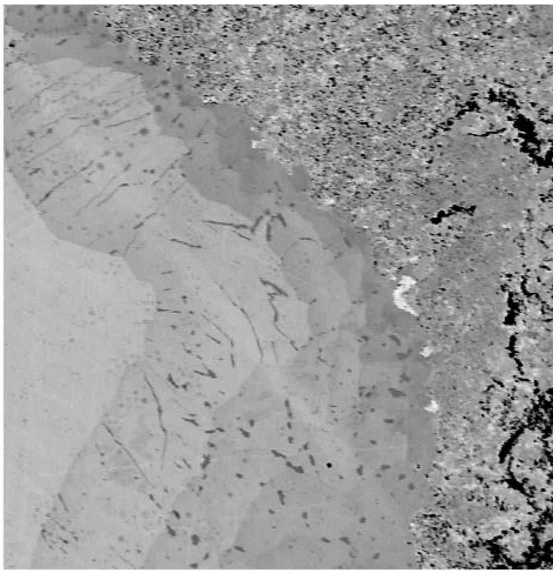

Fig. 4. *Image of a part of B zone in back-scattered electrons. Image size is 500 μm.*

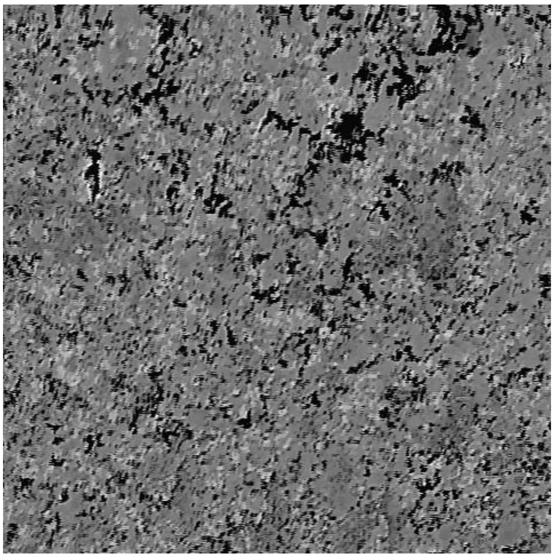

Fig. 5. *Image of a part of C zone in back-scattered electrons. Image size is 250 μm .*

liquids results in pseudomorphic substitution of outside zone of crystals. In this case, platinum of disintegrated primary phases forms the outside zone of grains of isoferroplatinum, and excess iron is transformed to hydroxides.

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