SHORT COMMUNICATION

DOI: https://doi.org/10.18599/grs.2020.4.98-100 Russian Original 2020. Vol. 22. Is. 4. Pp. 98–100

Noble metal mineralization in apatite titanomagnetite ores of the Suroyam massif (Middle Urals)

D.E. Saveliev[1*], *I.A. Blinov*[2]

[1]*Institute of Geology of the Ufimian Federal Research Centre of the Russian Academy of Sciences, Ufa, Russian Federation*
[2]*Institute of Mineralogy of the South Urals Federal Research Center of Mineralogy and Geoecology of the Urals Branch of the Russian Academy of Sciences, Miass, Russian Federation*

Abstract. The mineralogical composition of apatite-titanomagnetite clinopyroxenites of the Suroyam massif, characterized by stable elevated contents of platinum group elements with the leading role of palladium, has been studied. In association with accessory chalcopyrite, palladium and silver minerals have been identified – mertieite, merenskyite, hessite. It has been suggested that the presence of intrinsic mineral phases of palladium, represented by tellurides and arsenides-antimonides, allows us to consider the Suroyam massif as a promising deposit of complex Pd-P-Fe ores.

Keywords: ultramafic rocks, clinopyroxenite, apatite-titanomagnetite ore, palladium, mertieite

Recommended citation: Saveliev D.E., Blinov I.A. (2020). Noble metal mineralization in apatite titanomagnetite ores of the Suroyam massif (Middle Urals). *Georesursy = Georesources*, 22(4), pp. 98–100. DOI: https://doi.org/10.18599/grs.2020.4.98-100

The Suroyam mafic-ultramafic massif is located in the southern part of the Nyazepetrovsko-Bardymsky allochthon on the western slope of the Middle Urals (Figure 1) and is a complexly constructed polyformational complex, including rocks of dunite-wehrlite-clinopyroxenite, ophiolite and alkaline-ultramafic associations (Belkovsky, Seliverstov 1976; Volchenko et al., 1995; Zhilin, Puchkov, 2009; Zhilin, Fominykh, 1977). Most of the massif is occupied by clinopyroxenites containing titanomagnetite and apatite-titanomagnetite mineralization, accompanied by low-sulfide noble metal mineralization.

The massif forms an elongated lenticular body with an area of 15 km^2 with a thickness of 500 to 1500 m and is characterized by a linear-zonal structure. The axial part of the massif is composed of magnetite clinopyroxenites, which are replaced by apatite-titanomagnetite ones to the west and east. On the periphery, clinopyroxenites are surrounded by wehrlites and completely serpentinized ultramafic rocks. The latest rocks of the complex are alkaline gabbros and syenites that cut the ultramafic rocks of the earlier association. The massif appears to be a rootless outlier, tectonically displaced together with the volcanic rocks of the Tagil island arc from the east, and lying on the Paleozoic rocks of the margin of the East European continent (Zhilin, Puchkov, 2009).

According to I.V. Zhilin (Zhilin, 2006), the resources of iron ores concentrated in the Suroyam massif amount to about 16 billion tons in the P_1 category. They are characterized by gold-platinum-palladium geochemical specialization. Geochemical study of core and technological samples of titanomagnetite and apatite-titanomagnetite ores showed that the palladium content in ores varies from 30 to 700 mg/t with an average of 120 mg/t (Volchenko et al., 2009; Zhilin and Puchkov, 2009), and thepalladium resources in the central block of ferroclinopyroxenites is 504 tons to a depth of 300 m (Zhilin, 2006).

We studied core samples from well No. 7 drilled in the central part of the massif. According to the geochemical study data, apatite-titanomagnetite ores exposed by this borehole in the interval of 70–100 m are most rich in platinum group elements (PGE): the highest concentrations of palladium in the massif were discovered here (Figure 1c). The study of the compositions of accessory minerals of ores was carried out at the Institute of Mineralogy of the South Urals Federal Research Center of Mineralogy and Geoecology of the Urals Branch of the Russian Academy of Sciences (Miass) using a Tescan Vega 3 scanning electron microscope equipped with an Oxford Instruments X-act energy-dispersive spectrometer. Analyzes were carried out at a beam diameter of 3 μm, a current of 20 nA, an accelerating voltage of 30 kV, and a spectrum acquisition time of 120 s; pure metal standards were used for the platinum group minerals (PGM) (Micro-

*Corresponding author: Dmitry E. Saveliev
E-mail: savl71@mail.ru*

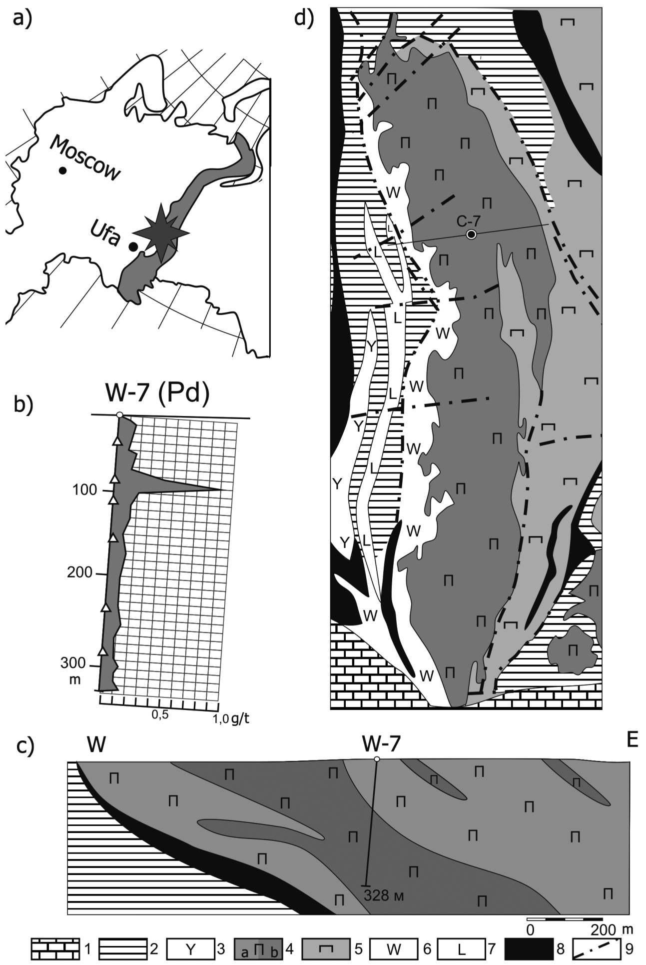

Fig. 1. Geological structure of the Suroyam ultamafic-mafic complex. a – an overview map, b – a diagram of the geological structure of the Suroyam massif; c – distribution of palladium contents along the section of well No. 7; d – cross section of the massif along the line of wells No. 1–9 in the central part of the massif; b-d – after (Zhilin, Puchkov, 2009). 1 – Paleozoic carbonate deposits; 2 – tuffs of basaltic porphyrites; 3 – syenites; 4 – ore clinopyroxenites (a – titanomagnetite; b – apatite-titanomagnetite); 5 – wehrlites and clinopyroxenites with potassium fieldspar; 6 – wehrlites; 7 – lherzolites; 8 – serpentinites; 9 – faults

Analysis Consultants Ltd., X-Ray Microprobe Standards, Registered Standard Number 1362).

Noble metal mineralization in the studied samples is represented mainly by palladium and silver minerals: submicron segregations of mertieite in the outer hydroxide-ferruginous rim around chalcopyrite (Figure 2a, b), small grains of hessite enclosed within chalcopyrite (Figure 2c), or elongated segregations of hessite located along cracks in clinopyroxene crystals (Figure 2d). Earlier, it was also reported that single grains of merenskyite were found in association with chalcopyrite (Volchenko et al., 2009). In addition to the palladium and silver minerals, cobaltine $(Co_{0.892}Fe_{0.067}Ni_{0.034})_{\Sigma 0.993}As_{0.972}S_{1.00}$, galena, and the finest inclusions of bismuth and mercury minerals are found in the form of inclusions in chalcopyrite.

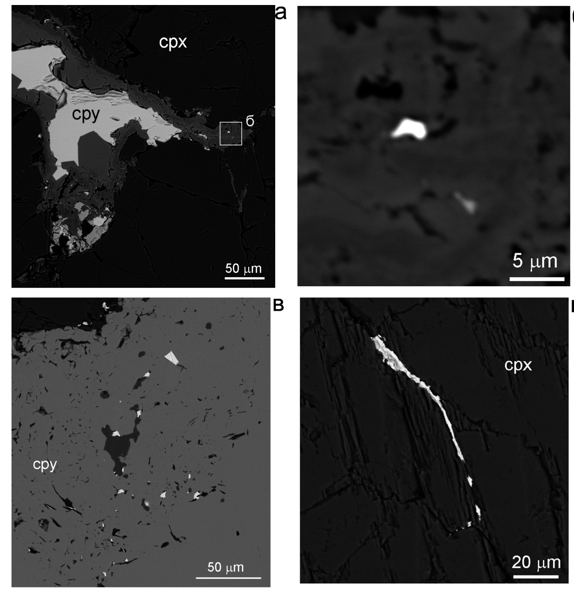

Fig. 2. Minerals of palladium and silver in low-sulfide apatite-titanomagnetite ores. a, b – precipitation of mertieite in the oxide rim of chalcopyrite, c – inclusions of hessite in chalcopyrite; d – precipitation of hessite along the fracture in clinopyroxene; cpx – clinopyroxene, cpy – chalcopyrite

The size of the precipitates of noble metal minerals is usually the first microns, as a result of which it is difficult to obtain quantitative data on their composition. It should be noted that the palladium minerals in the studied ores are characterized by the presence of significant amounts of silver (up to 3.78 wt% in mertieite) (Table 1), while hessite is characterized by impurities of PGE, mainly palladium (Volchenko et al., 2009).

In terms of geological and mineralogical criteria and geochemical specialization, the ores of the Suroyam massif are close to the deposits of the Baronsky and Kachkanarsky types of the Platinum-bearing belt of the Urals (Volchenko et al., 2009; Zhilin, 2006). The formation of noble metal mineralization in the studied samples occurred, apparently, at the late stages of the development of the magmatic system, as evidenced by the confinement of PGM and hessite segregations to chalcopyrite oxidation zones and fractures in silicates.

The increased contents of platinum group elements (mainly palladium) and the presence of intrinsic mineral forms of PGE, represented by tellurides and antimonide-arsenides, found in the studied apatite-titanomagnetite ores, allow us to consider the Suroyam massif as a promising deposit of complex Pd-P-Fe ores.

References

Belkovsky A.I., Selivyorstov G.F. (1976). About formational type of Suroyam alkali-ultramafic massif (Middle Urals). *Doklady Earth Sciences,* 230(13), pp. 660–663. (In Russ.)

Volchenko Yu.A., Koroteev V.A., Nesterova S.I. (2009). Comparative characteristic of Pt-bearings of ferroclinopyroxenite complexes of Uralian mobile belt. *Ezhegodnik-2008*. Ekaterinburg, pp. 209–216. (In Russ.)

Volchenko Yu.A., Zoloev K.K., Koroteev V.A., Mardirosyan A.N. (1995). Types of PGE-ores and their genetical meaning. *Proceedings of*

Item No.	S	Fe	Ni	Cu	As	Se	Pd	Ag	Pt	Sb	Te	Bi	Hg	Total
1	–	–	–	–	–	1.12	–	63.29	–	–	36.02	–	–	100.4
2	–	–	–	–	–	1.22	–	64.09	–	–	34.69	–	–	100.0
3	–	–	–	–	–	–	–	63.28	–	–	36.72	–	–	100.0
4	34.33	29.79	–	35.62	–	–	–	–	–	–	–	–	–	99.74
5	–	–	–	–	–	1.18	–	62.21	–	–	36.61	–	–	100.0
6	34.71	29.81	–	35.21	–	–	–	–	–	–	–	–	–	99.72
7	–	1.69	–	1.94	11.01	–	68.76	3.78	–	12.83	–	–	–	100.0
8	35.9	30.35	–	33.75	–	–	–	–	–	–	–	–	–	100.0
9	–	0.11	2.1	0.31	–	–	26.1	–	2.3	–	66.0	2.1	1.5	100.5

Item No.	Formula	Name
1	$Ag_{1,983}(Te_{0,952}Se_{0,048})_{1,00}$	Hessite
2	$Ag_{2,072}(Te_{0,946}Se_{0,054})_{1,00}$	Hessite
3	$Ag_{2,042}Te_{1,00}$	Hessite
4	$Cu_{1,038}Fe_{0,992}S_{2,00}$	Chalcopyrite
5	$Ag_{1,914}(Te_{0,95}Se_{0,05})_{1,00}$	Hessite
6	$Cu_{1,014}Fe_{0,982}S_{2,00}$	Chalcopyrite
7	$(Pd_{10,298}Ag_{0,556})_{10,854}(As_{2,33}Sb_{1,67})_{4,00}$	Mertieite
8	$Fe_{0,966}Cu_{0,94}S_{2,00}$	Chalcopyrite
9	$(Pd_{0,882}Pt_{0,042}Ni_{0,129}Fe_{0,036})_{1,107}(Te_{1,885}Bi_{0,014}Hg_{0,011})_{1,91}$	Merenskyite

Tab. 1. Chemical composition of accessory minerals of apatite-titanomagnetite ores (wt%). Note: "–" – the content of the element is below the detection limit; chalcopyrites 4 and 6 contain hessite grains 3 and 5, respectively; precipitation of mertieite (7) is located in the oxide rim of the chalcopyrite grain (8). Analysis of merenskyite (9) is borrowed from (Volchenko et al., 2009)

Actual problems of magmatic geology, petrology and ore forming processes. Ekaterinburg, pp. 38–58. (In Russ.)

Zhilin I.V. (2006). Au-Pt-Pd-specialization of apatite-Ti-magnetite ores of Suroyam alkali-ultramafic massif (West slope of Urals). *Metallogeny of ancient and modern oceans–2006.* Miass, pp. 214–217. (In Russ.)

Zhilin I.V., Fominykh V.G. (1977). Alkali metasomatism of Suroyam giperbasite massif on the Southern Urals. *Doklady Earth Sciences,* 233(2), pp. 465–467. (In Russ.)

Zhilin I.V., Puchkov V.N. (2009). Geology and ore-bearing of Nyazepetrovsky zone (Middle Urals). Ufa: DizaynPoligraphServis, 184 p. (In Russ.)

Manuscript received 7 May 2020;
Accepted 8 September 2020;
Published 11 December 2020

About the Authors

Dmitry E. Saveliev – Dr. Sci. (Geology and Mineralogy), Professor of the Academy of Sciences of the Republic of Bashkortostan, Institute of Geology of the Ufimian Federal Research Centre of the Russian Academy of Sciences

16/2, K.Marks st., Ufa, 450077, Russian Federation

Ivan A. Blinov – Cand. Sci. (Geology and Mineralogy), Institute of Mineralogy of the South Urals Federal Research Center of Mineralogy and Geoecology of the Urals Branch of the Russian Academy of Sciences

1, Ilmeny State Reserve, Miass, Chelyabinsk region, 456301, Russian Federation