ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 414, No. 4, pp. 526–529.
Original Russian Text © S.G. Kovalev, A.P. Chernikov, A.V. Burdakov, 2007, published in Doklady Akademii Nauk, 2007, Vol. 414, No. 3, pp. 364–367.

GEOLOGY

First Finding of Native Gold in Chromites from Rock Massifs of Kraka (Southern Urals)

S. G. Kovalev, A. P. Chernikov, and A. V. Burdakov

Presented by Academician Yu.M. Pushcharovsky August 7, 2006

Received July 24, 2006

DOI: 10.1134/S1028334X07040083

Rare findings of native gold in ultramafic rocks provide insight into specific features of their genesis or transformation. In [7], findings of native gold spherules (5–30 μm across) in olivine, pyrrhotite, and magnetite grains were reported from ultrabasic rocks of the Loveld deposit (South Africa). In the Urals, Pd-bearing native gold with high contents of Cu and Hg was found in metamorphosed chromites of stratiform complexes [1] and in olivine–antigorite rocks of the Syum–Keus Massif [6].

In ultramafic rock massifs of Kraka, native gold was discovered during the mineragraphic study of rock samples taken above the ore zone of the Bol'shoi Bashart deposit (Yuzhnyi Kraka Massif) [5]. The native gold was represented by tiny (from *n* μm to 0.08 × 0.01 mm) irregular segregations confined to thin cracks in chromites. Native gold particles of similar size (0.05 × 0.1 mm) were detected in panning samples of the ore-hosting ultramafic rocks of the Khamitov deposit and the Sarangaev ore occurrence located in the banded complex of the Srednii Kraka Massif (Fig. 1).

The Khamitov deposit incorporates two NW- to SE-striking orebodies composed of massive and densely disseminated chromites. The orebodies are up to 1 m thick and 30 m long.

The Sarangaev ore occurrence is represented by a vein-shaped body of disseminated chromite ores. The body is up to 40 cm thick and approximately 60 m long along the strike.

Chrome spinels in ores of these ore occurrences and deposits belong to chromites, Cr-picotites, and less common aluminochromites. For example, segregations of the chromite and aluminochromite types have compositions corresponding to formulas $(Mn_{0.08}Fe_{2.87-3.03}Mg_{5.13})_8 \times (Al_{2.86–3.42}Cr_{12.28–12.52}Fe_{0.22–0.62}Ti_{0.06})_{16}O_{32}$ and $(Mn_{0.13}Fe_{3.7}Mg_{4.17})_8(Al_{3.11}Ti_{0.02}Cr_{11.86}Fe_{1.01})_{16}O_{32}$, respectively. The chrome spinels have a rather wide and diverse assemblage of trace elements (%): Ni (up to 0.26), Co (up to 0.03), Mn (0.02–0.46), Si (up to 0.13), Cu (0.02–0.07), and Zn (0.09–0.11). In general, the ores are characterized by the following average contents of the major components (%): Cr_2O_3 11.4–25.9, Fe_2O_3 14.8–17.4, FeO 0.33–0.77, MnO 0.06–0.24, MgO 8.6–12.4, and SiO_2 6.7–9.32. The contents of trace elements are as follows (g/t): Cu 12–54, Zn 250–360, Co 110–140, and Ni 1050–1400.

The ores are characterized by elevated contents of platinum group elements (Table 1). Their distribution is scrutinized in [2].

Gold flakes found in the ores are marked by an irregular lumpy pelletal shape and specific composition of trace elements (Cu, Pd, and Pt). Table 2 shows that the Pt content is no more than 0.8 g/t ($2\sigma = 0.83$).

In addition, we found three gold pellets with rounded edges (maximal dimension 1.0 × 0.45 mm) in ultramafic rock massifs of Kraka. The gold pellets were discovered in the course of the panning of alluvial–deluvial sediments of Chernyi Klyuch Creek, which washes out mafic–ultramafic rocks of the banded complex of the Srednii Kraka Massif. The pellets contain significant Se, Rh, and S (Table 2).

In [2], we demonstrated that the distribution and redistribution of noble metals in the banded complex of the Srednii Kraka Massif is primarily related to its emergence as an autonomous lithostructural subdivision during the evolution of ultramafic massifs of Kraka under geodynamic conditions of the transitional continental/oceanic rifting stage. Elevated contents of Au, relative to the clarke value and contents in the undepleted mantle protolith [8], are typical of various petrographic varieties of rock massifs [5]. Such contents indicate that the massifs are characterized by a low degree of depletion.

We believe that the issue of the genesis of native gold cannot be discussed without consideration of the

Institute of Geology, Ufa Scientific Center, Russian Academy of Sciences, ul. Karla Marksa 16/2, Tsentr, Ufa, 450000 Russia; e-mail: kovalev@anrb.ru

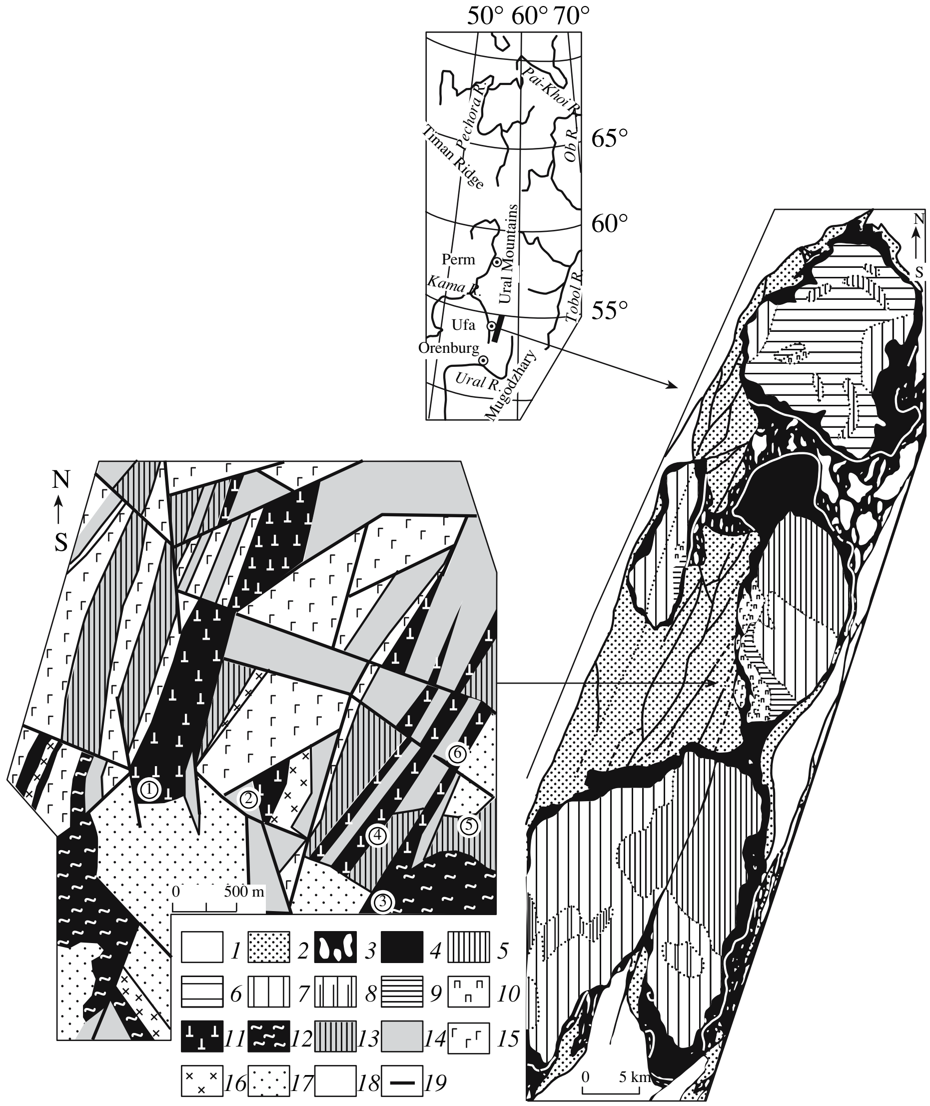

Fig. 1. Schematic geological structure of rock massifs in Kraka and the banded complex. (*1*) Undifferentiated rocks of the autochthon; (*2*) Ordovician–Siberian volcanosedimentary sequences (undifferentiated); (*3*) serpentinite melange; (*4*) marginal serpentinites; (*5*) lherzolites; (*6*) lherzolite–harzburgites (undifferentiated); (*7*) harzburgites; (*8*) dunite–harzburgite complex; (*9*) dunites; (*10*) pyroxenites; (*11*) marginal dunites; (*12*) apodunite serpentinites; (*13*) undifferentiated ultramafic rocks (pyroxenite–dunites); (*14*) pyroxenites (clinopyroxenites, olivine clinopyroxenites, and wehrlites); (*15*) gabbro; (*16*) apogabbro metasomatites (rodingites and chlograpites); (*17*) turf-covered sectors; (*18*) chromite ore occurrences and deposits: (1) Babai, (2) Bezymyannoe, (3) Khamitov, (4) Ak-Bura, (5) Sarangaev, (6) Severnyi Khamitov; (*19*) tectonic faults.

behavior of the whole assemblage of noble metals in ores and rocks of the banded complex of the Srednii Kraka Massif. Analysis of the distribution of Au and PGE in ore occurrences and deposits confined to the banded complex revealed that the type of noble metal specialization of ores depends on the spatial position of the ore deposit (Fig. 2). In particular, Pt shows a contrasting differentiated distribution: the maximal Au contents (5.19 and 3.10 g/t) are recorded in the western group of chromite deposits (Fig. 2, upper group in the summary section). The minimal contents are recorded in ores sandwiched between the banded complex and the ultrabasic section of the massif. In general, the distribution of noble metals in ores shows the following trend:

(1) Chromite ores confined to the intercalation of marginal dunites, gabbroids, and apogabbro metasomatites are characterized by elevated contents of PGE and Au (Pt and Au–Pt specialization);

(2) chromite ores developed in pyroxenites and their olivine-bearing varieties near the banded complex/ultramafic rock junction are depleted in PGE and anomalously enriched in Au (Au and Pt–Au specialization); and

Table 1. Average contents (g/t) of noble metals in ores of (1) the Khamitov deposit and (2) the Sarangaev ore occurrence

Ord. no.	Pt	Os	Ir	Ru	Äu
1 (3)	1.03 / 0.1–3.1	0.048 / 0.02–0.14	0.066 / 0.02–0.14	0.064 / 0.02–0.13	0.5 / 0.14–0.7
2 (3)	0.24 / 0.1–0.72	0.029 / 0.006–0.07	0.004 / 0.002–0.006	0.013 / 0.004–0.026	0.12 / 0.07–0.16

Note: The number of analyses is given in parentheses; the average content, in the numerator; and the scatter of values, in the denominator. Based on [5].

Table 2. Chemical composition of gold flakes in ore-hosting rocks of (1, 2) the Khamitov deposit, (3) the Sarangaev ore occurrence, and (4, 5) alluvial–deluvial sediments of the Chernyi Klyuch Creek, %

Component	1	2	3	4 (edge)	4 (center)	5 (edge)	5 (center)
Au	89.55	89.22	89.21	98.2	94.61	98.87	93.30
Ag	7.61	8.06	7.08	–	4.48	0.37	5.62
Bi	–	–	–	0.25	–	–	–
As	–	–	–	0.19	–	–	–
Sn	–	–	–	0.17	–	–	–
Sb	–	–	–	0.18	–	–	–
Se	–	–	–	0.98	0.76	–	–
Te	–	–	–	0.03	–	–	–
Ni	–	–	–	0.02	–	–	–
Cu	1.06	1.12	3.03	–	–	–	–
Pd	0.85	0.54	–	–	–	–	–
Pt	Trace	Trace	–	–	–	–	–
Rh	–	–	–	–	–	0.42	0.07
S	–	–	–	–	–	0.41	0.61
Total	99.07	98.94	99.321	100.02	99.85	100.07	99.6

Note: The Au content was determined with a JSM-840 scanning microscope equipped with Link (acceleration 20 kV, count time 50 s) at the Institute of Problems of Metal Superplasticity, Russian Academy of Sciences (Ufa). Elements of the noble metal group, Sn, Pb, As, Te, and Sb were analyzed based on spectra of the *L* series; the remaining elements, based on the *K* series. Calculations of compositions were based on the routine ZAF software package. Pure metals from the collection of the institute were used as standards. The contents are given in %.

(3) chromites from deposits of the Saksei group demonstrate a prominent Os–Ir–Ru specialization with the prevalence of Ru (Fig. 2).

This distribution pattern indicates a trend primarily related to the influence of temperature on the noble metal specialization of chromite ores in accordance with the general evolution of the process of partial melting [3]. The dependence of noble metal specialization of ores on the spatial position of the ore deposit is clearly shown by analysis of the Au/Pt ratio in them. For example, ores of the Babai deposit, the westernmost member (Fig. 2, the upper deposit in the summary section), are marked by Au–Pt specialization (Au/Pt = 10 : 90). In the eastern (harzburgite-rich) part of the massif, the Au/Pt ratio changes to 30 : 70 in ores of the Khamitov deposit and 70 : 30 in chromites of the Sarangaev ore occurrence.

We assume that this distribution pattern of noble metals (Au, in particular) is related to evolution of the major rock types of the banded complex from the partial melting of the mantle in the transitional continental/oceanic rifting environment with the following specific features: (1) fractionation of the fusible component from the primary (undepleted) mantle protolith and its reaction with restite (with the active participation of the fluid phase) in the course of a general decrease in pressure; (2) metamorphic–metasomatic reaction between the fluid-saturated melt and the solid-phase (crystalline) restite; and (3) auto- and epigenetic (synchronous) metamorphism of rocks of the protolith and the fractionated melt.

Thus, native gold detected in rocks of the banded complex of the Srednii Kraka Massif can be referred to the primary mantle type. The contribution of crustal processes (extraction of metals from host rocks of the

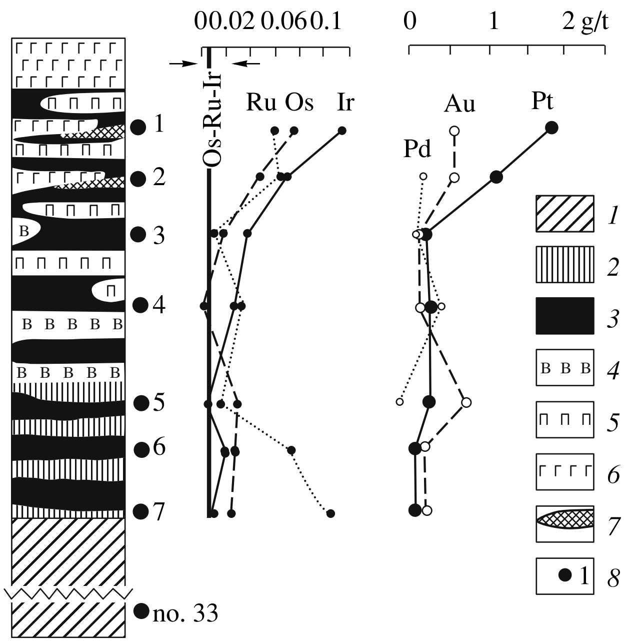

Fig. 2. Distribution of noble metals in ores from chromite deposits confined to the banded complex of the Srednii Kraka Massif. (*1*) Spinel lherzolites; (*2*) harzburgites; (*3*) marginal dunites; (*4*) wehrlites; (*5*) clinopyroxenites; (*6*) gabbroids; (*7*) apogabbro metasomatites; (*8*) chromite ore occurrences and deposits: (1) Babai, (2) Khamitov, (3) Severnyi Khamitov; (4) Ak-Bura, (5) Sarangaev, (6) Pravyi Saksei; (7) Levyi Saksei. The solid line shows the variation range of contents of Os, Ru, and Ir in high-aluminous ores of deposit no. 33.

framework) was insignificant in the genesis of this gold.

Retention of primary geochemical characteristics (contents of trace elements) in the composition of gold flakes described above is very important, because this feature can be used for the quantitative comparison with analogous data on bedrock deposits and placers located not only in the study region, but also in other ore provinces.

ACKNOWLEDGMENTS

This work was supported partially by the Division of Earth Sciences of the Russian Academy of Sciences, program no. 4, "Role of Magmatism and Fluids in the Formation of Crust and Mantle."

REFERENCES

1. Yu. A. Volchenko and A. A. Malyugin, in *Minerals of the Gold–Palladium–Mercury System in Ores of the Urals* (Sverdlovsk, 1986), pp. 17–18 [in Russian].
2. S. G. Kovalev, Geochem. Int., No. 3, (2005) [Geokhimiya, No. 3, 333 (2005)].
3. S. G. Kovalev, in *Ophiolites: Geology, Petrology, Metallogeny, and Geodynamics* (Inst. Geol. Geokhim. Ural. Otd. Ross. Akad. Nauk, Yekaterinburg, 2006), pp. 104–106 [in Russian].
4. S. G. Kovalev and I. V. Vysotskii, in *Geology and Perspectives of Expansion of the Raw Mineral Base of Bashkortostan and Adjacent Territories* (Ufa, 2001), Vol. 2, pp. 134–140 [in Russian].
5. S. G. Kovalev and V. I. Snachev, *Ultramafic Massifs of Kraka: Geology, Petrology, and Metallogeny* (Ufa, 1998) [in Russian].
6. A. B. Makeev, *Mineralogy of Alpine-Type Ultramafic Rocks of the Urals* (Nauka, St. Petersburg, 1992) [in Russian].
7. I. S. Rozhkov, in *Problems of Metallogeny of the Far East Soviet Union* (Nauka, Moscow, 1967), pp. 32–44 [in Russian].
8. G. Garuti, G. Fershtater, F. Bea, et al., Tectonophysics **276**, 181 (1997).