
Unnamed PGE Phases from Gold Placer Deposits of South Siberia, Russia

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The new unnamed phases of PGE were determined in gold placer deposits of Krasnoyarsk region and contiguous territories. There aren't any information about these phases in publications, some of them were described chemically only without physical properties.

The phase (Au,Pt)Cu was determined in placer by river Bolshoy Khaylyk (the tributary of the Yenisey) in Western Sayan. The grains have size 1x2 mm and oval sharp. This mineral makes composite association with other minerals and hosts them. The matrix of mineral is homogeneous and has light-pink (orange) color. This grain is aggregate of isometric crystals that have size up to 25x25 μm . Double-reflection of the mineral practically not noticeably. An anisotropy is strong with effects from hepatic to sulphur colors. The chemical composition of main body of grain (matrix) is well enumerated on the formula (Au,Pt)Cu, where the relation Au:Pt is stable and is equal 4:1 (Table 1). Probably, this phase is platinian tetra-auricupride. The grain contains inclusion of other minerals: native gold, magnetite, and minerals of irarsite-hollingworthite series, Rh-containing pentlandite and tulameenite. One grain with chemical composition adequate plagioclase (andesine) was found. Greatest interest in the grain is represented with inclusions of intricate sharp fine grains. Probably, this phase is platinian analog of stannopalladinite or Sn-containing hongshiite (Table 1). The phase has the greenish-grey color, anisotropy is strong in light-yellow tones. The double-reflection is clearly observed. The size of grains of this phase is up to 0,020 mm.

The compositions of Au-Pt-Cu alloys, which is similar with detected grain by authors, are known from three publications. The earliest mention about Au-Pt-Cu alloys meets at L.Cabri (Cabri et al., 1981). L. Cabri describes composition of the mineral from gold - platinum placer of river Tulameene (British Colombia), which is similar to ours - Au-58,45 %; Cu-23,51 %; Rh-0,02 %; Pt-15,80 %; Os-0,07 %; Ni-0,06 % and Fe-0,09%. The mineral has the orange-pale-pink color, but is isotropic in contrast to ours. The mineral was found in tulameenite and has xenomorphic shape of its

inclusions (up to 0,1mm). Extremely close chemical composition of this inclusion and association with tulameenite allow to assume, that this mineral is similar to ours. The fine sizes of minerals and determination in non-isotropic tulameenite may reduce to the erroneous conclusion about its isotropies.

The very similar composition of minerals ((Au,Pt)Cu, Pt(Cu,Fe) and Pt(Cu,Sn)) are described in the publication of I.Ya. Nekrasova et. al. (Petrology..., 1994). The minerals were detected in a concentrate from placer at Conder massive. Unfortunately, the authors have not reduced optical data of minerals, that does not allow to comparing with detected by us.

Another find of an alloy (Au,Pt)Cu ("Pt - tetraauricupride") was made by N.D.Tolstykh (Tolstykh et al., 1997) in gold placer of Gold river (Western Sayan), near the river Bolshoy Khaylyk. The indicated rivers are divided from each other small ridge and their sources are on a distance 10-15 km. The roundish shape inclusion of this mineral (by data of N.D. Tolstykh) is situated in the grain of native ruthenium, and, as well as in our case, precisely correspond to stoichiometry of tetraauricupride. The described mineral contains microinclusions of sperrylite and has the following composition: Au-54,52 %; Pt-14,69 %; Ir-1,96 %; Rh-0,51 %; Pd-1,64 %; Cu-22,68 %; Fe-0,09 %; As-2,16 % and Se-0,44%. Under the opinion of the quoted authors, platinum tetra-auricupride is relating to the secondary paragenesis of PGM. Its formation is connected with hydrothermal quartz-gold process, which is imposed upon ultramafic rocks and early primary-magmatic rutheniridosmine paragenesis. We agree with this opinion, because it proves by detection of minerals of hollingworthite-irarsite series and Rh-containing pentlandite in structure Pt-tetraauricupride. It especially is probable, because in the upper of the Gold and Large Khaylyk rivers the uncommercial gold-quartz ore manifestations are situated. They connected with devonian (?) acid intrusions.

It is interesting to compare our data with hydrothermal paragenesis of PGM from Waterberg (Southern Africa). The major part of PGM concerns

to such systems as Pt-Pd, Pt-Cu, Au-Cu-Pt and Pd-Pt-As-Sb-Sn (Distler et. al., 2000), and usually many of them contain the admixtures of gold (up to 3,26 % in the Pt-Cu system). The formation of this paragenesis on Waterberg happened at decreasing temperature from 370 up to 500 °C and reductive-oxidative evolution of composition hydrothermal solutions (Distler et. al., 2000).

By our sight the grain, detected by us, had composition of isoferroplatinum or toulaminita at first and contained plate sharp inclusions of sulphoarsenides Rh and Ir, magnetite and rock-forming minerals. The finds of isoferroplatinum with fine-latticed structures of structural breakdown of irarsite and erlichmanite are known, for example, in massive Conder (Petrology..., 1994). At superposition of gold hydrothermal mineralization the composition of grain has varied up to (Au,Pt)Cu, and the grains hollingworthite-irarsite have remained as not up to an extremity substituted relics. The «serrated» shape of these relics testifies to it.

The compositions of platinian and palladian gold from Conder massive are characterized by mandatory presence of cooper. Thus the content of platinum in it varies from 2,10 up to 10,33 %. In our case the content of Pt varies already from 13,79 up to 18,14 wt. of % at a practically stable content of cooper - 24,10-25,25 %. There is one more find of unusual gold-platinum solid solution, which was made in alluvium of Durance river (France). The

content of gold varies in 10-11 %, platinum - 64-65 %; average content of cooper - 21-22 % (Johan et al., 1990). It testifies to possible of full isomorphism in the series tetra-aurocupride-hongshiite: AuCu - (Pt, Au) Cu - (Au, Pt) Cu - PtCu.

The large grains platosmiride and rutheniridosmine with usual composition (No. 1 and 6, table 2) were found in same placer of Bolshoy Khaylyk river. The unknown in literature phases were detected in microcracks of cleavage of these grains (No. 2-5 and 7-8, table 2). At optical observations behind accretions of these phases become obvious, that all of them are secondary minerals. These minerals were formed at the time of exposure of hydrothermal fluids upon magmatic paragenesis of PGM. Fluids contained such component as Au, Cu, Ni, Fe.

Authors made another interesting find in gold-bearing alluvium of river Talanovaya (Kuznetsky Alatau). Among usual placer PGM minerals (isoferroplatinum, osmiride, iridosmine etc.) in one grain of rutheniridosmine the fine inclusion containing in its composition Pt, Cu, Sb and Au (Table 3) was found. This phase may appropriate Sb-hongshiite with increased content of gold. The optical properties of this phase are similar with Pt-tetra-aurocupride from placer of river Bolshoy Khaylyk. The phase has yellowish-cream color, clearly non-isotropic and is formed within hydrothermal fluids and cumulative PGM.

Table1. Compositions of Au-Pt-Cu-Sn-phases.

No.	wt. %							Total	Formula
	Fe	Ni	Cu	Au	Pt	Pd	Sn		
1.	0.0	0.0	24.85	58.65	16.89	0.04	0.0	100.43	(Au _{0.77} Pt _{0.22}) _{0.99} Cu _{1.01}
2.	0.0	0.0	25.09	60.62	14.93	0.0	-	100.64	(Au _{0.79} Pt _{0.20}) _{0.99} Cu _{1.01}
3.	0.0	0.0	25.25	61.37	14.65	0.0	-	101.27	(Au _{0.80} Pt _{0.19}) _{0.99} Cu _{1.01}
4.	-	-	24.23	62.62	14.83	-	0.0	101.68	(Au _{0.82} Pt _{0.20}) _{1.02} Cu _{0.98}
5.	-	-	24.51	63.22	13.79	-	0.0	101.52	(Au _{0.83} Pt _{0.18}) _{1.01} Cu _{0.99}
6.	-	-	24.29	61.67	14.75	-	0.0	100.71	(Au _{0.81} Pt _{0.20}) _{1.01} Cu _{0.99}
7.	-	-	24.15	58.46	18.14	-	0.0	100.75	(Au _{0.77} Pt _{0.24}) _{1.01} Cu _{0.99}
8.	-	-	24.29	60.19	16.91	-	0.04	101.43	(Au _{0.79} Pt _{0.22}) _{1.01} Cu _{0.99}
9.	-	-	24.10	60.50	16.03	-	0.0	100.63	(Au _{0.80} Pt _{0.21}) _{1.01} Cu _{0.99}
10.	-	-	24.46	60.81	15.74	-	0.0	101.01	(Au _{0.80} Pt _{0.21}) _{1.01} Cu _{0.99}
11.	1.01	0.37	14.64	1.37	58.82	7.69	15.23	99.13	(Pt _{0.79} Pd _{0.19} Au _{0.02}) _{1.00} (Cu _{0.60} Sn _{0.34} Fe _{0.05} Ni _{0.01}) _{1.00}
12.	0.92	0.31	14.49	1.39	64.22	3.28	14.19	98.80	(Pt _{0.89} Pd _{0.08} Au _{0.02}) _{0.99} (Cu _{0.62} Sn _{0.33} Fe _{0.04} Ni _{0.01}) _{1.00}
13.	0.99	0.36	14.78	1.39	59.63	7.37	15.77	100.29	(Pt _{0.79} Pd _{0.18} Au _{0.02}) _{0.99} (Cu _{0.60} Sn _{0.34} Fe _{0.05} Ni _{0.02}) _{1.01}
14.	1.03	0.33	15.23	3.94	62.01	3.63	12.42	98.59	(Pt _{0.86} Pd _{0.09} Au _{0.05}) _{1.00} (Cu _{0.65} Sn _{0.28} Fe _{0.05} Ni _{0.02}) _{1.00}
15.	1.32	0.43	14.71	0.55	59.66	7.96	15.30	99.93	(Pt _{0.79} Pd _{0.19} Au _{0.01}) _{0.99} (Cu _{0.60} Sn _{0.33} Fe _{0.06} Ni _{0.02}) _{1.01}
16.	0.82	0.35	14.94	2.67	57.17	8.30	16.14	100.39	(Pt _{0.75} Pd _{0.20} Au _{0.04}) _{0.99} (Cu _{0.60} Sn _{0.35} Fe _{0.04} Ni _{0.02}) _{1.01}
C _{lim}	0.028	0.040	0.048	0.159	0.136	0.033	0.027		

Table 2. Composition Pt-Ir-Ni-Cu-Fe – phases.

No.		Pt	Ir	Os	Pd	Rh	Ru	S	Fe	Ni	Cu	Total	Formula
1.	wt.%	3.37	65.30	30.06	0.0	0.23	0.19	0.0	0.26	0.06	0.0	99.47	Ir _{0.65} Os _{0.30} Pt _{0.03} Fe _{0.01} matrix grain 1
	at.%	3.29	64.73	30.11	0.0	0.43	0.36	0.0	0.89	0.19	0.0	100.0	
2.	wt.%	23.38	24.46	1.24	0.0	0.28	0.0	0.0	10.30	24.54	14.47	98.67	(Pt.Ir) _{0.94} (Ni.Cu.Fe) _{3.06} inclusion 1
	at.%	11.03	11.71	0.60	0.0	0.25	0.0	0.0	16.97	38.48	20.96	100.0	
3.	wt.%	31.20	17.03	0.23	0.0	0.22	0.0	0.0	11.08	24.33	14.61	98.70	(Pt.Ir) _{0.91} (Ni.Cu.Fe) _{3.08} inclusion 1
	at.%	14.61	8.09	0.11	0.0	0.20	0.0	0.0	18.12	37.87	21.00	100.0	
4.	wt.%	13.09	36.82	1.62	0.0	0.34	0.0	0.0	11.57	33.38	1.71	98.53	(Ir.Pt) _{1.00} (Ni.Fe.Cu) _{2.99} inclusion 2
	at.%	6.25	17.85	0.79	0.0	0.31	0.01	0.0	19.30	52.99	2.51	100.0	
5.	wt.%	12.84	36.71	1.76	0.0	0.34	0.0	0.0	11.58	33.33	1.69	98.25	(Ir.Pt) _{1.00} (Ni.Fe.Cu) _{2.99} inclusion 2
	at.%	6.14	17.83	0.86	0.0	0.31	0.0	0.0	19.36	53.01	2.48	100.0	
6.	wt.%	4.02	56.48	29.02	0.0	0.82	5.00	0.0	2.11	1.02	0.0	98.47	Ir _{0.51} Os _{0.26} Ru _{0.09} Fe _{0.07} Pt _{0.04} – Ni _{0.03} matrix grain 2
	at.%	3.56	50.69	26.32	0.0	1.37	8.54	0.0	6.52	3.00	0.0	100.00	
7.	wt.%	48.03	6.03	0.88	0.0	0.47	0.06	0.0	13.11	26.03	1.63	96.24	(Pt.Ir) _{0.87} (Ni.Cu.Fe) _{2.13} inclusion 3
	at.%	24.84	3.16	0.47	0.0	0.46	0.06	0.0	23.68	44.74	2.59	100.0	
8.	wt.%	48.69	9.41	1.74	0.0	0.43	0.43	0.0	13.17	23.47	1.49	98.83	(Pt.Ir) _{0.97} (Ni.Cu.Fe) _{2.03} inclusion 3
	at.%	25.59	5.02	0.94	0.0	0.43	0.44	0.0	24.18	41.00	2.40	100.0	
C _{lim}		0.137	0.122	0.036	0.035	0.032	0.029	0.015	0.028	0.038	0.049		

Table 3. Composition Au-Pt-Cu-Sb – phase.

No.		Au	Pt	Sb	Rh	Ru	Fe	Ni	Cu	Total	Formula
1.	wt.%	4.15	65.26	9.12	0.095	0.044	0.605	0.658	18.27	98.21	(Pt _{0.90} Au _{0.06}) _{0.96} (Cu _{0.78} Sb _{0.20} Fe _{0.03} Ni _{0.03}) _{1.04}
	at.%	2.84	45.11	10.10	0.125	0.058	1.46	1.512	38.78	100.0	
2.	wt.%	3.94	64.58	9.13	0.091	0.045	0.682	0.705	17.97	97.19	(Pt _{0.90} Au _{0.05}) _{0.95} (Cu _{0.77} Sb _{0.20} Fe _{0.03} Ni _{0.03}) _{1.03}
	at.%	2.72	45.04	10.21	0.120	0.060	1.661	1.634	38.46	100.0	
C _{lim}		0.176	0.152	0.036	0.037	0.035	0.034	0.047	0.063		

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