The Types of PGE Mineralization of Kansk's Greenstone Belt (South Siberia, Russia)

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There are three types of PGE-mineralization on the territory of Kansk's greenstone belt (East Sayan): 1) in sulfide Cu-Ni ores (including commercial Kingash deposit), 2) in gold - sulfide, 3) in chromium-bearing dunite-harzburgite formation. The brief description of these ore formations is in a Table 1.

The PR_1 Kansk's greenstone belt is situated in southwest frame of the Siberian platform. The belt is traced on a distance about 200 km in northwest direction. A width is up to 30 km. This greenstone belt is controlled by same name deep fault. There is PR_1 gneisses formation (Kulizha formation) in the foundation of Kansk's greenstone belt. On these gneisses formation the carbonaceous – volcanic - terrigene formation (Kingash PR_1 formation) occurs concordant. Kingash formation is presented by amphibolites, gneisses, marble, volcanic rocks of basalt-komatiitic complex, sulfide-siliceous-terrigene rocks (the part of ferruginous quartzites). A thickness of Kingash formation is about 4000 m. Intrusive complexes are presented by ultramafic, mafic, and granites. The intrusives of dunite-peridotite-gabbro formation is connected with basalt-komatiitic series of Kansk's greenstone belt and joined in one volcano-plutonic complex. These rocks occur in Kingash formation only. The intrusives of dunite-hartzburgite formation occure in Kulizha and Kingah formation. These intrusives have small dimentions (up to 500x60 m). Geological formations of Kansk greenstone belt is metamorphized in epidote-amphibolite and amphibolite facies.

Table 1. *Description of PGE-bearing ore formations of Kansk's greenstone belt.*

Parameter	Sulfide Cu-Ni	Au-sulfide	Chromium
Ore-containing formation, age	Basalt-komatiitic, PR_1	Basalt-komatiitic, hydrothermal-altered rocks of Kingash formation, PR_1	Dunite-harzburgite, PR_1
Geological setting	Basis of Kingash formation, flexure-form folds syncline structures	Usually in base of Kingash formation or in its bottom deposits, along with tectonic fractures	Bodies of small size in Kingash and Kulizha formation
Shapes of ore bodies	Bed-form deposits of disseminated ores, brecciform, massive	Zone of disseminated mineralization along with tectonic fractures and bed-form	Disseminated chromspinels mineralization in ultramafic rocks
Main opaque minerals	Pyrrhotite, pentlandite, chalcopyrite, magnetite	Pyrrhotite, pyrite, marcasite, rutile, ilmenite, graphite	Chromspineles, magnetite
Secondary and accessories	Cubanite, chromspineles, valleriite, pyrite, mackinawite, bornite, millerite, sfalerite, ilmenite, wolframite, nickeline, maucherite, gersdorffite, breithgauptite, parkerite, altaite, galena, etc.	Galena, sfalerite, pentlandite, chalcopyrite, etc.	Pyrrhotite, pentlandite, chalcopyrite
Minerals of precious metals	Gold, electrume, kustelite, hessite, amalgam of Au and Ag, sperrylite, maichenerite, sobolevskite, merenskyite, kotulskite, paolovite, froodite, moncheite, Pd-containing melonite, mertieite-II, cabriite, stibiopalladinite, irarsite, tetraferroplatinum	Gold, electrume, erlichmanite, iridarsenite	Gold, electrum, kustelite, Os-Ir-Ru alloys, isoferroplatinum

Table 2. *Concentrations of Ni, Co, Cu, S (wt. %) and PGE (ppm) in sulfide Cu-Ni ores.*

	No	Sample.	Ni	Co	Cu	S	Pt	Pd	Rh
I	1	4/119	0,72	0,02	0,28	1,30	0,52	0,54	0,05
	2	32/137,8	1,50	0,03	0,29	2,67	1,28	0,76	0,05
	3	32/140	1,05	0,03	0,92	3,00	0,82	1,60	0,06
	4	33/51	2,00	0,03	0,90	5,28	0,92	0,76	0,04
	5	36/82,2	0,70	0,02	0,47	1,29	0,26	0,22	0,03
	6	33/44	16,70	0,36	0,98	24,36	0,22	5,80	0,07
II	7	4/125	0,52	0,02	0,20	0,54	0,40	0,32	0,02
	8	31/23	0,46	0,01	0,15	0,52	0,30	0,34	0,03
III	9	32/45	2,90	0,07	0,85	13,52	0,03	0,50	0,04
	10	34/165	6,20	0,10	0,38	26,94	0,09	1,25	0,06
IV	11	17/127,6	0,12	0,02	0,07	2,55	0,03	0,01	0,01
	12	17/138	0,05	0,01	0,02	0,51	0,06	0,07	0,01
	13	17/168	0,08	0,01	0,05	1,18	0,08	0,02	0,01
V	14	k-3/1	0,23	0,15	0,015	0,76	0,30	0,03	0,005
	15	k-2/1	0,26	0,10	0,012	1,00	0,10	0,10	0,015
	16	k-2/10	0,25	0,30	0,012	0,99	0,20	0,20	0,15
	17	k-2/20	0,33	0,11	0,012	1,34	0,15	0,20	0,03
	18	k-2/30	0,37	0,11	0,086	0,87	0,15	0,15	0,01
	19	k-2/40	0,17	0,07	0,016	0,86	0,03	0,03	0,10
	20	k-2/50	0,24	0,10	0,015	0,72	0,10	0,10	0,08
	21	k-2/60	0,15	0,05	0,017	0,47	0,02	0,02	0,01
	22	k-1/4	0,12	0,03	0,078	0,29	0,01	0,005	0,006
	23	k-1/14	0,11	0,04	0,071	0,18	0,10	0,10	0,005
	24	k-1/25	0,07	0,04	0,005	0,23	-	-	0,015

Ores: 1 – 5, 7, 8 – disseminated; 6, 9, 10 – massive and brecciform (9); 11 – 13 – disseminated (with troilite), V - ores of Kuskanak manifestation.

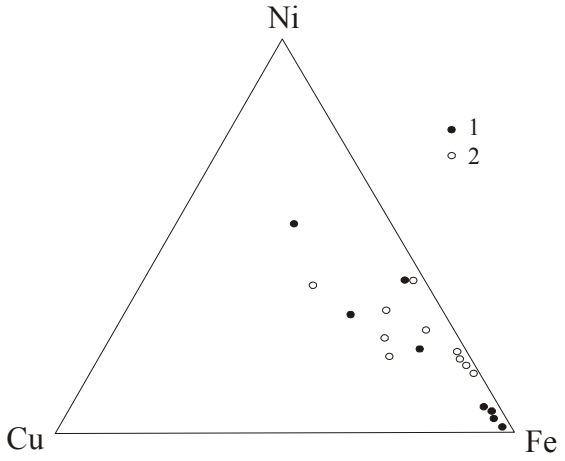

Figure 1. *Compositions of sulfide Cu-Ni ores (recalculated on 100-% sulfide) on ternary diagram CuS-NiS-FeS. 1 - ores of Kingash deposit, 2 - ores of Kuskanak ore manifestation. The composition of ores are in table 2.*

Au, PGE-Bearing Sulfide Cu-Ni Ore Formation

This formation is presented by Kingash deposit, and series of ore-manifestations (Kuskanak, Pryamoe Kue, Verhny Kingash). This type of ore mineralization has genetic connections with basalt - komatiitic formation, which is presented by (high-Mg komatiites (MgO > 30 %), komatiites (MgO = 20-30 %), picrobasalts, basalts, dunites, peridotites, pyroxenites, gabbro and dolerites).

Geological setting and petrological features indicate that mafic-ultramafic magmatism was exhibited in two phases (stage). The early phase is characterized by more differentiated structure of rocks, and more magnesium compositions in whole. Sulfide Cu-Ni ores are connected to early phase. Ore-bearing units are situated in the basis of Kingash formation and frequently are situated in the most differentiated magmatic associations (Kingash deposit) or peridotites with 25-30 % MgO. The regularity in localization of ore units in synclines, which complicating basic Karagan syncline and to flexure-shape folders of Kingash formation is marked.

The ores are dated to ultramafic rocks -

dunites, peridotites (mainly wehrlites), komatiites. With mafic rocks (gabbro, basalts) unindustrial ore mineralization is connected. Ores - disseminated, interstitional-disseminated (the main part of ores), brecciform, massive (these type of ores were found in Kingash deposit only). The ore mineralization is presented by minerals which are typical for the Cu-Ni deposits: pyrroothite, pentlandite, chalcopyrite, magnetite. The secondary and accessories minerals - cubanite, ilmenite, chalcocite, chromspineles, minerals of gold and PGE, etc. The content of sulfides in disseminated ores changes from 1 to 20 %. It is pyrrhotite-pentlandite type of ores with subordinate amounts of chalcopytite and magnetite. The epigenetic ores is pentlandite-chalcopyrite with less amounts of pyrrothite. Magnetite replaces sulfides and chromspineles.

On an example of Kingash deposit the geochemistry of PGE, Cu, Ni, Co, and S in application to genesis of ores is shown. There are compositions of ores from Kingash deposit and Kuskanak ore manifestation selected from their various types are shown. In ultramafic part of Kingash deposit some intervals enriched PGE are marked. In whole, the content PGE is increased to the bottom of deposit, that coincides with behaviour of Cr, Ni, Cu. A maxima of contents of Pt, Os and Ir are characteristic for primary sideronitic ores, and Pd, Rh and Ir - for epigenetic disseminated, brecciform and massive ores. The distribution of normalized on mantle PGE and Au conform with komatiite (by S.-J. Barnes et. el., 1988). The role fractional crystallization of sulfide melt is considered with application of the diagram FeS-NiS-CuS (Fig. 1). Analyses which shown in a table are isolated in 4 groups forming a uniform trend in the direction FeS-NiS with weak increase of Cu together with Ni. It indicates synchronous concentration of Ni and Cu in residual sulfide melt (Glotov et. l., 2001). It is typical to deposits connected with komatiites. Pt and Pd enriched residual sulfide melt. It agrees with increase in of contents Ni and Cu. The forming brecciform and massive ores of deposit connects with crystallization of mss, because their compositions (in recalculation on 100-% sulfide) are relatively enriched Fe and depleted by Ni, Cu, Co and PGE (Glotov et. al, 2001).

PGE mineralization is present in all types of ores. PGM occurs in silicate matrix and in chromspinels (sperrylite I), but the main part of finds of the PGM were made in chalcopyrite-cubanite and pyrrothite-pentlandite aggregates. The many of PGM have admixtures of Os, Ir and Rh. It is characteristic for PGM from Kingash deposit and Kuskanak ore manifestation. Mineralogical researches ndicate 3 stages of PGM formation. First - magmatic stage of becoming of a deposit (sperrylite I in chromspinelles and silicate matrix). Others two paragenesis – PdBiTe + $(Pd,Ni)Te_2$ + $PtAs_2$ and PdBiTe + Pd(Bi,Te) + $PdBi_2$ + Pd_2Sn were formed later at the time of crystallization of mss and in epigenetic stage (Shwedov et.al., 1997)

Gold-Sulfide Ore Formation

Gold-sulfide ore formation is detected recently and is poorly studied (Kornev et. al., 2001). The some types of gold mineralization were joined in this type. The ores of this formation occur in rocks of Kingash formation (amphibolites, gneisses, marble, sulfide-siliceous-terrigene rocks, quartzites). Sulfide mineralization is presented by bed-form deposits of disseminated or in zone of tectonic dislocations. This ore formation frequently occurs in association with sulfide Cu-Ni or can replace it formation along the strike. Ore mineralization (up to 20 %) is presents by pyrite, pyrrothite, marcasite, ilmenite, rutile, in less amounts - pentlandite, galena, chalcopyrite, gold, PGM, etc. Erlichmanite and iridarsenite were found by S.M. Kozyrev (Gipronickel) in rocks which occur under the Kingash deposit (marble, amphibolite, gneisses). In other zones PGE were determined analytical only. There are some of genetic types of gold-sulfide mineralization were joined in this formation (hydrothermal, metamorphized exhalation-sedimentary, meta-morphogenetic). The source of gold and PGE of gold-sulfide ores are basalt-komatiitic ore-magmatic system.

Chromium Ore Formation

This ore formation is connected with rocks of dunite-harzburgite formation. Massifs of this formation occur in Kingash and Kulizha formation. They form bodies of small size (500x60 m), which is composed by serpentinites upon ultramafic rocks. This formation contains minerals of Os-Ir-Ru system which presents in placers.

Acknowledgments

The author thanks T.Ya. Kornev (KNIIGIMS), G.I. Shvedov, N.A. Tretyakov (Krasnoyarskgeologiya), A.I. Glotov, A.P. Krivenko (UIGGM) and A.M. Sazonov (KSANFMG) for arguing of problems. The researches was partially support by Krasnoyarsk's fund of science (the grant 10F0187M).

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