

IRARSITE DISCOVERY IN COPPER-NICKEL ORES OF SHANUCH DEPOSIT (KAMCHATKA)

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In sulfide copper-nickel ores of the Shanuch deposit (Kamchatka) new for this deposit mineral – irarsite was found. The deposit is associated spatially and genetically with stocks and dikes of the Dukukhskiy basite-hyperbasite complex of Eocene age. Three mineral associations are distinguished in its ores: pentlandite-pyrrhotite, magnetite-chalcocopyrite-pyrrhotite and pyrite-marcasite one. It is established, that irarsite forms microinclusions in sulfoarsenides, more seldom in pentlandite of magnetite-chalcocopyrite-pyrrhotite association of massive sulfide ores. In irarsite composition there are constantly admixtures of iron, nickel and cobalt, sometimes of rhodium and platinum.

2 tables, 3 figures, 9 references.

Keywords: irarsite, sulfoarsenides, mineral associations, copper-nickel ores.

Irarsite – (Ir,Ru,Rh,Pt)AsS – a rare sulfoarsenide of elements of platinum group. It was discovered by A.D. Genkin with coauthors (Genkin *et al.*, 1966) in chromite ores of the Onfervacht deposit (Bushveld complex, RSA). The mineral is an end member of the hollingworthite-irarsite row. The most often irarsite is found together with gold, chromite and minerals of elements of platinum group in placers of Australia, Myanmar, Finland and Russia. The source of noble metals mineralization is represented by stratified massifs of rocks of ultrabasic-basic composition: dunites, gabbro-pyroxenites and others (Genkin *et al.*, 1991; Shcheka *et al.*, 1991; Nekrasov *et al.*, 1994; Cabri *et al.*, 1996; etc.). Information in literature about occurrence of irarsite in commercial copper-nickel ores is scarce. It is mentioned presence of irarsite in the ores of the Noril'sk deposit (Dodin *et al.*, 2000). V.V. Distler and I.P. Laputina found it among disseminated copper-nickel mineralization in some horizons of stratified ultrabasic (gabbro-norites-lerzolites) massif at the Kola Peninsula (Distler, Laputina, 1981).

The authors carried out mineralogical study of ore body No 1 of the Shanuch deposit. Rare and ore-forming minerals were analysed using X-ray spectral microanalyzer JEOL JXA-8100. In doing so in massive copper-nickel ores irarsite in association with sulfoarsenides was established.

Short description of the Shanuch deposit

The Shanuch copper-nickel deposit is located at the southern part of the Kamchatka

peninsula and is confined to median massif of the same name (Stepanov, Trukhin, 2007). At the area of the deposit are distributed crystalline schists of the Kamchatka series of late Proterozoic and gneissoid granites of the Krutogorovskiy complex of early Cretaceous. Nickel-bearing formations are represented by stocks and dikes of the Dukukhskiy basite-hyperbasite complex of Eocene age. Copper-nickel mineralization is spatially conjugated with one of dike swarms oriented subvertically. The best studied ore body No 1 has in vertical section lens-like form with a bulge in the central part. According to texture features one could distinguish four main types of ores: massive, densely impregnated, impregnated and breccial ones. It should be noted some zoning in their distribution in the limits of the ore body (Fig. 1). Thus, the central part of the latter is composed of predominantly massive ores. At near root and in subsurface parts of the ore body they are changed by breccial ores, which are predominant here. At the surface one could observe an iron hat of small thickness, composed of oxidized ores. Horizontal sections display conform zoning: the central part of ore body is most often composed of massive and densely impregnated ores, which towards periphery are changed by breccial ones then by veinlet-impregnated and impregnated ores. In the ore mineral composition pyrrhotite, pentlandite, violarite and chalcocopyrite predominate, pyrite, magnetite, millerite, mackinawite are less abundant, seldom occurrence is noted for gersdorffite, sulfoarsenides, sphalerite, galena, molybdenite, scheelite, as well as for native gold and platinumoids (Poletaev, 2004). The highest gold con-

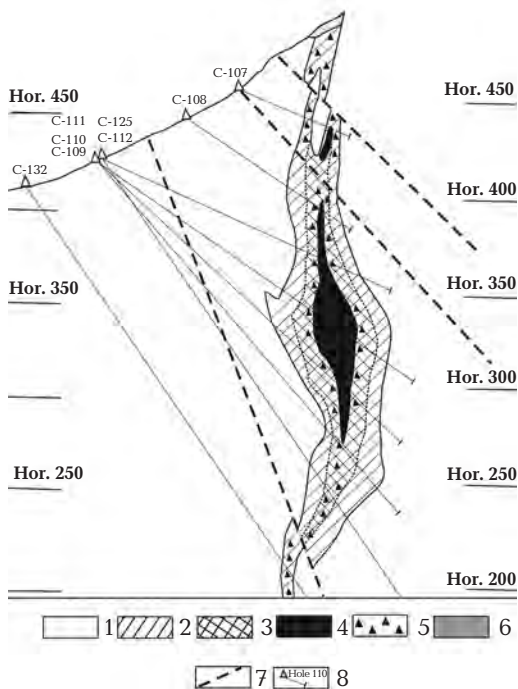


Fig 1. Sketch section of the ore body №1 from the Shanuch deposit. 1. Country rocks. 2–6. Ore types: 2 – impregnated; 3 – dense-impregnated; 4 – continuous (massive); 5 – breccias; 6 – oxidized ores. 7. Faults. 8. Boreholes and their numbers.

tents are marked in the middle part of ore body, enriched in nickel, copper and cobalt. Along dip and rise of ore body concentration of gold diminishes. Contents in ores of palladium and platinum gradually increase up the rise towards the central part of ore body, where maximum quantity of massive ores is concentrated.

The ores are characterized by the same mineral associations, among which one could distinguish pentlandite-pyrrhotite, magnetite-chalcopyrite-pyrrhotite and pyrite-marcasite ones. Two first associations are productive for copper-nickel mineralization. Sulfoarsenides with irarsite are spatially related to massive sulfide ores, in which magnetite-chalcopyrite-pyrrhotite association is developed.

Investigation results for sulfoarsenides and irarsite

Sulfoarsenides occur in all types of ores: massive, densely impregnated, impregnated and breccial ones. Usually they are represented by idiomorphic grains, which do not ex-

ceed 10 microns (seldom are found more large grains up to 50 microns), which are established in pyrrhotite, chalcopyrite and pentlandite. Crystals of skeletal form are observed very seldom. As regards their optical characteristics the minerals of this group don't differ from gersdorffite. The minerals have white color, high reflective ability; double reflection and anisotropy were not reported. By chemical composition and paragenesis one might distinguish two groups of sulfoarsenides. Sulfoarsenides with cobalt content of 5–9 wt.% are related to the first group. Minerals of the first group are often observed as intergrowths with pentlandite, forming coarse-looped structures of decay of solid solution in pyrrhotite, and are spatially attracted towards chalcopyrites of late generations, associated with monoclinic pyrrhotite and magnetite. Sulfoarsenides of the first group contain microinclusions of chalcopyrite, tellurobismuthite and argentite. Sulfoarsenides with cobalt content from 9 to 15.23 wt.% are related to the second group. Their composition is displayed in Table 1. These sulfoarsenides are spatially confined to pentlandite and pyrrhotite of early generations and often contain microinclusions of irarsite. Presence in sulfoarsenides of the second group admixtures of Ir, Rh, Pt is caused by occurrence of inclusions of such minerals as irarsite and sperrylite.

Chemical composition of sulfoarsenides of both groups is rather correctly calculated for the formula: $(\text{Ni}, \text{Co}, \text{Fe})\text{AsS}$ with insignificant deficit of the sum of nickel, cobalt and iron. Thus, one could note wide isomorphic substitution in the system of natural phases $\text{CoAsS} - \text{FeAsS} - \text{NiAsS}$, established by V.V. Distler and I.P. Laputina for another deposit (Distler, Laputina, 1979).

Irarsite is a rare mineral in the ores of the deposit (Fig. 2). Usually it forms microinclusions of rounded (Fig. 2a, f) and elongated oval (Fig. 2c) form 2–6 microns in size, locating in the central parts of idiomorphic micrograins of sulfoarsenides. Sometimes irarsite grains are found in pentlandite (Fig. 2b). Very seldom idiomorphic microcrystals (Fig. 2e) and grains of skeletal form (Fig. 2d) are observed. In one case in small idiomorphic crystal of irarsite was found micrograin (less than 1 micron) possibly of sperrylite (Fig. 3). As regards optical characteristics irarsite is not practically different from sulfoarsenides. The mineral has reflective ability close to 45% and, according to relief of relatively large (more than 5 microns; Fig. 2c) grains, higher hardness in comparison with sulfoarsenides;

Table 1. Chemical composition of sulfoarsenides, wt.%

| № an. | Fe | Ni | Co | As | Ir | Pt | Rh | S | Total |
|-------|-------|-------|-------|-------|------|------|------|-------|--------|
| 1 | 5.23 | 17.89 | 13.40 | 45.69 | — | — | — | 19.11 | 101.32 |
| 2 | 6.04 | 13.94 | 15.23 | 46.20 | 1.82 | — | — | 19.07 | 102.30 |
| 3 | 7.87 | 15.26 | 11.58 | 43.30 | — | — | — | 18.94 | 96.95 |
| 4 | 10.62 | 14.22 | 12.31 | 41.10 | 1.86 | 0.85 | — | 21.93 | 102.89 |
| 5 | 6.78 | 15.30 | 14.61 | 45.28 | — | — | — | 18.72 | 100.69 |
| 6 | 10.57 | 16.33 | 12.35 | 38.50 | — | — | — | 20.89 | 98.64 |
| 7 | 6.10 | 13.42 | 13.05 | 43.81 | 5.86 | — | 1.59 | 17.56 | 101.39 |
| 8 | 6.18 | 16.20 | 14.53 | 46.54 | — | — | — | 18.68 | 102.13 |

| Calculation of the analyses for apfu in (Ni, Co, Fe)AsS | | | | | | | | | |
|---|------|------|------|------|------|------|------|------|--|
| № an. | Fe | Ni | Co | As | Ir | Pt | Rh | S | |
| 1 | 0.16 | 0.51 | 0.38 | 1.01 | — | — | — | 0.94 | |
| 2 | 0.18 | 0.39 | 0.42 | 1.02 | 0.02 | — | — | 0.97 | |
| 3 | 0.24 | 0.45 | 0.33 | 0.98 | — | — | — | 1.00 | |
| 4 | 0.30 | 0.38 | 0.33 | 0.87 | 0.02 | 0.01 | — | 1.09 | |
| 5 | 0.20 | 0.43 | 0.41 | 1.01 | — | — | — | 0.95 | |
| 6 | 0.31 | 0.45 | 0.34 | 0.84 | — | — | — | 1.06 | |
| 7 | 0.19 | 0.39 | 0.38 | 1.01 | 0.05 | — | 0.03 | 0.95 | |
| 8 | 0.18 | 0.45 | 0.40 | 1.02 | — | — | — | 0.95 | |

Note. An. 1 – sp. 107-4; an. 2–4 – sp. 110-34 (an. 2 and an. 4 – with irsrite micro-admixture); an. 5–6 – sp. 107-4; an. 7–8 – sp. 110-22 (an. 7 – with irsrite micro-admixture).

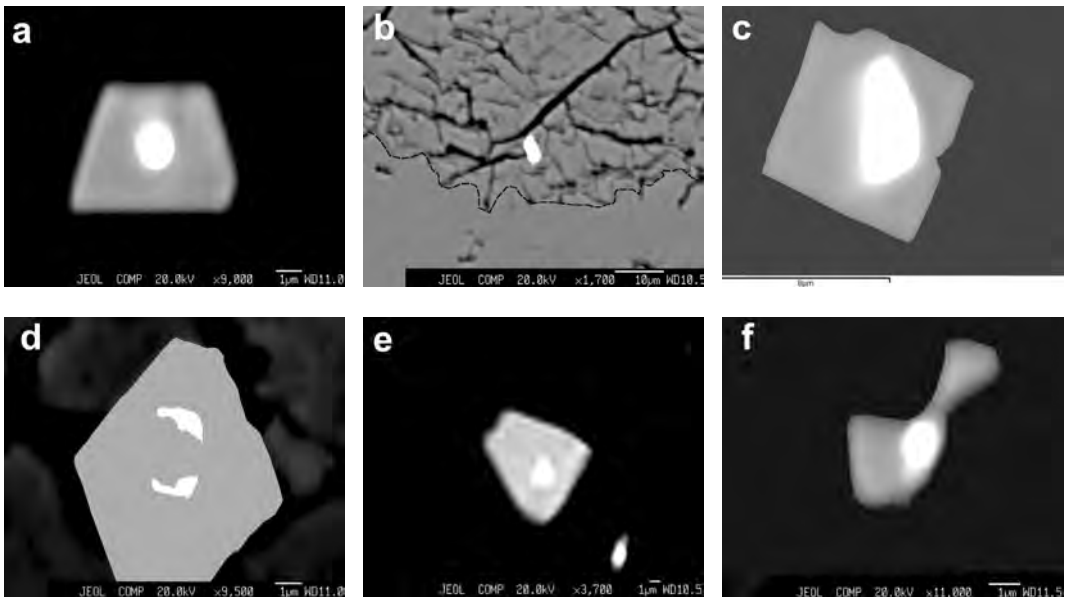


Fig. 2. Segregation shapes of irsrite and its interrelation with ore minerals: a – rounded phenocryst of irsrite (white) in idiomorphic crystal of sulfoarsenide (pale-grey); b – Idiomorphic grain of irsrite (white) in pentlandite (grey); c – isometric rounded grain of irsrite (white) in sulfoarsenide (pale-grey); d – irsrite hopper-crystal (white) in sulfoarsenide (pale-grey); e – idiomorphic grain of irsrite (white) in idiomorphic sulfoarsenide (pale-grey); f – rounded grain of irsrite (white) in sulfoarsenide (pale-grey). BSE images, using JXA JEOL-8100.

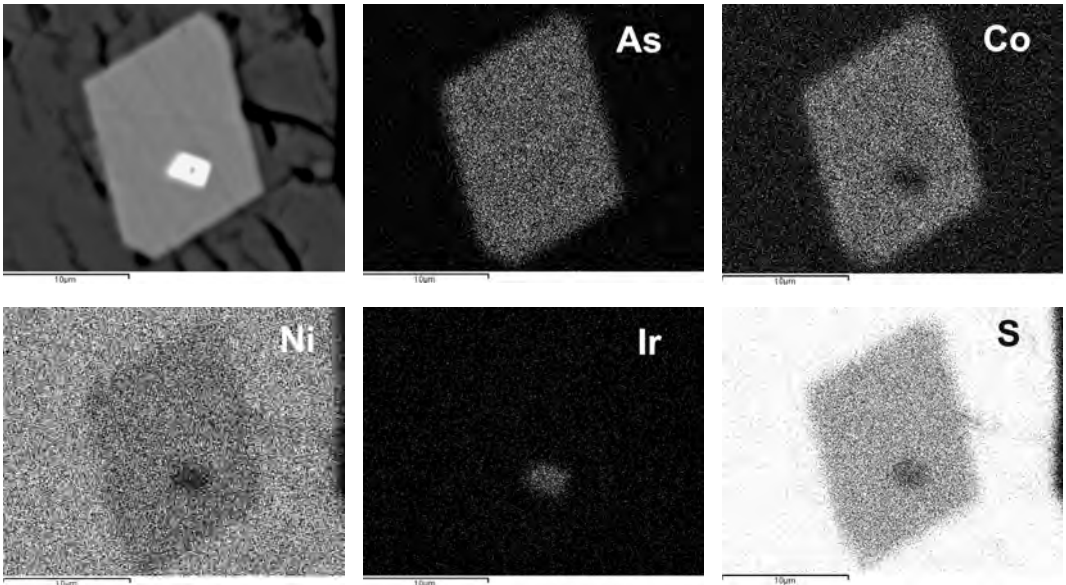


Fig. 3. Idiomorphic crystals of sulfoarsenide and irarsite with inclusions of sperrylite-(?), BSE image and characteristic emission of As, Co, Ni, Ir and S (sp. 107-4).

Table 2. Chemical composition of irarsite, wt.%

| №, an. | Fe | Ni | Co | As | Os | Ru | Rh | Ir | Pt | S | Total |
|--|------|------|------|-------|------|------|------|-------|-------|-------|--------|
| 1 | 3.36 | 5.61 | 4.34 | 32.49 | — | — | 0.96 | 38.57 | — | 12.60 | 97.93 |
| 2 | 3.04 | 5.08 | 3.01 | 30.86 | — | — | — | 44.49 | — | 11.64 | 98.12 |
| 3 | 2.71 | 4.53 | 2.64 | 28.83 | — | — | — | 44.00 | 6.00 | 11.35 | 100.06 |
| 4 | 3.47 | 3.96 | 1.20 | 30.88 | — | — | — | 45.19 | 5.43 | 10.68 | 100.81 |
| 5 | 3.61 | 4.02 | 1.49 | 29.86 | — | — | — | 45.06 | 5.07 | 11.50 | 100.61 |
| 6 | 3.80 | 5.76 | 4.86 | 33.82 | — | — | 0.92 | 31.79 | 6.92 | 12.51 | 100.38 |
| 7 | 4.20 | 5.89 | 4.77 | 34.49 | — | — | 1.03 | 30.75 | 6.98 | 13.35 | 101.46 |
| 8 | 2.33 | 7.97 | 4.29 | 32.52 | — | — | 0.92 | 36.08 | — | 13.32 | 97.43 |
| 9 | — | — | — | 24.96 | 1.48 | — | 2.65 | 59.62 | 1.20 | 10.79 | 100.70 |
| 10 | — | — | — | 34.50 | — | 9.40 | 7.20 | 23.00 | 12.60 | 11.60 | 98.30 |
| Calculation of the analyses for apfu in irarsite (Ir,Ru,Rh,Pt,Fe,Ni,Co)AsS | | | | | | | | | | | |
| №, an. | Fe | Ni | Co | As | Os | Ru | Rh | Ir | Pt | S | |
| 1 | 0.14 | 0.23 | 0.18 | 1.02 | — | — | 0.02 | 0.48 | — | 0.93 | |
| 2 | 0.13 | 0.12 | 0.13 | 1.03 | — | — | — | 0.58 | — | 0.91 | |
| 3 | 0.13 | 0.19 | 0.11 | 0.99 | — | — | — | 0.59 | 0.08 | 0.91 | |
| 4 | 0.16 | 0.18 | 0.05 | 1.06 | — | — | — | 0.62 | 0.07 | 0.86 | |
| 5 | 0.15 | 0.18 | 0.06 | 1.02 | — | — | — | 0.60 | 0.07 | 0.92 | |
| 6 | 0.15 | 0.23 | 0.19 | 1.04 | — | — | 0.02 | 0.38 | 0.09 | 0.90 | |
| 7 | 0.17 | 0.22 | 0.18 | 1.03 | — | — | 0.02 | 0.35 | 0.09 | 0.94 | |
| 8 | 0.09 | 0.32 | 0.16 | 1.04 | — | — | 0.02 | 0.42 | — | 0.95 | |
| 9 | — | — | — | 0.99 | 0.02 | — | 0.05 | 0.92 | 0.02 | 1.00 | |
| 10 | — | — | — | 1.18 | — | 0.24 | 0.18 | 0.30 | 0.17 | 0.93 | |

Note. Analyses: 1–8 – irarsite, Shanuch deposit (Kamchatka); an. 1–3 – sp. 107-4 (an. 1, 2 – edge, irarsite; an. 3 – centre: irarsite with sperrylite-? micro-admixture); an. 4–5 – sp. 132-15 (irarsite inclusion in oxidised pentlandite); an. 9 – irarsite from copper-nickel ores from ultrabasic rocks from Kola peninsula, after Distler et al., 1981; an. 10 – irarsite from platinum ores from Onverwacht mine, RSA, after Genkin et al., 1966.

double reflection and anisotropy were not observed. In chemical composition of irsarsite predominate iridium, arsenic and sulfur, that supports diagnostics of this mineral. It has constantly admixtures of iron, nickel and cobalt, sometimes of rhodium and platinum (Table 2). It should be noted that heightened concentrations of platinum in irsarsite are caused in one case (specimen 107-4) by presence at the spot of analysis of sperrylite microinclusion (?), in other cases – platinum is evenly distributed through the whole irsarsite grain (specimen 132-15, Fig. 2b; specimen 110-34, Fig. 2c). In the whole, the mineral is satisfactorily calculated for formula close to the theoretical one (Ir, Rh, Pt, Fe, Ni, Co)AsS, displaying insignificant deficit of sulfur and surplus of arsenic. Presence of admixtures of nickel, cobalt and iron, presumably, is specific feature of irsarsites at the Shanuch deposit. It is related to localization of irsarsite in massive cobalt-copper-nickel ores of this deposit. It should be considered also wide isomorphism of elements of iron and platinum groups in the minerals of cobaltite and pyrite (Genkin *et al.*, 1966). Heightened contents of platinum and rhodium in irsarsite are characteristic for the central and lower parts of the ore body (in contrast to the upper one). Close by composition irsarsites are known in ores of the deposits of Myanmar, Columbia, Canada (Cabri *et al.*, 1996), Russia (Distler, Laputina, 1981; Shcheka *et al.*, 1991; Nekrasov *et al.*, 1994).

Conclusion

In sulfide copper-nickel ores of the Shanuch deposit at Kamchatka for the first time irsarsite, which associated with sulfoarsenides was discovered. Irsarsite forms microinclusions of rounded and oval form, sometimes idiomorphic small crystals and grains of skeletal form in grains of sulfoarsenides and in pentlandite. The irsarsite formula is close to theoretical one with admixture of Ni, Co and Fe. This find adds a list of minerals of the platinum group elements (Poletaev, 2004), discovered in the ores of the Shanuch deposit.

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