# Study of the material composition to develop a rational technology for the enrichment of porphyry copper ores from the Yoshlik I and Kalmakyr deposits

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**Abstract.** The task of the tests was to study the material composition in order to develop a rational technology for the enrichment of porphyry copper balance and off-balance ores of the Yoshlik I and Kalmakyr deposits to obtain collective, copper- and molybdenum-containing concentrates, finished products in the form of copper, molybdenum and pyrite concentrates. The material composition of ore samples was studied using spectral, chemical, assay, granulometric, phase, rational for gold and silver, mineralogical, and other types of analyses. Due to the absence of significant bonds of gold with pyrite, there is no expediency to carry out extensive studies of the hydrometallurgical processing of pyrite concentrates. It is possible to set up a basic experiment to determine the proportion of cyanidated gold. When processing ore raw materials enriched by flotation, not only various flotation reagents-collectors, technological parameters, but also the grinding size and material composition of the ore are important for obtaining a concentrate, since grinding the ore to the required size is about half the cost of obtaining a concentrate.

## 1 Introduction

An important problem of the present time of the mining and metallurgical complex is the significant depletion of the reserves of non-ferrous and precious metal ores in terms of the content of the main components, the stages of enrichment of balance and off-balance ores of non-ferrous and precious metals, the development of technological regimes and enrichment schemes play a significant role [1]. The flotation enrichment process is one of the main stages of technology in the processing of non-ferrous and noble metal ores; the main physicochemical processes occur in the volume of the liquid phase and on the mineral surface, which determine the efficiency of flotation enrichment [2].

In this regard, the study of the material composition in order to develop a rational technology for enrichment by flotation of copper-porphyry balance and off-balance ores of

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the Yoshlik I and Kalmakyr deposits to obtain collective, copper- and molybdenum-containing concentrates is an important part of the study.

The authors in the work show the change in the fractional composition of the ore as a result of the duration of the grinding of ores, the distribution of copper by size class during enrichment, mixed copper-molybdenum ores. When varying the fineness of grinding, it was found that with an increase in the degree of grinding of the ore, the relative mass fraction of copper in the -10 μm class increases [3].

It was found in [4-7] that in order to improve the quality of extraction of metals into concentrate, in addition to achieving the required dimension, other approaches can be considered in detail, so in the work on a sample of stale sulfide copper-nickel off-balance ores and tailings, an assessment was made of the effect of grinding size on flotation performance, at different pH values (in alkaline and acidic environments) on the tailings. The extraction of nickel and copper into the total foam product in this case was 2.5 and 2.7% higher, respectively, than in an acidic medium.

In the work, it was established that with the help of fine and ultrafine grinding, the required completeness of the disclosure of intergrowths of sulfide minerals with each other and host rocks is achieved in comparison with traditional ball grinding, and hydropercussive-cavitational grinding increases the selectivity of the opening of intergrowths with the equality of the granulometric composition of the grinding products of rotary-pulsation apparatuses and ball mills [8].

## 2 Materials and methods

According to the results of laboratory analyzes, the average content of valuable components in the balance ore sample of the Kalmakyr deposit was: Cu-0.26%; Mo-0.0077%; Au-0.25 g/t; Ag-1.15 g/t; in the Kalmakyr sample off-balance: Cu-0.195%; Mo-0.01%; Au-0.2 g/t; Ag-1.395 g/t; in the Yoshlik-1 sample, the balance: Cu-0.432%; Mo-0.0067%; Au-0.42 g/t; Ag-1.14 g/t; in the Yoshlik-1 sample, off-balance: Cu-0.23%; Mo-0.0062%; Au-0.23 g/t; Ag-1.235 g/t; in the charge: Cu-0.25%; Mo-0.0034%; Au-0.26 g/t; Ag-1.25 g/t.

According to the results of a rational analysis for gold and silver, the content of cyanidable free gold in the charge is 63.08% and silver 46.29%; 14.77% of silver is associated with minerals and chemical compounds of antimony and arsenic; 13.85% gold and 17.2% silver are associated with carbonates and hydroxides of iron and manganese; sulfides (pyrite, arsenopyrite) are associated with 12.31% gold and 15.23% silver; 10.77% gold and 6.52% silver are finely disseminated in quartz, aluminosilicates and other acid-insoluble minerals.

The results of phase analysis of ore samples (Table 1) showed that copper is 2.1-4.87% represented by free oxidized minerals; 0.1-1.67% - bound by oxidized minerals; 0.81-5.44% - secondary sulfides and 88.97-96.44% - primary sulfides.

**Table 1.** Results of phase analysis of ore samples for copper.

| Form of finding copper | Mass fraction of copper, % | | Mass fraction of copper, % | |
|---|---|---|---|---|
| | Absolute | Relative | Absolute | Relative |
| | Kalmakyr balance sheet | | Kalmakyr off-balance sheet | |
| Free oxidized minerals (cuprite) | 0.01161 | 4.87 | 0.00367 | 21 |
| Related oxidized minerals | 0.00245 | 1.03 | 0.00263 | 1.51 |
| Secondary sulfides (chalcocite, covellite) | 0.00246 | 1.03 | 0.00948 | 5.44 |
| Primary sulfides (chalcopyrite) | 0.222165 | 93.07 | 0.15857 | 90.95 |
| Total: | 0.23817 | 100 | 0.17435 | 100 |

| | Yoshlik balance sheet | | Yoshlik off-balance sheet | |
|---|---|---|---|---|
| Free oxidized minerals (cuprite) | 0.01204 | 2.65 | 0.01829 | 8.16 |
| Related oxidized minerals | 0.00043 | 0.1 | 0.00375 | 1.67 |
| Secondary sulfides (chalcocite, covellite) | 0.00365 | 0.81 | 0.00268 | 1.2 |
| Primary sulfides (chalcopyrite) | 0.43639 | 96.44 | 0.19947 | 88.97 |
| Total | 0.45251 | 100 | 0.22419 | 100 |

According to the results of mineralogical analysis, the content of ore minerals ranges from 2-12%. The texture of the ores is disseminated, veinlet, nested, clusters, rarely replacement. The thickness of the veins is up to 1-2 mm. The structure of ore minerals is fine-grained, medium-grained, less often allotriomorphic-grained, uneven-grained.

Ore minerals are noted in the form of separate inclusions, monomineral accumulations, closely intergrown aggregates.

The main nonmetallic minerals in the samples are quartz, plagioclase, potassium feldspars, and sericite. According to the mineral composition, the provided samples are sulfide, i.e. represented mainly by sulfide minerals.

Pyrite predominates in the composition of ores, chalcopyrite and magnetite are noted in a subordinate amount. Hematite, molybdenite, sphalerite, galena, fahlore, marcasite, ilmenite, rutile, bornite, chalcocite, covellite, cuprite, iron hydroxides are found in frequent or single grains. Secondary minerals of copper iron are noted in isolated cases. The enrichment of samples and charge was studied by gravity and flotation methods.

The content of ore minerals in the studied polished sections ranges from 2-3% to 10-12%. The texture of the ores is disseminated, veinlet, nested, clusters, rarely replacement. The thickness of the veins is up to 1-2 mm. The structure of ore minerals is fine-grained, medium-grained, less often uneven-grained. Ore minerals are noted in the form of separate inclusions, monomineral accumulations, closely intergrown aggregates (Figures 1,2).

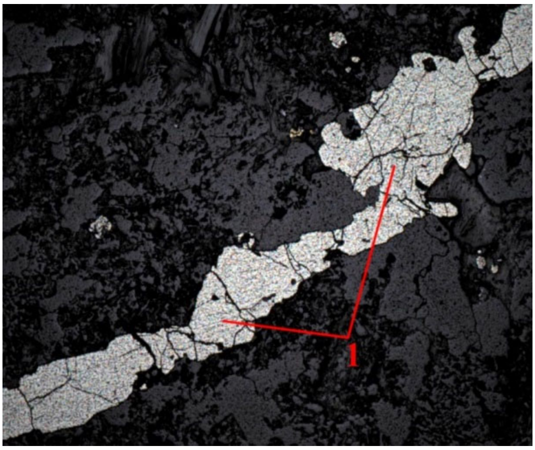


**Fig. 1** Pyrite veinlet of closely intergrown aggregates. Polished section Yozb-8. Increased 200x. 1-pyrite.

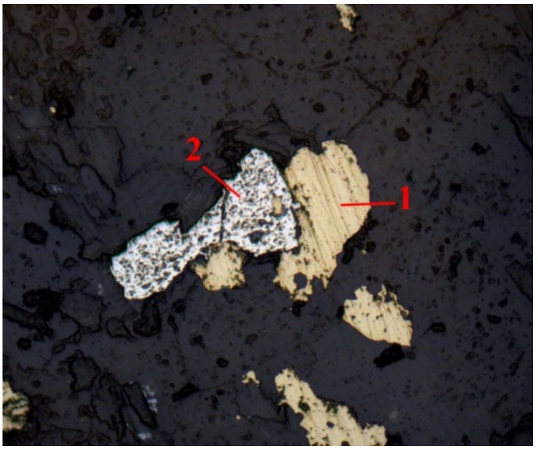


**Fig. 2.** Intergrowth of chalcopyrite with pyrite. Polished section Ezb-2. Increased 200x. 1-chalcopyrite, 2-pyrite.

According to the composition, sulfide ones are noted, i.e. represented mainly by sulfide minerals. In the composition of the off-balance ores of the Yoshlik deposit, pyrite predominates, chalcopyrite and magnetite are noted in a subordinate amount. Hematite, molybdenite, sphalerite, galena, fahlore, goethite, rutile, chalcocite, and iron hydroxides are found in frequent or single grains.

Pyrite is noted in all polished sections in the amount of 1-5%. Grain sizes predominate from <0.01 mm to 1.2 mm. The grains are xenomorphic, isometric, pentagondodecahedral, fractured, crushed. It occurs in free form, in the form of intergrowths with magnetite, chalcopyrite, as well as in the form of veinlets, clusters, individual inclusions. The thickness of the veins is up to 1 mm. Chalcopyrite is noted along cracks and intergranular spaces (Figures 1-2).

Chalcopyrite is noted in all polished sections in the form of separate inclusions, intergrowths with pyrite, galena, sphalerite and magnetite, in the form of veinlets along rock cracks. In intergrowths with magnetite, pyrite, chalcopyrite develops along their edges, cracks. The shape of the grains is xenomorphic, the edges are uneven. Grain size <0.01-0.6 mm, amount up to 2% (Figures 1-2).

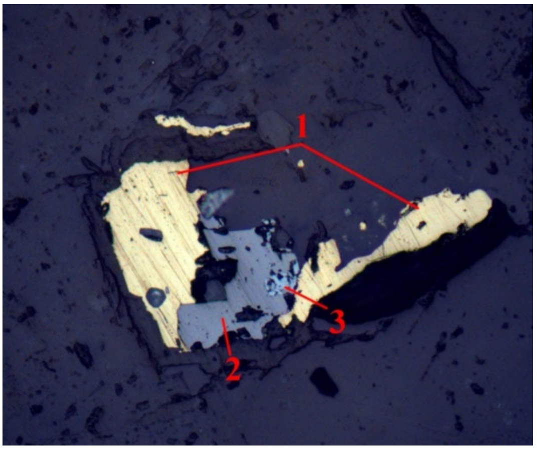


**Fig.3.** Intergrowth of chalcopyrite with magnetite. Polished section Yozb-5. Increased 200x. 1-chalcopyrite, 2-magnetite, 3-hematite.

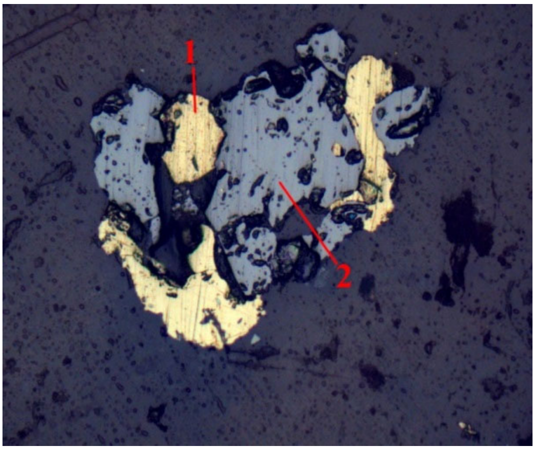


**Fig.4.** Inclusions of chalcopyrite in the intergranular space of magnetite. Polished section Yozb-10. Increased 200x. 1-chalcopyrite, 2-magnetite.

Magnetite was found in 14 polished sections out of 15, ranging from frequent signs to 3-4%. The shape of the grains is isometric, xenomorphic. Intergrowths with pyrite and chalcopyrite have been established. It is replaced by hematite, pyrite, chalcopyrite. The grain size varies from 0.01 to 0.4 mm. The structure is lamellar, isometric (Figures 3-4).

Hematite was found in 8 polished sections out of 15, mainly in intergrowths with magnetite. The grain size varies from 0.01 to 0.5 mm, ranging from single characters to 1%. The shape of the grains is elongated, prismatic, xenomorphic.

Molybdenite is found in single grains. The grain size varies from 0.05 to 0.2 mm. The shape of the grains is xenomorphic segregations, prismatic, elongated, angular. The manifestation form is separate inclusions in the non-metallic mass, as well as in intergrowths with pyrite (Figures 5-6).

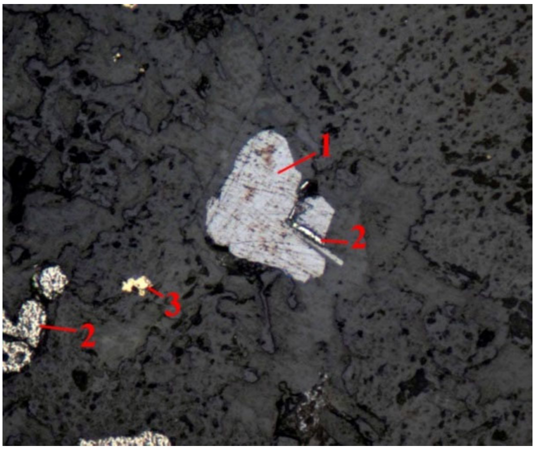


**Fig.5.** Intergrowth of molybdenite with pyrite. Polished section Yozb-12. Increased 200x. 1-molybdenite, 2-pyrite, 3-chalcopyrite.

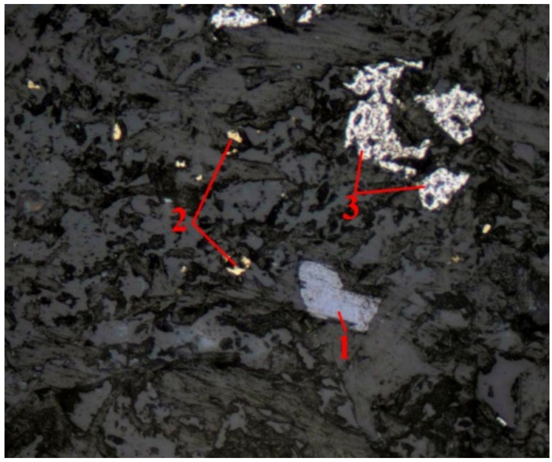


**Fig. 6** Molybdenite in clusters with pyrite and chalcopyrite. Polished section Yozb-6. Increased 200x. 1-molybdenite, 2-chalcopyrite, 3-pyrite.

Sphalerite is found in intergrowths with chalcopyrite in single grains. Grain size <0.01-0.1 mm. The shape of the grains is xenomorphic segregations. Sphalerite contains emulsion dissemination of chalcopyrite.

Galena is found in 2 polished sections out of 15, mainly as inclusions in chalcopyrite and intergrowths with chalcopyrite. Grain size <0.01-0.1 mm, in the number of single to frequent signs. The shape of the grains is xenomorphic segregations, with uneven edges.

## 3 Conclusion

When studying the material composition in order to develop a rational technology for the enrichment of porphyry copper balance and off-balance ores of the Yoshlik I and Kalmakyr deposits, it was determined that one of the important issues is the study of the gold content of pyrite to determine the feasibility of pyrite flotation and hydrometallurgical processing of pyrite concentrate, which is carried out by carrying out work on mapping of the deposit with delineation of the existing pyrite areas. To identify the best reagents from different manufacturing companies, it is recommended to conduct comparative tests in an open cycle with optimized parameters of the flotation process (time, reagent supply points, number of cleaning operations, etc.).

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