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Analysis of geological, mineralogical, and enrichment technology of polymetal ore of the khandiza deposit

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Abstract. This work is devoted to the study of the geological and industrial properties, mineralogical and chemical composition of the ores of the Khandiza polymetallic deposit, as well as the analysis of the technology of ore beneficiation by the flotation method. Based on the research results, the granulometry, mineral structure, and main useful minerals (sphalerite, galena, chalcopyrite, pyrite) of the ores were determined, and their chemical composition (Cu - 0.35-2.35%, Pb - 1.7-6.6%, Zn - 4.8-15.5%) was confirmed. Results of high metal recovery in open and closed cycles were obtained using a collective-selective flotation scheme. [5] The work contributes to the efficient operation of the deposit and the optimization of the process of complex metal extraction.

INTRODUCTION

The Khandiza polymetallic deposit is located in the central part of the Surkhanata Mountains, in the territory of the Hissar Range, approximately 50 km from the center of the Sariosiyo district, 50 km from the city of Denau and the Uzbekistan River. Polymetallic mineralization in this area has been studied for several decades. Although the initial geological exploration work did not give sufficient results in assessing the reserves of the deposit, further in-depth studies showed that the deposit is a promising object of industrial significance. [6;7]

During the study of the beneficiation process, the flotation process was recommended as an effective technological solution for ore processing. It is planned that the concentrates obtained by this method will be converted into a commodity metal by metallurgical processing. As a result of these scientific and technical studies, the presence of C1 category reserves of the Khandiza deposit was analyzed by geologists and confirmed by the State Committee for Reserves. [4]

The purpose of this work is to study the geological and industrial properties, mineralogical composition, and chemical composition of the ores of the Khandiza polymetallic deposit, as well as to analyze the technology of ore beneficiation by the flotation method and determine the optimal beneficiation regime. The research results will contribute to the efficient development of the deposit and the optimization of the process of complex metal extraction.

EXPERIMENTAL RESEARCH

Mineralogical analysis: The main minerals in the ores are sphalerite, galena, and to a lesser extent chalcopyrite and pyrite. The quantitative ratio of these main sulfides is as follows: sphalerite - 47.8%, galena - 15.8%, chalcopyrite - 6.7%, pyrite - 29.7%, [3;6] and their ratio directly affects the technological processing properties of the ore. The mineralogical structure of the ore is observed in the form of polymineral aggregates, cellular, vein-like, or crossed. Mineral grains are often uneven, characterized by intergrowth zones and complex interfaces. Useful sulfide minerals often have xeno- and hypidiomorphic forms, which complicates their technological separation.[1, 12]

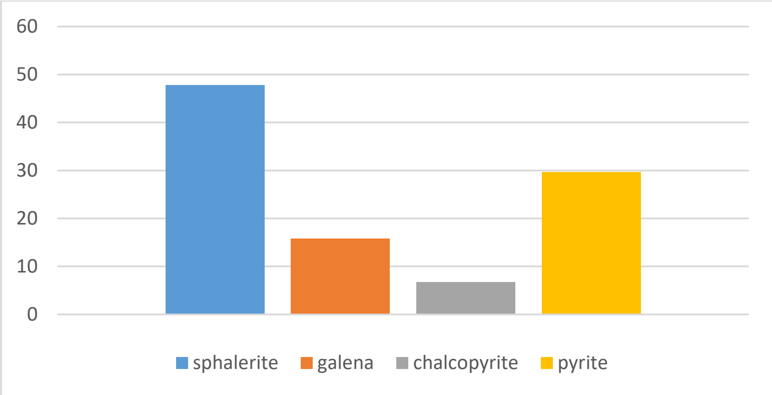

FIGURE 1. Main minerals in the composition of ores

The sizes of all mineral grains in the ore vary in a very wide range: from micron units to a few millimeters, but in most cases prevail in the range of 40-300 μm. Such variable granulometry requires the application of stepwise crushing techniques [7,9].

The ore structure consists mainly of allotriomorphic and hypidiomorphic grains, and the minerals do not have a clear crystallographic shape (with the exception of pyrite in some cases) [3]. This structural feature complicates the processes of crushing and grinding the ore. The main non-metallic components that make up the ore are quartz, stratified silicates (sericite, hydromica), as well as, to a lesser extent, chlorite and biotite. These components are often arranged as monomineral inclusions in the form of a fine-grained matrix or a separate lens. Feldspars and small amounts of carbonates (calcite, dolomite) are also found in the form of microscopic lenses [2].

TABLE 1. Quantitative ratio of minerals in the sample

№	Minerals	Amount, %
1.	Sphalerite	10,0
2.	Galenite	3,3
3.	Chalcopyrite	1,4
4.	Discolored ores	tenth
5.	Secondary minerals of zinc, lead and copper	tenth
6.	Pyrite	6,2
7.	Iron hydroxides	0,3
8.	Quartz	52,0
9.	Feldspars	1,6
10.	Layered silicates	24,3
11.	Carbonates (calcite, dolomite)	0,4

Layered silicates mainly consist of sericite (muscovite), hydromica (hydromuscovite), as well as a small amount of chlorite and biotite. Secondary minerals include smithsonite, covellite, chalcocite, anglesite, cerucite, and other forms of Pb, Zn, Cu carbonates, sulfates, and hydrosulfates.

If we dwell separately on the identified minerals, the following conclusions can be drawn: Sphalerite is the main useful mineral in the sample, located in the form of large veins, nests, and veins of uneven shape, often in the form of a matrix. The size of the discharge varies from 10 μm to 1 mm. Sphalerite usually has a light yellow color, which indicates a low iron content. It forms complex interstructures with galena and chalcopyrite, which complicates the extraction of minerals.

Galenite is the main sulfide mineral in the sample. It is widespread in combination with sphalerite. It is located in the form of an emulsion, in the form of veins, nests, and grains (10-800 μm). Morphology is very diverse, most often in the form of xenoform and sometimes idiomorphic grains.

Chalcopyrite is the least abundant useful sulfide in the ore, mostly located in thin sections or small zones within the sphalerite. Due to its emulsion dispersion, its separation requires complex technological approaches.

Chemical analysis: It was revealed that the main useful components in the approved reserves are: copper - up to 0.85%, lead - up to 3.29%, zinc - up to 4.45%, cadmium - up to 0.041%, gold - up to 0.35 g/t, silver - up to 1.14 g/t.

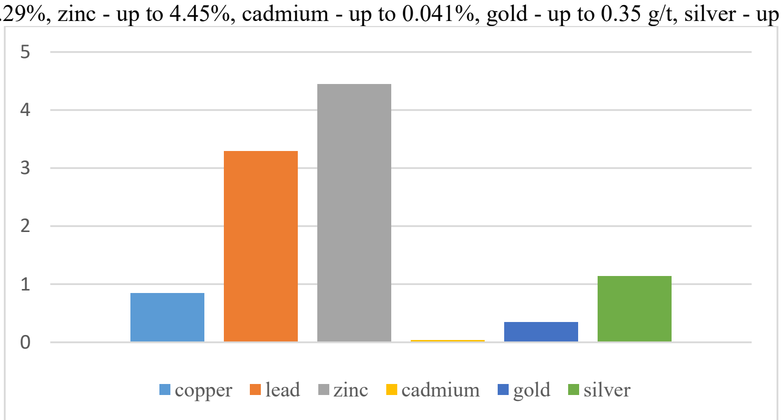

FIGURE 2. Composition of approved reserves

As a result of technological studies of four ore samples with the main useful components at the Khandiza deposit, the following chemical composition (wt.%): Cu - 0.35-2.35; Pb - 1.7-6.6; Zn - 4.8-15.5; C - 5.6-22.4; SiO2 - 22.8-71.8. The main useful minerals in the ore are chalcopyrite, galena, sphalerite, and pyrite, and quartz has been identified as the rock-forming minerals. [8]

As a result of technological studies of four ore samples with the main useful components at the Khandiza deposit under the conditions of JSC "AGMK," the following chemical composition (mass %) was determined: Cu - 0.35-2.35; Pb - 1.7-6.6; Zn - 4.8-15.5; C - 5.6-22.4; SiO2 - 22.8-71.8. The main useful minerals in the ore are chalcopyrite, galena, sphalerite, and pyrite, and quartz has been identified as the rock-forming minerals. [6].

RESEARCH RESULTS

Open-cycle flotation results: Based on the experimental work on enrichment, the following collective-selective scheme was developed:[1, 10]

• Crushing of ore to a fraction of 75% -0.074 mm;

• isolation of the collective concentrate Cu-Pb and its additional grinding to a fraction of 100% -0.044 mm;

• Selective separation of mixed copper and lead concentrate using Na2C2O4 (sodium hydrosulfide, 1500 g/t);

• Chemical processing of Cu and Pb flotation products with H2SO4; [11]

Sending for selective extraction of Zn from waste of the copper-lead cycle. The research was conducted in an open cycle, and the following main technological indicators were recorded. [5] (Table 2):

TABLE 2. Main beneficiation indicators based on the results of the open cycle

Concentrate type	Metal content, % Extraction rate, %	Metal content, % Extraction rate, %
Copper (Cu)	28,0	67,0
Lead (Pb)	40,0	81,0
Zinc (Zn)	47,0	47,0

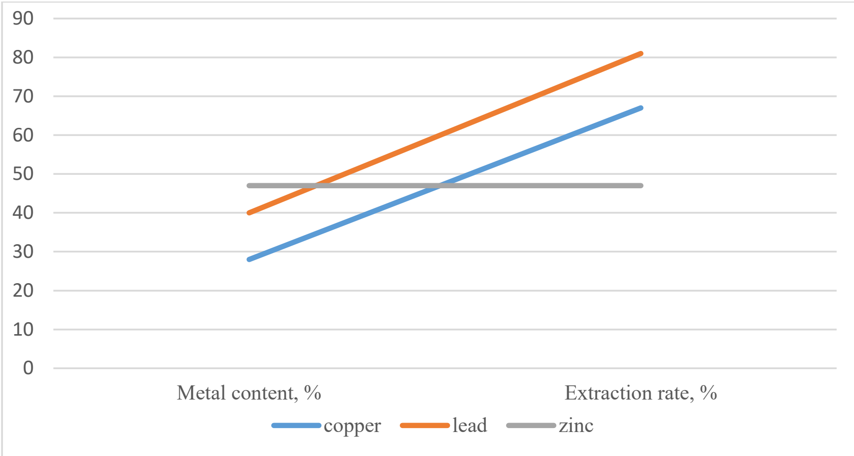

FIGURE 3. Main beneficiation indicators based on the results of the open cycle

Closed cycle flotation results: According to calculations, under closed-loop conditions, the following separation indicators can be achieved:

- Copper - 70%;
- Lead - 90%;
- Zinc - 70-80%.

The low degree of metal recovery during the complex extraction of metals as a result of polymetallic ore beneficiation necessitated a revision of the reagent regime, in which the following regimes were reviewed:

- Crushing of ore to a fraction of 90% -0.074 mm;
- obtaining a collective concentrate of Cu-Pb (Na_2S - 2000 g/t, ZnSO4 - 1400 g/t, KCN - 300 g/t);
- Desorption with Na_2S for 30 minutes (5 kg/t);
- selective separation with Na_2SO_3 (1700 g/t);
- obtaining Cu and Pb concentrates in H_2SO_4 (1500 g/t);
- Additional processing in a medium of cyanide (100 g/t) and soda;

Extraction of Zn from copper-lead tailings using CaO (100 mg/l) and $CuSO_4$ (300 g/t). [2]

As a result of the experiments conducted according to the proposed scheme, the following indicators were obtained (Table 3):

TABLE 3. Enrichment indicators based on closed cycle results

Initial ore composition	concentrate type	Metal (%)	Extract (%)
Cu – 0,56%; Pb – 2,55%; Zn – 5,2%	Copper (Cu)	23,5	79,0
	Lead (Pb)	48,2	83,4
	Zinc (Zn)	47,0	84,3
Cu – 0,45%; Pb – 1,7%; Zn – 6%	Copper (Cu)	19,7	68,0
	Lead (Pb)	49,5	78,7
	Zinc (Zn)	47,4	83,7

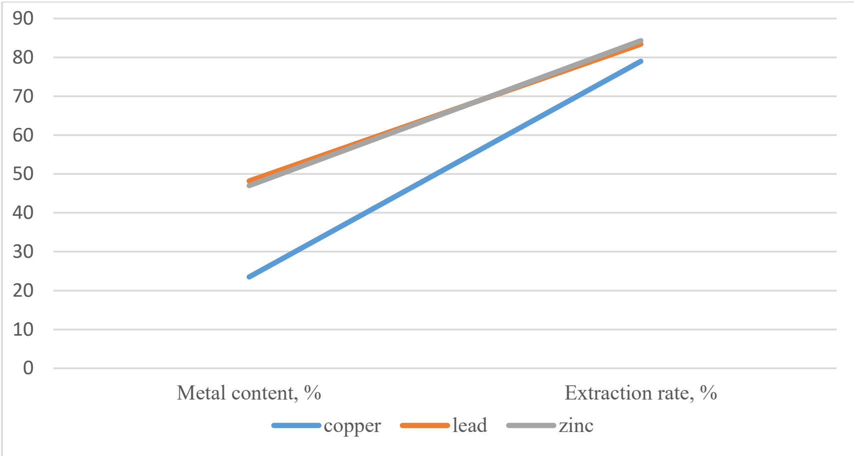

FIGURE 4. According to the results of the closed cycle, the beneficiation indicators are Cu - 0.56%; Pb - 2.55%; Zn - 5.2%

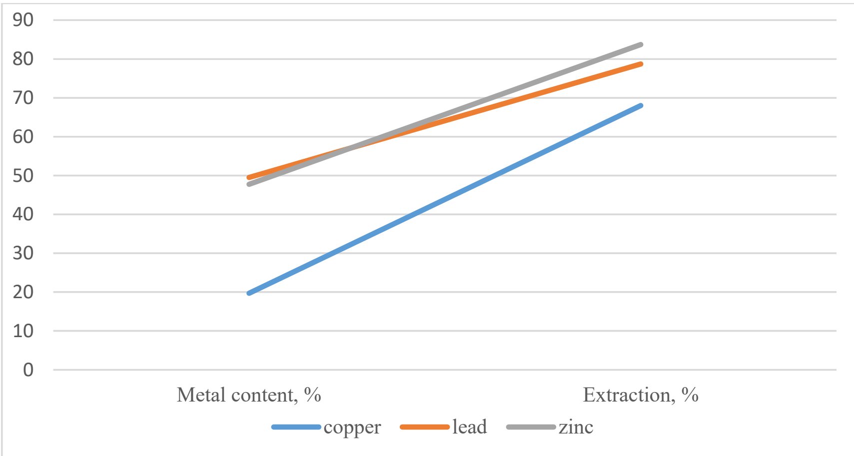

FIGURE 5 According to the results of the closed cycle, the beneficiation indicators are Cu - 0.45%; Pb – 1.7%; Zn -6%

CONCLUSIONS

The main useful minerals of the ore of the Khandiza polymetallic deposit are sphalerite (47.8%), galena (15.8%), chalcopyrite (6.7%) and pyrite (29.7%), the composition of which determines the technological properties of the ore. The granulometry of the mineral grains (10 μm-1 mm, in most cases 40-300 μm) and the allotriomorphic-hypidiomorphic structure complicate the processes of ore crushing and flotation [18-40].

The chemical composition confirmed the presence of copper - 0.35-2.35%, lead - 1.7-6.6%, zinc - 4.8-15.5%, C - 5.6-22.4%, and SiO_2 - 22.8-71.8%. The collective-selective flotation scheme, developed on the basis of experimental work, achieved copper (28%), lead (40%), and zinc (47%) recovery in the open cycle, while in the closed cycle, 70%, 90%, and 70-80% of the results were recorded, respectively.

Thus, the technology of flotation beneficiation of the ore of the Khandiza deposit is effective, allowing for high metal recovery and efficient industrial development of the deposit.

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