ХИМИЧЕСКИЕ НАУКИ

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STUDY OF ORE STRUCTURE AND CHEMICAL COMPOSITION FOR SUITABLE BIOLEACHING PROCESS

Biohydrometallurgical / Bioleaching is economic-efficiently and environment-friendly technology that is convenient to process low-grade, fine and complex distributed ore and now this technology research is developing rapidly. We selected the ore which is hard to process by the cyanide method and studied the ore structure and chemical composition to use in bioleaching research. The selected primary ore is sulfide ore that is containing 2.88ppm Au, 1.67ppm Ag, 0.13% Cu, 1.03% S and identified as containing minerals as pyrite, goethite, covellite, chalcopyrite, and arsenopyrite.

Key words: *chalcopyrite, copper, bioleaching, fraction.*

1. Introduction

Chalcopyrite ($CuFeS_2$), which accounts for approximately 70 % of the world's copper reserves, is the most abundant and widespread copper-bearing mineral. However, chalcopyrite is resistant to both chemical and biological leaching, mainly due to the slow kinetics of dissolution. The crystal structure of chalcopyrite shows that it is a covalent compound, its semiconducting properties. A single chalcopyrite lattice contains four Fe atoms, eight S atoms, and four Cu atoms. Each S atom forms a tetrahedral coordination with two Fe atoms and two Cu atoms, and each Fe or Cu atom forms a tetrahedral coordination with four S atoms [1–2].

Chalcopyrite is mainly present in unprocessed ores with characteristics of low grade, fine and complex distribution, and it is mainly processed by beneficiation-pyrometallurgy technology. Biohydrometallurgy (bioleaching) should be a hydrometallurgical technology alternative to traditional beneficiation pyrometallurgy for processing low-grade, fine-grained and complex distributed ores due to the following aspects. The pyrometallurgical process has some drawbacks which are often worsened by impurities in the copper concentrate and the pyrometallurgical process can produce smoke containing heavy metals, dust, CO_2 and SO_2, resulting in severe air pollution. Bioleaching mainly oxidizes sulfide minerals to elemental sulfur or sulfuric acid rather than SO_2, which reduces air pollution and acid consumption. The preparation of concentrates for the pyrometallurgical process requires a complex beneficiation process, which means high dosages of flotation reagents such as activators, depressants, collectors and frothers, as well as the reuse of water in the beneficiation process [3]. Thus, causing serious water and soil pollution. And the high energy consumption of traditional beneficiation-pyrometallurgy methods (such as ball mill and high-temperature smelting) makes it difficult to process these low-grade, small and complex ores economically and efficiently [4–5].

Bioleaching is an important and clean technology in the processing of low grade and complex ores, mainly because of its environmental benefits and low cost [6–7]. Consequently, research in the field of biohydrometallurgy is of great academic and practical importance, especially in the mining and metallurgical industries.

In the process of bioleaching gold ore, it is important to control the oxidation of the main components and their transformation.

In this study, we aimed to select an ore that is difficult to process by other hydrometallurgical methods and which will be used in the further bioleaching process. For this, first of all, it was necessary to study the structure and chemical composition of the ore.

2. Material and methods

2.1 Material

Samples were taken from the ore of the main explored gold deposit located in the Durvuldzhin sum of the Zavkhan aimag. To determine the degree of grinding and study the distribution of elements in the samples of sulfide ore from the gold deposit, fractional analysis was carried out. The ore was sieved through a 5mm, 3mm, 2mm, 1mm, 0.5mm, 0.25mm, 0.125mm, and 0.075mm sieve, and the Au and Cu content of each fraction was determined and the results were shown in Table 2. The ore sample was decomposed with aqua regia solution (3HCl: $1HNO_3$), and non-ferrous and precious metals were converted into solution and prepared for metal analysis [8].

2.2 Chemical analysis

The gold, silver and copper content in the sample was determined by SHMADZU Corporation's AA-6501F atomic absorption spectrophotometer, and the total sulfur content was determined by the Eschka's mixture (MgO: Na_2CO_3) by weight [9].

Elemental analysis of solid samples was examined by an AXIOS X-ray fluorescence spectrometer (WDXRF) from the Dutch firm PANalutical with 5 crystals and 3 detectors of wave dispersion.

2.3 Mineralogical analysis

For mineralogical analysis, samples were selected and three polished sections were prepared, numbered D-1, 2, 3, and the minerals were identified by reflected light microscopy.

3. Results and discussion

1. The results of the fractional analysis of the samples of the main gold deposit are shown in Table 2. The results of the fraction analysis show that the precious metal content increases as the sample size decreases.

Table 2

Gold and copper content in ore fractions and their distribution

Granulation diameter, mm	Yield, %	Element		Distribution	
		Au, ppm	Cu, %	Au, ppm	Cu, %
–5+3	27.12	2.34	0.11	22.83	23.51
–3+2	10.19	2.21	0.12	8.10	9.40
–2+1	20.95	2.3	0.11	17.34	18.05
–1+0.5	14.83	1.87	0.13	9.98	14.13
–0.5+0.25	9.83	3.53	0.13	12.49	10.01
–0.25+0.125	9.67	3.68	0.22	12.80	16.30
–0.125+0.075	5.40	5.55	0.14	10.78	5.68
–0.075	2.01	7.85	0.19	5.69	2.93
Total	100.00	2.78	0.13	100.00	100.00

The –5 + 3 mm particle fraction class has the highest distribution of precious metals and is 22.8ppm Au and 23.5 % Cu. Although the distribution of gold and copper in the –5 + 3 mm particle fraction class is the highest, gold and copper content is not the highest in that fraction class. So, it was considered appropriate to grind the sample to a particle size of less than 75µm for bioleaching under laboratory conditions. Distributions of copper and gold in the fraction class are shown in Figure 1.

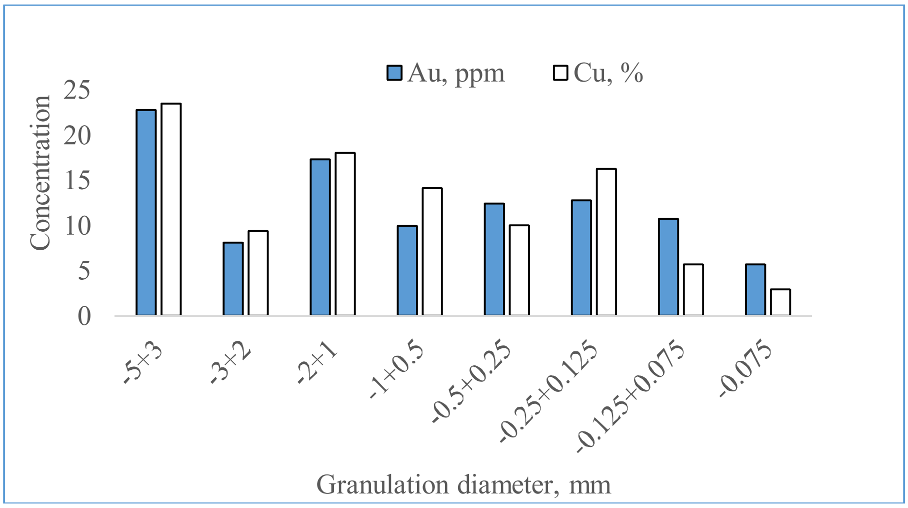

Fig 1. Distribution of copper and gold in the fraction class

2. The ore contained 2.88 ppm Au, 1.67 ppm Ag, 0.13 % Cu, and the total sulfur content was 1.03 %. The results in Table 4 show that the ore is composed of quartz minerals which are containing 9.11 % of total iron (Fe_2O_3), 1496 ppm of copper (Cu), 33 ppm of arsenic (As), and 80.5 % of quartz (SiO_2).

Table 3

Content of components in gold ore composition

Component	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	Na_2O	K_2O	P_2O_5	F	loi*
Content, %	80.5	0.364	4.82	9.11	0.03	0.01	1.01	0.023	0.08	0.08	3.44

**loi- Loss on ignition*

Table 4

Content of elements in gold ore composition

Element	As	Ba	Bi	Ce	Co	Cr	Cs	Cu	Ga	Hf	La	Mo	Nb	Nd
Content, ppm	33	379	<5	<30	<5	57	<30	1496	10	<15	<30	30	6	<50
Element	Pb	Rb	Sb	Sc	Sm	Sn	Sr	Ta	U	V	W	Y	Zn	Zr
Content, ppm	<3	16	<40	<10	<30	<30	42	<10	<5	31	<8	18	11	104

3. The results of the mineralogical analysis are shown in Figures 2.1, 2.2, and 2.3, respectively. The mineralogical analysis revealed minerals such as quartzite, hydrogenate, chalcopyrite, covellite, pyrite and gold.

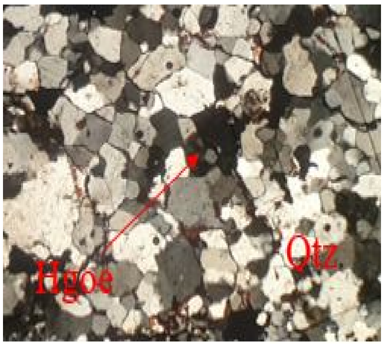

Figure 2.1

Figure 2.2

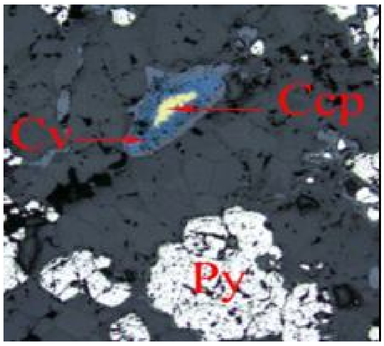

Figure 2.3

The mineralogical analysis revealed several gold particles of 0.05 x 0.05 mm – 0.2 x 0.2 mm size from the original sample. The particles of gold are poorly polished, bright yellow, and their pores are filled with iron oxide and quartz.

4. Conclusion

According to the results of fractional and chemical analysis, grinding the ore to a fineness of fewer than 75 μm is considered suitable for bioleaching. The selected gold ore deposit contains 2.88 ppm Au, 1.67 ppm Ag, 0.13–0.15 % Cu, 1.03 % S, 9.11 % total iron (Fe_2O_3), 33 ppm arsenic (As) and 80.5 % silicon (SiO_2) respectively. The mineralogical analysis revealed minerals such as hydrogenate, chalcopyrite, covellite, pyrite and arsenopyrite. The presence of vein gold in these oxidized and sulfide minerals suggests that the sample in our study is a type of ore that is difficult to process.

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ИЗУЧЕНИЕ СТРУКТУРЫ И ХИМИЧЕСКОГО СОСТАВА РУДЫ ДЛЯ ПОДХОДЯЩЕГО ПРОЦЕССА БИОЛОГИЧЕСКОГО ВЫЩЕЛАЧИВАНИЯ

Биогидрометаллургическое / биологическое выщелачивание – это экономичная и экологически чистая технология, которая удобна для переработки низкосортной, мелкодисперсной и сложной распределенной руды, и сейчас эта технология исследований быстро развивается. Авторами была отобрана руда, труднообрабатываемая цианидным методом, и изучена структура и химический состав руды для использования в исследованиях биологического выщелачивания. Выбранная первичная руда представляет собой сульфидную руду, которая содержит 2.88ppm Au, 1.67ppm Ag, 0.13% Cu, 1.03% S и идентифицирована как содержащая минералы, такие как пирит, гетит, ковеллит, халькопирит и арсенопирит.

Ключевые слова: *халькопирит, медь, биологическое выщелачивание, фракция.*