Research on the Efficient Recovery Technology of Gold Mineral in an Oxidized Ore

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Abstract. In view of the characteristics of high content of gold minerals in limonite and great difficulty of flotation recovery, the research on process mineralogy and efficient recovery technology was carried out respectively. The results of process mineralical analysis show that the particle size of gold mineral particles is coarse, the average particle size is 18.33μm, and the associated content with limonite is 28.36%, which is difficult to recover by a single flotation process. Through the efficient recovery technology research, the combined process of heavy dressing and flotation can realize the efficient recovery of gold mineral, and can obtain the mixed gold concentrate grade of 41.96g/t, the recovery rate of 88.21%, the grade of tailings gold reduced to 0.57g/t, difficult for the efficient recovery of gold resources, and provide technical support by increasing the economic benefit of enterprises.

1. Introduction

With the decrease of easy mining and selection resources in China, it is very important for the rational development and efficient recovery of existing resources. Limonite gold mine plays an important role in gold resources in China. It is of great significance to improve the overall utilization level of such resources. At present, the recovery process of gold-containing gold oxide ore mainly includes cyanide method, flotation method and redressing method, etc. The use of all-slime cyanidation will produce a large amount of cyanide tailings. With the continuous tightening of environmental protection policies and the increasing requirements of cleaner production, the disposal cost of cyanide method is high and the high risk, and the removal effect of gold.

This paper in northwest China, on the basis of process mineralogy analysis, the focus from flotation and separation of gold recovery process research, through the new pharmaceutical application, develop the more efficient recovery of gold minerals, for the maximum development and utilization of gold oxides to provide reliable basis.

2. Nature of ore

2.1. Chemical composition analysis

The results of the chemical composition analysis of the raw minerals are shown in Table 1.

Table 1. Main valuable element analysis results

Element	Au ($g \cdot t^{-1}$)	Ag ($g \cdot t^{-1}$)	Cu (%)	Pb (%)	Zn (%)	Fe (%)	S (%)
Grade	2.90	1.06	0.23	0.01	0.01	7.56	0.22

Element	As (%)	SiO_2 (%)	Al_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)
Grade	0.56	57.91	13.33	2.22	0.60	0.12	3.65

The analysis results showed that the gold content is 2.90g/t, silver content is 1.06g/t, copper content is 0.23%, harmful elements As content is 0.56%, and other metal elements are low. The main element of recycling value is gold.

2.2. Mineral composition

Through process mineralogy analysis, the occurrence status of major minerals is found out to provide theoretical guidance for the next step of efficient recovery research.[1,2] The results of the analysis showed that, the main metal minerals in the ore are limonite and pyrite, followed by a small amount of chalcopyrite, with its content of 7.74%, 5.59% and 0.64% respectively. Both limonite and pyrite had a large particle size, with 75.47% and 49.74% having a particle size> 150 μm, respectively. Pyrite is relatively small, with 65.13% of the particles distributed between 74 and 150 μm. The main gangue minerals are quartz, feldspar, calcite, garnet, chlorite, mica, and a small amount of amphibole, treborite and carbonate.

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2.3. Grain size distribution of gold minerals

The particle size analysis of gold minerals in the sample was measured with BPMA at 75% of sample size-200 samples. Table 2 is the particle size analysis table of gold minerals in cyanide slag samples.

Table 2. Analysis of gold minerals in samples

Particle size (μm)		Content (%)	Cumulant (%)
Medium-grain (-74+37)		15.2	15.2
Fine grains (-37+10)		29.89	45.09
Microparticles	-10+5	29.87	74.96
	-5	25.04	100
Average grain size		18.33	

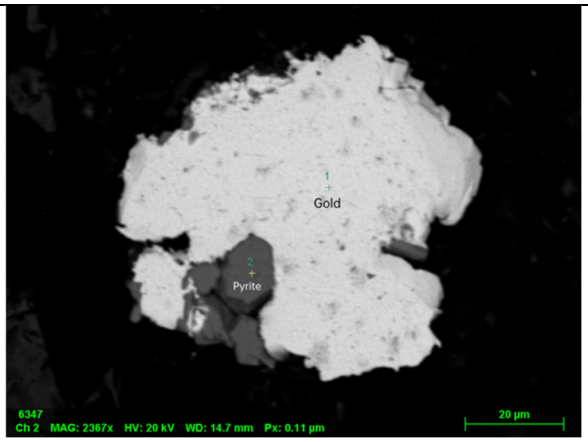
It can be seen from the analysis results that the gold particles in the sample are large, mainly fine gold, and the average particle size of gold mineral is 18.33 μ m. It is expected to achieve some results by using the reselection process, but the flotation process should be combined to improve the recovery rate.

2.4. Status of gold minerals

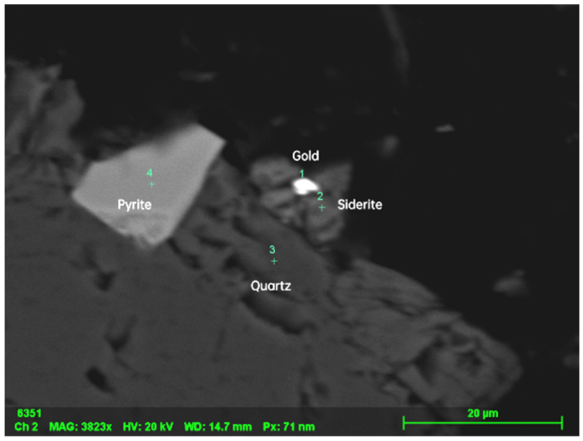
The main gold minerals are limonite, pyrite, chalcopyrite and a small amount of toxic sand. The main occurrence states of gold are monomer gold, continuous gold and wrapped gold. The small gold particles are fine gold and particulate gold, and the average particle diameter of gold minerals is 18.33 μm. Statistics of the main occurrence states of gold minerals are shown in Table 3, the occurrence status of some gold minerals is shown in Figure 1.

Table 3. Statistics of the main occurrence status of gold minerals Table

Mineral	Monomer (%)	Commensal (%)				Total (%)
		Pyrite	Chalcopyrite	Aetite	Gangue	
Gold mineral	12.25	51.84	2.31	28.36	5.24	100.00



a. Gold minerals are associated with pyrite



b. Gold mineral is associated with siderite

Figure 1. State of occurrence of some gold minerals

The associated content of gold minerals with pyrite and chalcopyrite is 54.15%, and that with limonite is 28.36%. The ore is deeply oxidized, and it is difficult to achieve the ideal technical index through a single beneficiation process, which is difficult to select a mineral, the pharmacy system needs to be optimized to ensure an efficient separation. After comprehensive consideration, it is recommended to adopt a combined process with reselection before flotation to maximize the recovery of gold minerals.

3. Recycling technology research

The results of raw ore properties show that the oxidation degree is deep, the sulfide mineral content of the ore is less, and the main element for recovery is gold, which is difficult to achieve the ideal index through a single beneficiation process. Based on the successful experience and scientific research achievements of the treatment of similar ores at home and abroad, the flotation process and gravity-floating combined process are mainly studied.[3-6]

3.1. Flotation test

The flotation of gold is mainly based on the mineral characteristics of the carrier, from the process structure, pharmaceutical system and other process parameters, through multiple groups of comparative tests, study and determine the reasonable flotation process, process system, optimize the technical indicators.

(1) Flotation test of grinding fineness

The raw samples were ground to-200 to 50%, 55%, 60%, 65%, 70%, 75%, 80% and 85%, for different grinding fineness. The test process is one rough selection and one sweep.

The results show that with the increase of grinding fineness, the recovery rate of gold will first rise and then decrease. When the grinding fineness is -200 mesh content of 75%, the recovery rate is the highest, 68.74%, and the grinding fineness continues to improve, and the recovery rate no longer changes significantly. Through comparative analysis, 75% content of-200 items was determined to be the best grinding fineness, and the pharmaceutical system was further optimized and the flotation index was improved.

(2) Catture species test

Yellow medicine and black medicine are widely used as the flotation collector of sulfide mineral. JB 05 is a newly developed oxidized mineral collector. In order to determine the best agent system of flotation, butyl yellow drug + butylammonium, isovaleryl yellow drug + butylammonium, butyl yellow drug + JB 05, isoperyl yellow drug + JB 05 and JB 05 were selected as collectors, and the flotation test of different collector species was conducted.

The results show that the collector species has little influence on the recovery rate of concentrate gold and great influence on the grade of concentrate gold. When the collector combination of isopentyl drug + JB 05, the recovery rate of concentrate gold is 69.74%, and the gold concentrate grade is the highest, so the isoperyl drug + JB 05 is selected as the best collector for the next condition optimization test.

(3)Activator type test

Activator can change the chemical properties of the surface of mineral particles, thus enhance the interaction between mineral and collector, and improve the flotation effect. Copper sulfate, oxalic acid, ammonium sulfate and sodium sulfide were used as activators for the flotation test of the activator species.

The results showed that the recovery of the gold and the grade of the concentrate decreased significantly, so the activator was no longer used in the subsequent test.

(4) Dispersant type test

Dispersant can effectively improve the selectivity of flotation, stabilize the solid particles in the pulp, reduce non-selective adsorption, and improve the quality and recovery rate of concentrate. Aqueous glass, sodium hexadetaphosphate, sodium fluorosilicate and SN5040 were used as dispersant to conduct the flotation test of dispersant species.

The results show that the grade of concentrate gold was improved after the use of dispersant, but the recovery rate of concentrate gold decreased significantly, mainly because the gold minerals in fine mud are difficult to be effectively recovered by flotation, and the dispersant failed to effectively change the flotation performance of fine mud, so the use of dispersant is no longer considered in the subsequent test.

(5) Flotation closed circuit test

Through the detailed flotation recovery technology research, the best grinding fineness is-200 mesh content 75.0%, pulp concentration is 40.0%, isopentyl yellow drug + JB05 is the best collector, the activator and inhibitor are no longer used, the flotation time is 10 minutes, when the best flotation recovery index can be achieved. At the same time, in order to ensure the reliability of the flotation test results and correctly reflect the real flotation recovery effect, the flotation closed circuit test of one coarse, two fine and two sweeps is carried out under the best process technology conditions. The test process and results are shown in Figure 2 and Table 4.

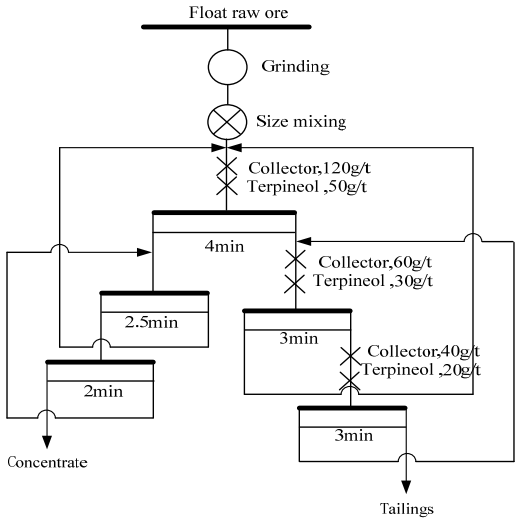


Figure 2. Main valuable element analysis results

Table 4. Results of the closed-circuit flotation test

Product	Productivity (%)	Gold grade ($g \cdot t^{-1}$)	Gold recovery rate (%)
Concentrate	4.66	43.20	69.43
Tailings	95.34	0.93	30.57
Total	100.00	2.90	100.00

According to the test results, through the flotation closed circuit test, the concentrate rate is 4.66%, the concentrate grade is 43.20g/t, the tailings grade is 0.93g / t, the recovery rate of gold is 69.43%, and the tailings have high grade and low recovery rate. This is mainly due to the flotation process can not achieve the effective recovery of gold minerals associated with limonite, resulting in the serious loss of gold minerals, which needs to further optimize the beneficiation process to improve the recovery rate.

3.2. Gravity concentration

Nielsen beneficiator is a kind of intensive gravity beneficiation equipment based on centrifugal principle, which can realize the effective recovery of monomer particle gold mineral, and has been successfully applied in gold beneficiation.[7-9] In the process mineralogy analysis, the content of monomer gold was 12.25%. In order to improve the recovery rate of gold, in this study, the combined process of gravity concentration and flotation was proposed, aiming to initially enrich monomer gold minerals through the gravity process, and then further improve the recovery rate of gold through flotation.

(1) Gravity concentration

At the fineness of -200 mesh, the Nielsen reconcentration test was performed and the results are recorded in Table 5.

Table 5. Results of Nielsen gravity test

Product	Productivity (%)	Gold grade ($g \cdot t^{-1}$)	Gold recovery rate (%)
Concentrate	0.89	150.33	46.08
Middling	2.28	10.89	8.55
Tailings	96.83	1.36	45.37
Total	100.00	2.90	100.00

According to the test results, the rate of Nielsen reconcentration concentrate is 0.89%, the recovery rate of gold in concentrate is 46.08%, the mineral rate in concentrated ore + medium ore is 3.17%, the recovery rate is 54.63, and the gravity gold grade is 50.03g/t, which meets the requirements of gold concentrate grade. Nielsen reconcentration has a good effect on gold recovery. It shows that the effective recovery of some coarse particle monomer gold minerals and gold mineral rich company is realized through the gravity process. The next step of flotation test research is carried out to further recover the gold minerals in the gravity tailings.

(2) Flotation test of gravity tailings

The flotation test is carried out for the gravity tailings, and the conditions refer to the process conditions determined by the oxidized ore flotation test, the flotation test is carried out, and the feasibility of continuing gold recovery in the gravity tailings is studied. The results of the flotation closed circuit test are shown in Table 6.

Table 6. Flotation test results of gravity tailings

Product	Operation yield (%)	Gold grade ($g \cdot t^{-1}$)	Gold recovery rate (%)
Concentrate	3.03	33.22	74.01
Tailings	96.97	0.36	25.99
Total	100.00	1.36	100.00

According to the test results, in the tailings flotation test of Nielsen, the recovery rate of concentrate gold is 74.01%, and the grade of concentrate gold is 33.22g/t. Comprehensive analysis of the results of the gravity-flotation test is shown in Table 7.

Table 7. Gravity-flotation test results

Product	Productivity (%)	Gold grade ($g \cdot t^{-1}$)	Gold recovery rate (%)	Cumulative gold grade ($g \cdot t^{-1}$)
Gravity concentrate	3.17	50.04	54.64	41.96
Flotation concentrate	2.93	33.22	33.53	
Tailings	93.90	0.36	11.79	0.36
Total	100.00	2.90	100.00	2.90

The test results show that through the process of gravity-flotation, the final tailings gold grade can be reduced to 0.36g/t. The cumulative grade of concentrate is 41.96g/t, and the recovery rate is 88.21%, and the recovery rate is 18.78% higher compared with flotation alone. Multi-process combined application realizes complementary advantages and improves the overall recovery rate.

4. Summary

(1) Process mineralogy analysis results show that the sample oxidation degree is deep, the gold mineral particles are coarse, the associated content of gold minerals and limonite is 28.36%. Using the single flotation process is difficult to reach the ideal technical index, difficult to choose minerals, need to study the process combined recovery technology, clear the direction for the next research.

(2) Through the optimization study of flotation process conditions, the gold recovery rate can be increased to 69.43%, through the combined process of gravity concentration and flotation, the gold recovery rate can be further increased to 88.21%, the grade of mixed gold concentrate is 41.96g/t, the recovery rate can be increased by 18.78% compared with flotation alone, the grade of tailings is reduced by 0.57g/t, and the beneficiation index is significantly improved. This is mainly because flotation realizes the efficient recovery of gold minerals associated with sulfide minerals, gravity concentration realizes the efficient recovery of monomer gold minerals, and the combined application of multiple processes to realize the complementary advantages of mineral processing process, which shows great advantages in the efficient recovery of complex and difficult to select minerals.

(3) The research results show that the combined process of gravity concentration and flotation has significant advantages in the treatment of refractory oxidized ore, which provides an effective reference for the efficient recovery of similar minerals, and is of great significance to promote clean production, cost reduction and efficiency increase.

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