

Comparative experiments on the activation cyanide and chloride re-leaching of gold from the secondary mineral material of heaps of Aprelkovo mine

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Abstract. This article presents the results of comparative experiments on the activation chloride and activation carbonate-cyanide leaching of gold from the secondary mineral material of heaps of Aprelkovo mine. A cyanide scheme with a gradual increase in the cyanide concentration in the pregnant solution was adopted as a control scheme for percolation leaching. To establish the maximum recovery of gold and associated components, preliminary experiments with agitational cyanide leaching were carried out. In the course of the experimental work, some of the problems of gold recovery according to the classical cyanide scheme applicable to this deposit were identified and, thanks to the use of activated solutions, were solved. The reasons for the insufficiently high recovery are clogging and limited access of the complexing agent to encapsulated and chemically bound gold inclusions due to their high dispersion in the crystal lattices of concentrating minerals and the presence in the ore of minerals that tend to absorb water with a pronounced hydration effect.

Keywords: activation chloride leaching, activation carbonate-cyanide leaching, pre-oxidation of samples, secondary mineral material of heaps of leaching, additional gold recovery

1 Introduction

At the moment, in connection with the depletion of reserves of easily-milling gold-bearing ores and placer sands containing precious metals, the extraction of useful components from refractory ores is quite in demand. Gold and other valuable metals from such ores cannot be recovered for one reason or another in conventional cyanide leaching, which is used in the mining industry, so new methods of leaching are being sought. Currently, the processes of extracting useful components from refractory ores by active chloride and cyanide solutions are being studied in depth.

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2 Methods of experimental research

The object of this study was the Aprelkovo mine, which is part of CJSC Nordgold, which developed the Pogromnoye deposit. The Pogromnoye deposit is represented by low-sulfide gold-bearing metasomatites of variable mineral composition with a predominance of quartz, sericite, and carbonates. Sulfide minerals are mainly represented by pyrite and pyrrhotite.

The studied samples from the Aprelkovo mine are tails of heap cyanide leaching. The main problem of cyanide heap leaching in production was the low level of gold recovery due to the predominance of dispersed forms of its occurrence and clogging of the leached material. According to the rational analysis carried out by CJSC TOMS, fine free (released during grinding) gold prevailed in the ores of the oxidation zone, and its recovery during heap leaching reached more than 70%. With the development of mining operations in the open pit, processing began to involve mixed, and then primary ores, and the recovery of gold with heap leaching began to decrease progressively, reaching critical values. Therefore, in the secondary mineral material of heap leaching of the Aprelkovo mine, the gold content reaches values close to the industrial level (more than 0.55 ppm), and therefore they can potentially be objects of reprocessing when solving the problem of its additional extraction from such mineral raw materials.

To conduct experiments on activation leaching from heap leaching tails, they were crushed and sorted to fraction +0.5 mm and -0.5 mm. During the input chemical analysis of tails for the content of gold and silver in individual size fractions, the following results were obtained, shown in table 1.

Table 1. Gold and silver content in tails of heap leaching

Fraction, mm	Au, ppm	Ag, ppm
+0,5	0,6	0,15
-0,5	1,5	0,3

2.1 Agitation cyanide leaching

A number of agitation and percolation cyanide leaching experiments have been carried out. For agitation leaching, powdered and non-powdered samples of fractions +1 mm and -1 mm were used. Solutions with a CN content of 0.05%, 0.1%, 0.3% and 0.7% were used as leaching solutions. The samples were leaching in agitation mode for 8 hours. This series of experiments was necessary to establish the maximum recovery of gold and silver, as well as to establish the relationship between the concentration of cyanide in the pregnant solution and the recovery of iron. The experimental results are presented in table 2.

Based on these results, we conclude that 87.1 % of gold is recovered from powdered samples in the coarse fraction and 70.9% in the fine fraction; from non-powdered samples, it regularly reaches lower values (49.4%) in the coarse fraction compared to the fine one (67.7%). Thus, it can be concluded that during abrasion in coarse fraction, an intracrystalline spatial redistribution of dispersed gold occurs with its concentration at the outer surfaces of the carrier minerals and the inner surfaces of microcracks and pores through which the leaching solution penetrates. In addition, as can be seen from the data given in the table, the recovery of gold is to a certain extent affected by the release of iron, cyanide consuming elements, i.e. an element that forms a complex with cyanide, thus reducing the chance of cyanide-gold interaction. Thus, with an increase in the CN concentration in solution from 0.3 to 0.7%, both in the +1 and -1 fractions, the gold recovery decreases slightly or its growth slows down, but the iron recovery continues to increase.

Table 2. Results of agitation leaching

Sample	Size fraction, mm	Scheme	Recovery			
			Au, %	Ag, %	Cu, %	Fe, g/kg
1	+1	CN 0,05%	24,4	31,5	3,1	0,11
2	+1	CN 0,1%	30,5	41,3	3,6	0,30
3	+1	CN 0,3%	31,4	32,5	4,5	1,20
4	+1	CN 0,7%	49,4	33,3	7,6	3,16
5	+1 (powdered)	CN 0,05%	83,1	31,4	11,1	0,19
6	+1 (powdered)	CN 0,1%	84,1	44,7	11,4	0,91
7	+1 (powdered)	CN 0,3%	87,1	68,0	14,2	3,73
8	+1 (powdered)	CN 0,7%	86,5	65,9	25,6	6,25
9	-1	CN 0,05%	67,7	43,2	7,1	2,76
10	-1	CN 0,1%	45,1	39,7	7,6	7,13
11	-1	CN 0,3%	40,5	25,4	9,4	26,71
12	-1	CN 0,7%	51,7	35,4	12,1	50,68
13	-1 (powdered)	CN 0,05%	66,6	35,9	9,7	3,18
14	-1 (powdered)	CN 0,1%	66,2	38,8	19,9	10,53
15	-1 (powdered)	CN 0,3%	70,7	50,2	24,4	41,56
16	-1 (powdered)	CN 0,7%	70,9	54,7	35,0	62,44

2.2 Percolation cyanide leaching

The next stage of the experiments was the percolation leaching of gold from the initial tails with cyanide solutions. Two schemes were researched on different sizes of the test material: +1 mm fraction was used in the 1st scheme, -1 mm fraction was used in the 2st scheme. Leaching solution was introduced into percolators with gradual increase of cyanide concentration, starting with a CN concentration of 0.05%. The solutions were introduced until the end of the extraction of useful components into the pregnant solution. As a result of the experiments, the maximum gold and silver recovery was 40.3% and 13.6%, respectively.

The probable reasons for their insufficiently high recovery are clogging and limited access of the complexing agent to encapsulated and chemically bound gold inclusions due to their high dispersion in the crystal lattices of concentrating minerals and the presence of minerals in the ore that tend to absorb water with a pronounced hydration effect. A possible solution of the problem of low gold recovery from such ores in heap leaching may be the use of activated solutions. Activated solutions contain components deep penetrating into the crystal lattice of minerals, ensuring their ionization, relocation and / or oxidation with oxygen when interacting with atoms of cation-forming elements (iron, aluminum, magnesium, etc.). Accordingly, in the crystal lattice of minerals, with encapsulated and dispersed gold, a system of additional microcracks and pores develops and access to it is provided for oxidizing and complexing components of leaching solutions.

2.3 Activation chloride and carbonate-cyanide leaching

Experiments were carried out on 4 schemes of activation percolation leaching. Samples for schemes №1 and №2 were taken from tails of +0.5 mm fraction, samples for schemes №3 and №4 were taken from tails of -0.5 mm fraction. Irrigation took place in laboratory percolators, an active chlorine-containing solution was used as a reagent for schemes №1,2,3. The solution was obtained by photoelectrochemical treatment of a 2% sodium chloride solution with addition and acidification with hydrochloric acid. As a result of solution activation, the content of active chlorine reaches 13 g/l. An active solution of sodium bicarbonate and sodium cyanide was used as a reagent for scheme №4. The activation of the leaching solutions in this experiment was carried out by their photoelectrochemical treatment. The processing steps include bubbling, electrolysis, and ultraviolet irradiation of the solution.

Before leaching with an active chlorine-containing solution, the samples were subjected to diffusion oxidation for four days. Pre-oxidation before leaching is necessary to reduce the unproductive consumption of active chlorine for its reaction with iron. Sulfuric acid-peroxide solution was used as an oxidizing agent for sample №1, nitric acid-peroxide solution for sample №2, and hydrochloric acid-peroxide solution for sample №3. Sample №4 was not pre-oxidated. The leaching process lasted until the complete end of the recovery of useful components into the pregnant solution. The results of the extraction of gold and silver are presented in table 3.

Table 3. Result of leaching

Sample	Fraction, mm	Scheme		Recovery, %	
		Pre-oxidation	Leaching solution	Au	Ag
1	+0,5	H ₂ SO ₄ +H ₂ O ₂	Activated (NaCl+HCl)	46,0	28,4
2	+0,5	HNO ₃ +H ₂ O ₂	Activated (NaCl+HCl)	33,7	11,7
3	-0,5	HCl+H ₂ O ₂	Activated (NaCl+HCl)	80,0	53,9
4	-0,5	-	Activated (NaHCO ₃ +NaCN)	78,7	62,7

Throughout the entire leaching process due to the use of activated solutions, as well as pre-oxidation, no clogging occurred in all samples.

3 Results and discussion

The results of laboratory experiments on re-leaching of gold by the activation leaching method show the effectiveness of these schemes, based on a high gold recovery in a fine fraction (up to 80%) and an increased recovery (up to 46%) in a coarse fraction compared to the cyanide scheme.

In the course of experiments on percolation leaching with active solutions, the samples were not subjected to either colmatation or hydration aggregation, which, in turn, was a possible problem of low gold recovery in the classical cyanide scheme in this field. Also, during activation chloride leaching due to pre-oxidation, the iron recovery, which could significantly increase the flow rate of the pregnant solution, decreased to almost zero.

4 Conclusions

Based on the results of the study, it can be seen that these schemes give a positive result for the extraction of gold from heap leaching tails, and, accordingly, from refractory ores,

especially in the -0.5 mm fraction. Thus, it can be concluded that it is advisable to use activation heap leaching with chloride and carbonate-cyanide solutions from refractory ores of Aprelkovo mine, as well as for additional recovery of useful components from previously secondary mineral material of heap leaching. At the same time, in order to establish the effective parameters of the industrial version of the technology, it is necessary to experimentally establish a rational degree of ore crushing and additional crushing of coarse fractions of heap leaching tails for the purpose of their microstructural transformations and directed relocation of chemically bound gold before heap leaching, which ensures the most efficient use of activated solutions. For fine fractions of tails, it is necessary to establish the comparative efficiency of the activation cuvette leaching of gold from them and pelletizing using active solutions.

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