ARPHA Proceedings

Proceedings CAUSummit 2024, 0045-0052
doi: 10.3897/ap.7.e0045

World Summit: Civil Engineering-Architecture-Urban Planning Congress

Manufacturing and Testing of a New Column-Type Flotation Cell to Produce Concentrate from Poor Ores Containing Gold and Silver

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Abstract. Both mechanical and hydrometallurgical beneficiation methods are used in the processing of precious metals. One of the common methods of precious metals processing is hydrometallurgy, where the risk of environmental contamination is higher due to the fact that toxic chemicals are mostly used. In the combined technology, the environmentally friendly gravity method is mainly used in the initial stage. Flotation beneficiation process does not always provide the maximum recovery of gold and silver in the concentrate and is replaced by hydrometallurgical processes in production. Therefore, obtaining high quality concentrate by flotation processing is very topical. The paper presents the results of obtaining high quality concentrate of precious metals by flotation method of beneficiation. Within the framework of the project, a column-type flotation cell was manufactured, in which the presence of an ascending air flow ensures the distribution of bubbles in the pulp and the maintenance their floating up speed, which determines the homogeneity of the pulp and helps to attach the reagent to hydrophobic minerals. In order to obtain a high quality concentrate and reduce economic costs, the sample was divided into three size classes, the finished flotation class -0.074 mm was separated and each class was ground separately. As a result of grinding, the above-mentioned classess were combined. In order to obtain high quality concentrate and reduce the loss of useful components, two collectors were used simultaneously. Potassium butyl xanthogenate and aeroflot were selected as collecting agents. Their ratio and cost were determined. As part of the research, chemical, silicate, sieve and mineralogical analyses of the sample were performed, as well as petrographic description was carried out. The optimal regime parameters of the flotation process were determined, as a result of which a high-quality concentrate of precious metals was obtained, with gold content of 14.25 g/t, silver content of19.05 g/t, recovery of useful components in the concentrate - 93.8. % and 90.4%, respectively.

Keywords: Beneficiation, solution, pick out, content, flotation

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Published by CAUSummit and peer-reviewed under the responsibility of "World Summit: Civil Engineering-Architecture-Urban Planning Congress - CAUSummit-2024".

INTRODUCTION

Increasing market prices and demand for precious metals, as well as declining reserves, have made it extremely important to comprehensively process deposits and maximize the recovery of useful component in the beneficiation

process [1,2]. Both mechanical and hydrometallurgical beneficiation methods are used in the processing of precious metals. In most cases, the environmentally friendly gravity method is not used independently, but in a combined technology at the initial stage, and for additional enrichment of tailings and intermediate products - hydrometallurgical or flotation beneficiation [3,4,5]. One of the common methods of precious metals beneficiation is hydrometallurgy, where the risk of environmental contamination is higher due to the fact that toxic chemicals are mostly used. In the world practice, there have even been cases of their spillage with devastating environmental consequences [5,6]. Environmental safety should be maximised in the mining and processing of minerals. Flotation is also often used as a beneficiation method, but it does not always provide the maximum recovery of gold and silver in the concentrate and is replaced by hydrometallurgical processes in production. Therefore, it is very important to obtain high quality concentrate in flotation beneficiation and reduce the loss of useful component. The objective of this work was to obtain high quality concentrate of precious metals by flotation beneficiation method. To achieve this goal, a new column-type flotation cell was manufactured (Figure 1), and two collectors were used simultaneously in the flotation process.

FIGURE 1. A new column-type flotation cell

Pulp aeration in the cell of a standard mechanical flotation machine is carried out by suction of atmospheric air as a result of rotation of the impeller. The degree of pulp aeration is characterized by the type, number and uniformity of distribution of bubbles in the pulp. The accumulation of bubbles leads to a decrease in their floating speed, so the pulp is no longer homogeneous, in some cases the useful component sticks to the walls of the flotation cell and settles to the bottom. In order to eliminate this disadvantage, a column-type flotation cell has been manufactured in which the air supply system has been improved by means of aerators fixed to the bottom of the cell. The presence of ascending air in the cell ensures the distribution of air bubbles in the pulp, maintaining the speed of their floating, which does not allow the useful components to settle to the bottom and stick to the walls of the flotation cell, as a result of which the pulp becomes homogeneous, the repeated contact of air bubbles with hydrophobic minerals leads to the fixation of the foam film to the mineral, and transfer of them to the foam product, the so-called concentrate.

RESEARCH, RESULTS AND DISCUSSIONS

Precious metal ore (containing gold and silver) from the Sakdrisi deposit of Daba Kazreti, Bolnisi Municipality was selected for the study, from which a sample grading 1.05 g/t gold and 1.45 g/t silver was taken. Chemical, silicate, sieve and mineralogical analyses and petrographic characterization were carried out. The results of the silicate analysis are presented in Table 1.

TABLE 1. Results of silicate analysis

Content of component, %												
SIO_2	Al_2O_3	Fe_2O_3	FeO	MgO	MnO	TiO_2	CaO	P_2O_5	SO_3	Na_2O	K_2O	Loss on ignition
73.2	10.1	6.37	0.29	2.15	-	0.24	0.8	0.1072	1.05	0.03	2.77	2.9

According to the mineralogical analysis data, pyrite, chalcopyrite, sphalerite, galena, magnetite, malachite, azurite, chalcosine, covelin, limonite and among the vein minerals - quartz, calcite, dolomite, gypsum and zeolite were found in the ores. According to the petrographic analysis (Fig. 2), the rock is a hydrothermally altered tuff.

The structure of the rock is fragmented; the grain size is fine, rarely medium. Rock fragments and highly chloritized volcanic glass are also rare in the rock. Minerals: chloritized volcanic glass, quartz, chlorite, chlorite, carbonate, zoisite and a variety of ore minerals (pyrite and chalcopyrite). For sieve analysis, technological samples were crushed to -2.5 mm, precious metal content in each size class was determined by acid decomposition of samples ignited at 550°C in chloronitric acid, DIBK extraction and finally by atomic absorption analysis. The results are shown in Table 2.

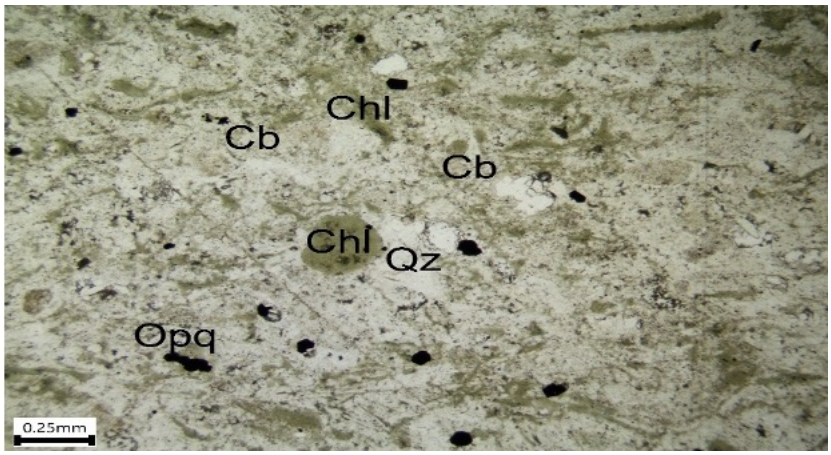

FIGURE 2. The photo from the petrographic analysis

TABLE 2. Results of sieve analysis of sample crushed to 2.5 mm. Gold and silver distribution by size classes

Size class, mm	Yield of class, γ %	Content of useful component, β % g/t		Recovery, ε %	
		Au	Ag	Au	Ag
-2.5+1.25	23.3	0.87	0.92	22.18	15.2
-1.25+0.63	12.5	0.79	1.38	10.81	12.23
-0.63+0.315	16.4	0.82	1.49	14.72	17.33
-0.315+0.16	6.7	1.58	1.58	11.59	7.51
-0.16+0.08	14.2	1.35	1.67	20.98	16.82
-0.08+0	26.9	0.67	1.62	19.72	30.91
-2.5+0	100	By calculation-0.91 By chemical analysis-1.05	By calculation - 1.41 By chemical analysis -1.45	100	100

According to the data in Table 2, gold and silver contents are not uniform across the size classes. The highest gold content of 1.58 g/t was recorded in the -0.315+0.16 mm class and the highest silver content of 1.67 g/t - in the -0.16+0.08 mm class. In order to evaluate the effect of grinding degree on the flotation process, the sample was ground to 60%, 70%, 80% and 90% - 0.074 mm to liberate gold and silver minerals from the waste rock matrix. The sample was crushed to -1+0 mm and the following size classes were distinguished: -1+0.315 mm, -0.315+0.074 mm, -0.074+0 mm. The first two size classes were ground separately and combined with the -0.074+0 mm size class. The results of the experiments are summarized in Table 3.

Test conditions:

- ✓ Grinding degree -0.074 mm, 60%, 70%, 80% and 90%;
- ✓ Soda ash – 400g/t;

- ✓ Collector - 80 g/t;
- ✓ Liquid glass - 400 g/t;
- ✓ Frother T-92 -50 g/t.

According to the table, the technological indicators of beneficiation (concentrate yield, content of useful component and recovery) increase with the increase of the grinding degree, and at grinding up to 90%-0.071 mm the ore is regrind and the concentrate yield increases, the content of useful component in it decreases. According to the results, the optimum grinding degree is 80%-0.074 mm

TABLE 3. Effect of grinding quality on flotation process

Grinding degree, -0.074 მმ, %	**Name of product**	**Product Yield, γ %**	**Content of useful component in product, β % g/t**		**Recovery, ε %**	
			Au	**Ag**	**Au**	**Ag**
60	Concentrate	6.8	7.81	9.34	50.43	43.92
	Tailings	93.2	0.56	0.87	49.57	56.08
	Raw ore	100	1.053	1.446	100	100
70	Concentrate	8.2	8.63	10.25	67.6	58.1
	Tailings	91.8	0.37	0.66	32.4	41.9
	Raw ore	100	1.047	1.446	100	100
80	Concentrate	9.3	9.12	11.57	81.00	74.30
	Tailings	90.7	0.22	0.41	19.00	25.70
	Raw ore	100	1.048	1.448	100	100
90	Concentrate	11.5	8.14	10.28	89.05	81.66
	Tailings	88.5	0.13	0.3	10.95	18.34
	Raw ore	100	1.05	1.45	100	100

Experiments continued to determine the optimum flow rate of the soda ash media regulator. The results are shown in Table 4.

Test conditions:

- ✓ Grinding degree -0.074 mm, 80%;
- ✓ Soda ash - 300 g/t, 400 g/t, 500 g/t, 600 g/t;
- ✓ Collector - 80 g/t;
- ✓ Liquid glass - 400 g/t;
- ✓ Frother T-92 -50 g/t.

According to the data, the increase in soda ash consumption from 300 g/t to 500 g/t is directly proportional to the increase in the tehnological properties of the beneficiation, and in the case of using 600 g/t the loss of useful component in the tailings increases, this is due to the fact that in a highly alkaline environment some gold and silver minerals are depressed and remain in the cell product. Accordingly, an optimum soda ash flow rate of 500 g/t was assumed.

To evaluate the effect of collector flow rate on concentrate quality, the following tests were conducted using potassium butylxanthogenate and aeroflot in a 1:1 ratio as collectors (Table 5).

Test conditions:

- ✓ Grinding degree -0.074 mm, 80%;
- ✓ Soda ash - 500 g/t;
- ✓ Potassium butyl xanthogenate/Aeroflot - 70 g/t, 80 g/t, 90 g/t and 100;g/t;
- ✓ Liquid glass - 400 g/t;
- ✓ Frother T-92 -50 g/t.

TABLE 4. Effect of soda ash consumption on the flotation process

Soda ash consumption, g/t	Name of product	Product Yield, γ %	Content of useful component in product, β % g/t		Recovery, ε %	
			Au	Ag	Au	Ag
300	Concentrate	8.7	7.72	10.29	63.66	63.65
	Tailings	91.3	0.42	0.61	36.34	36.35
	Raw ore	100	1.055	1.45	100	100
400	Concentrate	9.3	9.12	11.57	81.00	74.30
	Tailings	90.7	0.22	0.41	19.00	25.70
	Raw ore	100	1.051	1.447	100	100
500	Concentrate	9.2	9.65	12.51	85.20	78.90
	Tailings	90.8	0.17	0.34	14.80	21.10
	Raw ore	100	1.042	1.459	100	100
600	Concentrate	9.3	9.21	10.38	81.81	66.76
	Tailings	90.7	0.21	0.53	18.19	33.24
	Raw ore	100	1.047	1.446	100	100

TABLE 5. Effect of butylxanthogenate consumption on concentrate quality

Collector consumption, g/t	Name of product	Product Yield, γ %	Content of useful component in product, β % g/t		Recovery, ε %	
			Au	Ag	Au	Ag
70	Concentrate	8.1	8.23	9.51	63.3	53.10
	Tailings	91.9	0.42	0.74	36.7	46.90
	Raw ore	100	1.053	1.45	100	100
80	Concentrate	9.2	9.65	12.51	85.20	78.90
	Tailings	90.8	0.17	0.34	14.80	21.10
	Raw ore	100	1.043	1.447	100	100
90	Concentrate	9	10.13	13.09	87.00	81.81
	Tailings	91	0.15	0.3	13.00	18.64
	Raw ore	100	1.048	1.451	100	100
100	Concentrate	9.7	8.67	11.52	80.20	77.49
	Tailings	90.3	0.23	0.36	19.80	22.51
	Raw ore	100	1.049	1.442	100	100

According to the results of the experiments, the optimal flow rate of the collector is 90 g/t, its increase leads to contamination of the concentrate with waste rock. Experiments were continued to determine the optimal flow rate of the liquid glass - waste rock depressor. The results are shown in Table 6.

Test conditions:

- ✓ Grinding degree -0.074 mm, 80%;
- ✓ Soda ash - 500 g/t;
- ✓ Collector - 90 g/t;
- ✓ Liquid glass – 300 g/t; 350 g/t; 400 g/t, 450 g/t;
- ✓ Frother T-92 -50 g/t.

TABLE 6. Effect of liquid glass consumption on concentrate quality

Liquid glass consumption, g/t	**Name of product**	**Product Yield, γ %**	**Content of useful component in product, β % g/t**		**Recovery, ε %**	
			Au	**Ag**	**Au**	**Ag**
300	Concentrate	7.8	8.29	11.57	62.00	62.40
	Tailings	92.2	0.43	0.59	38.00	37.60
	Raw ore	100	1.043	1.446	100	100
350	Concentrate	8.3	9.38	12.07	74.54	
	Tailings	91.7	0.29		25.46	
	Raw ore	100	1.0445	1.447	100	100
400	Concentrate	9	10.13	13.09	87.00	81.81
	Tailings	91	0.15	0.3	13.00	18.64
	Raw ore	100	1.05	1.45	100	100
450	Concentrate	8.1	9.27	12.86	71.90	72
	Tailings	91.9	0.32	0.44	28.10	28
	Raw ore	100	1.045	1.446	100	100

According to the table, the optimum flow rate of liquid glass for waste rock depression in flotation process is 400 g/t. Its increase up to 450 g/t leads to depression of gold and silver minerals together with waste rock minerals, accordingly the losses of useful components in tailings increase and their recovery in concentrate decreases.

T-92 is widely used as a collector in the flotation of precious metals. In the tests conducted to determine the optimal value of its consumption, the range of variation was 50-70 g/t. The results of the experiments are shown in Table 7.

Test conditions:

- ✓ Grinding degree -0.074 mm, 80%;
- ✓ Soda ash - 500 g/t;
- ✓ Collector - 90 g/t;
- ✓ Liquid glass - 400 g/t;
- ✓ Frother T-92 -50 g/t, 60 g/t, 70 g/t.

As a result of the tests carried out to assess the effect of the consumption of the frother T-92 it has been found that increasing the consumption of frother from 50 g/t to 60 g/t has a positive effect on the flotation process, leading

to an increase in the technological parameters of enrichment, while increasing the consumption of frother to 70 g/t leads to contamination of the concentrate, reducing the content and recovery. Therefore, the optimal frother consumption is 60 g/t.

TABLE 7. Effect of T-92 consumption on the precious metal flotation process

T-92 consumption, g/t	Name of product	Product Yield, γ %	Content of useful component in product, β % g/t		Recovery, ε %	
			Au	Ag	Au	Ag
50	Concentrate	9	10.13	13.09	87.00	81.81
	Tailings	91	0.15	0.3	13.00	18.64
	Raw ore	100	1.05	1.45	100	100
60	Concentrate	6.9	14.25	19.05	93.8	90.4
	Tailings	93.1	0.07	0.15	6.2	9.6
	Raw ore	100	1.048	1.454	100	100
70	Concentrate	9.9	8.58	12.37	81.10	84.46
	Tailings	90.1	0.22	0.25	18.90	15.54
	Raw ore	100	1.047	1.45	100	100

CONCLUSION

Precious metal ore (containing gold and silver) from Sakdrisi deposit of Daba Kazreth in Bolnisi Municipality was selected for the study from which a sample was taken. Sieve, mineralogical, petrographical and full chemical analysis were carried out.

Flotation tests were conducted and the parameters of optimal flotation regimes were established, which include: grinding -0.074 mm - 80%; soda ash 500 g/t, potassium butylxanthogenate/aeroflot 90 g/t; liquid glass 400 g/t and frother T-92 50 g/t.

As a result of the experiments, a concentrate with gold content of 14.25 g/t and silver content of 19.05 g/t was obtained, the recovery of useful components into the concentrate is 93.8% and 90.4%, respectively.

ACKNOWLEDGMENTS

We would like to express our gratitude to RMG Gold LLC for their cooperation and support of the ongoing research. This article was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG) [grant number #YS–22-221]..

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