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Leaching of gold-containing ores with application of oxidation activators

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Abstract: The Article presents the results of studies conducted to process gold-bearing rocks from one of the fields in Kazakhstan. We studied a phase of the chemical and mineral composition of the ore using semi-quantitative X-ray fluorescent, chemical (assay), electron raster and rational (phase) analysis. We found that the test sample contained 1.4 g/t Au and 0.14 g/t Ag. The granulometric analysis showed that the main gold (36.51%) was concentrated in a class of -2.5 +1.25 mm size, with 1.42 g/t gold content. The main components of the initial sample composition were quartz 38.9%, albite 20.3%, pyrite 5.8%. We studied the gravity recovery possibility of gold-bearing ore using laboratory equipment, i.e. Knelson KS-MD 3 centrifugal concentrator. We obtained a gold-containing concentrate with 6.04 g/t gold content on a centrifugal concentrator with extraction of 52.65%, and 0.82 g/t gold in gravity tailings under the one-stage recovery flow sheet. We determined the optimal leaching parameters for the recovery products (gravity concentrates and gravity tailings) using various oxidation activators. The gold recovery degree was 77.3% with direct gravity concentrate cyanidation, and 85.7% with preliminary oxidation using calcium hypochlorite increasing the gold recovery degree by 8.4%, when leaching the gravity tailings using calcium hypochlorite -73.1%, sodium peroxide - 75.6%, Ascor oxidation activator (AS-45102) - 71.9%.
Key words: gold-bearing rock, leaching, gravity concentrates, gravity tailings, recovery, oxidation activator.

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Introduction

Modern and highly efficient technologies for their recovery are required due to the depletion of alluvial gold and silver deposits and the use of raw materials with a low content of valuable components and complex composition during the processing [1]. These ores are characterized with the presence of free, very fine gold uniformly distributed in the ore [3]. There are three main ways to process raw materials depending on the mineralogical composition of the ores and the size of gold in them: gravity concentration; flotation recovery; gold leaching with pre-oxidation [4]. Cyanides forming highly soluble complexes of gold and silver are now widely used to leach gold-bearing ores and concentrates [5]. An active search for alternative cyanide reagents and ways to intensify the precious metals recovery process from ores has been conducted within recent years due to the cyanidetoxicity and the complex composition of the feedstock [2].

One of the important issues in the gold ore treatment is the pre-oxidation of the sulphide part for more complete gold recovery. The use of oxidation activators, such as sodium peroxide and calcium hypochlorite, promotes the gold leaching from refractory sulphide raw materials. The implementation of the intensive cyanidation process for gravity concentrates and gravity tailings in the presence of activator reagents enables to increase the efficiency of gold-bearing rocksprocessing significantly.

The purpose of this study is to develop a method to leach gravity concentrate and gravity tailings using various oxidation activators.

Experiment and discussion of the results

We used a representative sample of the original ore from one of the deposits in Kazakhstan. A chemical analysis was carried out using a mass spectrometry method with the help of Varian Optical Spectroscopy Instruments atomic absorption spectrometer with an inductively coupled plasma. The research results showed the following elemental composition in %: 1.95 Fe; 0.46 S; 0.19 Cu; 0.52 Zn; 0.033 As; 1.45 ° C; 1.6 g/t Au, 0.14 g/t Ag.

It was found under the rational analysis results (Table 1) that 46.43% gold was found in this sample in a bound form, in association with sulfides, 25.0% in intergrowths and 25.0% in visible fine-dispersed native form (native gold).

X-ray phase analysis was performed using a D8-ADVANCE BRUKER X-ray diffractometer. X-ray phase analysis data (Table 2, Figure 1) of the sample showed that the main components of the initial sample phase composition were quartz 38.9%, albite 20.3%, pyrite 5.8%.

The electron microscopic analysis of ore (Figure 2) was performed using an electron scanning microscope with a JEOLJXA-8230 electron probe microanalyzer (JEOL, Japan). It follows from the results obtained that gold, and the silver, iron, sulphur carbon are present in the sample microstructure. The form of gold grains is lamellar, irregular, isometric.

Table 1 Results of rational (phase) analysis of the original ore sample.

Gold Forms in Tailing	Gold distribution	
	g/t	%
Free gold with a clean surface at 90% class minus 0.071 mm	0.35	25.0
Gold in intergrowths (cyanidable)	0.35	25.0
Gold associated with sulphides	0.65	46.43
Gold in minerals and quartz insoluble in nitrohydrochloric acid	0.05	3.57
Total gold	1.4	100.0

Table 2 X-ray phase analysis of the original ore

Наименование	Formula	%
Quartz, syn	SiO_2	38.9
Albite (heattreated)	$Na(AlSi_3O_8)$	20.3
Riebeckite	$Na_2(Fe^{2+}{}_3Fe^{3+}{}_2)Si_8O_{22}(OH)_2$	9.7
Clinochlore 1MIa	$Mg_{2.5}Fe_{1.65}Al_{1.5}Si_{2.2}Al_{1.8}O_{10}(OH)_8$	7.3
Pyrite, arsenian	$Fe(S_{0.99}As_{0.01})_2$	5.8
Calcite	$Ca(CO_3)$	4.6
Dolomite	$CaMg(CO_3)_2$	4.2
Orthoclase	$(K_{.88}Na_{.10}Ca_{.009}Ba_{.012})(Al_{1.005}Si_{2.995}O_8)$	3.9
Muscovite 2M1,syn	$KAl_3Si_3O_{10}(OH)_2$	3.2
Clinoptilolite	$(Na,K,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12H_2O$ $Na_{4.12}Si_{36}O_{72}(H_2O)_{23.12}$	2.3

Table 3 Results of the gold distribution by size class

Size classes, mm	Classesyield %	Gold content, g/t	Gold distribution %
-2.5+1.25	36.0	1.42	36.51
-1.25+0.8	19.0	1.5	20.36
-0.8+0.5	13.6	1.59	15.45
-0.5+0.25	13.6	1.2	11.66
-0.25+0.1	14.6	1.3	13.56
-0.1+0.071	2.2	1.1	1.73
-0.071	1.0	1	0.71
Total	100.0	1.4	100.0

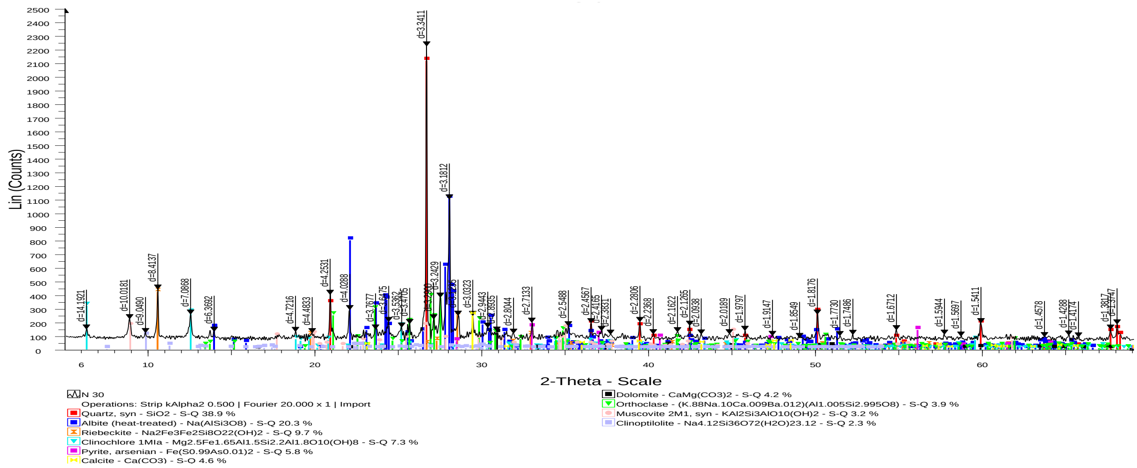

Figure 1 The results of x-ray phase analysis of ore samples

It was revealed under the results of the particle size analysis that the main ore fractions were represented by a particle size of -2.5 +1.25 and -1.25 +0.8 mm; the yield was 36.51 and 20.36%, respectively (Table 3).

Thus, the physical and chemical studies of the original ore showed that the gold content in the ore sample was 1.4 g/t, including 46.43% of gold in a bound form in association with sulphides, 25.0% in intergrowths, and 25.0% of the visible fine-grained native form (native gold). The phase composition was mainly represented by quartz - 38.9%, albite - 20.3%, pyrite - 5.8%. According to the particle size analysis, the main ore fractions were represented by a particle size of -2.5 +1.25 and -1.25 +0.8 mm, the yield was 36.51 and 20.36%, respectively.

Gravity recovery is widely used to process gold ores.

The method of gravity concentration using centrifugal concentrators is one of the effective gravitational recovery methods for gold-bearing ores enabling to extract free not only large, medium and fine, but also thin and dusty gold from ores.

We carried out gravity recovery tests using ore with a particle size of 85% of the 0.071 mm class (Table 4).

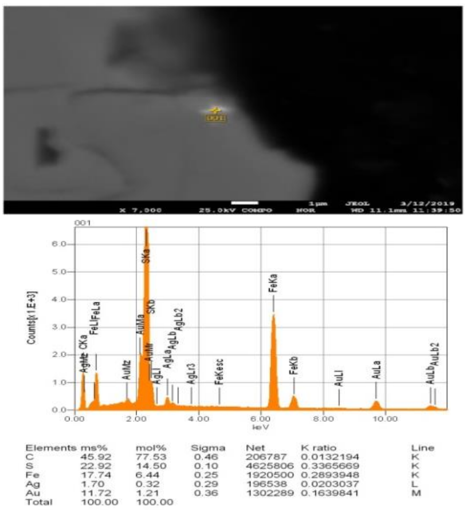

Figure 2 Electron-microscopic analysis of ore

Gravity recovery was carried out using a 3-inch Knelson KS-MD 3 centrifugal concentrator.

Selection of the gravity concentration mode for the ore sample:

Gravity recovery parameters:

- Centrifugal acceleration 60 G;
- Fluidising water flow rate 3.5 l/min;
- Solids intake 0.5-0.6 kg/min;
- Fluidising water excessive pressure 15 kPa;
- Solids content in the pulp supplied to the gravity concentration, 25-30%.

Table 4 Results of the original ore gravitational recovery

Product Name	Yield		Au content, g/t	Au recovery, %
	г	%		
Concentrate	558	13.95	6.04	52.65
Tailings	3442	86.05	0.82	43.75
Total	4000.0	100.0	1.4	100.0

Under the gravitational recovery results of the ore specified in the Table, the yield of gold-bearing concentrate was 14% with gold content - 6.04 g/t and gold recovery was 52.65%, gravity tailings contained 0.82 g/t.

We leached the concentrates and gravity recovery tailings by direct cyanidation, as well as using oxidizing agents: calcium hypochlorite ($Ca(ClO)_2$), sodium peroxide (Na_2O_2), and Ascor oxidation activator (AS-45102). It should be noted that the preliminary oxidation studies considered in scientific papers [11–14] showed high efficiency of the reagents used.

Cyanation products were subject to atomic absorption and assay (cake) analysis methods. We studied the cyanidation dynamics (with direct cyanidation and in the presence of oxidizing agents), controlled the sodium cyanide concentration and the pulp pH during the tests. The cyanide leaching parameters and results are shown in Tables 5-6.

Table 5 Gravity concentrate cyanidation mode

Parameter	Unit of measurement	Value
Grain size	mm	
W:Tratio = (1:3)	g/ml	100:300
Cyanide concentration	%	0.1
Cyanation duration	h	24
Температура	°C	22
With air supply		+
Medium value	pH	11.2 – 11.5

It follows from the data in Tables 5 and 6 that the process conditions (Table 5) enableto achieve 77.3% gold recovery from the concentrate during direct cyanidation and with 90%particle size of 0.071 mm
class, as well as with 0.1% sodium cyanide concentration, 85.7% for cyanidation with preliminary oxidation with calcium hypochlorite, i.e. ore pre-oxidation contributes to an increase in the gold recovery degree by 8.4%. A method was proposed to process the refractory gold-bearing ore from the Kazakh deposit based on the studies conducted.

Table 6 Results of gravity concentrate cyanidation tests

Names	Parameters	
	Test 1	Test2
Sample weight, g	70	70
Solution volume, ml	280	280
NaCN concentration, %	0.1	0.1
pH	10.7	11.03
Duration, h	24	24
Type of oxidizer, g		1.0 $Ca(ClO)_2$
With air supply	+	+
Au content in the initial conc. under assay analysis, g/t	6.04	6.04
Au content in cake, g/t	1.37	0.86
Au recovery rate from cake, %	77.3	85.7

Conclusion

Thus, the best leaching parameters for gravity tailings were obtained by preliminary oxidation with such reagents as Na_2O_2,and $Ca(CLO)_2$, i.e. 75.6% and 73.1%, respectively, and pre-oxidation increased the gold recovery degree by 8.4%when leaching gravity concentrateindicating the sulfide oxidation efficiency. The maximum gold recovery degree of gravity concentrate was 85.7%.

A method was proposed to process the refractory gold-bearing ore from the Kazakh deposit based on the studies conducted.

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Байытылған өнімдерді тотықтырғыш қосып шаймалап алтынды бөліп алу

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Туйіндеме. Мақалада Қазақстанның алтынқұрамды шикізатты өңірлерінің зерттеу нәтижелері келтірілген. Сынама алынып кендердің фазалық құрамы зерттелді. Жартылай сандық рентгендік флуоресцентті, химиялық (талдау), электронды-растрлық және рационалды (фазалық) талдауды қолдану арқылы кендердің химиялық және минералды құрамы берілген. Сынақ үлгісінде 1,4 г/т Au және 0,14 г/т Ag бар екендігі анықталды. Гранулометриялық талдау көрсеткендей, алтынның негізгі бөлігі (36,51%) мөлшері -2,5 +1,25 мм мөлшерінде шоғырланған, алтын мөлшері 1,42 г/т. Бастапқы сынаманың негізгі фазалық құрамы кварц - 38,9%, альбит - 20,3%, пирит - 5,8%. Рентгендік флуоресцентті талдау нәтижелері бойынша кремний сынамадағы басымдыққа ие екендігі анықталды. Зертханалық құрал-жабдықтарды пайдалана отырып, алтыннан алынған кендерді гравитациялық байыту мүмкіндігі: Центрифугалық центрифулаушы Knelson KS-MD 3 бір сатылы байыту схемасына сәйкес, алтынның құрамында 6,04 г/т болатын центрифугалық концентраторда 52,65%, гравитациялық қалдықтарда - 0,82 г/т алтын мөлшерін құрады. Байыту өнімдерінің оңтайлы шаймалау параметрлері (гравитациялық концентрат және гравитациялық қалдықтар) түрлі тотығу активтендіретін реагенттерді пайдаланып көрсетілген. Ең жоғары көрсеткіштер гравитациялық концентраттың тікелей цианидтеу кезінде алтын өндіру дәрежесі 77,3% құрады; кальций гипохлоритімен алдын-ала тотықтырумен 85,7%, ол алтын өндіру дәрежесін 8,4% -ға арттырады. Гравитациялық қалдықтарды шаймалау кезінде кальций гипохлоритін пайдалану арқылы - 73,1%, натрий пероксиді 75,6%, AS-45102 - 71,9% құрайды.
Түйін сөздер: алтынқұрамды шікізат, шаймалау, гравитациялық концентрат, гравитациялық қалдықтар, алу, тотығу активатордар.

Извлечение золота выщелачиванием продуктов обогащения с применением окислителя

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Аннотация. В статье приведены результаты исследований переработки золотосодержащего сырья одного из месторождений Казахстана. Изучены фазовый химический и минеральный составы руды с применением рентгенофлуоресцентного полуколичественного, химического (пробирного), электронно-растрового и рационального (фазового) анализов.Установлено, что в исследуемой пробе содержится 1,4 г/т Au и 0,14 г/т Ag. Гранулометрический анализ показал, что основная масса золота (36,51 %) сосредоточена в классе крупности -2,5 +1,25 мм, при содержании золота 1,42 г/т. Основные компоненты фазового состава исходной пробы - кварц 38,9 %, альбит 20,3 %, пирит 5,8 %. Изучена возможность гравитационного обогащения золотосодержащей руды

с использованием лабораторного оборудования: центробежного концентратора Knelson КС-МД 3. По одностадиальной схеме обогащения на центробежном концентраторе получен золотосодержащий концентрат с содержанием золота 6,04 г/т при извлечении 52,65 %, в хвостах гравитации содержится 0,82 г/т золота. Показаны оптимальные параметры выщелачивания продуктов обогащения (гравитационного концентрата и хвостов гравитации) с применением различных реагентов-активаторов окисления. При прямом цианировании гравиоконцентрата степень извлечения золота составило 77,3 %, с предварительным окислением гипохлоритом кальция 85,7 %, что повышает степень извлечения золота на 8,4 %, при выщелачивании хвостов гравитации с применения гипохлорита кальция -73,1 %, пероксидом натрия - 75,6 %, активатора окисления Ascor (AS-45102) - 71,9 %.
Ключевые слова: золотосодержащее сырье, выщелачивание, гравитационный концентрат, хвосты гравитации, извлечение, активатор окисления.

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