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RESEARCH OF GOLD EXTRACTION TECHNOLOGY FROM TECHNOGENIC RAW MATERIAL

Abstract. The results of the leaching of the tailings from the heap leaching section with the aim of extracting gold associated with sulfides are presented. A representative sample of the tailings of the heap leaching section was selected and its chemical, phase, and mineralogical composition were studied. It was established that the test sample contains 1.2 g / t Au. According to a rational analysis, by sorption cyanidation at a fineness of 95% class minus 0.071 mm, 76.09% of gold is extracted from a sample of heap leaching tailings, which is mainly (71.74%) represented by intergrowths with ore and rock-forming components. The mass fraction of free (amalgamable noble metal is insignificant (4.35%). The main reason for the persistence to sorption cyanidation is the close association of gold with sulfide minerals. In the optimal mode of cyanidation of oxidation residues, 71.7 % of gold is recovered in 24 hours.

Keywords: gold, heap leaching tailings, phase composition, cyanide.

Introduction

Currently, the state of world mineral resources is characterized by a decrease in the quality of minerals. Due to the depletion of placer gold and silver deposits and the involvement of raw materials with a low content of valuable components and a complex composition, new, more modern and highly efficient technologies for their extraction are required. The intensification technologies currently used make it possible to obtain un-extracted gold from technogenic raw materials. Technogenic wastes are environmentally hazardous, they cause significant harm to the environment, polluting water bodies, soil and air, as dust storms increase the content of toxic elements in the air to a level exceeding the maximum permissible concentrations.

In article [1], dissolution of noble metals by solvents of various types was considered. It should be noted that one of the promising technologies for processing technogenic raw materials is chemical leaching with preliminary oxidation, nitric acid opening, and bacterial leaching [2-4].

Abroad, in particular, South Africa, the tails of gold deposits are involved in recycling, and in Russia example are the tailings of the processing plants of Baleizoloto LLC [5-7].

At present, most gold processing plants process ores in which sulfide minerals are present. Gold in such ores is partially associated with sulfides, and partially is in a free state. In most cases, ores of this type are classified as refractory [8-25].

Technological mineralogy methods allow us to identify useful and harmful minerals and their associations in ores, determine the features of their real composition and structure, the nature of relationships between themselves and with rock-forming phases, control, explain and predict the properties of ores in technological processes.

The raw materials for the re-extraction of gold are heap leach tailings, sorption tailings, flotation ore tailings and substandard raw material reserves. In this regard, the aim of the present research was to develop new methods for additional extraction of gold from the tailings of the heap leaching site.

Experimental methods and results

The object of research was the tailings from the heap leaching section of a gold extraction plant (Kazakhstan). The chemical composition of the studied tailings sample is represented by the following main components, %: 1,385Fe; 0.132 S_{total}; 0.005 Zn; 0.006 Cu; 1.4 g / t Au. A sample of the tailings of the heap leaching area is a finely ground material with a particle size of 90% of the class minus 0.071 mm.

The tail cyanidation products — solution and cake — were subjected to atomic adsorption and assay assays, respectively.

Electron microscopic studies of the main sulfide mineral, arsenopyrite, extracted from the initial tail sample, were performed on a JEOL JXA-8230 scanning electron microscope (Japan) equipped with an energy dispersive analyzer. As can be seen in Figure 1, pyrite, in addition to the main structural elements - iron and sulfur, also contains gold and trace elements of copper and zinc.

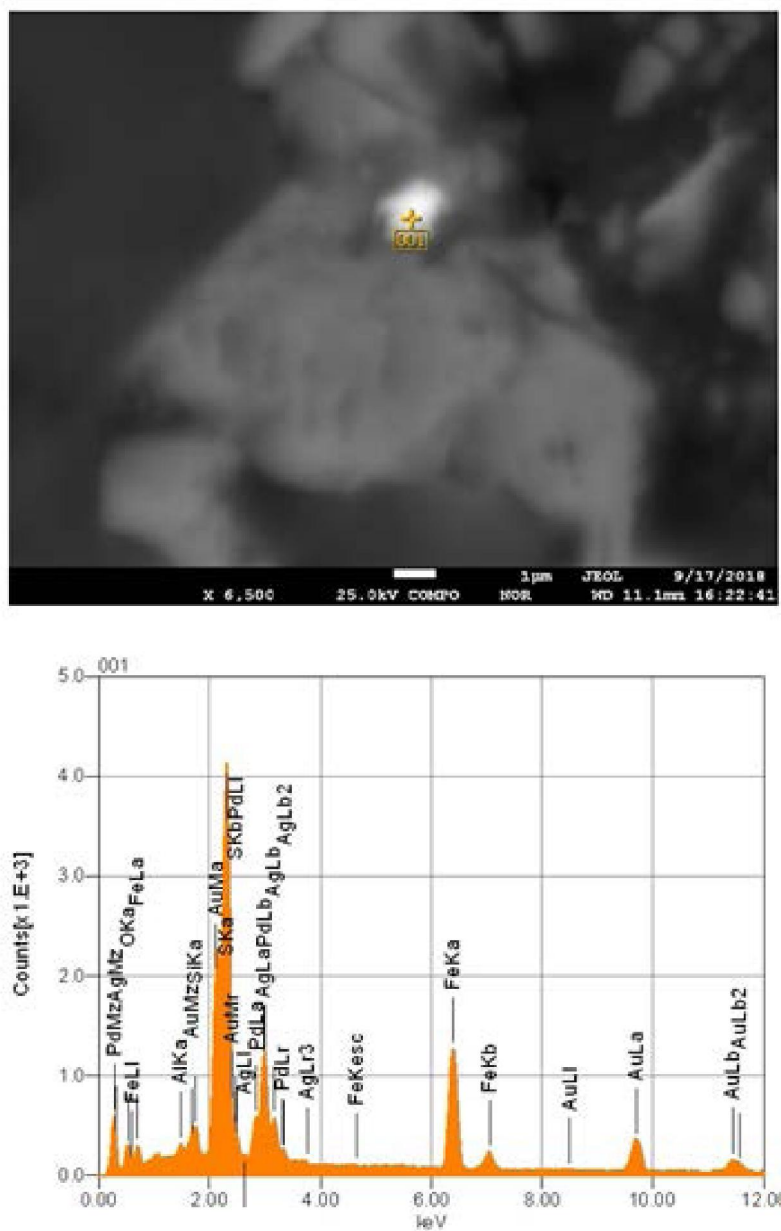


Figure 1 - The microstructure of the initial sample of the tailings (a) and energy dispersive analysis of pyrite (b)

It was established that silver, gold, and silicon are present in the microstructure of the sample. A large part is dominated by non-metallic minerals (quartz more than 30%). According to the electron - probe analysis, we see a particle of gold with a silver content, which develops in sulfides. The shape is gold-plate, irregular, isometric.

X-ray phase analysis showed that the main sulfide mineral in the sample is pyrite (5.8%). In addition, the tail contains a mineral, phyllosilicate of magnesium and aluminum with hydroxyl 7.3% clinoclhorine. The mineral composition of the test sample is represented by the following non-metallic components, %: 20.3 albite; 3.2 muscovite; 38.9 quartz; 4.6 calcite. Mineralogical analysis showed that gold is mainly present in finely divided form in quartz and sulfide. The particle size of free finely divided gold is 2.5–3.9 μm , in intergrowths it is 1.2–4.0 μm , and gold grains of irregular isometric shape.

From the results of a rational (phase) analysis of gold in the tails, finely ground to a fineness of 95% class –0.071 mm (table 1), it follows that 76.09% is extracted by sorption cyanidation. Of these, 71.74% fall to intergrowths with ore and rock-forming components, and 4.35% fall to free (amalgamable) metal.

Table 1 - The results of a rational analysis for gold samples of the tailings of the site of heap leaching

The forms of gold and the nature of their association with ore and rock-forming components	Gold allocation	
	g/t	%
Free gold (extractable by amalgamation)	0,040	4,35
In the form of intergrowths with ore and rock-forming components (extracted by sorption cyanidation)	0,660	71,74
Total in possible for cyanidation form	0,700	76,09
Extractable by cyanidation after treatment with alkali (associated with amorphous silica, coated with surface membrane)	0,050	5,62
Extractable by cyanidation after treatment with hydrochloric acid (associated with iron hydroxides, chlorites, carbonates, iron sulfates, sphalerite, etc.)	0,018	1,94
Extractable by cyanidation after treatment with nitric acid (associated with sulfides: pyrite, arsenopyrite, chalcopyrite, etc.)	0,120	13,02
Finely interspersed in rock-forming minerals	0,031	3,33
Total (on balance):	0,920	100,00

The mass fraction of refractory (not extractable by cyanidation) gold is 23.91%. It is mainly associated with sulfides (13.02%), partially - it is coated with surface membranes (5.62%). To a lesser degree, tenacity is affected by the relationship of gold with a complex of minerals soluble in hydrochloric acid — hydroxides, chlorites, and iron carbonates (1.94%).

Determination of the sorption activity of the solid phase was carried out according to the method of JSC Irgiredmet [8]. For this, two parallel cyanidation experiments were carried out on the ground ore sample: in the sorption mode in the presence of activated carbon with a concentration of 10 vol. % and without loading of activated carbon in the following conditions: ratio Liquid: Solid= 2: 1; NaCN concentration - 2.0 g / l; CaO loading - 3 kg / t; cyanidation duration - 24 hours

The relative sorption activity (A , %) was calculated by the formula:

$$A = \left(1 - \frac{R \cdot C_{Au}}{\beta_{source} - \beta_{cake}} \right) \cdot 100 \%,$$

where R – ratio L:S; C_{Au} – the concentration of gold in solution (in the experiment without a sorbent), mg/l; β_{source} and β_{cake} – accordingly, the gold content in the initial product and cyanide cake in the experiment with the sorbent, g / t

The experimental results are presented in the table 2.

Experimental part

Vat-agitation cyanide leaching of the initial sample of the tailings of the heap leaching site. The results of studies on propaganda cyanide leaching of tailings using an oxidizing agent and a surfactant are presented.

Table 2 - The results of experiments to determine the sorption activity of the tailings from the heap leach plot

Mass fraction of class minus 0.071 mm, %	Experimental conditions	Concentration Au in solution, mg/l	Au content in cake, g/t	Extract Au from operations, %	Relative sorption activity, %
95	Without sorbent	0,47	-	-	4,1
	With sorbent	-	0,22	82,1	

* gold content in the initial sample according to the analysis - 1.2 g / t

The results presented in table 2 show that the initial tailings sample does not have sorption activity with respect to the gold cyanide complex.

The optimal parameters for processing the tailings of the heap leaching section were selected by comparing various leaching variants. Taking into account the significant content of carbonates in the tails, in all cases they were pre-treated with acid in order to dissolve the carbonates.

In the process of preparing a sample of the tailings from the heap leaching site for hydrometallurgical studies, it was ground to a particle size of 0.040 mm in a planetary mill. Leaching pulp density is 30% solid. The pH of the pulp during leaching of the tests was maintained at a level of 10.5-11.0. Leaching time is 24 hours (Table 3).

Table 3 - Leaching of the initial sample tailings from the heap leaching section

Variant	The fineness of the material, mm	Gold Content, g / t		Gold extraction, %
		In the original	In cake	
<i>Direct cyanidation</i>				
1	90 % -0,071	1,2	0,54	55,0
2	90 % -0,04	1,2	0,52	56,7
<i>Using calcium hypochlorite Ca(ClO)₂</i>				
3	90 % -0,071	1,2	0,47	60,8
4	95 % -0,04	1,2	0,34	71,7

As a result, the following gold recovery indicators were obtained for various options for processing the tailings from the heap leaching samples: variant 1- 55.0%; variant 2 - 56.7 %; variant 3 - 60.8 %; variant 4 - 71.7 %.

The results obtained indicate that in the process of leaching the tailings from the heap leaching section, sulfides are oxidized, resistant gold is opened and its extraction is increased during subsequent cyanidation of oxidation residues. Gold recovery reaches 60.8 and 71.7 %, respectively, in variants 3 and 4 of tailings processing.

Conclusion

It was revealed that the gold content in the test sample is 1.2 g / t. Gold is found in the form of very fine grains in sulfides (arsenopyrite, pyrite), as well as in a finely disseminated state in silicate minerals.

As a result of rational (phase) analysis, the mass fraction of refractory (not extractable by cyanidation) gold is 23.91%. It is mainly associated with sulfides (13.02%), partially - it is coated with surface films (5.62%).

Extraction of gold from the tailings from the heap leaching section with preliminary oxidation is 71.7 %.

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ТЕХНОГЕНДІ ШИКІЗАТТАРДАН АЛТЫН БӨЛІП АЛУДЫҢ ТЕХНОЛОГИЯСЫН ЗЕРТТЕУ

Аннотация. Қазіргі кезеңдегі алтын гидрометаллургиясының маңызды міндеті - оны техногендік шикізаттан бөлудің ұтымды әдістерін табу. Қалдықтарды қайта өңдеуге тарту үшін қалыпты емес әдістер қажет. Техногендік шикізатты өңдеудің перспективті технологияларының бірі - үлкен материалдық шығындарды қажет етпейтін және атмосфераны ластамайтын шаймалау процесінде алдын ала тотығуды қолдану. Бұл әдіс сульфидтердің терең ашылуына байланысты құрамында алтыны бар құрамында шикізаттан алтын алудың тотығу процесін күшейтуге мүмкіндік береді.

Сульфидтермен байланысты алтынды алу мақсатында үйінділерді қалдықтарын шаймалау нәтижелері келтірілген. Үйінділерді қалдықтарынан үлгілері алынып, оның химиялық, фазалық және минералогиялық құрамы зерттелді. Үлгідегі алтынның құрамы 1,2 г/т анықталды. Рационалды талдаудың нәтижесі бойынша, 95% класты 0.071 мм мөлшерінде сорбциялық цианидтендіру арқылы 76,09% алтын алынды, бұл негізінен кен және тау жыныстарын құрайтын өсінділермен ұсынылған (71,74%). Бос (араласатын асыл металдың) үлес салмағы шамалы (4,35%). Сорбциялық цианидтенудің негізгі себебі - алтынның сульфидті минералдармен тығыз байланысы.

Өңделуі қиын (алынбайтын сорбциялық цианизация) түрінде алтынның 23,91% құрайды. Ол келесідей бөлінеді: аморфты кремниймен байланысқан және беттік қабыршақтармен қапталған - 5,62%; тұз қышқылында еритін минералдар кешенімен байланысты (гидроксидтер, карбонаттар, темір хлориттері) - 1,94%; сульфидтермен байланысты: пирит, арсенопирит - 13,02%; тау жыныстары түзілген минералдармен өте жақсы араласады - 3,33%.

Электронды микроскопиялық анализ (SEM) арқылы үйінділерді шаймалау секциясының (жұқа секциялар) қалдықтарының бастапқы үлгісін зерттеу нәтижелері сынаманың микроқұрылымында күміс, алтын және кремний бар екенін көрсетті. Үлкен бөлігін металл емес минералдар құрайды (кварц 30% -дан астам). Электронды-зондтық анализге сәйкес, сульфидтерде дамиды күміс құрамы бар алтын бөлшегін көреміз. Пішіні алтын тәрізді, изометриялық.

Бастапқы үлгіні (жіңішке секцияларды) минералогиялық талдау бір жағдайда бос жынысы бар бөлшекке түтікшелі беті бар жұқа дисперсияланған Au (3.6x5.3 мк) таяз шығанақ тәрізді кірістірудің қарапайым жиегі табылғандығын көрсетті. (12x18 мк). Суретте алтынның көкшіл-жасыл реңкі бар, ол бор, ковеллит композицияларының болуы мүмкін екенін көрсетеді (Борнит - Cu₅FeS₄; Ковеллин - CuS). Мұндай фильмдер цианидтің алтынға қол жеткізуіне кедергі келтіреді. Күміс аз мөлшерде жұқа бөлшектер түрінде болады, мөлшері Ag-да (1-5,7 мк), негізінен еркін. Таралуы бойынша тізімделген ассоциацияланған компоненттер: Арс арсенопириті (FeAsS), пирит (FeS₂), халкопирит Сп (CuFeS₂) және аз магнитит Мgt (Fe₃O₄), сфалерит Сл (ZnS); және теннантит tn (Cu₁₂As₄S₁₃); бір жағдайда галена га (PbS) бар шоғырланған арсенопирит табылды.

Алынған нәтижелер үйінділерді шаймалау секциясының қалдықтарын сілтілеу процесінде сульфидтер тотығады, өңделуі қиын алтын ашылады және одан кейінгі тотығу қалдықтарын цианизациялау кезінде оның экстракциясы жоғарылайды.

Тотығу қалдықтарын цианидтендірудің оңтайлы жағдайында алтынның 71,7 % -ы 24 сағат ішінде алынады.

Түйін сөздер: алтын, шаймалау аймағының үйінділерінің қалдықтары, фазалық құрамы, цианидтеу.

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ИССЛЕДОВАНИЕ ТЕХНОЛОГИИ ИЗВЛЕЧЕНИЯ ЗОЛОТА ИЗ ТЕХНОГЕННОГО СЫРЬЯ

Аннотация. Важнейшая задача гидрометаллургии золота на современном этапе - изыскание рациональных способов его извлечения из техногенного сырья. Для вовлечения отходов в переработку

требуются нетрадиционные методы. Одной из перспективных технологий переработки техногенного сырья является применение в процессе выщелачивания предварительное окисление, которое не требует больших материальных затрат и не загрязняет атмосферу. Этот метод позволяет интенсифицировать процесс окисления извлечения золота из упорного золотосодержащего сырья за счет более глубокого вскрытия сульфидов.

Приведены результаты процесса выщелачивания хвостов участка кучного выщелачивания с целью извлечения золота, ассоциированного с сульфидами. Осуществлен отбор представительной пробы хвостов участка кучного выщелачивания и изучены ее химический, фазовый и минералогический состав. Установлено, что в исследуемой пробе содержится 1,2 г/т Au. По данным рационального анализа сорбционным цианированием при крупности 95 % класса минус 0,071 мм из пробы хвостов кучного выщелачивания извлекается 76,09 % золота, которое в основном (71,74 %) представлено сростками с рудными и породообразующими компонентами. Массовая доля свободного (амальгамируемого благородного металла незначительна (4,35 %). Основной причиной упорности к сорбционному цианированию является тесная ассоциация золота с сульфидными минералами.

В упорной (не извлекаемой сорбционным цианированием) форме находится 23,91 % золота. Оно распределено следующим образом: ассоциированное с аморфным кремнеземом и покрытое поверхностными пленками - 5,62 %; ассоциированное с комплексом минералов, растворимых в соляной кислоте (гидроксидами, карбонатами, хлоритами железа) - 1,94 %; связанное с сульфидами: пиритом, арсенопиритом - 13,02 %; тонко вкрапленное в породообразующие минералы - 3,33 %.

Результаты исследования исходного образца хвосты участка кучного выщелачивания (шлифов) методом электронно-микроскопического анализа (РЭМ) показали, что в микроструктуре пробы присутствуют серебро, золото, кремний. Большую часть преобладают нерудные минералы (кварц более 30%). По данным электро - зондового анализа мы видим частичку золота с содержанием серебра, который развивается в сульфидах. Форма золотинпластинчатая, неправильная, изометричная.

Минералогический анализ исходного образца (шлифов) показали, что в единичном случае обнаружен простой краевой сросток золота, представленный неглубоким заливообразным включением тонкодисперсного Au (3,6x5,3 мкм) с бугорчатой поверхностью в частице вмещающей пустой породы п.п. (12x18 мкм). На снимке золото имеет синевато-зеленоватый оттенок, свидетельствующий о наличии пленок, вероятно борнит-ковеллинового состава (Борнит – Cu_5FeS_4 ; Ковеллин - CuS). Подобные пленки затрудняют доступ цианида к золоту. Серебро присутствует в незначительном количестве в виде тонкодисперсных частиц с вариацией размеров в пределах Ag (1-5,7 мкм), преимущественно в свободной форме. Сопутствующие компоненты, перечисленные в порядке их распространенности, представлены: арсенопиритом Ars ($FeAsS$), пиритом (FeS_2), халькопиритом Cp ($CuFeS_2$), и реже магнетитом Mgt (Fe_3O_4), сфалеритом Sl (ZnS); и теннантитом tn ($Cu_{12}As_4S_{13}$); в единичном случае обнаружен сросток арсенопирита с галенитом ga (PbS)

Полученные результаты свидетельствуют о том, что в процессе выщелачивания хвостов участка кучного выщелачивания происходит окисление сульфидов, вскрытие упорного золота и повышение его извлечения при последующем цианировании остатков окисления.

В оптимальном режиме цианирования остатков окисления за 24 ч извлекается 71,7 % золота.

Ключевые слова: золото, хвосты участка кучного выщелачивания, фазовый состав, цианирование.

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