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Research of textural and structural features of refractory gold-bearing ores

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Research of textural and structural features of refractory gold-bearing ores

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Abstract. The article studies the material and mineralogical composition of the refractory gold-bearing ores of the weathering crust of one of the deposits in Eastern Siberia. It is revealed that, according to the textural and structural features, ores are multi-mineral and have significant differences in the composition of the detrital, granular material and the loose component. All ore is saturated with iron hydroxides and limonite crusts with clay components. The results of the analysis showed that large classes contain an insignificant amount of a valuable component. Increased gold content is noted starting from -4 + 0 mm size. In the free state are about 3-5%. Processing of these types of raw materials is a rather complicated task. Analysis of the enrichment methods showed that the use of new solvents of noble metals with their subsequent concentration is promising. Of practical interest are alkaline solutions obtained by dissolving sulfur in an aqueous suspension of calcium hydroxide. The reagent is non-toxic and environmentally friendly. Leaching was carried out in a wide range of concentrations of the solvent used. The optimum solvent concentrations and the duration of the leaching process for extracting the valuable component into the filtrate were determined to be 97–98%. Chemical analysis of cakes showed that the reagent does not enter into chemical interaction with other elements that make up the ore. As well as the content of elemental sulfur in dump cakes averages 0.64%, that is, it corresponds to a content in the raw material of up to 0.8%. At the same time, cakes are not environmentally harmful and can be stored on special platforms.

1. Introduction

Simple by the structure and the most available deposits of gold are substantially worked out. Into operation are being put difficult and refractory placers, characterized with a high clay content in sand, fine particles of gold, conglomeration and ductility of productive strata. Such deposits, particularly of loose type contain no less than 45% from the general amount of known reserves of Central and Eastern Siberia and their amount under exploration will increase over time.

At the same time, the main source of gold production remains the primary gold-bearing ores, which are divided into oxidized and sulphide ores. For these types of ores, independent technological processing processes are formed, in particular, oxidized ores are processed by gold leaching with cyanic aqueous media, followed by sorption by sorbents. Oxidized quartz and sulphide ores are enriched by gravity and flotation methods with the production of appropriate concentrates suitable for further processing in the metallurgical process.

Recently, due to the depletion of rich and easily-rich gold-bearing ores, there have been trends in the development of technological schemes for the processing of mineral raw materials and the commissioning of new deposits with refractory ores with a finely dispersed phase and a low content of valuable components, as well as a high content of clay components. Listed reasons and a high content of clay components require a higher quality of textural and structural researches of source ores.

The purpose of these studies is the research of textural and structural features, the development of technology for processing these types of ores and its introduction into operation in the existing areas of the processing plants. In this regard, the study presents the ore from one of the fields in Eastern Siberia. The analysis of methods for enrichment of these types of ores revealed the advantages of using the most promising effective solvents of noble metals with their subsequent leaching [1], [2].

2. Research materials and methods

Gold ores presented for the study are colored brownish-gray in color and consist of fragments of rocks and minerals (~ 70%) and a sandy-clay component (~ 30%). The structure of the ore is determined by the size of detrital grains - from coarse-grained (debris size from 2 to 85-100 mm) to pelitic (<0.01 mm), there are also fragments of psamlita and aleuritic structures (with fragments from 1-2 mm to 0.01 mm).

Fragments of rocks are mainly represented by quartzites (18–70 mm), marbled limestones (30–50 mm and core fragments 86 mm), weathered sandstones and shale (1-2 mm to 3 42 mm), single fragments of amphibolites and granites (24-32 mm), large pebbles of limonite (86 mm) and small (23 mm) of its nodules, small pebbles of goethite (~ 10 mm) and rounded fragments of quartz of a granular structure (42 mm).

The composition of the multi-mineral ore. It contains the minerals quartz: plagioclase, potassium feldspar, limonite, hornblende, biotite, muscovite, ilmenite, pranate, tourmaline, zircon, apatite, genite, finely dispersed clay matter.

As a result of selective weathering from the surface, debris is predominantly weathered with an abundance of cells, grooves, pores filled with clay. All ore is impregnated with iron hydroxides, especially the clay part.

Clay with a particle size of 0.01-0.001 mm was analyzed by thermal method. The analysis of the thermogram shows that the bulk of the clays according to the composition is kaolin-hydromica with the presence of 0.5-1% impurity of quartz and calcite, as well as iron hydroxides.

Scintillation analysis of clay shows that the maximum amount of gold is at the first level of discrimination, i.e. gold size ranges from 3 to 15 mm.

Chemical analysis of gold-containing ores showed an increased content of silicates (SiO2 up to 66-81%), aluminum oxide (Al2O3-11.5%), iron oxide (Fe2O3- 12.5%), and also K2O-2%, Na2O-0,9%.

Spectral analysis of impurity elements indicates their insignificant content.

From the jointly encountered impurities, their content does not exceed: MnO-0.09%, Mg-1.14%. Gold content averages up to 3 g / t.

The granulometric analysis of the source ores showed that the content of coarse material, represented by a set of different rocks, is 25% of the class -60 + 4 mm, with an average gold content of 0.009 g / t. In the granular part of the 40% grade -4 + 0.074 mm with an average gold grade of 0.2 g / t. The highest content of clay components is up to 35%, the gold content is on average up to 2.8 g / t.

3. Result and discussion

The results of the sieve analysis show that large classes contain an insignificant amount of a valuable component in the granular material, starting with a grain size of 4 mm, the gold content increases. Increased gold content is noted in the grade -0.074 + 0 mm [3], [4].

On the basis of the obtained results of material, particle-size and chemical analyzes of gold-bearing sands, it was established that gold is closely associated with all the minerals represented by the fine phase. It is covered with a film of iron hydroxides, limonite crusts, and also cemented by limonite and clay components. About 3-5% of gold is in the free state, in the finely dispersed state it is mainly concentrated in small classes - 0.074 + 0 mm. Extraction of gold from these types of raw materials is a rather complicated task of.

The analysis of the enrichment of these types of gold-bearing raw materials showed that the most promising is the use of effective solvents of noble metals, followed by their concentration.

In world practice, cyanide compounds are used to isolate noble metals. But there are clay refractory ores that are practically not amenable to cyanidation [5], [6].

Alternative cyanide compounds reagents, well proven in the extraction of gold, are used only on a pilot scale. The main advantages of cyanide compounds over other gold solvents are high selectivity with respect to noble metals, low consumption of reagents, high recovery of gold into the solution and its subsequent isolation from cyanide solutions, low corrosivity of the medium.

With undoubted advantages, the cyanation process is characterized by significant drawbacks. The main technological disadvantage of the cyanide process is its high leaching time. From the point of view of ecology, the disadvantages include the extremely high toxicity of cyanides of alkali metals, belonging to substances of the first class of hazard, and products of their interaction with ores. For a number of gold-producing regions, the high costs of environmental measures make the development of promising deposits unpromising. The problem of decontamination of wastewater processing plants is not fully resolved.

At present, a sufficiently wide range of solvents has been identified, which are considered as an alternative to cyanide salts in the processes of extracting gold from ore raw materials.

The search for and evaluation of noble metal solvents is made not only for environmental reasons, but also pursues other goals, for example, the possibility of processing gold-bearing ores that are difficult to leach to cyanide. In relation to this type of ore of interest is a range of solvents, among which the thiocarbamide leaching attracts the most attention. Thiocarbamide (thiourea) $CS(NH2)2$ represents a crystalline powder, which dissolves well in water. For the leaching of gold use a solvent containing 0,5-2% $CS(NH2)2$, 1% $H2SO4$, 0,3-0,4% $Fe2(SO4)3$. Iron oxide sulfate is an oxidizing agent. Ores with a noticeable amount of acid soluble minerals before leaching using thiourea must be subjected to acid processing with a following washing with water, otherwise these minerals will cause a high consumption of thiourea and, passing into solution, will slow down dissolution of gold. Processing with the use of thiourea has been held at a temperature not higher than 20-25°C to avoid excessive solvent degradation.

Thiourea pulps differ in difficult condensability and filterability, therefore during the processing of them is need to use polyacrylamide and other flocculants. Compared to cyanation, ore processing with the use of thiourea has following advantages: a higher degree of gold leaching, relatively low level of thiourea toxicity and the gold extraction from clay ores reaches 97-98%. Foreign researchers suppose that this reagent as a solvent of noble metals is the most promising for the heap and underground leaching.

Thiourea leaching is accompanied by a range of disadvantages:

- relatively high cost and deficiency of the reagent;
- need of acidproof equipment;
- significant acid consumption (120-180 kg/t $H2SO4$);
- decomposition (oxidation) of thiourea that leads to the increase of that solvent's consumption and cakes' wash till the neutral medium.

The presence of compounds of antimony, cuprum, arsenic and some other mineral impurities using thiosulfate solvents ($Na2S2O3$ with a concentration of 36 g/l; oxidizing agent $CuSO4$ 4 g/l; environment regulator – 10 g/l $NH4OH$) do not render a noticeable depressive impact on gold in leaching. For achievement of acceptable indicators for the gold extraction into solvents the increase in temperature till 100-130°C is necessary. Extraction of gold into a solvent is up to 95-97%.

As further studies have shown, thiosulfate leaching might also be implemented at lower temperatures at the expense of significant dilution of pulp (to S:L = 1:10), increase in concentration of solvent or application of combined process to ores: leaching – sorption of gold from pulp with the use of ion-exchange resins. However, such conditions lead to the dramatically increase of the reagent consumption and general ore processing expenses. Specified circumstances substantially obstruct the technological use of this reagent [7], [8].

Alkaline solutions are formed by the interaction of elemental sulfur with solutions of various hydroxides. These are multicomponent systems containing mono- and polysulfides in various ratios, metal thiosulfates, and free alkali. In the interaction of elemental sulfur with an aqueous suspension of calcium hydroxide, lime-sulfur decoction is formed. It is a cherry-red liquid containing hydrosulfide ion (HS-), thiosulfate ion S2O3 polysulfide Sn2-.

Sulfur and calcium hydroxide concentrations ranged from 25–200 g / l sulfur and from 50–200 g / l Ca(OH)2. The leaching process was carried out at room temperature for 24 hours at a ratio S:L = 1:3 in bottle-type agitators. Class -4 + 0.074 mm was crushed to a particle size of -0.074 + 0 mm and combined with small classes of the original ore.

The results of the studies showed that the dissolution of gold with an alkaline solution proceeds over the entire range of concentrations of sulfur and calcium hydroxide. The optimal composition of this solvent is the concentration of sulfur from

g / l, calcium hydroxide from 100-200 g / l, depending on the composition of the processed raw materials. The duration of leaching ranged from 5-7 hours. With the increase in the duration of the process, the extraction efficiency of gold has not changed. The residual gold content in the cakes was 0.0006-0.001 g / t.

As studies have shown, with an increase in the alkali content in the serum alkaline solution, the extraction of gold in the filtrate decreases, since the concentration of the polysulfide ion Sn2- and hydrosulfide ion HS- decreases. With increasing sulfur concentration, the transition of gold into the filtrate also decreases, since in this case, along with polysulfide-Sn2-, and hydrosulfide- HS-, thiosulfate- S O2 3 ions, sulfate SO42- and sulfide S2- ions are formed, leading to the precipitation of slightly soluble sulfates and sulfides calcium.

Extraction of gold in the filtrate was 97-98%. Cakes were obtained with a residual gold content of up to 0.006-0.001 g / t.

4. Conclusion

Chemical analysis data on the material composition of cakes indicate the selective nature of the reagent's action on the original ore. The reagent dissolves the metal, without entering into chemical interaction with other elements in the original ore (sulfur, arsenic, titanium, etc.), which are transferred to dump cakes.

The analysis results show that with the content of elemental sulfur in the initial ore up to 0.8%, its content in dump cakes varies from 0.14 to 1.14%, averaging 0.64%, i.e. actually corresponds to the content in the feedstock.

From this, it follows that in the leaching process there is no transfer of sulfur from the process reagent in the form of sulphate ions to dump cakes. Moreover, the cakes are not environmentally harmful and can be stored as substandard ores at specially prepared sites. According to the results of the research, the technological regulations for the extraction of gold from refractory ores have been drawn up [4].

Consequently, the proposed gold leaching technology has an undoubted advantage over cyan technology in both technological and environmental aspects, since it excludes such an element as storing and storing cyanide tails from the ore processing process, the need to develop special security measures when working with cyanides. In environmental terms, this technology is not dangerous to the environment and can be recommended for use in production.

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