ГЕОТЕХНОЛОГИЯ. ГОРНЫЕ МАШИНЫ

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Combining the stages of mineral deposits development

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Abstract

Relevance. *The article substantiates the feasibility of complexing the capabilities of metal mining technologies that provide for creating favorable working conditions at previous stages for subsequent development stages. In ore mining, the raw material base of mining enterprises weakens when the reserves are transferred to the inactive category. Traditional mining technology combination with innovative technologies is a priority in metal production development.*

Methods of research. *Methodologically, the phenomenon of leaching process activation is based on changing the properties of metal-containing raw materials through mechanical-chemical-physical impact.*

Results. *Stage-by-stage development of a metal deposit is characterized. Stages of mineral deposit development are summarized and typified. Quantitative indicators of metal extraction in ore processing tailings are given. The sorption process indicators in an electric field are detailed. A pattern of gold content change depending on ore piece size is established. The methods of changing the properties of minerals under various impact options are classified. An algorithm for selecting the parameters of the process of leaching metals from processing tailings is developed. It has been proven that stage-by-stage development of deposits and involvement of mixed-grade reserves of technogenic deposits into development when complexing mining operations allows varying the quantity and quality of extracted raw materials and the productive capacity of the enterprise. The research results may be in demand when upgrading technologies at existing and designed mining and processing enterprises and when strengthening the economy of depressed enterprises.*

Keywords: *technologies; metals; stage; mining enterprises; leaching; deposits; content; extraction.*

Introduction. Mineral resource base of Russia weakens because mixed-grade reserves are mined selectively and transferred to the inactive category. To speed up the marketable mineral products receipt, high-grade reserves are recovered in the first phase and poor reserves are recovered in the second phase. Metal-containing tailings form technogenic deposits in underground workings and on the earth's surface. Traditional mining technology combination with innovative technologies is a priority in metal production development. Under certain specific conditions, refuse ore and noncommercial reserves involvement can reduce the cost of metals significantly. Technologies for waste-free utilization of tailings and bringing secondary tailings to sanitary standards are proposed in a number of publications [1]. This issue's implementation shapes a global-scale problem. A solution to this problem is proposed in [2] and is based on improving the

efficiency of using activated ore processing tailings in underground mining. A systematic review of paste technology in metal mines aimed at improving the quality of raw materials is proposed in [3]. When complexing the capabilities of technologies for metals extraction from off-grade raw materials, favorable conditions are created for subsequent phases of deposit development. Mining is a complex of recovery systems, united by the economic feasibility criterion [4]. The problem under study coexists with the task of the mined underground space reuse, which is another issue of modern mining [5].

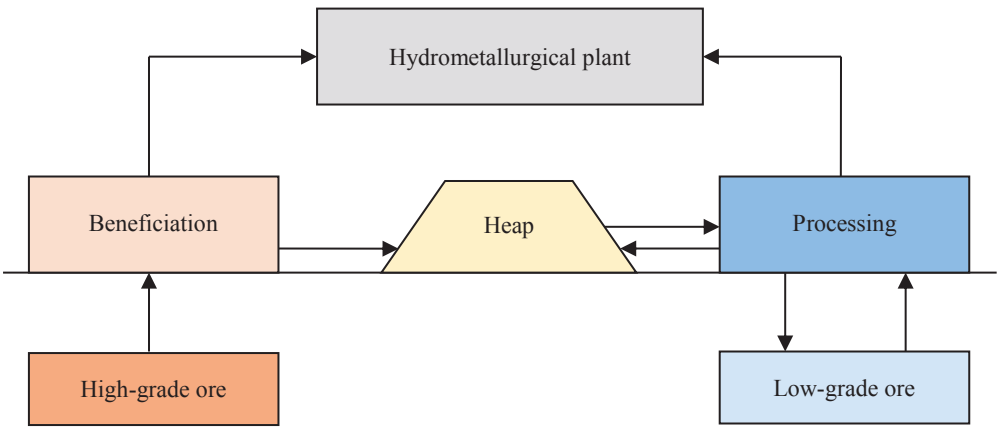

Figure 1. Combining the technologies of producing mixed-grade ores
Рисунок 1. Комбинирование технологий добычи разносортных руд

As early as in the 20th century, metals were leached from mining waste and refuse ore in the USSR, USA, Canada and other countries. Half of the metals recovered from the adjacent strata globally are mined by heap leaching [6, 7]. Works [8, 9] are dedicated to the practice leaching metals from off-grade raw materials and refuse ore. The theory and practice of photochemical and electrochemical processes in geotechnology are vastly being improved in terms of specifying them separately for groups of metals [10]. When solving 3D geoecological problems with spatial interpolation of data, national and international issues in subsoil public administration are being developed [11–12]. With greater depth of mining and worse qualitative composition of metal-containing raw materials, amount of waste increases, and the rate of technogenic deposits formation outpaces the rate of new deposits development. Recovery of metals from technogenic deposits provides real opportunities for the Russian gold base development [13–15]. When developing ore deposits with special geological and mining conditions, in course of high-grade ores advance recovery at the first stage and subsequent recovery of low-grade ores, conditions are created for recovering off-grade raw materials at the final stage of operation.

Methods of research. A study of metal recovery mechanisms and parameters at the stages of deposit development proves the possibility of solving the problem under consideration. The indicators of combined traditional and new technologies for metals leaching from low-grade ore and refuse ore are analyzed and serve as a basis for decision-making.

Changing the properties of metal-containing raw materials through mechanical-chemical-physical impact provides a methodological basis for the leaching process activation phenomenon.

The modernization is aimed at creating favorable conditions for the successful interaction of leaching reagents. The results of analytical and laboratory studies

performed according to standard practices are interpreted graphically creating a basis for recommendations on the subject matter in question. Extraction possibilities were studied on ore processing tailings at a temperature of 18–20 °C and a pressure of 760 mm Hg. Sulphuric and hydrochloric acids were used as reagents. Tailings leaching results were approximated in Excel 2007 using averaged experimental results.

Results. *The first stag*e of a metal deposit development is characterized by advance recovery of the richest sections of the deposit. During beneficiation, at least 30% of useful components are lost with tailings.

The second stage is characterized by a significant increase in the production of lower-grade ore and is aimed at maintaining the amount of metal produced. Technologies with underground leaching allow increasing production efficiency. Mining rationalization is reduced to a rational combination of the quantity and quality of ores released to the earth's surface and left for processing in situ.

The third stage is characterized by metals extraction from reserves previously considered off-grade.

Table 1. Stages of deposits development
Таблица 1. Этапы разработки месторождений полезных ископаемых

Object	Phase of work	Product	Category	Stage
Deposit	Prospecting and exploration	Ore reserves	Commercial ore	1
			Noncommercial ore	2
			Metallic rocks	3
Commercial reserves	Mining	Recoverable	Standard	1
			Off-grade	3
		Unrecoverable reserves	Temporary loss	3
			Irrecoverable loss	–
Rock mass	Beneficiation	Concentrate	Standard	–
			Middlings	3
		Tailings	Fluid	2–3
			Mature	2–3
Concentrate	Metallurgy	Metals	High-quality	–
		Tailings	Fluid	2–3
			Mature	2–3

The optimal scheme for the deposit development is the implementation of all three development stages coherent in time and space (Figure 1).

The first stage of development is characterized by a two-phase extraction of reserves. Low-grade ores in the form of pillars are left to divide the masses into safe sections or according to other process-related features. High-grade ore reserves are involved in the development by the technologies with higher technical and economic indices. Savings are achieved by transferring less capital works to future periods, when the enterprise can perform part of the work at its own expense.

The second stage of development is characterized by the involvement of reserves of lower-grade ores in the exploitation. The main object of development are previously abandoned pillars.

At the third stage, noncommercial ore in underground blocks, sorting tailings of the rock mass brought to the surface, and refuse ore from the first stages of development are processed.

Mineral extraction consists of processes carried out in a certain sequence at various stages of development (Table 1).

Deposit development technology is improved in context of the processes of exploration, mining, beneficiation and metallurgical extraction. The profitability of the enterprise is ensured either by better product quality or production growth, or by combined methods.

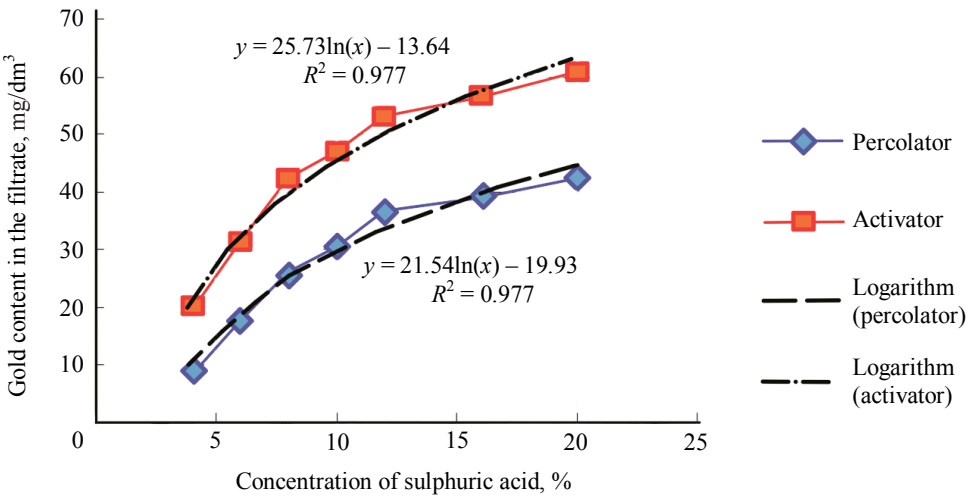

Figure 2. Indices of metal extraction into solution
Рисунок 2. Показатели извлечения металла в раствор

The possibilities of combining were studied on ore processing tailings of the following composition, %: 1.1 zinc; 0.6 lead; 1.1 copper; 20.6 iron; 1.4 calcium oxide; 1.9 aluminum oxide; 43 silicon dioxide; 6.1 sulfur; 17.1 carbon; and 1.2 g/t gold; 240 g/t silver at a temperature of 18–20 °C and a pressure of 760 mm Hg. 75% silver and 52% gold were extracted from flotation tailings [4].

Linear functions describe the curve of metal extraction into solution (Figure 2).

Sorption processes in an electric field were studied on ore processing tailings of the following composition, %: 1.1 zinc; 0.6 lead; 1.1 copper; 20.6 iron; 1.4 calcium oxide; 1.9 aluminum oxide; 43 silicon dioxide; 6.1 sulfur; 17.1 carbon; and 1.2 g/t gold; 240 g/t silver. To intensify mass transfer in the sorbent capillaries, frequencies of an alternating electric field of 5–40 Hz were used.

Sludge from an aluminum smelter containing zeolites was used as the sorbent. Electric field superposition increases the extraction of gold into solution by 1.5 times. When leaching gold from pulps, the leaching rate increases by 25–30%, and the sorption capacity of the AM-2B anion exchange resin increases by 2.5–3 times.

The maximum gold extraction into solution was recorded under the following parameters: relation between the Liquid (L) and solid (S) phases L : S = 3: 1; NaCl content – 28%; current I = 1000 A/m^2; voltage V = 4.7 V; temperature T = 76 °C; pH = 2.3; Eh = 1050 mV; time t = 3.5 h, gold extraction into solution is 85%.

Innovative technologies require guaranteed rock breaking and separation of commercial component grains from the grains of waste rock. The size of the ore pieces is determined by the leaching reagent penetration into the depth of the piece.

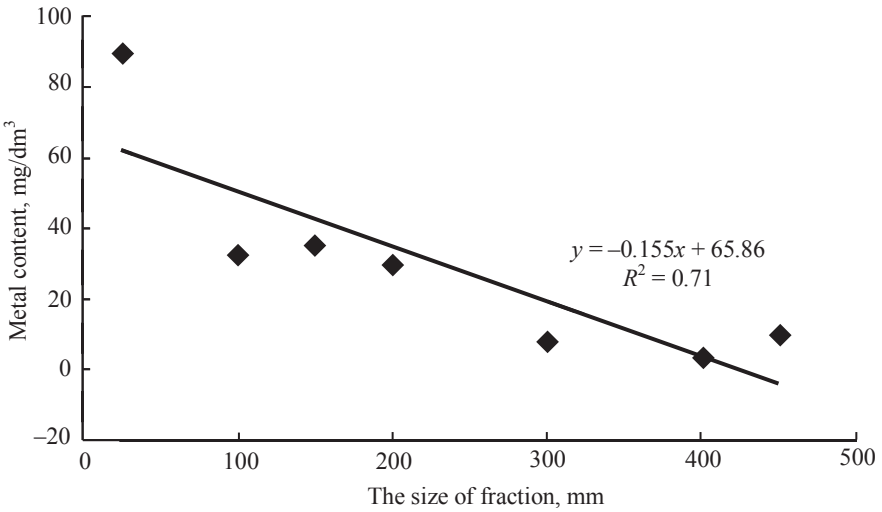

Figure 3. Gold content change depending on the size of fraction
Рисунок 3. Изменение содержания золота в зависимости от крупности фракций

For many lode deposits, the average content in oversized classes (+200 mm) is 5 or more times lower than in 0–200 mm pieces, and the total content of metal exceeds 90% of the reserves in the in-situ leaching block (Figure 3).

Table 2. Classification of the methods of changing mineral properties
Таблица 2. Классификация способов изменения свойств минералов

Classification feature	Type of impact	Variant of impact
Mechanism of mineral transformation	Mechanical	Crushing Activation
	Biological	Bacteria Bacterial metabolites
	Chemical	Reagent Electrochemical
Type of the field of force	Gravitational Magnetic Thermal Radiation	Depending on physical properties
Types of reaction agents	Acid Alkaline Saline Gas	Depending on chemical properties

The strategy of rational subsoil use is based on preparing reserves for subsequent development (Table 2). The strategy of rational subsoil use includes a permanent impact on metal-containing raw material at the stages of deposit development.

The algorithm for selecting the parameters of leaching metals from processing tailings is shown in Figure 4.

The efficiency of staged development of deposits is determined by the through coefficient of mixed-grade gold-bearing minerals extraction, which varies depending on the natural and technogenic factors of exploitation. The main production is made cheaper by marketable products created in the processes of metals extraction from waste. Processing of tailings improves ecosystem dramatically.

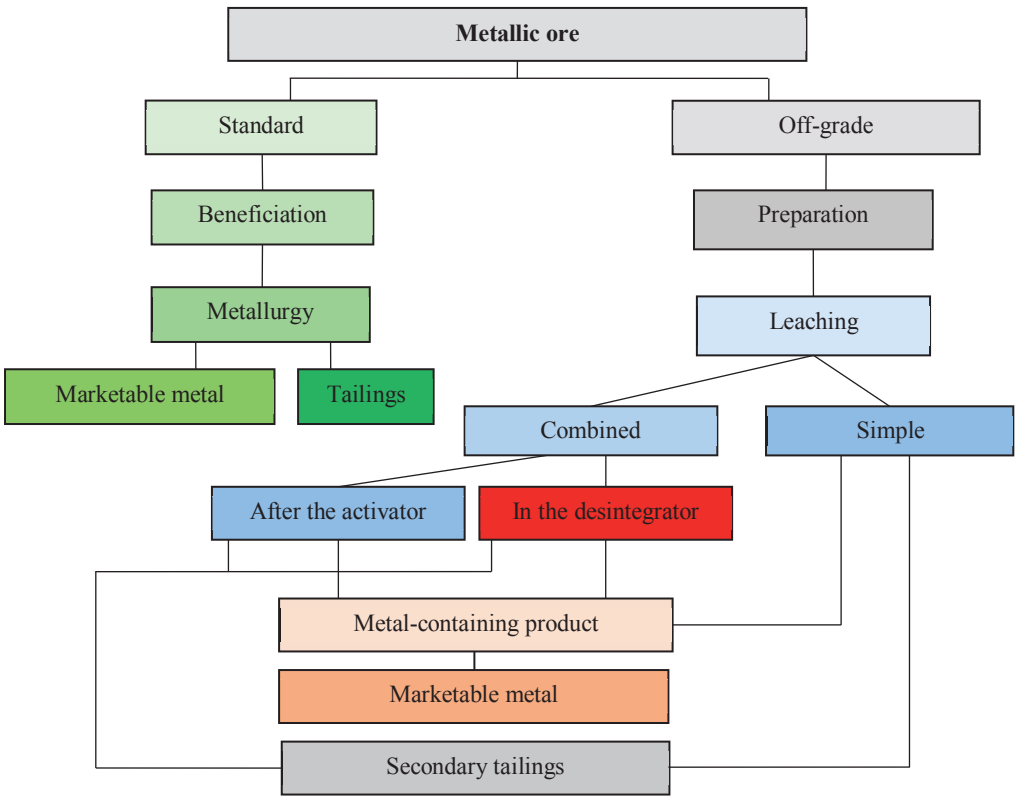

Figure 4. The scheme of metals extraction from refuse ore
Рисунок 4. Схема извлечения металлов из хвостов обогащения

Conclusion. When developing ore deposits, technogenic deposits of off-grade raw materials are created. Staged development and involvement of mixed-grade reserves of technogenic deposits makes it possible to vary the quantity and quality of the recovered raw materials and plant capacity. The efficiency of staged development is assessed by the amount of through extraction of metals.

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Особенности комбинирования этапов разработки рудных месторождений

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Реферат

Актуальность. *Статья посвящена обоснованию целесообразности комплексирования возможностей технологий добычи металлов с созданием на предыдущем этапе благоприятных условий работ для последующих этапов разработки. При добыче руд сырьевая база горных предприятий ослабляется переводом запасов в категорию неактивных. Приоритетным направлением развития производства металлов является комбинирование традиционной горной технологии с инновационными технологиями.*

Методика. *Методологической основой феномена активации процесса выщелачивания является изменение свойств металлосодержащего сырья посредством механо-химико-физического воздействия на него.*

Результаты. *Дана характеристика поэтапной разработки металлического месторождения. Обобщены и типизированы этапы разработки месторождений полезных ископаемых. Приведены количественные показатели извлечения металлов в хвостах переработки руд. Детализированы показатели сорбционных процессов в электрическом поле. Установлена закономерность изменения содержания золота в зависимости от крупности рудных кусков. Приведена классификация способов изменения свойств минералов при различных вариантах воздействия. Разработан алгоритм выбора параметров процесса выщелачивания металлов из хвостов переработки. Доказано, что поэтапная разработка месторождений с вовлечением в разработку разносортных запасов техногенных месторождений на этапах комплексирования добычных работ позволяет варьировать количество и качество добываемого сырья и производственную мощность предприятия. Результаты исследования могут быть востребованы при модернизации технологий на действующих и проектируемых горно-перерабатывающих предприятиях и при упрочнении экономики депрессивных предприятий.*

Ключевые слова: *технологии; металлы; этап; горные предприятия; выщелачивание; месторождения; содержание; извлечение.*

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