International Business Management 10 (20): 4726-4730, 2016
ISSN: 1993-5250

Combination Prospects for Ore Deposit Development Stage

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Abstract: The urgency of internal resource use concerning the conservation of mineral-raw material base of mines due to the termination of subsidies for loss-making enterprises and the limited resources for new field exploration. The principles of traditional mining technologies combination with new technologies of metal leaching from ores and tailings are described. The scheme for the selection of environmental and resource-saving technologies is proposed. The ecological and economic profit model is provided from full subsoil use increase by combining the field development stages. It was shown that the combination of technologies solves the basic problems of mining industry: the increase of extracted mineral resource amount and natural environment improvement.

Keyw ords: Mineral-raw material base, field, combination, technology, leaching, metal, tailings, subsoil, stage, environment

INTRODUCTION

Weakly predicted changes of metal market conditions and the weakening of state control with the change of enterprise ownership forms exacerbated the problem of mineral subsoil resource completeness. The development of ore deposits was characterized always by stage extraction of reserves: the rich reserves are extracted during the first stage and poor reserves are extracted during the second stage with the transfer of ore reserves in the category of inactive ones. Thus, Sadonskaya group of deposits has at least 50% of such reserves. Other fields also have the same amount of reserves or more, especially at long operated ones (Dubinski, 2013).

Due to the termination of state subsidies for loss-making enterprises and the limitation of resources for the exploration and the development of new deposits the relevance of existing internal conservation and the development reserves of mineral-raw material base at mines is increased.

A possible way out of this situation is the combination of traditional mining technologies with new technologies, such as the leaching of metals from ores in the underground blocks or piles, as well as the waste-free extraction of metals from the waste of ore primary enrichment previously thought impossible for the conventional methods of enrichment. Gold, copper and uranium have been actively leached from such resources for a long time at mining countries (Bian *et al*., 2012; Golik *et al*., 2015a).

The issues of metal obtaining from sub-standard resources develop a major problem of development stages, the essence of which is to ensure that every previous stage of field development creates some favorable conditions for the recovery of metals during the subsequent phases (Golik *et al*., 2015b).

In practice, it looks like this: mining a block with a conditioned content, an adjacent block with substandard content is prepared for mining by leaching, maintaining the communication and providing rock crushing. This approach is an alternative for today's situation when the movement of the excavation works within an ore field demands for overhead costs to restore the previously abandoned mining operations with technologically difficult access to reserves.

MATERIALS AND METHODS

The development of ore deposits is characterized by the following features:

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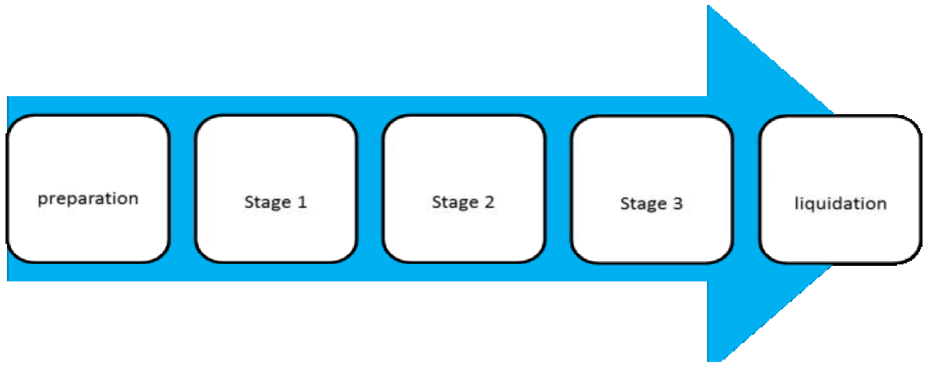

Fig. 1: Field development stages

- Man-made reserves are created on the earth surface and in the depths
- The involvement of man-made reserves in the production allows to vary them by profit using their amount and the production capacity of an enterprise
- The indicators of metal leaching technologies from industrial stocks, are better by an order approximately, so the processing costs are compensated and recovered extra metal reduces the production costs

A ining ompany oes through several stages (Fig. 1). The first stage is characterized by an advanced extraction of deposit rich sites in order to facilitate the funding through the implementation of metal. An ore bearing array is controlled by leaving pillars and the areas of low ore content and the production losses are compensated by the increase of high-grade ore production. The effectiveness of development:

$$\sum_{1}^{t}\Pi_1 = \sum_{1}^{t_1} A_1(u_1 - c_1)\Big/(1+E)^{t_1-1}$$

$$A_1 = f(3_б) = (3_O - 3y + 3_б)$$

$$\sum_{1}^{t}\Pi_1 = \sum_{1}^{t} A_1()$$

Where:

Π_1 = Profit (rub.)
A_1 = Production capacity (t/year)
u_1 = Recoverable value of ore (rub/unit)
c_1 = The cost of production and processing (rub/unit)
E = The discount rate, the shares of unit
$3_б$ = Balance ore reserves (t)
3_o = Estimated reserves of a field (t)
$3_{y+3б}$ = The reserves of poor and balanced ores

The second stage is characterized by metal content decrease in ore which is compensated by the extraction volume increase of less rich ores. One may optimize the values of subsequent steps using more efficient technologies, for example by underground and heap leaching. The effectiveness of development is the following one:

$$\sum_{1}^{t}\Pi_2 = \frac{1}{(1+E)^{\Delta t}}\sum_{1}^{t_2} A_2(u_2 - c_2)\Big/(1+E)^{t_2-1}$$

$$A_2 = f(3_y + 3_б) = (3_O - 3_б)$$

Where:

Π_2 = Profit (rub.)
A_2 = The production capacity of an enterprise (t/year)
μ_2 = The extracted value of ore (rub./un)
c_2 = The cost of extraction and processing (rub./un)
E- = Cost and profit discounting ratio, shares of un
$3_б$ = Balance ore reserves (t)
3_o = Estimated deposit reserves (t)
$3_{y+3б}$ = The reserves of poor and balanced ores

Finally, the third stage is in metal obtaining from previously unused resources: pillars, cut-off grade ores, the tailings of production and processing. The effectiveness of development is the following one:

$$\sum_{1}^{t}\Pi_3 = \frac{1}{(1+?)^{\Delta t}}\sum_{1}^{t_3} A_3(?_3 - ?_3)\Big/(1+E)^{t_3-1}$$

$$A_3 = f(?_{??} + ??) = (?o - ?_?)$$

Where:

Π_3 = Profit (rub.)
A_3 = The production capacity of an enterprise (t/year)

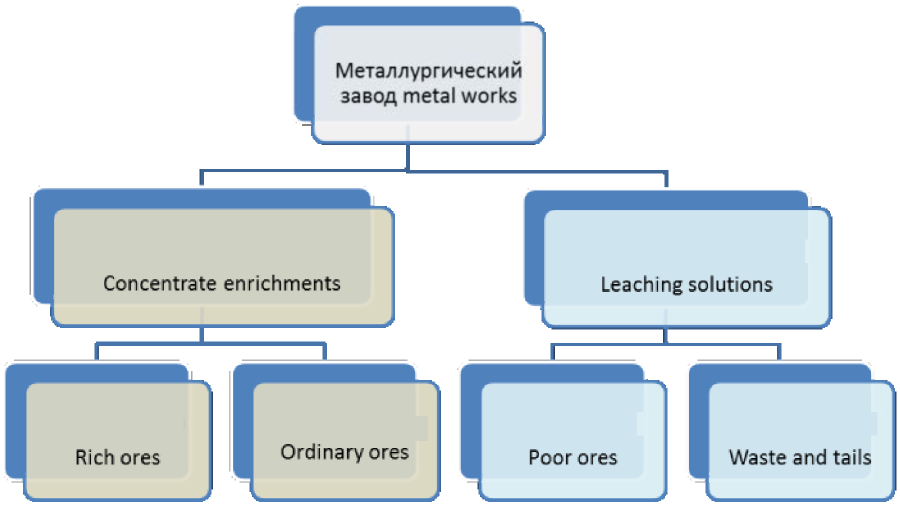

Fig. 2: Combination of mining development product scheme

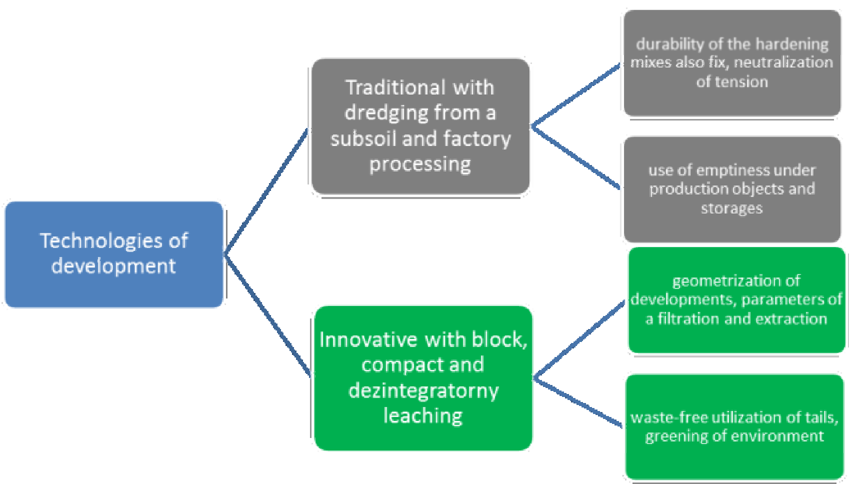

Fig. 3: Technology selection strategy for deposit mining

u_3 = The extracted value of ore (rub/unit)
c_3 = The cost of extraction and processing (rub/unit)
E = Discounting ratio, shares of un
$З_б$ = balance ore reserves (t)
$З_о$ = estimated deposit reserves (t)
$З_{зб+хб}$ = the reserves of cut-off grade ores and mine refuses

The effectiveness of a field development is determined by the completeness of stage combination in time and space (Fig. 2). To create the reasonable conditions for the introduction of all stocks in production since the selective mining of a deposit is carried out during the first years of an enterprise existence (Golik *et al*., 2015c).

The selection of environmental and resource-saving technology is carried out in conjunction of reserve exploration, production, beneficiation and metallurgical processing with the priority of rock basic properties and the prospects of their future use (Fig. 3). The indicators of metal extraction from sub-standard reserves are improved by the use of leaching innovative technologies. Leaching is performed most efficiently in a disintegrator, when the extraction of metals in a solution occurs with the reagent pressing into microcracks (Table 1) (Golik *et al*., 2016, 2015d, e).

The leaching of poor ores improves the recovery of metals to an acceptable level for economic reasons, but requires the provision of a set raw material size. The goal of ore destruction for leaching is the separation of useful

Table 1: Gold leaching by hydrochloric acid

	Hydrochloric acid concentration						
Experiments units	4	6	8	10	12	16	20
Percolator (%)	8.7	17.7	26.2	30.4	36.8	39.0	42.4
Disintegrator (%)	20.1	31.4	42.3	47.0	53.1	56.6	60.9

component grains from the grains of waste rock which is achieved at the energy consumption for interatomic bond breaking. The size of pieces is determined by the penetration period of of a leaching reagent into a piece depth. An excessive grinding of ore reduces the filtration capacity of a leaching array.

The concept of subsoil use ratio increase implies a permanent impact on mineral resources at all stages of field development. The ecological and economic profit model from the fullness of subsoil use increase by combining the stages of a field development (Golik *et al*., 2015f-h):

$$\mathbf{\Pi}=\left(M_{ey}\mathbf{\text{Ц}}_{My}+Q_y\mathbf{\text{Ц}}_{qy}\right)-\sum_{\text{з}=1}^{\text{з}}\left[K\left(1+E_{Hy}\right)+E_q+E_x\right]-$$
$$-\left[\left(M_e\mathbf{\text{Ц}}_M+Q\mathbf{\text{Ц}}_q\right)+Q_{\text{г}}\mathbf{\text{Ц}}_{\text{г}}\right]K_c K_y K_T K_{\text{б}} K_{\Gamma} K_{\text{Вр}} K_{\text{ч}}$$

Where:

- M_{ey} = The amount of metals from tailings
- $\text{Ц}_{\text{ìó}}$ = Metal price
- Q_y = The amount of restored effects
- Ц_{qy} = The price of recycled materials
- E_q = Loan interest rate for disposal
- E_x = Loan interest rate ratio for the production of metals
- E_{gy} = Interest rate ratio for environment restoration
- M_e = The amount of lost metals
- Ц_M = Lost metal price
- Q = The amount of lost effects
- Ц_q = The price of lost useful substances
- Q_{Γ} = The number of effects destructing environment
- Ц_{Γ} = Compensation costs from global destruction factors
- З = Management costs
- K = The costs of storage facility management
- K_c = The coefficient of tail self-organization
- K_y = The coefficient of leaching product leakage
- K_t = The coefficient of solution leakage distance
- $K_{\text{б}}$ = The coefficient of influence on biosphere
- K_{Γ} = The coefficient of pollution influence on adjacent regions
- K_{bp} = The danger implementation ratio in time
- K_r = The coefficient of environment destruction risk from unaccounted factors

Thus, at the combination of techniques when 40% of ore is extracted to the surface and 60% of ore is leached under the ground at the same performance by rock mass the productivity by metal is 2 times higher than at a conventional method. The productivity of a mining metal workshop is increased 1.5 times. At the increase of a metal mine productivity 1.5 times the mining performance by rock mass production makes only 40% from the traditional method indicator. In order to increase the annual reduction of mining according to a mine productivity increase 1.5 times the ore areas in simultaneous mining, increases 3 times.

In the process of combining the additional commodity products are produced: metals and non-metals; environmentally friendly secondary tails; demineralized water; chlorine, hydrogen and oxygen. During the first phase of a field development no more than 20% of the deposit reserves is produced, about 50% of low-grade ores is produced during the second stage, so the main reserves of output volume maintaining ensures the involvement in the processing of substandard raw materials for traditional technologies. The problem of extraction and ore processing technologies combining becomes a priority, solving two main problems of mining industry at the same time: the increase of extracted mineral resource amount and the improvement of natural environment condition (Bian *et al*., 2012; Franks *et al*., 2011; Golik *et al*., 2015a).

CONCLUSION

The stage development of metal containing deposits is one of the promising areas for relation humanization to subsoils and it has the prospects of realization with the increase of requirements to the environment conditions of the habitat at the use of natural resources.

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