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The economic efficiency of investment in the development of reserves of small groups of geographically contiguous gold deposits

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Abstract. The object of the research is a group of geographically contiguous low volume gold deposits. The subject of the study is an economic justification for a way to involve economic turnover to get a positive commercial result on a specially formed group of gold deposits, in which individual field development is unprofitable. A small production volume, combined with high capital and operating costs are objective reasons for the reduction in investment attractiveness of the deposits which have reserves of gold of <25 tons in the "supply and demand" chain. The economic result will be fundamentally different if the production capacity of the company is increased by combining geographically contiguous low volume deposits in the group where the total reserves of the mountain holding are represented as one deposit. A criteria was developed and it was determined that the economic and technological constraints for the deposit to enter the group would be outpacing growth of the recoverable value of reserves as compared with a decline in their gold content. Deposits of the group are rationally developed on a rotational basis with a seasonal operating mode of small mining enterprises (with an annual underground mining of 5000-50000 tons up to 100,000 tons, with private ownership> 50%), equipped with a mobile processing complex with deep processing technology on highly liquid commodity products on site. An economic-mathematical model was devised to determine the rational placement of the processing capacity of the group.A simulation was conducted and an economic evaluation was performed on the effectiveness of investments in individual and group mining projects. The simulation results show that the joint exploitation of the reserves of the group of deposits, the internal rate of return on investments exceed the rate of return of funds to the bank deposit, the return on investment is above the level of inflation. The group project complies with the strategic line of small mining companies in terms of cost recovery terms, availability of financial sources to cover expenses, provision of stable means of income and obtaining competitive advantage.

1 Introduction

Gold mining companies have no competition in product sale, since gold is a standardized commodity with almost absolute liquidity. According to the agency Thomson Reuters GFMS, the total volume of global demand for gold is more than 4100 tons. Gold is widely used in electronics and pharmacology, but the traditional and the largest consumer of it (with a share of aggregate demand consistently above 50%) is the jewelry industry. The relationship between its supply and demand on the part of the gold mining industry - the most stable of the world gold market segments - is a key factor in determining the price of gold. The largest consumers of gold are India and China, the undisputed leader among the gold-producing countries which also increases its production volumes on an annual basis. Gold is a popular investment vehicle. Against the background of high risks of inflation in the major developed economies, central banks hold a growing share (11-13%) in the structure of demand[1-4].

2 The relevance of the task to be solved

In Russia there are about 30% of proven gold (with the total balance reserves of over 39 million ounces of metal) in the undistributed fund, concentrated in about 100 small sources of gold (with gold reserves of up to 800 thousand ounces) [5]. The reason lies in the fact that individual exploitation of these georesources is unprofitable [1, 6-9], due to the small production volume, arising from the need to comply with the normal depreciation life of the mining enterprise, which is not sufficient for the payback on the production costs. Considering the problem of growth of the gold production in Russia as a relevant state-significant program, it can be argued that the solution to the problem of increasing investment demand for low volume raw mineral sources of gold by reducing the level of costs and payback period of investment will increase the amount of metal handed over to

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GOKHRAN in the next 10-20 years to 650-970 thousand. ounces annually.

3 The theoretical part

According to Taylor's formula relating the rational development period T (years) of the deposits with its reserve balance reserves M (t)

$$T = \frac{\sqrt[4]{M}}{5}$$

specific cost value (capital, operational and organizational) are reduced with an increase in the value of reserves ΔM. Consequently, the way to increase the commercial efficiency of operation of small deposits is to form (including to account for licensing and the creation of a group of auction items) a group for joint operation [10-13].

Mixing ores with the same gold content, but with different enrichment might be disadvantageous when separated [14-16].Gold content a_Σ (g/t) in the total reserves of the group of deposits MΣ is calculated based on the content of gold α_i (i = 1 ... n) and the reserve amount in different deposit group M_i (t)

$$a_\Sigma = \frac{M_1 a_1 + M_2 a_2 + ... + M_n a_n}{M_1 + M_2 + ... + M_n}$$

The deposit may be included into the group for joint exploitation under the condition that upon joining its reserves with that of the group, the criteria shown in equations (1) and (2) are met

$$\frac{M_\Sigma}{M}\frac{a_\Sigma}{a} \geq \frac{Y}{Y_\Sigma} \quad (1)$$

where is the economic efficiency criterion of separation of ore mixture

$$\mathrm{Y} = \left[\frac{Q\,(C_{dob} + C_{usr} + C_{ob})}{\mathrm{y}} + C_{T1} + C_{T2} + \Sigma C + C_{met}(\beta) \right] \varepsilon_{met}(\beta) \quad (2)$$

here M - available reserve of the basic gold deposit α; Q–processed ores; C_{dob}, C_{usr}, C_{ob} - cost of production, averaging and enrichment of 1 ton of ore, respectively; y - concentrate output; C_{T1}, C_{T2} - the cost of transportation of 1 ton of ore to the mill and 1 ton of concentrate to the transport hub; $C_{met}(\beta)$ –the cost of production of metallurgical processing of 1 ton of concentrate from its β content of gold; ΣC–other expenses for 1 ton of ore; ε_{met} (β) –extraction of gold with metallurgical limits depending on the quality of concentrate. The geological and technical parameters of the gold deposit, «Pavlik» (Magadansk region) were used as the base for the economic and mathematic model.

The profitability of extracting gold (R) depends on the sum of expenses on extraction and enrichment of the ore (3), the gold content in the ore (αΣ), gold extraction (εΣ) at the mill, transport costs (bS), the price of 1 g of gold (C_{Au}) and mathematically related equations of the models (3)-(5):

$$R\left(\alpha_\Sigma, S, \varepsilon_\Sigma\right) = f\left[\left(C_{Au} \times \alpha_\Sigma \times \varepsilon_\Sigma\right) \times (3 + bS)^{-1}\right] \quad (3)$$

$$\varepsilon_\Sigma\left(\alpha_\Sigma, R, S\right) = f\left[R \times \left(C_{Au} \times \alpha_\Sigma\right)^{-1} \times (3 + bS)\right] \quad (4)$$

$$\alpha_\Sigma\left(\varepsilon_\Sigma, R, S\right) = f\left[R \times \left(C_{Au} \times \varepsilon_\Sigma\right)^{-1} \times (3 + bS)\right] \quad (5)$$

The practical significance of the model (3)-(5) is the ability to determine the optimal placements of the mills within the deposit groups, based on the calculation of the maximum distance for ore transport considering the acceptable economic damage for the subsoil user (given the profitability).

4 The results of economic-mathematical modeling

The reduction of unit cost with an increase in production capacity of the mining company was proven (Fig. 1) with the analysis of the investment plans to develop a series of deposits in the Northern-Eastern regions of the Russian Federation.

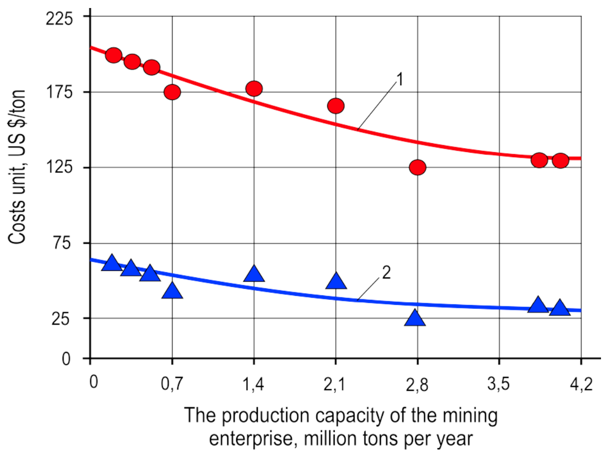

Fig. 1. Unit cost as function of production capacity of the mining enterprise, 1 - Capital expenditures for the annual processing of ores; 2–unit exploitation costs for drill, extraction, enrichment and transport.

Figure showing the unit costs as a function of the production capacity of the mining company

From the simulation calculation results of the models (5)-(7) it is deduced that it is rational to place the mills near the deposits with the most extraction significance in terms of reserves (Fig. 2).

Table 1. Results of the efficiency evaluation of investment in mining projects.

Item no	Name of indicator	Individual processing of georesources from Petinikan-Bastachsky Square							Joint developmentofgroup
		Oreoccurrence 1	Oreoccurrence 2	Oreoccurrence 3	Oreoccurrence 4	Oreoccurrence 5	Oreoccurrence 6	Industrialplacers	
1	The volume of sales (Q) of gold in thousand ounces	22.645	135.935	65.207	19.309	45.058	163.459	4.516	456.129
2	The average weight selling price of gold P, $ per ounce of gold equivalent	1275	1275	1275	1275	1275	1275	1275	1275
3	Revenues from sales (TR) of gold, $ mln.	28.872	173.317	83.139	24.619	57.449	208.410	5.758	581.564
4	The total cost (AISC) of production of gold, $ mln.	32.9	108.7	52.3	27.8	65.6	130.0	5.8	376.3
5	Operating costs for drilling, extraction, transportation and refining, $ mln.	25.9	66.6	32.1	21.8	51.6	79.3	4.2	266.8
6.	Capital costs for extraction and enrichment, $ mln.	7.0	42.	20.2	6.0	14.0	50.7	1.6	109.5
7.	Net present value (NPV), $ mln.	-2.1	34.0	16.2	-1.7	-4.3	41.2	-0.02	107.8
8.	Profitability index PI of discounted investment	-0.61	+1.43	+1.64	-0.60	-0.63	+1.70	-0.04	+3.77
9.	Discounted payback period (DPP), years	Doesnot payoff	5	5	Doesnotpayoff	Doesnotpayoff	6	Doesnotpayoff	5
10.	Thediscountrate E%	-	15	15	-	-	15	-	18
11.	Internal rate of return IRR,%	4.3	26.3	28.4	4.2	4.5	29.2	14.7	35.2

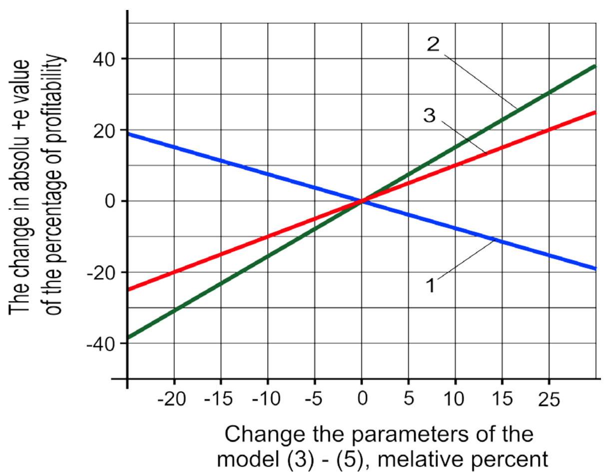

Fig. 2. The affinity of the profitability of the project to changes in the transportation distances of the ores (1), its gold content (2) and its extraction at the mill (3).

The methods described in [1, 5, 17, 18, 19, 20], were used to conduct a simulation of the individual and group exploitation of geographically contiguous low volume gold deposits and the waste from the alluvial gold mining on Petinikan-Bastachskaya square (Yano-Kolyma gold-mining province). The georesources of the group are treated as a single deposit site (single auction item), the reserves of which are developed by small mining enterprises of the holding. Raw material processing facilities are absorbed consequently just as the mining system on a rotational basis with a seasonal mode of operation. Collapsible mobile processing complex (CMPC) is used a processing unit, which reduces capital costs by 25%. The complex is equipped with CMPC technology to obtain the commercial product at the site in the form of fused gold ligatures, which thus reduces the costs of refining.

The simulation results show that for the transition from individual to joint development of deposits, the overall economic effect is significantly positive, the total gold reserves of the groups provide a return on investment within acceptable terms for the investor, the internal rate of return on capital investment exceeds the rate of return from the placement of funds into bank deposit, which in turn favours growth of investment demand for low volume deposits.

5 Conclusion (findings)

A cost-effective way to operate geographically contiguous gold deposits with small reserves is their joint development into a single auction lot. The economic criteria for the selection of the deposit in the group is to anticipate the growth of recoverable value of inventories as compared to the decline in gold content. The optimal location of the processing capacities within the group is determined by the model, linking economic and mining parameters of gold production.

It is rational to develop deposits in the group on a rotational basis with seasonal operation mode of small mining enterprises, equipped with mobile enriching complexes with deep processing technology to obtain a highly liquid commercial product on site.

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