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Research Article

SUBSTANTIATION OF RATIONAL METHODS OF EXCHANGE AND LOADING WORKS DURING THE MINING OF RESERVES OF SMALL-SCALE GOLD DEPOSITS

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ABSTRACT

Studies have been carried out to determine the optimal bench height, recommendations have been made to improve the completeness of extraction of gold-bearing ore and recommended excavation and loading equipment for small-scale deposits. The change in the values of losses and impoverishment of the ore, as well as the gold content in the ore, depending on the height of the ledge for various thicknesses of ore bodies, has been established.

KEYWORDS

Berm, understep, ore losses, dilution, ore body thickness, ore reserves, gold content in ore, extraction efficiency, excavator, front loader.

INTRODUCTION

When developing gold deposits using traditional methods, a bench height of 10-15 m is the most commonly used in mining practice, while economically justified values of losses and impoverishment are achieved, as well as the gold content in the mined ore. When using this development system, a sufficiently high productivity of mining and transport equipment is ensured. And when developing small-scale deposits, the situation will change radically. When working off low-power ore bodies, the metal content in ore mined with a traditional ledge height of 5-10 m may be so low that ore processing will not be profitable, and it will accordingly be taken to the dump of off-balance ores or waste rocks. In such cases, it is necessary to consider the possibility of excavation of ores and rocks with the introduction of appropriate changes in the parameters of the development system, or rather in the height of the ledge.

High values of losses affect an increase in the share of redeemable fixed assets in the costs of mining, and dilution of ore affects its value, metal recovery rates during enrichment and, ultimately, the cost of final products.

One of the most important ways to increase the efficiency of subsurface use in the development of small-scale deposits is to reduce economically unjustified losses and dilution of ore during extraction.

MATERIALS AND METHODS

One of the main elements of the development system is a ledge. The height of the ledge, in turn, is an important parameter that affects the qualitative and quantitative indicators of mineral extraction.

In the practice of designing, building and operating quarries, it is always necessary to determine the height of the ledges in accordance with specific mining and geological conditions, mining capabilities and a number of other factors that require consideration to determine this important parameter.

When designing , such factors should include:

- The size of the mineral productivity and the duration of a stable period at this level: deadlines for achieving the selected or specified productivity with minimum construction time and volumes of mining and capital works;
- The calendar distribution of the volume of work on the rock mass is the most advantageous for this productivity;
- Minimum costs for the sum of the main processes for the excavation of 1 m3 of rock mass; technological equipment that meets these conditions and productivity;
- The grade and quality of the extracted mineral, and so on.

In other words, the entire main range of issues related to the design of the quarry must be solved in conjunction with the determination of the optimal height of the ledge.

The problem of optimizing the parameters and designs of the sides of quarries is inextricably linked with the possibility of radically reducing the costs of operating the field as a whole, by reducing the volume of stripping operations, or increasing the share of mining the reserves of the field in an efficient open method, with an economically feasible stripping coefficient.

Currently, the existing regulatory documents and accepted methods for assessing the stability of the slopes of ledges and sides of quarries are based mainly on the provisions of soil mechanics and at one time

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were developed mainly for relatively shallow quarries in the conditions of massifs represented by loose or fragile sedimentary rocks.

The spread of these methods to rocks is accompanied by an excessive margin in the calculations of the design of the sides and ledges. Instructions for choosing the height of the ledge are not given either in the norms or in the methods of technological design of quarries. As a result of the analysis of past studies, the existence of two directions in the study of the height of the ledge was revealed: the first is based on the accounting of technical indicators, the second is based on the method of technical and economic analysis. The height of the ledge is determined and is usually assigned to be constant for the entire period of mining the quarry. It is more correct to assume that the height of the ledges should correspond to the conditions of the quarry development in each of its periods of operation.

When developing small-scale gold deposits, electric and hydraulic excavators of direct and reverse ladles of small volumes, as well as front loaders, are used as the main excavation and loading equipment for stripping and mining operations. Currently, there is a new, more productive and functional mining equipment, for which there is no feasibility study of the height of the ledges.

According to the provisions ingrained in the science and practice of open-pit mining, the complex of basic mining and transport equipment should ensure systematic, in accordance with the capacity of the cargo flow, preparation of rocks for excavation, their excavation and loading, movement, storage within each technological zone of the quarry in which the cargo flow is formed. When choosing the means of excavation and transport, the following basic requirements for equipment complexes should be followed:

1. The complex of equipment should include only machines whose passport characteristics correspond to the mining and technological characteristics of rocks during each process.
2. The complex of equipment must comply with the accepted systems of development and opening, the size and shape of the quarry, its capacity, construction and operation period, organizational conditions of mining operations.
3. The smaller the number of operating machines and mechanisms included in the complex, the more reliable, productive and economical its operation.
4. Individual machines and mechanisms of the complex in their parameters must correspond to each other, be standard and serial, so that they can be replaced.

In addition, the remoteness of deposits from engineering infrastructure, limited ore reserves and small capacities of ore bodies, which characterize the features of mining small-scale gold deposits, it seems, should also be taken into account when choosing excavation and loading equipment. Based on this, the following additional requirements are imposed on equipment and technology:

- The equipment must be mobile, not requiring the construction of separate access roads;
- There is no need to lay engineering communications (power lines, industrial water lines, gas pipelines, etc.);
- The possibility of using transport equipment in combination with other loading equipment (for example, the use of front loaders at the quarry);
- To ensure maximum extraction of ore while preserving its natural quality.

In modern regulatory sources, there are practically no methodological provisions and recommendations for

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choosing the height of the ledge and the dredging and loading equipment for the development of low-power ore bodies of small-scale deposits. In many small-scale deposits with approximately the same mining and geological and mining technical conditions, losses differ by 2-3 times, and, conversely, in deposits with unequal mining and geological conditions and different ore values, they are practically the same. One of the reasons for this situation is the application of the same parameters of the mining system and the height of the ledge without taking into account the specific conditions of the occurrence of ore bodies, their structure and the ratio of the value of the extracted mineral to the costs of mining and processing of ore. In our opinion, optimal indicators of losses and dilution of ore, maximum preservation of the initial metal content in the extracted ore are achieved by reducing the height of the mining ledge when mining ore bodies of low power.

The determination of the optimal height of the mining ledge is proposed to be determined by the proposed graphoanalytic model developed in the Microsoft Office Excel program. A schematic diagram for determining the losses and dilution of ore in the contact zones and a schematic diagram for an ore body with a capacity of 6 m, when mining an ore block with a 5 m high ledge, as well as two 2.5 m sub-steps is shown in Fig. 1.

In this paper, the values of losses and dilution of ore are investigated on the basis of the above methodology for ore bodies with a capacity of 2, 4 m and 8 m without changing the balance reserves of ore and metal. At the same time, the height of the ledge varies in the range: 6, 5, 4, 3, 2,5 m and 2 m .

The developed model makes it possible to simultaneously determine the values of losses and dilution in the contact zones, both for the ledge and for the approach. The basis for the implementation of all the above calculated data is the methodology for determining the indicators of losses and dilution for the conditions of small-scale gold deposits, developed by associate professor A.B. Tukhtashev and O.I. Zhabborov, coordinated with the regional inspectorate for the control of mining and geological activities "Samarkand-Bukhara" of the State Committee of the Republic of Uzbekistan for Geology and Mineral Resources.

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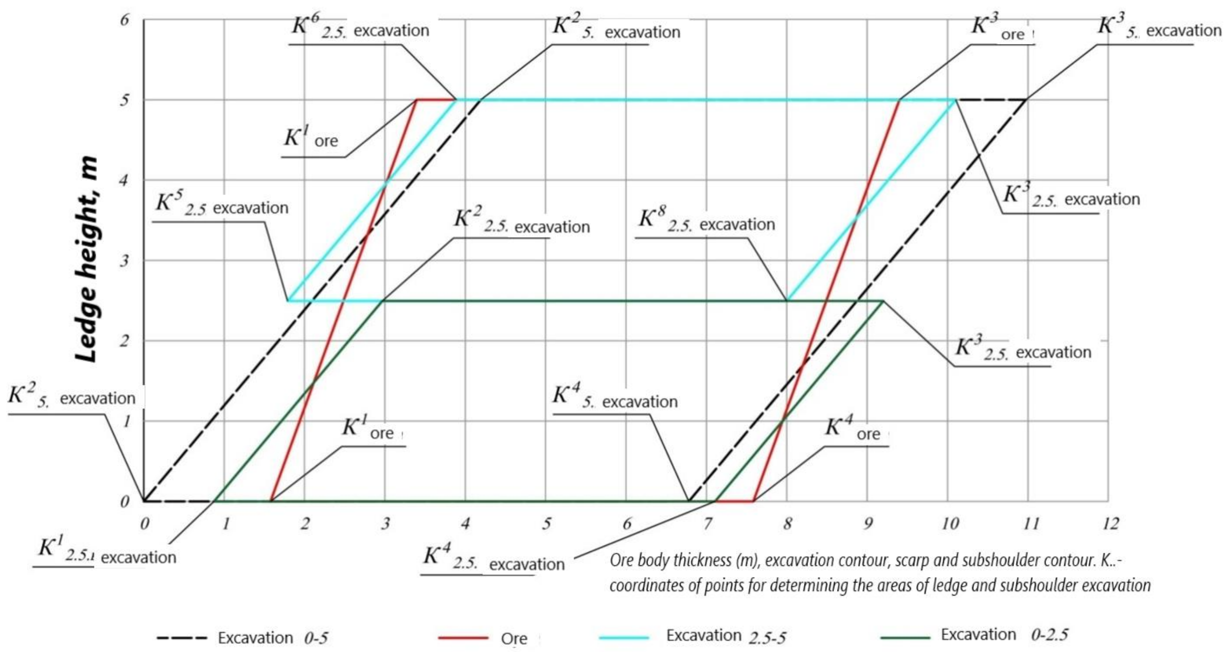

Fig. 1. Schematic diagram of the determination of losses and dilution of ore.

In the calculations, the parameters of loss and dilution are determined depending on the influencing factors in the form of a function:

$K_n(K_p)=f$ (Э, h_y, m, α, β, Δ) (1)

where Э – passport characteristics of the excavator;

h_y – berm height, m;

m – average ore body capacity, m;

α – angle of incidence of ore bodies, degrees;

β – angle of slope of the excavator face, deg.;

Δ – grip power, m.

To simplify the task , the following initial parameters are conditionally accepted in the calculations:

1. Ore density ρ = 2,6 *m/m³*;
2. The angle of incidence of the ore body α = 75°;
3. The height of the ledge h_y = 6 m (а также 5, 4, 3, 2,5 и 2 *m*);
4. The angle of incidence of the slope of the excavator face (conditional) β = 50°;
5. Ore body capacity m = 2, 4 *m* и 8 *m*;
6. Ore reserves, B= 2 500 thousand tons;
7. Metal reserves, $M_{геол}$ = 4 000 *kg*;
8. Average metal content in ore C = 1,6 *g/t*.

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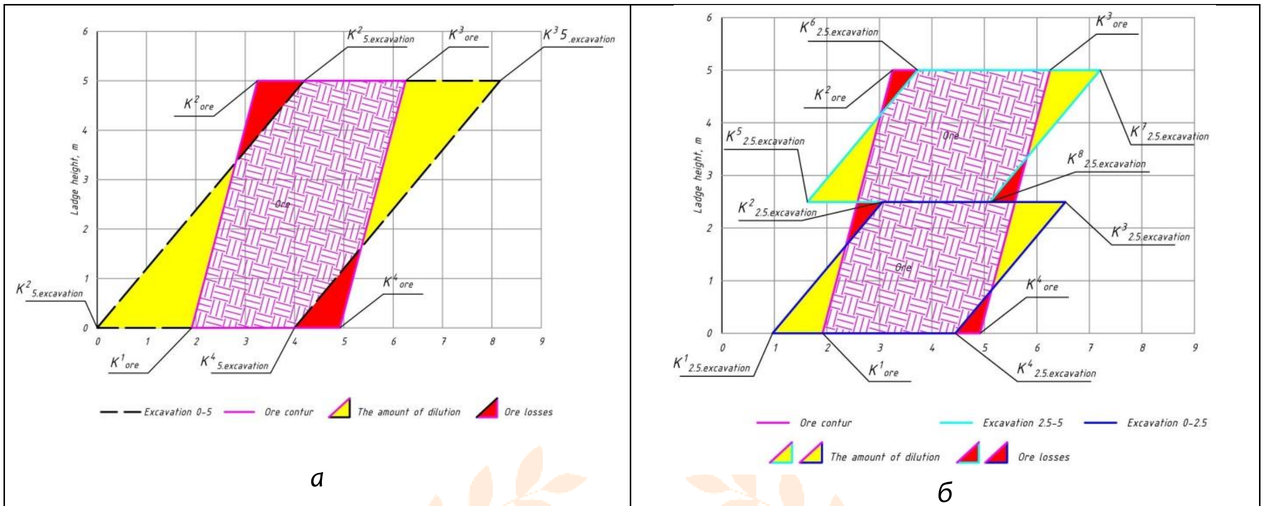

Fig. 2. Schematic comparison of the areas of losses and dilution of ore at the height of the mining ledge of 5 m (a) and 2.5 m (b) at the capacity of the ore body of 4 m

According to the above initial parameters, using the proposed model, a calculation was performed for each considered ledge height and graphoanalytical data were obtained at the ore body thickness of 2, 4 m and 8 m.

Figure 2 shows a schematic comparison of the areas of losses and dilution of ore at the height of the mining ledge of 5 m and 2.5 m with the capacity of the ore body of 4 m.

As can be seen from the above, with a decrease in the height of the ledge from 5 m to 2.5 m, the areas of losses and dilution decrease, which eventually form the basis of the values of losses and dilution.

THE MAIN PART

In order to justify the choice of a rational type of excavation and loading equipment for mining small-scale gold deposits, calculations and comparison of the performance of a single-bucket hydraulic excavator and a front loader with different indicators of the height of the ledge were made (Table 1)

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Table 1

Comparison of the performance of a hydraulic excavator and a front loader with a bucket volume of 6 m^3 when changing the height of the ledge

№	Name	Ledge height, m									
		10	9	8	7	6	5	4	3	2,5	2
1.	Annual performance of the excavator gidravlic excavator Vк = 6m³, thousand m³/year	1 533	1 497	1 453	1 401	1 337	1 257	1 153	1 013	924	816
2.	Annual performance of the front loader c Vк = 6m³, thousand m³/year	1 351	1 326	1 298	1 267	1 230	1 188	1 137	1 071	1 031	982

Based on the calculated data obtained, the dependence of the annual productivity of a hydraulic excavator and a front loader with a bucket volume of 6 m3 in various operating conditions with a change in the height of the ledge from 2 to 10 m is constructed (Fig. 3).

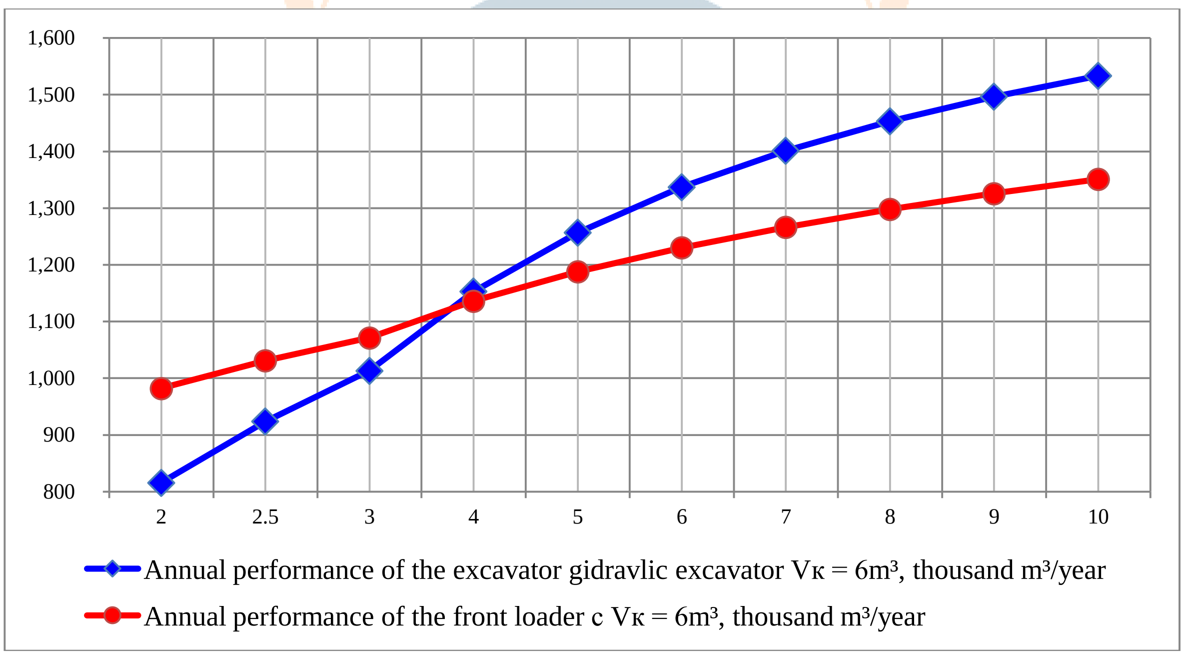

Fig.3. Change in the performance of a hydraulic excavator and a front loader with a bucket volume of 6 m3 when changing the height of the ledge from 2 m to 10 m

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RESEARCH RESULTS

After performing calculations according to the developed algorithm, we obtain the corresponding values of losses, dilution and operational parameters of the ore for the conditionally accepted initial parameters, which are given in Tables 2, 3 and 4.

Table 2
Calculated indicators of ore loss and dilution at the ore body capacity, m=2 m

Ledge height, m	Involved geological reserves			Losses, П, %	Dilution, P, %	Operational stocks		
	Ore reserves, thousand tons	Average. content, g/t	Metal, kg			Ore reserves, thousand tons	Average. content, g/t	Metal, kg
6,0	2 500,0	1,6	4 000,0	18,80	48,60	3 949,42	0,82	3 248,0
5,0				15,60	43,10	3 708,26	0,91	3 376,0
4,0				12,50	36,90	3 466,72	1,01	3 500,0
3,0				9,50	29,60	3 213,78	1,13	3 620,0
2,5				7,90	25,60	3 094,76	1,19	3 684,0
2,0				6,30	21,30	2 976,49	1,26	3 748,0

Table 3
Calculated indicators of ore losses and dilution at the thickness of the ore body, m = 4 m

Ledge height, m	Involved geological reserves			Losses, П, %	Dilution, P, %	Operational stocks		
	Ore reserves, thousand tons	Average. content, g/t	Metal, kg			Ore reserves, thousand tons	Average. content, g/t	Metal, kg
6,0	2 500.0	1,6	4 000,0	9,40	29,70	3 221,91	1,12	3 624,0
5,0				7,80	25,80	3 106,47	1,19	3 688,0
4,0				6,30	21,40	2 980,28	1,26	3 748,0
3,0				4,80	16,70	2 857,14	1,33	3 808,0
2,5				4,00	14,20	2 797,20	1,37	3 840,0
2,0				3,20	11,60	2 737,56	1,41	3 872,0

Table 4
Calculated indicators of ore loss and dilution at the ore body capacity, m=8 m

Ledge height, m	Involved geological reserves			Losses, П, %	Dilution, P, %	Operational stocks		
	Ore reserves, thousand tons	Average. content, g/t	Metal, kg			Ore reserves, thousand tons	Average. content, g/t	Metal, kg
6,0	2 500,0	1,6	4 000,0	4,70	16,80	2 863,58	1,33	3 812,0
5,0				3,90	14,30	2 803,38	1,37	3 844,0
4,0				3,10	11,70	2 743,49	1,41	3 876,0
3,0				2,40	8,90	2 678,38	1,46	3 904,0
2,5				2,00	7,50	2 648,65	1,48	3 920,0
2,0				1,60	6,10	2 619,81	1,50	3 936,0

On the basis of the calculated data obtained, the dependence of the change in the indicators of loss and dilution of ore at the thickness of the ore body m = 2 m, m = 4 m and m = 8 m is constructed (Fig.4).

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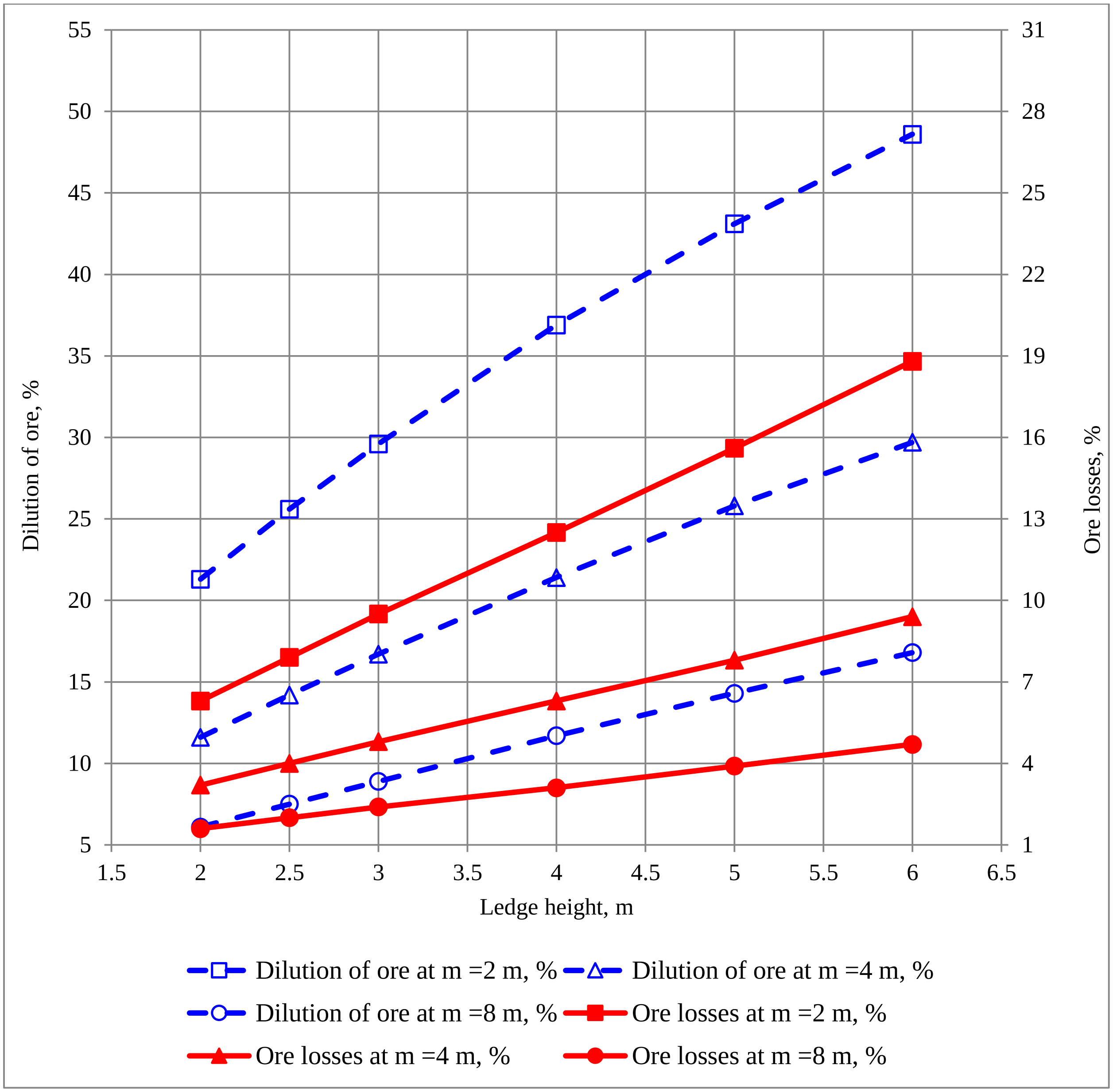

Fig.4. The change in the indicators of loss and dilution of ore depending on the height of the ledge at the thickness of the ore body m = 2 m, m = 4 m and m = 8 m.

As can be seen from Tables 2, 3 and 4, as well as Fig. 4, with a decrease in the height of the mining ledge, the following positive results are achieved:

1. The reduction of ore loss values is achieved by almost three times.

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2. With the traditional method of mining an ore body with a capacity of m = 2 m, the height of the mining ledge hu = 5.0 m, the production metal is obtained Me = 3,376.0 kg, with an average metal content in the ore – 0.91 g / t, and with a height of the ledge hu = 2.0 m, it is Me = 3,748.0 kg of metal with an average metal content in the ore 1.26 g/t thereby the ore becomes profitable for processing at hydrometallurgical plants with an onboard content of 1 g/t and below or at heap leaching sites.
3. The decrease in the volume of processed ore is 731.77 thousand tons, an increase in the amount of extracted gold by 372 kg.

Reducing the height of the ledge has not only positive indicators, but also some disadvantages:

1. Reduced productivity of the mining and transport complex involved on the thoracic ledge.
2. The volume of auxiliary work on the sinking of split trenches will slightly increase and the rate of deepening of the quarry will decrease.
3. Reducing the height of the ledge to 2.5-3.0 m and below requires the use of special excavation and loading equipment, or changing the technological schemes of mining ore blocks.
4. On the basis of the calculated data obtained, the dependence of the annual productivity of a hydraulic excavator and a front loader with a bucket volume of 6 m3 is constructed. It is recommended to use front loaders in the conditions of working off ledges (approaches) at a height below 4 m.

CONCLUSION

Based on the work carried out, the following conclusions were made:

1. The choice of a rational ledge height for the development of small-scale gold deposits is of current scientific and practical importance for the mining industry and requires further detailed study.
2. To reduce losses and impoverishment at the stages of pre-project and design work for each small-scale deposit, it is necessary to choose the optimal height of the mining ledge depending on the thickness of the ore body and the metal content in the ore, and also consider options for selective mining of ore bodies of small thickness with the introduction corresponding changes in bench height and consider various options for the level of completeness of extraction of ore reserves with the introduction of appropriate changes in bench height.
3. The excavation and loading equipment must be selected depending on the height of the ledge, respectively, the elements and parameters of the development system must be determined depending on the parameters of the mining and transport equipment.
4. For mining ore bodies with a thickness of 2 m, the height of the mining bench should be 2 m, with a thickness of ore bodies of 4 m, respectively, 3 m, with a thickness of ore bodies of 8 m, the height of the mining bench should be 5 m.
5. From Table. It follows from Table 1 that with a ledge height of 2 m and a gold grade in geological reserves of 1.6 g/t, the content in the mined ore is 1.26 g/t, while the ore becomes profitable for further processing at the hydrometallurgical plant GMZ-2 of the Navoi MMC or in the heap leaching area.
6. The excavation and loading equipment must be selected depending on the height of the ledge, respectively, the elements and parameters of the development system must be determined

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depending on the parameters of the mining and transport equipment.

7. For the development of ore bodies of low thickness, it is advisable to reduce the height of the mining ledge from 2 to 4 m; it is recommended to develop such an excavation unit with a front loader.
8. When mining ledges with a height of 4 m and above, the generally accepted technology of excavation and loading operations with hydraulic excavators seems to be optimal.

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