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Loss and Dilution Optimization of Valuable Minerals in Mining Complex Structured Limestone Deposits

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Abstract: *The paper analyzes kinds of losses of basic valuable minerals in mining complex structured limestone deposits. Diagrams of loss of valuable deposits and the blend of waste rock are also made in mining bedding deposits. Technical and economic data explaining for the proper decrease of the loss show that raising the dilution or loss needs to base on the comparison of mining alternatives fulfilled in the contact area of waste rock and material. Norm of loss of valuable mineral is created to determine the technical and economic of each mining block using geological exploration documents. The criterion of maximum NPV of mined deposit should be used to determine the norm of loss of valuable mineral. In addition, the paper proposes a technology to ensure a proper use of mineral resource and to decrease the loss of valuable loss in mining complex structured limestone deposits.*

Keywords*: loss, dilution, limestone deposits, NPV;*

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I. INTRODUCTION

Almost limestone deposits are bedding and lens. Complex structured limestone deposits, which are inserted by the limestone layers containing standard grades and nonstandard grades as well as the change of valuable grades and unvalued grades, of bedding and thick within the limestone deposits, are characterised by mine geology and mining technology

The degree of complexity of structure of mined rock blocks are featured by the complex ratio of geological structure. This ratio is determined in mining the block by the equations:

$$\bar{\varphi} = \frac{\sum_{i=1}^{i=p} \varphi_i}{p} , \qquad (1)$$

When: φ_i – Complex ratio of geological structure of geological section i[th] of the mining block.

$$\varphi_i = \frac{L_{ki}\,\omega_{пр}}{s_i} , \qquad (2)$$

When: L_{ki} – Total contact length of the limestone body, which meets the standard, and the waste within geological section i[th], m; $\omega_{пр}$ - Thickness of the overburden within the layer of the valuable ore or thickness of the limestone layer which meets the standard within the waste layer in the case of the excavator is used, m; s_i – Area of geological section i[th], м^2; p – Number of geological sections in the mining block.

It can be seen that the ratio $\bar{\varphi}$ shows the correlation between the total area of contact layers within all sections of the mining block and total area of all geological sections

$$\bar{\varphi} = \frac{\sum_{i=1}^{i=p} \omega_{пр} \cdot L_{ki}}{\sum_{i=1}^{i=p} s_i} . \qquad (3)$$

II. Loss and blend of valuable ore:

Loss of valuable ore in open pit mining is classified into general loss and mining loss.

General loss includes the loss due to protection areas, boundaries, protection pillars, mine slopes, and the loss underneath haulage berms, and the loss due to mine geological and hydrogeological condition as well as the loss due to other reasons.

Mining loss includes the loss related directly mining, depending on mining technology and mining operation management at the contact area between ore body and interburden. This loss is determined by percentage variance with the industrial reserve and in a certain period.

Classification of design loss, normal loss and scheduled loss is in need. Valuable ore loss is related to the design and hence, it is determined in mine design. The degree of both general loss and mining loss is determined in mine design. The degree of general loss do not change frequently. Mining loss can be changed depending on geological condition, management and mining technology.

Normal loss of valuable ore is used to determine economic and technical factors for each mining block according to exploration databases. The part of industrial reserve will be recovered by this loss.

Scheduled loss is determined for a part of or entire deposit that meets mining plan in various mining period, corresponding with the normal loss being approved.

According to analytical method of equivalent material model, the paper determines the most typical features of loss categories in complex structured limestone deposit mining as followings:

❖ Loss exists at the floor of mined limestone layer where sandstone and argillit are available. This limestone layer is left for the convenience of excavators in moving and parking, as well as the avoidance of the swell of the below argillit layer;

❖ Loss exists at the floor of the mined limestone layer where dolomite and unvalued limestone are available. This limestone layer is left so that the blend of value and unvalued limestones can be avoided;

❖ Mining loss of the industrial limestone (is determined by the percentage of mine volume);

❖ In the area where the thickness of overburden is large, the loss of limestone exists at protection pillars which are used to support the overburden above, avoiding the landside because of the unstability of the overburden;

❖ Mining loss of industrial limestone is at the karst area.

III. Optimization of loss and blend

In mining industrial limestone deposit, the thickness is not variable and the boundaries with the waste layers below and above are clear, the determination of blend is not necessary. Optimization of blend and loss of valuable ore contributes to reduce mining cost and increase revenue and profit of mining enterprises.

$$\Delta A = f(L, D).$$

Where: ΔA – An increment of volume of end products in mining which is made in mining by reducing the loss and the blend; L – Ore loss; D – Ore blend.

Theoretical factual foundations of economy and technique for reducing the loss by increasing the blend or rising the loss by decreasing the blend must base on plans making comparisons in the mining area where is the contact between the ore and the waste. In mining complex structured and horizontal layered deposits, the loss factor for contact layer i^{th} of ore and waste is determined as the equations below: [1-5]

$$K_{\Pi_i} = \frac{h_{T_i}}{\sum_{j=1}^{N} M_{pj}}, \qquad (4)$$

Where: h_{Ti} – Thickness of valuable ore being lost at the contact part i^{th}, m; M_{Pj} – Vertical thickness of ore layer j^{th}, m (j = 1, 2, 3, ..., N); N – Number of mining ore layers.

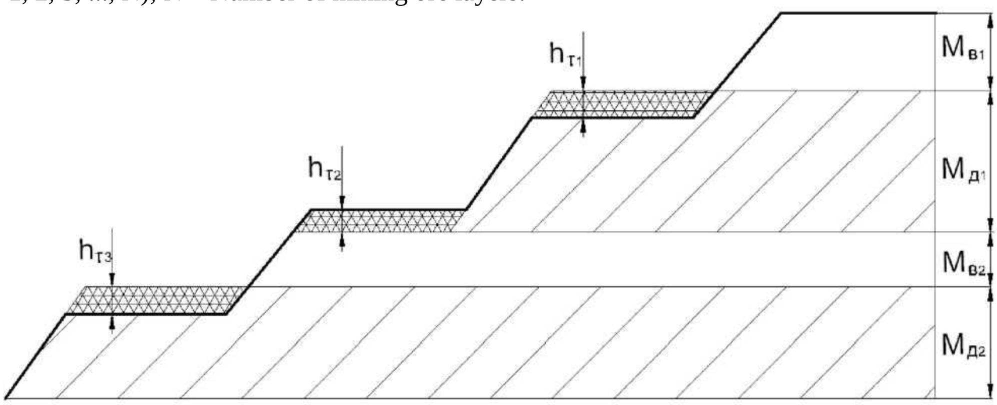

Figure 1. Diagram of determination of valuable ore loss

M_b – Thickness of waste rock (or interburden) or unvalued ore layers (m)

If n layers is mined individually, the loss factor due to the contact between the layers is:

$$K_{П} = \sum_{i=1}^{n} K_{Пi}\ , \tag{5}$$

Blend factor due to the waste rock in the contact layer i[th] is:

$$K_{ПР_i} = \frac{h_{П_i}\gamma_B}{\gamma_P \sum_{j=1}^{N} M_{pi}}, \tag{6}$$

Where: $h_{Пi}$ – Thickness of waste layer i[th] being blended, m; γ_B – Density of waste rock being blended, t/m^3; γ_P – Density of ore t/m^3; M_{Pj} – Vertical thickness of ore layer j[th], m.

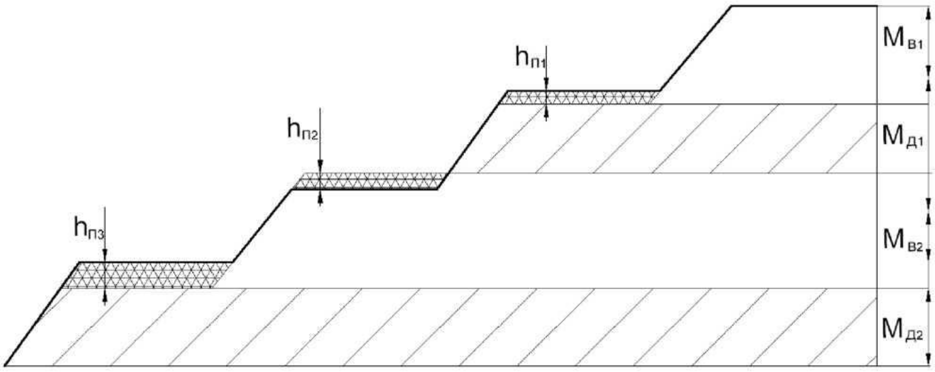

Figure 2. Diagram of determination of waste rock being blended

$h_{Пi}$ – Thickness of waste layer i[th] being blended, m
If n layers is mined together, the loss factor due to the waste mixing is:

$$K_{ПР} = \sum_{i=1}^{n} K_{ПРi}\ , \tag{7}$$

The loss due to a limestone layer being left at the seam floor for ensuring the movement and parking of excavator is determined as followings:

$$П_1 = L_F A_3\, h_T\, \gamma_P\ , т. \tag{8}$$

Where: L_F – Mining length due to a excavator being responsible, m; A_3 – Cut width, m; h_T – Thickness of the valuable ore layer being lost, m.
Limestone loss at kart areas:

$$П_2 = A_{ПU} \cdot K_3\ . \tag{9}$$

Where: $A_{ПU}$ – Volume of commercial limestone according to mining schedule, T; K_3 – Karst factor.
Loss of the limestone at the protection pillars which are used to support the above overburden and to prevent the landslide because of the unstable overburden.

$$П_3 = L_C\, W_C\, h_C\, \gamma_p\ ,Т. \tag{10}$$

Where: L_C – Total length of protection pillars being left, m; W_C – Width of protection pillar, м; h_C – Height of protection pillar, m.
Optimal values of loss and dilution of valuable ore are determined based on the standard – Net present value of ore deposit mining or annual average profit is maximum considering mining alternatives in a period which is one year or less than.
Loss factor $K_П$ and blend factor $K_{ПР}$ are determined as followings: [1]

$$K_п = \frac{L}{B}, \tag{11}$$

$$K_{пр} = \frac{D}{B}. \tag{12}$$

Where: L – Ore volume being lost of the industrial reserve, t; B – Ore volume being mined of the industrial reserve, t; D – Waste rock volume being blended, t.
Ore volume being mined actually according to the mining plan:

$$A_{ПУ} = B(1 - K_П + K_{ПР}), \text{ t.} \quad (13)$$

Recover cost price of a specific product is calculated to be:

$$S_R = \frac{S \cdot \varepsilon \cdot A_{ПU} \cdot \alpha_T}{B}, \text{ \$/t.} \quad (14)$$

Where: S – Selling price of end product of enterprise, \$/t; ε – Recovery factor of valuable elements of ore in concentrating; α_T – Grade of valuable elements of ore being mined.
Grade of valuable element within the valuable ore is:

$$\alpha_T = \frac{B(\alpha_b - \alpha_b \cdot K_П + \alpha_P \cdot K_{ПР})}{A_{ПU}}, \text{ \%.} \quad (15)$$

Where: α_b – Grade of valuable element within the industrial reserve being mined; α_P – Grade of valuable element within the waste rock being blended.
Total cost being calculated individually of end product is

$$C_b = Z_{sum}(1 - K_П + K_{ПР}), \text{ \$/t.} \quad (16)$$

Where: Z_{sum} – Specific total cost for ore mining and processing.
Net present value (NPV) gained by mining the ore deposit: [6-10]

$$NPV = \sum_{t=0}^{T} \left[(S_{Rt} - Z_{bt}) A_{ПUt} + A_t - K_t \right] \frac{1}{(1+E)^t}, \text{ \$} \quad (17)$$

Where: A_t – A part is extracted for the depreciation; K_t – Investment capital during t years; E – Discount ratio; T – Number of years (t = 0, 1, 2, …, T).
Average value of net value is used to choose a right mining plan:

$$NC = (S_R - Z_b) A_{ПU} \cdot 0{,}5\ K_o E, \text{ \$.} \quad (18)$$

Where: K_o – Investment cost to gain the designed mining capacity in k years; E – Discount ratio.
Normal loss ratio and normal blend ratio are determined as followings:
Normal loss ratio:

$$K_{ПН} = K_П \cdot 100 \text{ \%.} \quad (19)$$

Normal blend ratio:

$$K_{PH} = \frac{\alpha_b - \alpha_T}{\alpha_b - \alpha_P} \cdot 100 \text{ \%} \quad (20)$$

or

$$K_{PH} = \frac{B \cdot K_{ПР}}{A_{ПU}} \cdot 100 \text{ \%} \quad (21)$$

IV. CONCLUSION AND RECOMMENDATION

In limestone mining, there is the loss at the floor of industrial limestone layer (up to 60 %), at safety berms (up to 30%) and within the Karst area beside the other basic types of loss. Calculation of loss is done by measuring on geological documents or surveying.
In order to ensure the right use of mineral reserve and the reduction of ore loss in complex structure limestone mining, it is necessary to be interested in:

- The floor of industrial limestone layers underneath the mining level needs to leave a limestone layer (up to 0,5 m in thickness) in order to ensure the safety for excavators moving and loading;
- The floor of industrial limestone layers above the mining level needs to leave a limestone layer (up to 0,4 m in thickness) in order to prevent the blend of unvalued limestones.

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