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ANALYSIS OF ORE LOSSES AND DILUTION FACTORS IN BAUXITE UNDERGROUND EXPLOITATION

Majstorović Slobodan[1], Tošić Dražana[1]

[1]*University of Banja Luka, Mining faculty Prijedor, Bosnia and Herzegovina*
e. mail. majstorovicslobodan@yahoo.com

ABSTRACT

In this article are presented the analysis of ore losses in bauxite underground exploitation as well as the manner and possibility to increase recovery factor of ore deposit and exploitation with minimum of diluted ore with overburden. The largest losses of ore are the caracteristics of the mining process itself and the results of model studies of the ore losses and recovery for the various parameters of sublevel - transverse caving method are given in the article.

Key words: *ore losses, ore recovery, mining method*

INTRODUCTION

At the present time the undergound exploitation of bauxite is primary for ore deposits of high quality, resulting that the high quality ore was mixed with ore of lower quality from the open pits, which yielded the optimum quality of ore at the entrance of the plant for ore processing (alumina). It is therefore very important that such high quality ore deposits are excavated with little grade of ore losses, and less ore impoverishment or ore dilution. The ore impoverishment presents an increase of overburden content in final excavated ore and bauxite exploitation is defined in a very important parameter that directly determines the recovery (losses) in ore deposit [1]. Bauxite is mineral ore which goes to the processing without prior preparation, and as such raw material is limited by content of undesirable waste components. As the first is content of CaO (usually CaO max 1.5%) and SiO2.
For underground exploitation of bauxite is characterized the sublevel caving method in different variants. Depending on the physical and mechanical characteristics of the ore and surrounding rocks, the size and shape of ore bodies in the bauxite deposits used the two main variants of sublevel mining methods.

1. Sublevel- tranverse mining method with roof caving, which applies in ore deposits in the conditions of roof of poor physical and mechanical characteristics, such as marl, marly limestones and clay, or in conditions of solid roof with strong discontinuities [2]. This variant of mining method is characterized by the high losses during the ore deposits excavation that range from 30% to 50% (g_r = 0,3 to 0,5), and increased dilution of final ore with waste material.

2. Sublevel transverse mining method with open excavated areas, it is posible to apply in conditions of the solid and stable roof rocks and for limited size of ore body. In the case of

larger ore bodies the open spaces significantly increases causing the stresses in the roof which exceed the allowable value, with caving of roof rocks. For this variant the very low losses in ore excavation is characterized, which range from 2% to 5% (g_r= 0,02 - 0.05), without ore dilution and diminished security due to work in the conditions of uncontrolled open excavated area.

GENERAL CHARACTERISTICS

The ore losses which occur in the underground exploitation of deposit can be divided into:

1. Ore losses as result of the natural character of deposit, where they belong:

a. The ore losses from irregular shape of ore body.

According to the appearance in nature the bauxite deposits can be:

- Bauxite deposit in one ore body,
- Bauxite deposit in the group of more small ore bodies.

According the form of appearance the bauxite ore bodies can be divided in shape as: lens, sink, bags, pocket, nest, irregular columnar and layered. These names of deposit shapes were imposed by the forms of depression in the floor rocks where is ore and reflect the essence of ore body shapes and therefore their usage is completely justified. For each form of ore body the certain ore losses are characteric for ore that remains in the inaccessible parts of the ore body [3].

b. The losses due to to the variable thickness and size of the ore body

According to the structural and morphological characterics, size and economic importance of bauxite deposits are classified into the following groups:

Group 1: deposits which have a certain stratigraphic level, an aread greater than 60000 m^2, irregular stratification and the average thickness of over 1.8 m
Group 2: deposits which have a certain stratigraphic level, an area of 30000 to 60000 m^2, irregular stratification and the average thickness of over 1.8 m^2
Group 3: deposits which have a certain stratigraphic level, an area of 10000 to 30000 m^2, nested lens. shaped form, and the average thickness of over 1.8 m
Group 4: deposits, which have a certain stratigraphic level, an area of 2000 to 10000 m^2, an irregular shape and an average thckness of over 0.5 m
Group 5: deposits which have a certain stratigraphic level, an area up to 2000 m^2, irregular shape and average thickness of over 0.5 m

The ore losses is expressed in irregular layered deposits when ore remains in depression of foot contact. In the lens deposits as with other forms of irregulat deposits there are parts of deposit of small thickness, which remain inaccessible for excavation. This problem is expressed in conditions of application of robust mining equipment in the stopes, where parts of the deposits less than 0.8-1.2m remain unexcavated.

c. Ore losses from hanging and floor paleorelief

Hanging wall and foot paleorelief is very strong, most often there are overlying or underlaying "rock pyramid" which significantly influence the ore losses during when floor excavated and cave, or rock is mixed with ore and increase losses.

The ore losses as result a natural character of deposit can be partially (limited) have a influence of the apapropriate parameters of stope (floor height), as well as the application of stope mechanization that is in accordance with the size of the ore body (small machinery for small ore bodies).

2. Ore losses during the ore body excavation depend on the physical and mechanical characteristics of the ore and surrounding rocks, methods of excavation and contact of ore and the surrounding rocks, where they belong:

a. Ore losses during roof caving or excessive dilution ore with overburden.

The occurrence of these losses is mainly related to the application of sublevel tranverse caving method in the conditions of unstable or weathered rocks. The weathered rocks present the rocks of poor physical and mechanical characteristics, as well as a very solid cracked rocks. Unstable roof is formed under the hard poor cracked rocks in case of the increased sizes of the open stope when caused tensile stress in immediate roof exceeds the tensile strength of the immediate overlying rocks. This phenomenom is manifested as occurance of the block wedges in the immediate roof and caving.

Caving of excavated stope is usually to 2m, rarely total caving. In order to prevent caving of rock materials directly into the stope is common to that in the old work (caved materials) leaves a protective panel of bauxite ore, which temporarily protects the stope from direct breakage of caved materials (Figure 1).

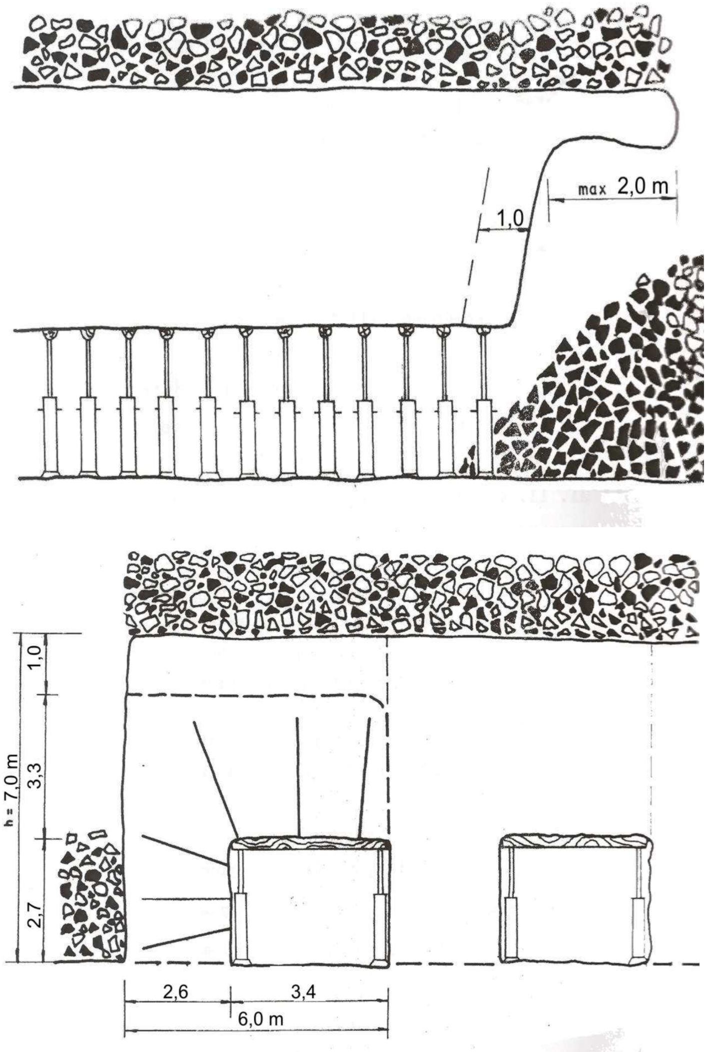


Figure 1. Sublevel caving with transverse excavation

The protective panel of bauxite depends on mechanical and structural characteristics of ore and is usually 0,8 to 1,0 m thick, while maximum length of the protective panel is about 1,5m. In the conditions of poor mechanical and structural characteristics of the ore it is not possible to leave a protective panel, which causes increasing of ore losses.

Ore losses during immediate roof caving on such case that caved material is mixed with blasted ore on the stope, and the ore loading with waste material. When the waste materials had reached a maximum required value in excavated ore then loading stop and the unloaded ore presents a loss. Maximum required amount of waste material in excavated ore depends on the quality of excavated ore and the demands of alumina where the ore processed. The calculation of losses based on the method of blocks, whereby the ore impoverishment expresses by reducing of useful minerals content (Al_2O_3) [4].

$$O_r = \frac{(m - m_1)}{m}$$ - The dilution factor

m - Al_2O_3 content of the ore block
m_1 - Al_2O_3 content of ore from ore blocks

$$g_r = 1 - \frac{T_1 \cdot m_1}{T \cdot m}$$ - The factor of ore losses

T- quantity of ore in the ore block
T_1- quantity of ore from the ore block

The results of the measurement and the calculation of losses and dilution of ore at the stope presented in Figure 1, is given in Table 1.

Table 1. The results of ore losses and dilution factor for stope

No. of measurement	1	2	3	4	5
O_r (%)	2,3	3,2	2,9	1,5	2,7
g_r (%)	58,0	42,0	35,0	37,0	32,0

The measurements No. 1 and No. 2, are carried out in the conditions of protective bauxite panel caving while the measurements No.3, No. 4 and No. 5 was carried out under conditions of normal excavation with a protective panel.

MODEL TESTING

By determination of the optimal design parameters of mining method obtained the best values of parameters of deposit recovery and dilution of the excavated ore. Model testing on the models of similarities are conducted in the order to determine of the optimal parameters of sublevel caving in function of ore body recovery and dilution of ore. During the research on models of similarity the certain principles must be respected based on the similarity that must exist between the occurrance of the models and those that occur in nature [5].

The requirement of similarity can be achieved only if all the parameters that characterize the system can be obtained by multiplying the parameters of the model with a constant, implying the size of the material (ore and overburden) with which is the experiment performed.Minimum allowable size of material should be such as to preserve the existence of the physical and mechanical properties of materials [4].

$$n_{dop} < \frac{\tau_n - f \cdot \sigma_n}{c_n}$$

τ_n - the main tangential stresses of particles
σ_n - principal normal strain
f - coefficient of friction
c_n - the adhesion force

When choosing a scale of model it is necesarry that scale to be as small as possible where conditions and the results were as close to natural. For proposed parameters of blocks, caving methods of excavation and loading and transport equipment adopted in scale 1:20. Model is transparent lastic and the edges are reinforced with the metal angles. Model charged with bauxite ore, whick is a block of ore that is excavated and with overburden material from the roof of the ore body mixed with ore. That is caved old work. It is very important that the grain size distribution of ore and waste material is proportional to the actual situation and adopted the scale 1:20. Simulation of mining ore block is performed by moving a part of output model which represents the stope drift by withdraw for the length which is equal to adopted width of blasting (*b*). By withdrawal of stope drift for blasting width leads to collapse of the excavated block parts above the drift and pillar toward to the old work area, with "blasted" ore and the part of earlier caved waste rock and waste rock from the possible new caving. Ore loading is carried out with model bucket with dimensions in scale 1:20, and characterictics of load and transport mechanization at the stope [6].

The size of these losses in ore excavation by the natural characteristics of the ore and overlying rocks is significantly influenced by technical parameters of sublevel mining method and the important effects are:

- Floor height (h)
- Width of blasting panel (b)

The influence of these parameters was studied on the modeling models of similarities were performed three sets of the experiments:

The first series of experiments: h=6 m

1. b =1,0 m
2. b =1,5 m
3. b =2,0 m

A second series of experiments: h=7 m

1. b =1,0 m
2. b =1,5 m
3. b =2,0 m

The third series of experiments: h=9 m

1. b =1,0 m
2. b =1,5 m
3. b =2,0 m

For each series of experiments for ores from drifts is pure ore without impoverishment, and load of blasted ores is done until waste rock material appears on the stope. The resulting ore is pure ore (T_c) and on the basis of it, ore recovery is determined

$$i_r = \frac{T_c}{T}$$

T_c- quantity of ore from drifts and stope (till apperance of waste rock) for blasting width (b),
T- quantity of ore in excavation block $T = b \cdot h \cdot š \cdot \gamma$ (t).

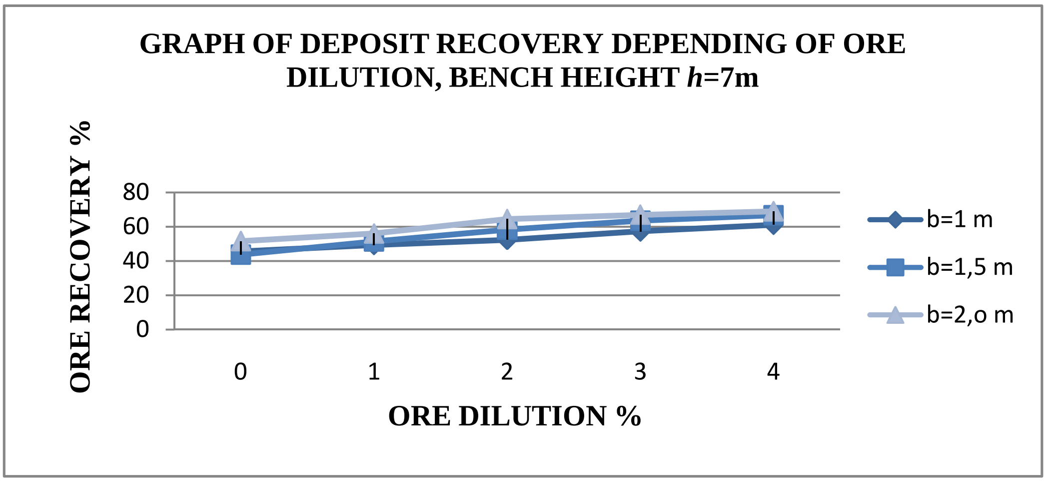
Then the load continues, separation and weighing of the ore and overburden performed, and waste rock from the relation of amount of waste rock which is separated and total amount of ore, the coeffient of recovery is determined by

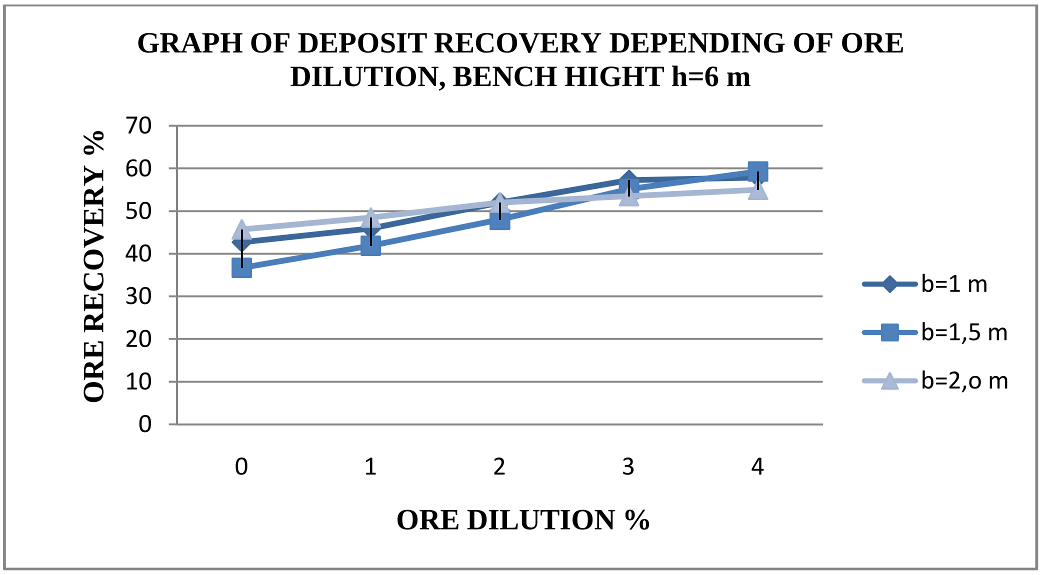
$$O_r = \frac{T_j}{T_r}$$

The results of the model tests are given in Table 2, and Figure 2, where a series of different experiments give a value of ore recovery for different values of the dilution factors with presented the best values from each of them.

Table 2. The results of model research

h (m)	*b* (m)	Ore recovery factor (i_r), %				
		O_r= 0.0%	O_r= 1.0%	O_r= 2.0%	O_r= 3.0%	O_r= 4.0%
6	1,0	42,7	45,9	52,0	57,3	57,9
	1,5	36,7	41,9	48,0	55,2	59,3
	2,0	45,7	48,5	52,0	53,5	55,0
7	1,0	45,5	49,2	52,3	57,2	61,0
	1,5	43,7	51,3	58,3	63,5	66,7
	2,0	51,6	56,0	64,5	67,0	69,0
9	1,0	54,5	61,5	67,3	72,2	76,7
	1,5	63,5	67,0	69,5	71,5	73,0
	2,0	58,7	62,5	66,0	69,1	71,5





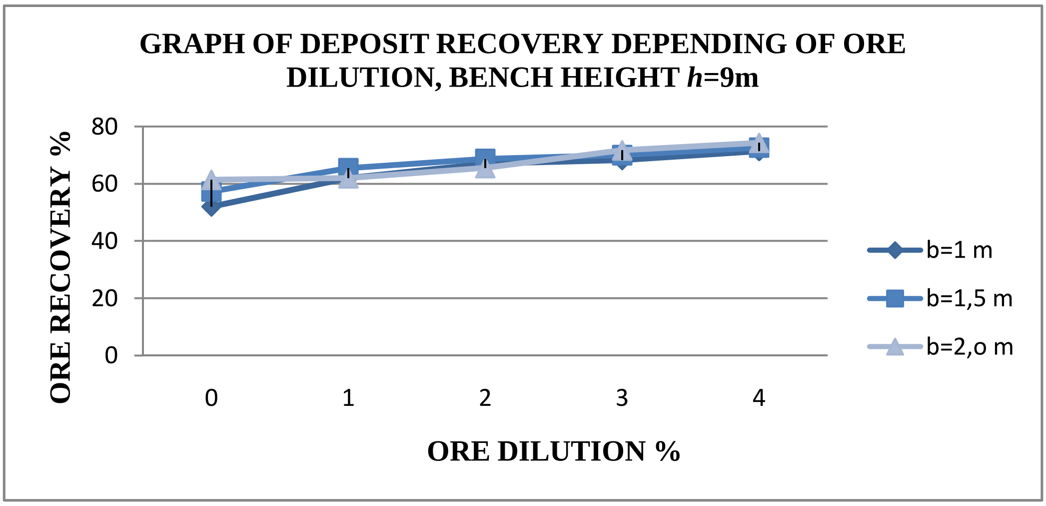


Figure 2. Three graphic display of recovery of ore, depending on the ore dilution

a. Ore losses which be left in the pillars toward to the old stopes in the case of suddenly breakage to the stope.

In the cases of larger roof rock caving and protective bauxite panel into the stope, the activities on the stope is interrupted, stope retreats and protective pillar width 1.0 to 1.5m leaves toward the caved part of stope, where they formed a new stope and continuous with the excavation [7,8].

CONCLUSION

Recovery coefficients and dilution in bauxite underground exploitation are technical and economic parameters of special importance, primary because the underground mining methods used for exploitation of mainly high- quality and high-quality bauxite deposits.

The losses due to natural character of the ore body where losses belong due to irregular shape of the ore body, the variable thickness, size and hanging wall and floor paleorelief must be separately analyzed for each ore body, so that the selected parameters of mining method and stope mechanization correspond to the natural character of the ore body.

Sublevel transverse method with open stope is very acceptable according to the recovery factor (i_r = 0.98 to 0.95) and dilution factor (O_r=0), but the application of this mining method is limited to a small ore bodies in hard and solid immediate hangingwall.

The sublevel transverse mining method with caving is characterized by high losses during the excavation of ore deposits that range from 30% to 50% (i_r = 0,70 to 0.50) and increased dilution of ore with overburden. The research of the model similarities show that for the certain parameters of mining method can be significantly improved the recovery factors of deposit, however, the problem of completely caving of open stope with hangingwall of uniform size distribution. In practice, this condition is very difficult to achieve that is necessary to carry out the more research in terms of replacement of these mining methods.

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