ASSESSMENT OF UNDERGROUND MINING COPPER DEPOSIT "BREGU I GESHTENJËS"

UDC: 553.43(496.5)

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SUMMARY

In the last 20 years, the mineral extraction industry in Albania has experienced a significant decline. The main reasons for this decline have been the lack of market for these minerals. Nowadays, several new copper deposits have been evaluated but it is worth underlining that the amount of mineral reserves in these deposits has been limited. Although the constant interest in these copper deposits, from foreign and domestic companies, still today, there is a lack in investments for opening new mines in these deposits. The main reason is the limited amount of copper ore in these deposits. This paper analyses the mining assessment of one of these copper deposits with about a million tons of extracted mineral reserves. Based on the geological medium of this deposit and the continuity of the ore bodies, the mining method and the dimensions of the mining units have been selected which, due to the concrete conditions, realize a high annual production of mineral with low mining loss indicators. The impacts of indicators of mineral losses and dilution in the breakeven cutoff grade in mineral processing and operative cost in extraction of one ton concentrate are estimated.

Keywords: Copper deposit, restricted mineral reserves, mineral losses and dilution.

INTRODUCTION

Copper deposits in our country are mainly located in the north part of Albania, with the exception of copper deposit in Rehova district, located in the south-east. Today in Albania there are more than 20 mineralized copper deposits, with total geological reserves of 22 million tons and with an average grade of 1.4 % Cu (Shushku B. etc, 2015). Some of these deposits are under mining activities and most of them are in the phase of feasibility study. Since the amount of geological reserves for each of

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these copper deposits is limited in quantity, there is little chance that these copper deposits will be taken for exploitation. One of these copper deposits is the deposit called “Bregu i Geshtenjes” that belongs to the known copper mine Rehova.

Before some data on the technical and economical assessment of this copper deposit is shown, a briefly discussion on the main factors that determine whether an ore deposit is to be taken for exploitation is presented. Generally speaking, the main factors for a feasibility assessment are (1) grade of metal in ore bodies (2) the size of the deposit (3) mining technology (4) accessibility and (5) social development and environmental requirements where the new mine will be located.

Starting from the last point, social development and environmental requirements where this copper deposit is located do not cause any obstacles to starting a new mining activity. Considering the low-income and the lack of employment opportunities, the community of Rehova welcomes the realization of a new mining activity. Meanwhile, residents of these villages have worked for more than 15 years in mining and geological activities performed in this district and do possess good professional skills in this area. Currently the environment in this area has undergone noticeable negative changes from mining activity. The negative physical changes, especially from surface mining activity developed in those copper deposits, have been a major environmental problem for this area. Negative impacts on the environment are present even today after more than 20 years since the closure of the mining activity in this area. It is so worth noting that starting a new mining activity can also help to regenerate the present damaged environment.

The new deposit "Bregu i Geshtenjes" is located in a mountainous terrain, at a height of about 1000 meters above sea level, with a climate that favors considerable snowfall. The area is rich in surface and underground water. The site is connected with the auto road to the city of Korça. The electrical network is present. The mining works, previously carried out in this area, provide internal roads and ample space for collecting sterile waste that can be extracted from the new mine. The copper mining complex in our country is located in the north of Albania, far from this deposit. This does not favor the cooperation of the new mine with the opportunities that these mining complexes offer in the field of mining technology and large capacity for copper ore processing.

The copper mining technology with underground mining is well known in this mining area. The work experience gained in mining activities, developed in this mining region will be a positive factor that will support the start of work in the new mining activity.

The main obstacle in the opening of this activity is the size of mining deposit. According to geological studies carried out at this mineralization zone (Kalina P. etc, 1986), an amount of around 1 350 000 tons of copper ore with an average content of about 1.92% Cu is estimated. Although this estimation of the mineral reserves capacity of this deposit is satisfying, several other factors must be taken into account. Considering the spatial position of the mineralized material, the distribution of these reserves in some ore bodies with different quantity of ore, the poor continuity of the geometry of the ore bodies and the mining method that can be adapted to this deposit, the amount of mineral reserves that can be extracted from this deposit is even smaller.

The average metal content (1.92% Cu) in the mineralized material is acceptable, compared to other mineral deposits that are today in used. Some economic indicators relevant for a mining activity are presented hereafter.

1. MINERAL RECOURSES OF A DEPOSIT THE ONLY ASSET OF A MINING ACTIVITY

The management of the mineral reserves of a deposit is firstly associated with a detailed study of geological medium, the creation of a data base of geological works, analytical processing and their graphic representation. Then the management of the mineral reserves continues with design of mining project. Booth these phases begin after an approximate assessment of the value of a mineral deposit. Let's write the simplified equation for the calculation of the value of a tone of mineral (v) and the value of the entire mineral resources (V):

$$v = \bar{g}_m \times R_t \times s_m \qquad (1)$$

$$V = v \times Q_m \qquad (2)$$

Where:

$\bar{g}_m$ - Average grade of metal in extracted mineral

R_t - Total recovery in enrichment and smelting.

s_m - Price of metal ($/ton)

Q_m - Quantity of extracted mineral

As can be seen from the equation (1), the value of one tone extracted mineral depends directly on the average grade of metal in the extracted mineral ($\bar{g}_m$), and the recovery index (R_t) in enrichment and smelting of mineral. The higher the grade of metal in the extracted mineral and the higher the recovery indicators, the higher the value of one tone of extracted mineral will be. While the value of the entire mineral resource (equation 2) depends on the value of one tone of extracted mineral and the quantity of extracted mineral. The average grade of metal in extracted ore ($\bar{g}_m$) depends on the average grade of metal in mineralization material ($\bar{g}$), but also from the recovery indicators determined by the processes of mining. The amount of minerals extracted (Q_m) depends on the amount of mineralized material (Q) in the deposit given for exploitation. We underline that the two parameters, the amount of mineralized material (Q) and the average grade of metal ($\bar{g}$) determine the only assets for a mineral deposit.

While metal prices (s_m) cannot be dictated by mining companies. Metal price fluctuations are very difficult to predict, especially from mining companies with a small influence on the production of minerals, such as companies operating in our country. In the periods when the price of metals is increasing, mining companies can profit by increasing production capacities, but note that this growth is limited by the selected mining technologies that determine the maximum production and processing capacities. In the periods when metal prices decrease, mining companies are forced to reduce the sales of the mineral produced, or to reduce production capacities or, in extreme cases, to interrupt mineral extraction. Interruption of mineral extraction was observed during 2016 – 2018 period in some copper mines in our country, and this extreme measure was assessed as a wrong solution.

Based on some preliminary data on the quantity and quality of the ore of this copper deposit, the recovery coefficients in the mining, milling and metallurgy (Goskolli E. etc, 1998), and the selling price of a tone of metal, we can estimate approximately the value of this mineral deposit.

$\bar{g}_m \approx$ 18 kg copper per ton; $R_t \approx 0.76$; $s_m \approx$ 6500 \$/ton; $Q_m \approx$ 900. 000 ton

$v = \bar{g}_m \times R_t \times s_m \approx$ 89 \$/ton of extracted mineral; $V = v \times Q_m \approx$ 80 000 000 \$

We note that the final product of this mining activity will be copper concentrate. The question that arises now is weather the value received from the sale of that concentrate will cover all costs for conducting mining operations?

2. SOME ASSESSMENTS ON GEOLOGY AND MINING TECHNOLOGY FOR COPPER DEPOSIT “BREGU I GESHTENJES”

The copper deposit in Rehova is located in the south east of the country, 25 kilometers from the city of Korca and far away from the copper mining complex located in the north of Albania. This deposit is formed by four different sources named, “Kanisqel”, “Dushku i Trashe”, “Çifligu” and the new deposit “Bregu I

Geshtenjes". All these deposits located within an area of no more than 4 km^2. The first three deposits have been exploited and know they are closed. The Kanisqel deposit is exploited with open pit mines, the "Dushku i trashe" have been exploited by combining the open pit and underground mine, while the "Chifligu" deposit was exploited only with underground mines. From the work experience in these mines (Mançka A. Kiço. L, 1987) are noted some conclusions such as:

- The contacts of orebodies with the hosted rocks are not sharp. Mineralized zone with an average grade 0.3% to 0.6% Cu envelop the ore bodies.
- In some cases during the exploitation works are encountered small mineralized lenses, non-assessed by geological works, with small size and with a grade more than 2% Cu. This phenomenon appeared more often during the mining works on the two open pits developed in this copper deposit.
- Generally the mineralized material and the hosted rock were unstable.
- To maintain the size of the mining units, they often expanded to the mineralized material around the boundaries of the ore bodies
- Quantity of extracted mineral from each mining units is high compared to the calculated reserves.
- The dilution indicator in some mining units reached up to 15%.

2.1 SOME DATA ON THE GEOLOGY OF THIS COPPER DEPOSIT.

The pyritic copper mineralization of "Bregu i Geshtenjes" ore deposit located at the uppermost parts of the lower volcanogenic package, some 30 to 180 meters from the contact agglomerate – diabase. The thickness of mineralized zone varies 20 to 40 meters, while the thickness of the body is from 1 to 12 meters. The mineralized zone consists of breccious diabase and volcanic diabase highly affected by the hydrothermal alterations.

The industrial mineralization goes to the direction of strike from 900 to 1000 meters, and widely to the direction of dip from 100 to 400 meters. The ore bodies have the shape of lenses and they are located mainly at the northeastern part of the centriklinale closure. The typical cross section of this deposit consists of 3 to 5 ore bodies, while there are some 22 known ore bodies in the entire ore deposit and among them the ore body number 2 is the most consistent one.

Generally the contacts of ore bodies and mineralization zone are determined by chemical analysis. The transition of ore bodies to mineralized zone is gradual. The same is also the contact between the ore bodies and hosted rocks on hanging and foot walls. Changes in the metal content in the ore bodies and mineralized zone is irregular without any trends.

The ore body number 2 located some 3 to 25 meters below the ore body number 1, and it represents the most consistent ore body of the entire deposit. It extends for 900 meters along N-NW to S-SE and develops for 50 to 320 meters along its dip westwards with angel 20^0 to 35^0. The thickness of the ore body varies from 1meter to 12 meter. The average grade of copper is 2.22% and 15.44% S.

There are some others mineralized occurrences in this copper deposit, but not of the grade to be contoured like industrial ore bodies. Considering the geological condition of these ore bodies, it can be mentioned that only ore body number 2 has a consistent continuity of the curve tonnage – ore grade, this estimated according to the mining technology adopted for this ore deposit. In following, only for this ore body it is continued with designed levels and mining units, based on the parameters of selected mining methods and extractable of ore reserves from this ore body are calculated.

2.2. A SHORT DESCRIPTION ON MINING TECHNOLOGY

The opening of the new mine will be done with two main works, a mining works with a moderate slope, no more than 10 degree, will start in the quota +968 and a ramp that will start at +1020 and will drop down to the lower level of the mine + 780. Opening works will be 4 meters wide and with a section 12 m^2. From the ramp will initially open the main levels every 50 meters and then the intermediate levels every 25 meters. Sublevel height should be maximized, reducing drift meters per tonne. Mining works, with a total length about 14 500 meters, will be realized in three years, where in the first two years there will be a higher intensity. With these mining works have to be prepared for mining all mineral reserves of ore body number 2, from lower level + 780 to upper level + 1000 meters. Reserves above level + 1000, where there are some ore bodies with limited reserves, will not be taken into account in this study. Also the mining reserves that are located below the level + 780, where there is a small body with no more than 50,000 tons mineralized material with a grade 1.08% Cu, was not taken into account in this study because mining of this reserves is assessed as non-economic.

In order to increase the quantity of extracted mineral it is intended for the preparation and mining of this ore body will be performed in two levels simultaneously. The Increasing of the amount of extracted mineral each year, will contribute to shortening the life of the mine, so the costs for mining activity will be decrease.

Based on the geological medium, stability of hoisted rocks and ore body, size and continuity of the ore bodies and the experience of mining in this deposit, two mining methods have been selected. The upper part of ore body, exactly from level + 968 to level + 855 will be mining with **sublevel caving method**. The rock mass is stable enough to allow sublevel drifts to remain stable. The hanging wall is unstable and will collapse to follow the cave created from mineral extraction. For this mining method dilution and ore losses are a big problem. In this case host rock contains copper mineral that fluctuated from 0.3% to 0.7 % Cu. In this condition dilution have a moderate influence on the copper grade in extracted mineral.

Because the small depth of upper mining level from the surface, and based on the work experience in this mine, it is expected that during the extraction of the ore, there are many opportunity to have sinkholes.

Mineral reserves from level + 780 to level + 855 will be prepared by sublevels and mining with **cut and fill method**, starting from the lower sublevel and advancing upward. When 2 ore 3 vertical slice has been mined, voids are backfilled with a mixed material create with hydraulic sand tailings and waste rock. This method gives possibility to avoid extraction of minerals with low grade ore and to recover pockets of mineralization material in the host rock. This method provides low indicators of mineral loss and dilution, but has a higher cost per one ton of ore extraction compared to sublevel caving method (Lipo S. Bakiu A. 2013).

In order to maintain a high level of safety in the mine, sublevel must be dimensioned in accordance with the actual conditions, keeping in mind that sublevel design has a high influence on mining efficiency, recovery and costs. The sublevel height for both mining methods will be 12.5 meters.

By evaluating the size of the mining body at each level, the dimensions and rate of exploitation of mining units, the mineral losses and dilution indicators for each block and levels, are estimated quantities of mineral to be extracted from each level. In the table are given the quantities of minerals that expected to mining from different levels by years.

From the data given in this table we note that the amount of extracted mineral will be 897 755 tons, with an average content of 1.81% copper. The amount of metal found in this mineral is only 162 482 tons. The graph given in figure 1 shows the expected amount of metal production planned by levels, quarters and years.

2.3 SOME DATA FOR ORE ENRICHMENT PROCESS

The final product will be the concentrate produced by the enrichment factory. In this mine has been working for more than 10 years an enrichment plant with processing capacity of 60,000 tons of mineral per year, with an average recovery index of 82% and a grade of copper in concentrate about 16.5%. Today, this plant has been out of function. A new enrichment plant has to be build, with a full cycle of enrichment, where there will be some successive enrichment. After the first flotation process, milling of materials obtained will again be used to provide a better distribution of copper during the last flotation phase.

Tabela nr. 1 Planning of mineral production organized by levels and years

Level	Cutoff grade 0.5 %		Years							Sum
			1	2	3	4	5	6	7	
968	Ton	9206	9206	0	0	0	0	0	0	9206
	% Cu	1.71	157.4	0	0	0	0	0	0	157.4
930	Ton	86431	86431	0	0	0	0	0	0	86431
	% Cu	1.55	1340	0	0	0	0	0	0	1340
905	Ton	59309	0	59309	0	0	0	0	0	59309
	% Cu	1.05	0	622.7	0			0	0	622.7
880	Ton	169909	0	0	98800	71109		0	0	169909
	% Cu	1.55	0	0	1531.4	1102.2		0	0	2633.6
855	Ton	182634	0	0	0	0	40000	85000	57634	182634
	% Cu	2.25	0	0	0	0	900	1912.5	1296.8	4109.3
830	Ton	67719	0	0	0	0	0	67719		67719
	% Cu	1.79	0	0	0	0	0	1212.2		1212.2
805	Ton	196343	0	0	0	80000	116343		0	196343
	% Cu	2	0	0	0	1600	2326.9		0	3926.9
780	Ton	126204	0	75000	51204	0	0	0	0	126204
	% Cu	1.78	0	1335	911.4	0	0	0	0	2246.4
Sum +780	**Ton**	**897755**	95637	134309	150004	151109	156343	152719	57634	897755
	% Cu	**1.81**	1497.4	1957.7	2442.8	2702.2	3226.9	3124.7	1296.8	16248.2

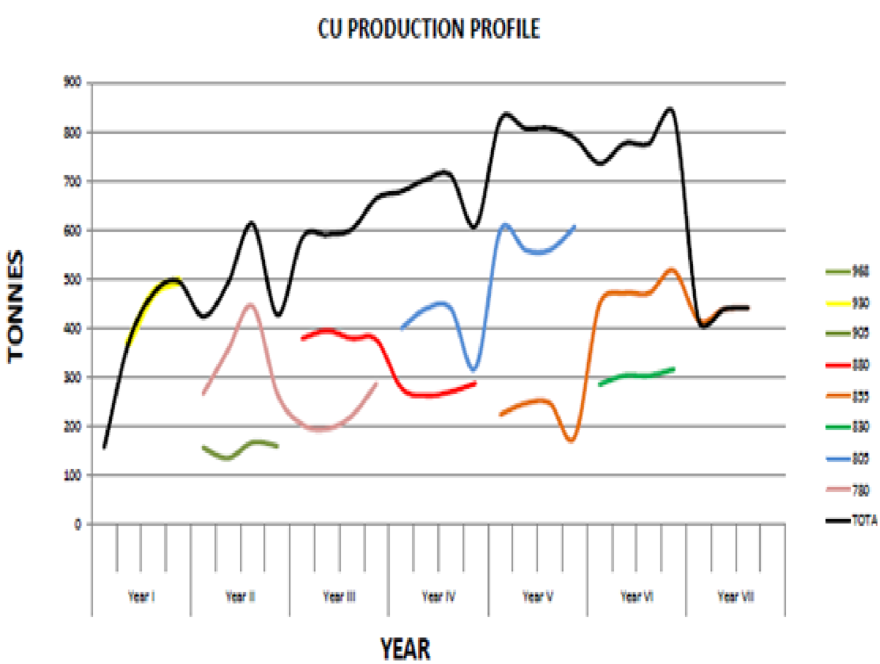

Fig. 1 Expected amount of metal production planned by levels, quarters and years

Then, the cleaning phase will give a better quality concentrate (25% Cu). Gold and silver can be obtained at 74% with new techniques in similar processes. Based on the work experience and well-known minerals qualities, it is thought to achieve a recovery of about 85% during the enrichment. The enrichment cost will not be high (North Stars Studi, 2010).

Capital expenditures for the construction of the new enrichment plant and the complex of mine office are expected to be about $ 2.8 million. The operational cost for extracting and processing one ton of mineral extracted is estimated at about $ 25 per tone.

Ultimately, this new mine is expected to produce around 55,250 tones of concentrate with a grade of copper 25%. From this concentrate is expected to be taken about 250 kg gold and 6000 kg silver.

3. MINING ACTIVITY IN THIS COPPER DEPOSIT AND SOME EXPECTED ECONOMICAL INDICATORS.

Mining activity in this mine is restricted by the amount of mineralized material and the metal content in this material. Under these conditions, during selection of mining technology, it is intended that the amount of mineral reserves, expected to be extracted from underground, to be as high and the indicator of mineral losses to be as small.

After determining the shape and boundaries of ore body and mining methods to be used, it was no easy to determine the dimensions of the production units. Clear lack of continuity of the shape and size of ore body at different levels, created problems in the design of the size of production units. Dimensions of the production units were selected in each case, with the idea that for every mining unit have to realize lower indicators of mineral losses. The boundaries of the mining units, in some cases, have been extended to the hosted rock. The hosted rock in most cases contains copper ore in the range of 0.3% to 0.6%. Extracting this poor material together with the ore bodies will bring an increased indicator of dilution, but at the some time will minimize the losses of mineral.

Evaluation of impact of losses mineral and dilution in rate of profits for each mining unit (see Figure 2), it seems that the increase of mineral losses has a greater impact on reducing profit, compared with this impact caused by the increase of dilution. This is explained by the fact that the increase in dilution is accompanied by the reduction of the mineral losses, and the dilution material contains copper ore at the limits of 0.5%. From the evaluations performed, see the graphs in Figure 2, we conclude that the mineral dilution to 15% would significantly reduce the losses of mineral. With this working regime, economic indicators for each production unit, will be the best for this new mine. The increase in dilution index to 15%, when the waste material contains no less than 0.5% copper, bring a small negative impact on the profit. Figure 2a show change of profit curve from change of indicators of mineral losses and dilution. Impact of increase of dilution at the profit curve is made when the dilution material contains copper ore at 0.4% and when the dilution material does not contain copper ore.

From the analysis of this mining technology, we conclude that the indicator of recovery mineral (1- mineral losses), for every mining unit is reduced faster by the increase of mineral losses, compared with the increase of dilution. This does not mean that a high dilution should be accepted, as this would significantly increase the production cost of concentrate. The graph shows that when the metal content in the mineral delivered to enrichment is less than 0.7% Cu, the enrichment process will be without profit. So the grades of the metal in the extraction mineral have to be high than break even cut-of grading (0.7%Cu) for processing in enrichment plant. Minerals extracted from different production units must be averaged in order that the grade of copper in averaged mineral to be as high as possible.

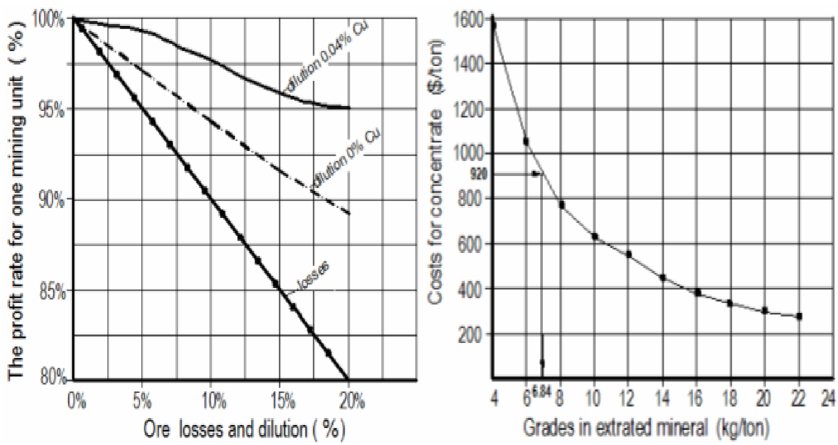

Fig. 2 The relation between indicators of profits, losses and dilution (a), and increase of cost of concentrate with decrease of grade of copper in extracted mineral (b).

Based on the mining and enrichment technology accepted for this new mine, we calculate the amount of concentrate to be produced:

$$Q_c = \frac{Q_m \cdot \bar{g}_m \cdot R_c}{g_{con}} = 55248 \text{ ton concentrate}$$

Where:

Q_m - The amount of ore expected to be extracted from this mine (Q_m = 897755 ton)

$\overline{g}_m$ - Average grade of metal in extracted mineral after process of averaging ($\overline{g}_m$ = 1.81 % Cu.)

R_c - Recovery indices in mineral processing (R_c = 0.85 %)

$\overline{g}_{con}$ - Average grade of metal in concentrate ($\overline{g}_{con}$ = 25 % Cu)

To estimate the economical profit, expected to be obtained from a mining activity, it is necessary to pre-evaluate firstly a number of technological parameters (geological, mining, enrichment and metallurgical), and then to evaluate a range of economic parameters, such as capital costs, operating costs, bank interests, various taxes, environmental obligations and product sales prices. Both sets of parameters require increased care in their assessment for every concrete mining activity. Every mining deposit and any mining activity are unique in the geological conditions approaching and pre-assessment of these parameters is very difficult. Under these conditions, the pre-assessment of the above parameters is always approximate and the true values of these parameters will be determined only when the mining activity is completed.

Considering once again the production capacity of this new mine, about 55 200 ton of concentrate with a grade 25% Cu, remains to be estimated all the capital expenditures and operating costs that will accompany this mining activity. For this copper deposit some capital and operational expenditure studies are carried out for different mining technology. In these studies, where other mineral indicators have been chosen, it has resulted that total costs are very close to the income that can be obtained from the exploitation of this deposit.

CONCLUSIONS

The “Bregu Geshtenjes” copper ore deposit has a limited amount of reserves. A successful mining activity under such conditions can be assured only if the necessary guarantees are taken:

- The mining method that is selected to be used in such ore deposits, with limited mineral reserves, should first to provide a mineral extraction with minimal mineral losses. Selected mining methods in this deposit are sublevel caving (with approximate indicators of losses and dilution, respectively 8% and 15%) and sublevel with cut and fill (with approximate indicators of losses and dilution, respectively 5% and 8%).
- Based on the mining technology proposed to be used in this mining activity, the maximum size of mining units were determined, to increase production rates and reduce the costs for mining works for each mining unit.
- From the assessment of the impacts of the mineral losses and dilution on the economic effectiveness for each mining unit, were determinet the

optimal indicators of mineral losses (not greater than 8%) and diluotion (not greater than 15%).

- The grade of copper in extracted mineral will be fluctuated from 0.5 % Cu to 2% Cu. The extracted mineral will be averaged before sending for enrichment, so the grade of copper in the extracted mineral that will be sent for enrichment should not be less than 0.7%.
- Përmbajtja e bakrit qe do te nxirret nga miniera do te luhatet ne kufijtë 0.5 deri 2 % cu. Minerali i nzjerre do te mesatarizohet para se te cohet për pasurim.
- To optimize operating costs, annual mining production should be as high as possible. For this purpose, it is planned to work in several mining units simultaneously.
- The processing capacities in the enrichment plant should support the annual production of mines.

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