



EVALUATION OF EXPLOITABLE LEAD AND ZINC ORE RESERVES AT THE RIBNIK DEPOSIT, REPUBLIC OF MONTENEGRO

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Abstract

This paper presents the applied process of evaluation the exploitable reserves of lead and zinc at the Ribnik deposit, using the Whittle software, according to the criteria of maximum net present value and maximum deposit utilization, as a necessary prerequisite for responsible management of mineral resources.

In addition to the mentioned general criteria, a specific criterion, related to the requirement of the technological process of flotation processing that the input minimum average content of equivalent metal (Zn + PbEqZn) in the ore should be 2.5%, was applied in the evaluation the exploitable reserves.

Keywords: *exploitable reserves, evaluation, economic value of deposit.*

1. INTRODUCTION

The Ribnik ore deposit, which belongs to the Suplja Stijena ore field, is a hydrothermal polymetallic sulphide lead-zinc deposit of the vein-impregnation type.

Zinc and lead contents are moderately variable, with the variation coefficients of variation that are moderately uniform (up to 120). Contouring of the mineralized area for calculation the reserves was carried out over the limit content. Considering the occurrence of ore mineralization, the quality of mineral raw material, as well as the characteristics of geological environment in which the mineralization is located in the contour of the limit content of 0.5% Pb+Zn, the vein ore body is contoured.

The ore body is represented by two ore veins with 5 to 6 apophyses that are separated. The direction of extension is northwest - southeast, with a dip of 50-60°.

2. METHODOLOGY

Evaluation of exploitable ore reserves at the Ribnik deposit is based on implementation an integral planning process, which begins with creation a deposit model and resource evaluation, followed by optimization the surface mining and evaluation the ore reserves.

The limit optimization of the Ribnik open pit deposit was carried out on the basis of a deposit block model and defined input techno-economic parameters. The economic value of the deposit is determined on the basis of the value of present metals in the ore, i.e. lead and zinc. The economic effects of ore exploitation are calculated on the basis of the selling price of payable metals in the ore (lead and zinc). Since it is a polymetallic deposit, the optimization was done for the sum of zinc and lead converted into zinc (Zn

+ PbEqZn). The limit content of the sum of Zn and Pb, converted to Zn, is $GS = 1.4\%$. Blocks with content below the GS are treated as waste.

The open pit optimization was performed on the balance reserves using the Dassault Systems Whittle software, which is the industry standard for this area. The Whittle program package in the optimization process uses a modified Lerch Grosman algorithm, by which the optimal mine contour is obtained on the basis of the economic value of individual mini-blocks in the deposit. The software has the ability to apply the Revenue Factor to the metal prices to change the amount of revenue and thus generate more possible mine contours [1].

In the optimization process, the results are generated for individual boundaries of the mine, i.e. the profit is calculated as the present value for three variants of analysis: the "best case", "worst case" and "specified case" defining the way of spatial development of the open pit.

Optimization implies the software analysis in order to determine the final open pit on the basis of the following criteria:

- maximum possible profit (NPV),
- optimal life of exploitation,
- optimal overburden coefficient,
- maximum possible utilization of deposits (balance reserves).

In practice, the mentioned criteria are interdependent, and the final result implies their optimal relationship.

In addition to the above-mentioned criteria, the following were also taken into account when determining the exploitable reserves:

- 1) that the requirement of the technological process of flotation processing is that the input minimum average content of the equivalent metal (Zn + PbEqZn) in the ore is 2.5%, and
- 2) that the C2 category ore reserves must not be captured.

These two conditions had a significant impact on the obtained quantities of exploitable reserves.

3. WHITTLE BLOCK MODEL OF THE RIBNIK DEPOSIT

The block model of the lead-zinc ore deposit was made in the Geovia Gems software package and is a block model with the regular blocks, dimensions $2 \times 2 \times 2$ m.

The optimization process begins by importing the digital geological block model as the "mod" and "par" files in the appropriate format into the Whittle software. In order to adjust the height of the working floors at the open pit by 10 m, a re-blocking procedure was carried out, i.e. sub-blocks were joined in the x, y and z directions, thus obtaining the regular blocks with dimensions of $10 \times 10 \times 10$ were obtained.

Figure 1 shows a block model of the Ribnik deposit.

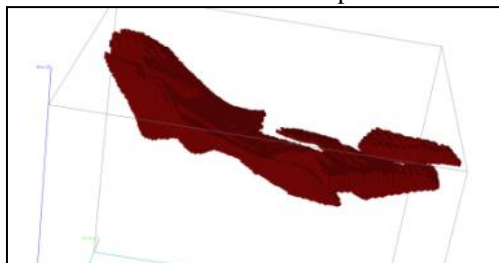


Figure 1. Block model of the deposit

4. OPTIMIZATION RESULTS - DISCOUNTED CASH FLOW ANALYSIS

The optimization process was carried out by varying the base price of zinc metal in the Revenue Factor range from 0.2 to 1.2 with a step of 0.015, thus generating a series of 37 potential open pit contours/shells.

The amounts of waste, ore and metal were determined for each open pit contour with the operating NPV discounted at 10%. Three NPV values were calculated for each open pit contour:

- 1) The best NPV scenario (with and without discounting), which implies that each inner shell of the open pit is excavated one after the other.
- 2) The scenario of the worst NPV, which implies that each inner shell of the open pit is excavated floor by floor according to the depth of the open pit.

The best case provides the maximum NPV, while the worst case provides the lowest NPV value. As the difference between the best case NPV and the worst case NPV increases, higher cash flow is generated. This effect between the NPV values is observed in practice through a gradual development of the open pit, that is, through the mine development per stages [2,3].

Figure 2 shows the resulting income factor graph with optimization parameters, formed on the basis of the mine annual production of 50,000 tons of ore.

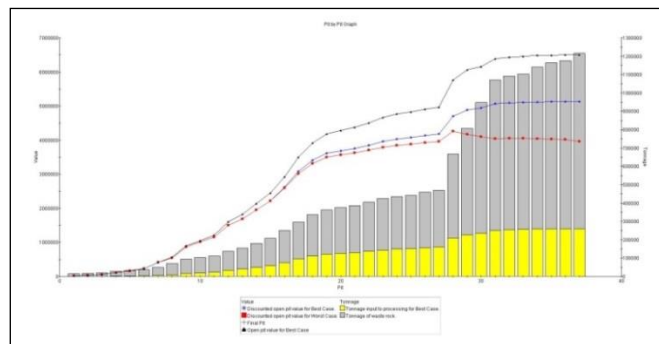


Figure 2. Graphic representation of the Whittle economic optimization results

The evaluated values of the cash flow are not taken as the absolute values, since these are preliminarily determined costs and values of use, where the capital costs or total exploitation costs are not included (e.g. redemptions and compensations, state compensation, etc.). The optimal open pit is the mine with the boundary that generates the highest revenue (discounted or undiscounted) using previously specified the input techno-economic parameters. However, in this case, the open pit that meets the conditions of flotation processing so that the minimum average content of the equivalent metal Pb+Zn in the ore is 2.5%, is the open pit number 28, for the value of the Income Factor of 0.47. By further increasing the Income Factor (up to 1.2), the amount of ore does not increase. The obtained results are a consequence of restrictions set for the open pit development in the plan, so as not to include the C2 ore reserves. The open pit includes 208,954 t of ore reserves with an average Pb+Zn equivalent metal content in the ore of 2.499%.

Figure 3 shows the 3D view of the open pit, conditionally divided into two sections - the northwest section and southeast section.

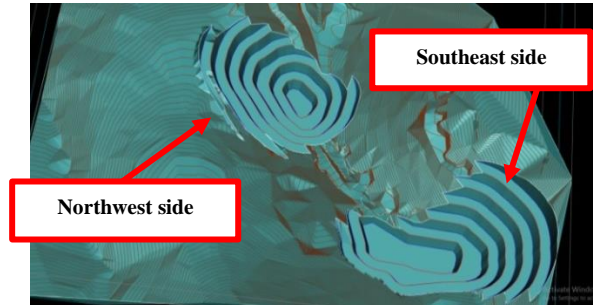


Figure 3. 3D view of the Ribnik open pit

5. CONCLUSION

The Ribnik deposit is a polymetallic deposit with a low content of lead and zinc metals in the ore. The average content of the sum of zinc and lead, converted into zinc ($Zn + PbEqZn$) in the total geological reserves, is 1.66%.

The use of a modern software tool for strategic planning and optimization of the Whittle deposit is extremely important for the rational use of the deposit and achievement the maximum profit in exploitation.

Based on the conducted optimization process, the contour of the open pit was defined including 208,954 t of ore reserves. The condition of flotation processing is fulfilled so that the minimum mean content of the equivalent metal $Pb+Zn$ in the ore is 2.5%.

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