

"BORSKA REKA" OREBODY, THE FUTURE OF THE EXPLOITATION IN BOR MINE

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Abstract: The most orebodies in Bor copper mine have been excavated during the more than a hundred year period of exploitation, and a part in a final stage of excavation. For these reasons, as long as thirty year of work on analysis and consideration possibilities for exploitation one of the largest ore bodies in Bor copper ore deposit. That is "Borska Reka" orebody. "Borska Reka" copper ore deposit dip in great depth and above the ore body there are part of the town, as well as transportation object essential for the region located. Analyses of the proposed methods applicable for this ore body are presented in this paper.

Key words: "Borska Reka" ore body, block mining method, block caving method

1. INTRODUCTION

During the mining of Bor copper mine, which lasts more than a century, almost all of the richer ore bodies, that were closer to the surface, were excavated. "Borska Reka" orebody, as a largest ore body in Bor copper ore deposit, has been the subject in numerous studies and analysis more than three decades. The fact that ore body lie at great depth and quite low copper content in ore are main influencing factors to the choice of excavating method for this ore body.

Currently the excavation is performed in orebody "Brezonik" and orebody "T". Exploitation of these ore bodies, with this intensity of excavation, will last maximum two years. Excavation in orebodies "Tilva Roš" and "P₂A" had stopped in 2007 after eruption of mud and water from the bottom of open pit. There are finished researches and final project documentation for two small orebodies "T₁" and "T₂" which are located near orebody "T". Ore reserves in these orebodies can not provide long term exploitation. Geological ore reserves in orebodies "T₁" and "T₂", according to (Department of Geology RBB Bor, 2011), are:

"T₁" $Q_{\text{geol}} = 585,577 \text{ t}$ with 1.933% Cu;

"T₂" $Q_{\text{geol}} = 167,211 \text{ t}$ with 1.029 % Cu.

2. ABOUT "BORSKA REKA" OREBODY

"Borska Reka" orebody is an integral part of Timok magmatic complex and it is located in north-western part of Bor town, below of the Bor river valley and it is

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within active Bor mine. The deposit has a length of about 1,000 m and a thickness about 500 m, dipping to the west at an angle of 45° to 55°, according with dipping of Bor conglomerates and sandstones, and from zones of hydrothermal Bor separated by Bor cleavage. Detailed studies were carried out to k-455 m by exploration drilling from underground (XVII horizon, k-155 m). There is a need for deposits exploration below the k-455 m in width and depth, (Institute of Mining and Metallurgy Bor, 2010).

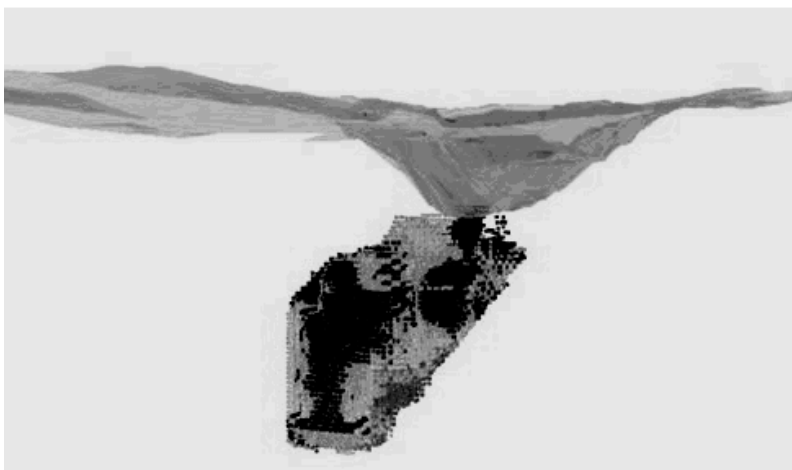


Figure 1 - Block model "Borska Reka" ore body (Mihajlović et al. 2008)

Exploration works on "Borska Reka" deposit were carried out in the period 1976-1999 with a large volume of research works and with 53,390 m exploration drilling from the surface, 6,489 m exploration drilling in parts of the mine, 1,378 m of mining works and 1,119 m of additional mining operations, all accompanied by geological and laboratory work with about 20,000 chemical analysis, mineralogical and physico-chemical petrologic testing (Institute of Mining and Metallurgy Bor, 2010).

Geological cross-section of "Borska Reka" orebody is shown in figure 2.

Detailed exploration works were carried out to the level -155 m and it is assumed that deposit is dipping to the elevation of -800 m and even deeper. Part of the deposit above the level of -235 m, above the horizon XIX, is opened by transportation system for the ore bodies "Tilva Roš" and "P₂A".

Total geological ore reserves in "Borska Reka" deposit in the contours of the border 0.3% Cu content, which belong to A, B and C1 categories to -455 m level are 556.9 million tons of ore and 3.15 million tons of copper with additional elements (gold, silver, molybdenum, etc.). Certified balance reserves are determined on the basis of research data, and techno-economic evaluation of the part above the level -455 m. To this level a total of 319.9 million tons of copper ore with 0.50% Cu, 0.204 g gold/t ore, silver 1.62 g/t, Mo 335.89 g/t and 7.8% sulfur has been calculated (Milić et al. 2011).

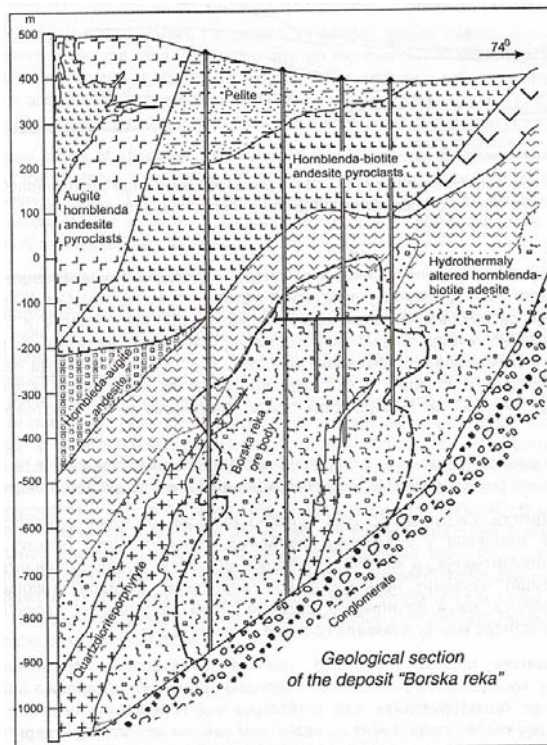


Figure 2 - Geological cross-section of ore body "Borska Reka" (Milićević et al. 2009)

3. ORE BODY OPENING

"Borska Reka" orebody is opened and developed above the level of -235 m. Above the horizon XVII orebody is opened to transportation collecting horizon XVII, system exploration drifts and existing transportation routes. Ore body is associated with primary crushing, it is also on the horizon XVII. That is used in current extraction. By drifting of hauling system at level XIX horizon, which replace horizon XIII, mine was deepened by 220 m. Hauling XIX horizon was driven to enable ore extraction from the current position and extraction of shallowest parts of "Borska Reka" ore body, too. Large capacity belt conveyors are installed for the ore hauling and hoisting from the horizon XIX to the main hauling horizon XIII.

Figure 3 shows a schema of current mine situation and one of variants of the opening ore body "Borska Reka" to the level -505 m.

4. ANALYSIS OF PROPOSED METHODS

In the last thirty years "Borska Reka" orebody has been a subject of detailed analysis, discussed possibilities and ways for economical extraction this orebody. In

these analyses solutions for optimal way of opening and mining method were searched in order to provide positive economic indicators.

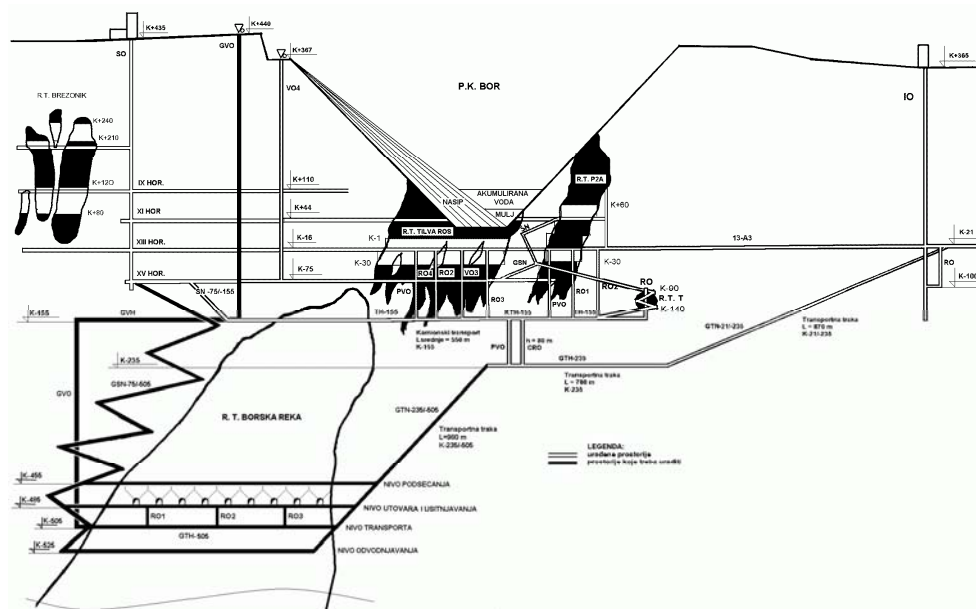


Figure 3 - Variant of opening "Borska Reka" orebody to the -505 level (Milić et al. 2011)

The big problem is the fact that above of orebody there are the parts of the "Sever" and "Brezonik" settlements, railroad Bor-Majdanpek with tunnel, Bor river valley, collector of Bor river, Bor-Gornjane-Majdanpek road and old Bor cemetery.

In the last period many techno-economic analysis and scientific researching studies were done considering ore extraction possibility from "Borska Reka" orebody. Many scientific papers on mining method selection were published and several doctoral dissertations. For exploitation of "Borska Reka" deposit highly capacitive and highly productive mining methods that would enable economically viable mining of ore with low metal content were considered. These methods belong to the group of methods with caving of ore and the surrounding rock mass. In addition, the possibility of applying the methods of excavation back filling the extracted space was analyzed in order to preserve the surface and objects that are above the ore body.

Among the documentation there was also a study "Analysis of the potentialities of application block caving method into the 'Borska Reka' orebody". Development and experience in the application of block caving method in the world as well as the available data support the possibilities of its applying for this deposit. Improved procedures and methods of forced intervention in any anomalies in caving control of stratum massif, reduce risks in the application of methods to a minimum. The analysis has shown that this method can produce the cheapest way of copper extraction (Institute of Mining and Metallurgy Bor, 2010).

The methods that are studied and considered as the possible for extraction of ore body "Borska Reka" until now belong to the group of methods with induced caving of ore and associated rocks. Some of them are given in the literature (Kojdić 1991; Milić 1996; Šćekić 1996). Most of the methods that have been discussed as possible for "Borska Reka" ore body are analyzed in the literature (Milićević, 2008).

5. A REVIEW OF THE PROPOSED METHODS

Currently opened ore reserves in the Bor mine are not at a high level and with current production capacity the remaining ore reserves in active ore bodies will be finished in a couple of years as far. If the production can not be started in "Borska Reka" ore body, the mine would come into the situation to be closed after more than 100 years. Therefore efforts are made to find optimal solutions and select the best methods for extracting this huge but low-graded ore body.

The main problem is, as already mentioned, the depth of ore body and the existence of objects of public interest on the surface above the ore body "Borska Reka." Another problem is the fact that ore body "Borska Reka" belongs to a group of low-graded ore bodies.

Until now, subject of studies have been variants of excavation methods, such as block induced method and block back filling of excavated space, due to important objects on the surface. Some of the methods have been the subject of research in the eighties when the degree of mechanization and automation was not at the current level, so this method of research should be reconsidered. Besides the block method with induced ore caving, studies for block caving were performed too, as a highly productive method that has been successfully applied in many of the world's mines.

The researches that have been done on the Technical Faculty in Bor, the Institute of Mining and Metallurgy and Faculty of Mining and Geology in Belgrade were performed mainly on physical models, provided a very significant knowledge of the method indicators. However, models tests did not provide an answer to the question of which would be the most economical method of excavation of "Borska Reka" ore body, so it would be best to conduct research in the ore body.

Researches on the model could not include all factors that affect excavation as well as other mining-geological factors and therefore it would be best to carry out testing in the ore body. Open parts of the ore body above the level of k-235 m could serve the as the best part of the trial, where in real conditions could be seen behavior of working area and results of method application, e.g. "Block caving" method, as one of the most interesting methods for mining in this ore body. In the same way, it would be possible to research the application of some of the block methods, such as sublevel caving with the best parameters and the best drawing from stope. The results would be compared in order to determine which method is better and more economical.

Experience on drifting through the upper parts of the ore body indicates that the ore is quite hard and compact, free of cracks. This is positive from the aspect of drift stability in the bottom of the block and advantage of using the block method with induced ore and block stope filling method. On the other hand, it is adverse from the aspect of applicability of the block caving method because hard rock could lead to the creation of natural arches and difficulties in ore drawing process.

6. CONCLUSION

"Borska Reka" ore body represents a new perspective in underground mining in Jama Bor. With exploitation this ore body, which contains about 600 million tons of ore reserves, mine life can be significantly extended. Constructed hauling system in the horizon XIX as well as ore transport solutions designed and inclusion in the existing hauling system make it possible to continue underground exploitation in Bor mine. Using modern methods, from the block method group, the current price of copper on the metals market, it is possible to achieve economic extraction of ore from the largest ore body in the Bor copper deposit.

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