Journal of Mining and Metallurgy, 43 A (2007) 9 - 17

SUGGESTION FOR MINING METHOD IN REMAINING ORE RESERVES OF CENTRAL PART OF "P_2A" ORE BODY AT JAMA BOR

Vitomir MILIĆ [#*], Igor SVRKOTA [*], Dejan PETROVIĆ [**]

[*] *University of Belgrade, Technical faculty Bor, VJ 12, 19210 Bor, Serbia*
[**] *JP PEU Resavica, Serbia*

(Received 24.8.2007; accepted 30.11.2007)

Abstract

"P_2A" ore body is one of three active ore bodies in Jama Bor underground mine. Copper ore is extracted by Swedish variant of sublevel caving.

However, due to poor ore properties, central part of ore body couldn't be extracted regularly. Significant ore reserves were left in this part of ore body.

Analysis of current situation in central part of ore body, led us to conclusion that it is possible to extract ore reserves in this area, by application of different mining method. Considering the layout, dimensions, ore properties and existing drifts and equipment in the central part of "P_2A", we suggest application of block caving.

This paper gives main parameters of method design, block development and loading and haulage of drawn ore, together with expected results of application of block caving.

Key words: *Underground mining, sublevel caving, block caving.*

[#] ***Corresponding author:*** *vmilic@tf.bor.ac.yu*

1. Introduction

Mining of copper ore lasts for more than a century in Jama Bor underground mine. Current mining works include three ore bodies, “Tilva Ros”, “P_2A” and “Brezanik”. Tilva Ros and P_2A ore bodies provide most of the output, while Brezanik ore body nears end of excavation. Mining is followed by numerous problems related to mechanical and structural properties of rock, old equipment, lack of spare parts for equipment, etc. As ore extraction depth increases, problems are enlarging. Tilva Ros ore body suffers from increased water inflow, while rock mass is heavily interrupted in P_2A. Due to poor roof stability, development and mining of central part of P_2A differed from designed pattern of sublevel caving. After several failures in crosscuts and ore pass, mining of central part was abandoned. Crosscuts were damaged at level K+45 m, while ore pass RO-1 was unstable above level K+45 m. Development of lower sublevels was only partial, with serious damages in crosscuts.

Considering the fact that remaining ore reserves of Jama Bor underground mine are deep, low – graded and require development, it would be a real shame to leave a significant part of P_2A reserves. This paper provides the idea for possible extraction of remaining ore reserves in P_2A ore body central part, above level K-15 m.

2. Ore body layout. Condition of mining works. Main problems

After the end of mining of massive sulphide ore bodies, mining at Bor ore deposit continued with stockwork – impregnated ore bodies. P_2A ore body has been extracted by open pit mining for many years, before the start of underground mining at level K+180 m [1]. Applied mining method is Swedish variant of sublevel caving.

P_2A ore body is situated eastern of Tilva Ros ore body, while western boundary is close to Kamenjar 2 ore body. Eastern boundary of ore body is tectonic, with large fault called Bor fault. Towards west, south and east, ore body changes into altered biotitic andesite, which could be siliceous, chlorinated or with pyrite. These andesites are low – graded. Shape of ore body is irregular, with strike directed northwest – southeast. Top of the ore body appears at level K+310 m, while deepest point is bellow K-155 m level, known as “XVII horizon”. Thickness varies between 30 and

80 m, while dip is between 30 and 60^0. Ore grades are 0,88 % Cu, 0,175 g/t Au and 0,785 g/t Ag [2].

Main problems occurring in Jama Bor, especially in central part of P_2A, are following:

- Roof stability is poor and it is difficult to maintain crosscuts,
- Fractured and weak rock causes problems in blasthole maintenance and loading of explosive,
- Ore containing propylite easily turns into mud in contact with water, thus making huge difficulties in loading and other processes,
- Instable roof easily caves, causing increase of crosscut height and difficulties in drilling process,
- Damaging of drawpoints cause problems in process of ore drawing.

In drifting, main problem is existence of numerous systems of fractures in the roof. Fractures are perpendicular to ore body, so direction of crosscuts and fractures is almost identical [3].

In central part of ore body, several crosscuts couldn't been driven and maintained (from OH-14 to OH-19, fig.1). Also, ore drawing was incomplete. So, now we have contours of central part of P_2A made of caved ore and waste, while vertical limits are contours of ore graded with 0,4 % Cu.

Furthermore, at level K+45 m, crosscuts OH-15, OH-16, OH-17 and OH-18, due to bad conditions, couldn't be driven all the way to the footwall. Same reasons caused inability to draw all of the blasted ore. These crosscuts lay close to ore pass RO-1, which is also damaged, so its diameter at this level reaches 15 to 20 m.

At level K+30 m, as a consequence of damaging of ore pass RO-1, crosscuts OH-16 and OH-17 were not driven at all, while OH-18 and OH-19 were driven only partially, without any ore drawn from them. Due to heavy damages, ore passes RO-1 and RO-2 were not in function, so new ore pass RO-3 was driven from K-16 m to K+15 m level. This ore pass should reached K+30 m, but it also laid in instable rock and couldn't been driven to the end.

At level K+15 m, there was a try to bypass caved RO-1 by diagonal drifts from OH-18 crosscut. However, these drifts required huge amount of support works, followed by very unstable crossroads. Crosscuts OH-14 to OH-19 also couldn't been driven to the footwall.

At level K 0 m, crosscuts from OH-15 to OH-18 were not driven. There are plans for development at level K-15 m. At this level, there is a haulage drift GTH 13-A1, which is also partially damaged, near ore pass RO-2. Development should start by drifting crosscuts from OH-21 to OH-24.

After the review of entire situation, we can conclude that upper part of P_2A ore body is almost completely mined. However, central part of ore body had irregular extraction from OH-14 to OH-20, with caved ore pass RO-1 near crosscuts OH-15 and OH-16 [4].

Figure 1 shows the profile of central part of ore body P_2A.

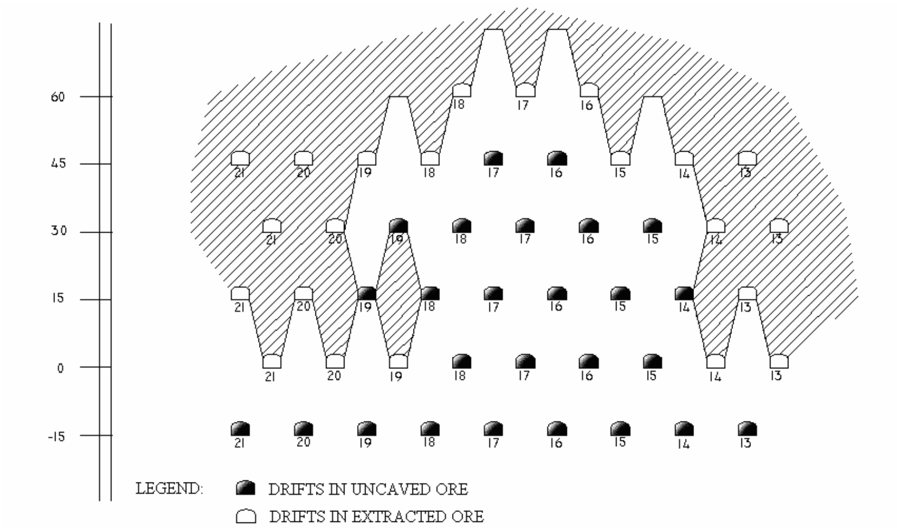

Fig. 1. Strike profile of P_2A central part above level K-15 m

3. Suggestion for mining method in central part of P_2A ore body

Ore reserves of Bor ore deposit lay at significant depth and require development. Central part of P_2A is already developed, and with small changes this part of ore body could be connected to existing haulage and ventilation drifts. Current mining method is Swedish variant of sublevel caving. This method provides high outputs and utilization of modern equipment for each mining process [5].

However, heavily interrupted rock in central part of P_2A ore body, caused many problems in application of sublevel caving. Problems occurred in maintenance of crosscuts, ore passes, and even blastholes. Such situation enabled mining in a part of ore body from crosscut OH-14 to OH-19, while at level K 0 m there was no ore drawing at all. One of the characteristics of P_2A ore body is weak footwall, and because of that development drifts are placed in hanging wall. Development consists of a drift in the hanging wall along the strike and crosscuts lined from that drift towards the footwall, at 14 m spacing.

Main sublevel drifts are connected with ore passes and ventilation shafts, with service drift connecting sublevel drifts at different levels and main transport level.

Analysis of current situation and rock properties lead us to consideration of different mining method for central part of P_2A.

Since sublevel caving causes major difficulties, and dimensions of unexcavated ore are significant, we suggest block caving as a possible solution in this situation. Due to required block height needed for block caving, block would include K-15 m level too, regardless on fact that some development for sublevel caving was already performed on that level.

Block undercutting should be at K-15 m level. Block caving provides many advantages comparing to sublevel caving, such as significantly lower development works and better ventilation. Besides, all of the existing equipment would be used.

A single block would include all of the remaining ore above level K-15 m (horizon XIII). Block dimensions are [6]:

- Block width $B_{bl} = 60\ m$
- Block length $L_{bl} = 60\ m$
- Block height $H_{bl} = 60\ m$

Transport level is at K-15 m, with haulage drifts along the strike. There are three haulage drifts, with 24 m spacing. Above them lay undercut drifts, with 12 m spacing. Trench undercutting is planed, with 5 trenches 12 m wide. Undercut drifts lay closely under haulage drifts, to avoid excessive weakening of undercut level. One haulage drift is used for two trenches, except fifth trench near the footwall, which has its own haulage drift. Loading crosscuts are driven from loading drifts at 12 m spacing [7]. From loading crosscuts up, short ore passes called raises are driven. Raises are used for ore drawing from the block. Drawn ore is loaded and hauled by LHD machines (Wagner ST-6C). From draw point, ore is hauled through loading crosscut, haulage drift and main transport drift towards ore pass which reaches horizon XVII (Figure 2).

Block development includes access drifts, such as service – ventilation drift (SVH), cross service – ventilation drift (PSVH), development slope (PU), along with main transport drift (TH) and main ventilation drift (VH), for connection with ore pass and ventilation pass. Ore and ventilation passes are driven from K-155 m level (horizon XVII) to K-15 m level for southeast part of ore body. Ore pass RO-2 will be used rather than RO-1, because of lower transport lengths. Service and ventilation shaft (PVO -155/-15 m) is used for ventilation of the stopes. Service – ventilation drift is used as a connection with horizon XIII, and it is driven from crosscut OH-21, at 20 m spacing from sublevel crossroad, across the strike. This drift is 22 m long. From this drift, vent crosscut is lined outside the block boundaries and it is 47 m long. From vent crosscut, three haulage drifts are lined at 24 m spacing, which are 60 m long. At the end of haulage drifts, there is cross haulage drift, which is connected to ore pass RO-2 over main transport drift, 25 m long (Figure 2).

Air flow at the stopes is established by main ventilation drift, 45 m long, from PVO-155/-15 m to cross haulage drift. Loading crosscuts are going from haulage drifts at 12 m spacing, with 45^0 inclinations, on both sides of haulage drifts, except in the third haulage drift, where loading crosscuts head only towards hanging wall. From loading crosscuts, raises are opening to connect with trenches.

For ventilation connection with undercut level, it is necessary to drive a slope from crosscut OH-21, 16,5 m long, which enables connection with undercut level. Undercut level is 3,5 m above the transport level. The slope enters into cross undercut drift, 56 m long. From this drift, five undercut drifts are lined at 12 m spacing, going parallel with haulage drifts. Trenches are opening from undercut drifts, using ring drilling.

Layout of block development drifts is shown in Figure 2, while characteristic vertical crosscuts are shown in Figure 3.

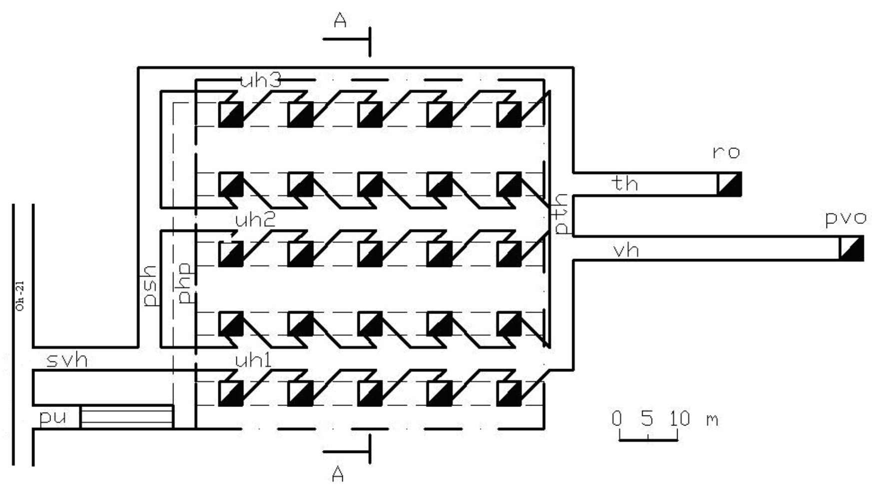

Fig. 2. Block development

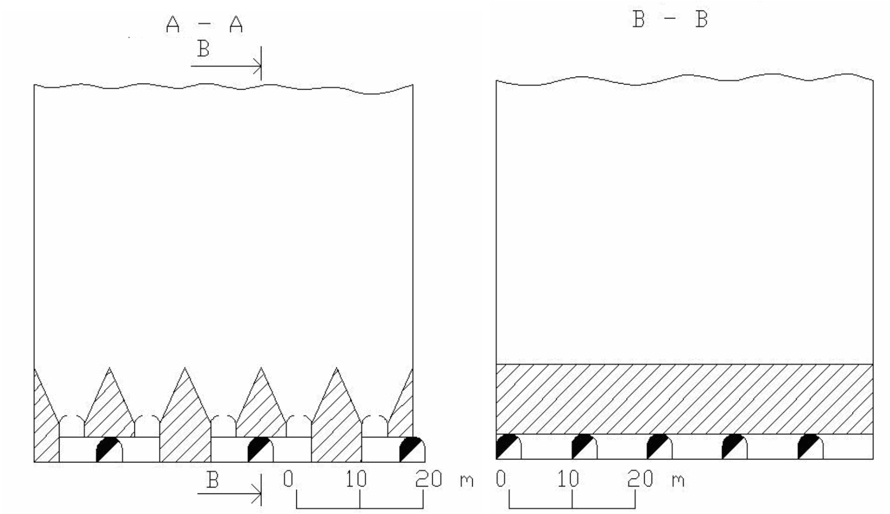

Fig. 3. Vertical block crosscuts

Block development with lateral loading crosscuts enable simultaneous ore drawing from entire block.

Ore drawing from entire area of block bottom provide increase of loading equipment utilization, and also the increase of overall ore recovery. Careful and well planned ore drawing provides minimal ore dilution, lower than average ore dilution for this group of mining methods [7], [8].

4. Conclusion

Block caving is a highly productive and low-cost method. Its application enables using of existing equipment in Jama Bor copper mine for each mining process. According to analyses of possibilities for application of this method, with parameters gained by lab testing, and after applying these results to actual conditions in P_2A ore body, following results could be expected:

- Development ratio: $k_p = 1,8\ mm/t$
- Recovery ratio: $k_i = 0,86$
- Dilution ratio: $k_o = 0,1$

Block caving was suggested as possible solution of this problem after reviewing all of influential factors and actual situation in the ore body. That is why block caving is considered as most suitable in this case.

Using the mathematic formula from ore drawing theory, overall amount of ore gained from central part of P_2A ore body by block caving is:

$\boldsymbol{Q_{rr} = 464.678\ t}$,

with average ore grade of 0,752% Cu.

There is no doubt that this method has never been applied in our country before and there are possible difficulties in its application.

However, all of these problems could be solved by appropriate technical solutions. There are lots of factors which couldn't be estimated right now, such as ore fragmentation. However, this could be an appropriate test for further application of this method in deeper parts of Bor ore deposit.

5. References

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