

Review of the Previously Considered Mining Solutions for the Ore Body „Borska Reka”

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Abstract: The ore body „Borska reka” is the biggest one discovered in the metalogenetic Zone of Bor. On the contrary of the others, previously discovered and mined highly grade ore bodies, „Borska Reka” is the ore body with low grade ore and it’s the deepest one in the Zone. Therefore, only underground mining could be applied to mine this ore body. But there were some difficulties about the possibilities for the mining because on the surface above of the ore body exist a few very important facilities as well as in previous years the copper price was too low. Therefore from the time when the ore body had been discovered, during the years, many possibilities and opportunities for profitable mining of the ore body were considered by many experts from almost all Researching Institutions and Consultants in Serbia. In this paper work the review of those researching is shown, focused on the considered mining methods.

Key words: Ore body, mining depth, profitable mining, the methods

INTRODUCTION

The ore body „Borska Reka” is shown on the figure no.1 and it is a massive mineralisation shape. The lenghtway direction is the northwest-southeast, and it is dumped to the west-suothwest direction with general angle of 45°-55°. The maximum lenght of the ore body had been estimated on the K -400 level and it is reached 1410 m distance. On the same level had been estimated the maximum width of 360 m as well. The above data are valid for the cut – off – grade of 0.3 % Cu. For that cut-off-grade, the average high from the top to the bottom of the pre body is approximately 620 m^[1].

Taking account the location of the ore body as well as the existing facilities on the surface above of the ore body, the question tag is about the opportunities for its profitable mining. On the other point of view, discovering a possibility for economic sustainable mining would be extended the working life of the currnet active underground site „Bor”.

During the researching about the mining method selection, two group of methods habe been considered: backfilling group of methods and caving group of methods^[2]. But the most important issue about the method selection is relocation of the facilities on the surface above the ore body and the costs for their relocation^[3, 4]. The relocation cost are

In the second stage some other variants had been considered, but the works were focused to the cutting the costs. More attention was considered about the application of different types of mining equipment for bogging, loading, haulage transport, crushing and hoisting. Previously considered solutions included LHD diesel boggars. In the second stage the same method were designing like in the first stage but with application of the electrical power equipment, due to high ventilation costs in the case of diesel equipment application.

Some new variants of sublevel caving methods were proposed, with higher distance between the levels. During the designing of those methods the application of the vibrofeeder for bogging and ankle – conveyors for haulage transport. Some of those solutions were original ones^[3, 8].

One of the most important outcome from the performed researching was about the possibility to take a higher distance between the levels and this result focused further reserachings in that way. As a result of those efforts „The Level Caving” methods were designed and on the basis of those one, finally two variants of „Semi-Level Caving” methods were proposed^[3, 12].

To keep surface of collapsing due to mining activities only one method was considered. It was Open Stope method with backfilling, with some modifications and improvement in mining layout pattern.

The third researching stage has being performed during the last ten years related with the start use of mining software

„Gemcom” and statr work of the new Rock and Soil Mechanics laboratory in the Copper Instiute Bor. Then were analysed all previously considered methods and the Room and Pillar methods were excluded for further considerations because of the following reasons:

- too low level of ore recovery (32 % , 40 %) and
- impossibility to keep persistant the open stops without backfilling, but bacfilling would be significantly increasing the operating costs.

Finnaly, the caving methods were accepted as the best solution, taking account technical and economical aspects of the mining operations. In this researching stage some variants of Block –Level Caving and Sublevel Caving methods were considered.

Because the decision about the most appropriate mining method has not done yet, it's obiously that the researching will continuing in the fiture as well. The authors af this paper, because of the reasons mentioned above, decided to show a review of all researchings related with the mining method selection for the ore body „Borska Reka” with analyses of the outcomes from past researchings, with the aim to show to future researchers the issue which should be focused. In some considerations even Block Caving methods have been taken account, althought Block Caving was not been considered in the past researhings, but as an possible option was proposed for the mining of the remained ore reserves in some other ore bodies (Veliki Krivelj and Južni Revir – Majdanpek)^[22].

THE RESEARCHED MINING METHODS

The 1st Researching Stage

The first considerations about the possibilities for ore body „Borska Reka” mining were done in 1983. Then was made in „Copper Institute Bor” a project „Researching, Exploitation and Processing of the Base Metals” and as a part of that project a „Study of Longterm Development and Mining the Copper Ore Bodies in Basin Bor”^[5]. In that study, in the chapter related with underground mining in RTB Bor, in a few words was mentioned that in north-western part of the ore deposit Bor a geological exploration was going on. It was noticed that the current proved ore reserves were more than 250 million tonnes with average copper grade of 0.7 % and that the

explorations would be continued according to the official programme. Also, in the study was noticed that the ore body, later named „Borska Reka” is a future of mining activities in Bor Mine. About the mining methods it was just mentioned that the prospective method had to provide high level ore recovery, minimum ore dilution, to be low costs and maximum take care about safety aspect of work. In the continuation of the above mentioned project, „The Study of Ore Body »Borska Reka« Mining Applying Sublevel Caving” was done^[6]. Considering possible mining methods, a broadly selection was made and the following methods were emphasized:

1. The Longhole Block Mining Method with the Compensation Room,
2. The Longhole Block Mining Method with Shrinkage Mining without Pillars,

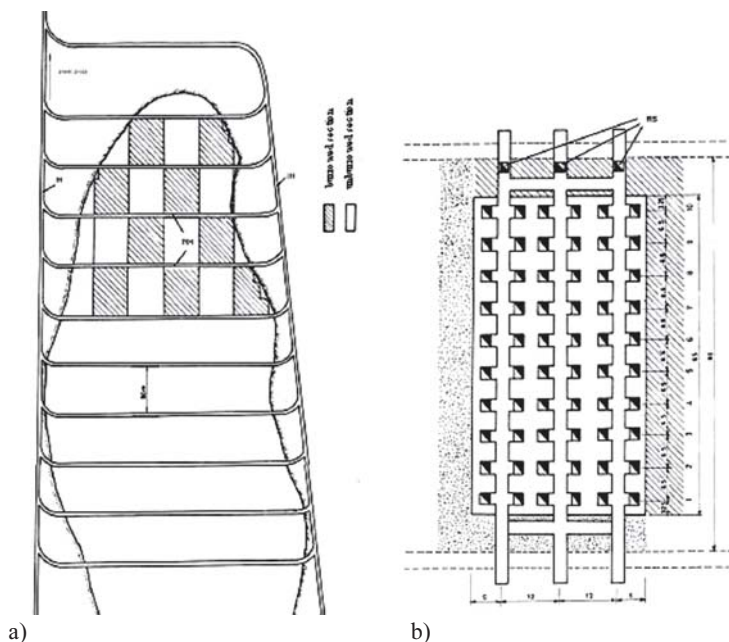


Figure 2.: a) The mining layout scheme for cross-disposed mining blocks and mining development drives on a level, b) The scheme of a mining block on the loading level

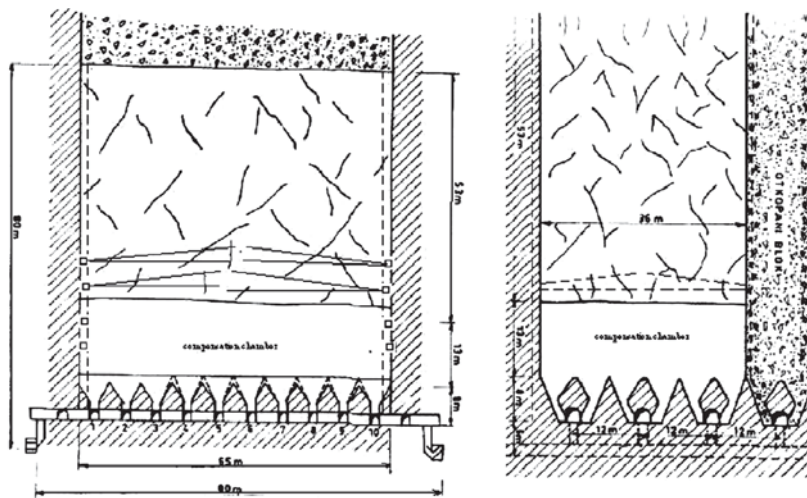


Figure 3. The shema of the mining method in the vertical section planes^[6]

3. The Longhole Block Mining with Shrinkage Mining and Post-Mining of the Remained Pillars,
4. Sublevel Caving – the Swedish Variant,
5. Sublevel Caving in Compressed Environment with Shrinkage Mining,
6. The Frontal Sublevel Caving Method.

After above review, authors of this study decided to consider the first three methods ^[6].

1. The Longhole Block Method with the Compensation Room

The mining layout for this method is consist of mining blocks with rectangle shape and dimensions of 65 x 36 m, as it shown at the figure 2. High distance between the levels is 80 m, and the mining blocks are disposed on the lenghtway of the ore body. The main haulage and loading levels are connected by ore passes.

The loading and cutting level where is a compensation room, are connected by funnel – shaped ore passes. The distance between the ore passes is 6.5 m. The ore mining is

going on by drilling and blasting works with horizontal drill holes. The compensation room is extended across the all block area due to set down the volumetric surplus of ore, as it shown at the Figure 3.

2. The Longhole Block Mining Method with Srinkage Mining without Pillars

The mining blocks here are disposed cross over the lenghtway of the ore body. The width of the blocks is 15 m and the height 80 m as wells as the height between the levels.

Mining development on each level is consist of the number of parallel loading ore drives with 15 m distance between each of them, as can be seen on Figure 4. 20 and 50 m Above of the loading ore drives are the drilling ore drives of the first and the second drill level respectively. The mining activity at each block beginning with boring a slot ore raise in the middle of a block, and then to extend a ore raise to reach a width of a block and that extended ore raise should be used as a vertical compensation room (the start free space). The drill holes are bored

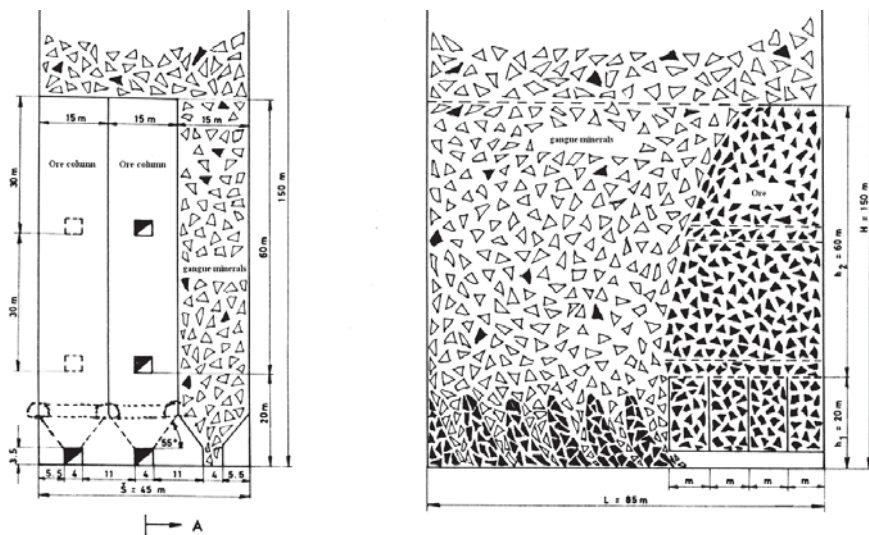


Figure 4. Scheme of The Sublevel Caving Method with Temporarily Shrinkage Mining^[6]

from the both sublevel ore drives and simultaneously are blasted rings from the upper and lower drilling ore drives. From the loading ore drives are bored shorter rings due to cut off the blocks and to provide access for boggging the ore. Blasted ore is loaded by boggars from the loading ore drives, Because of the too much hight of the blocks due to

achieve a good caving process of ore, the ore is bogged from an extended ore belt (on the figure is marked as „m”). As an effect of that activity there is a certain amount of ore loss in the lower part of the block , as is shown on the figure. This is one disadvantage of the method , because when the blocks are too hight there is higher level of ore dilution.

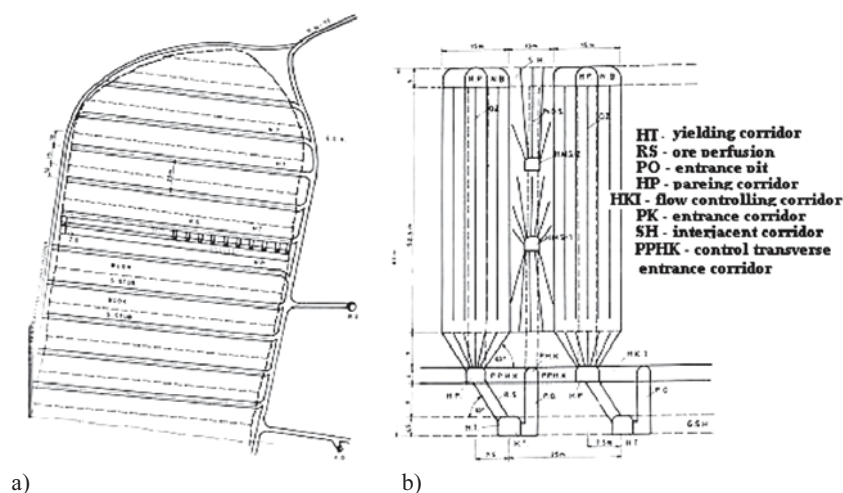


Figure 5.: a) Disposition of the mining blocks and loading ore drives on a level;
 b) Vertical sectionplane of the method^[6]

Also, this construction of the method with the sublevel drilling ore drives is related with higher level of development works.

3. The Longhole Block Mining with Shrinkage Mining and Post-Mining of the Remained Pillars

In this method the mining is consist of two stages, the primary and the secondary mining stage. The primary mining stage is going on in the blocks 15 m width using parallel long hole drilling and blasting pattern. Between the blocks (rooms) the pillars 10 m width are left, those pillars would be drilled and blasted later, in the second stage, and the ore would be caved from the drawpoints of the primary stage. The location and the shape of the mining methods and the vertical sectionplane of the method are shown in the Figure 5. As can be seen, the mining layout on the each level is consist of loading ore drives and cutting ore drives, and ore is caved from the cutting ore drives. Due to control of the caving process, would be done the control ore drives with the transverse ore drives to the each drawpoint.

In the first mining stage ore is mined by parallel drill longholes which are drilled from the cutting drives below of the roof on the upper level. After mining and bogging the ore from the blocks are finished, then start mining of the remained pillars, this is the second stage, using the drill holes blasting which are drilled from two sublevel ore drives in the middle of the pillars. The mined ore is bogging from the same drawpoints as the ore from the first stage.

At the end of the „The Study of Ore Body »Borska Reka« Mining Applying Sublevel Caving” it was emphasized that the correct

selection of the mining method of the ore body „Borska Reka” could be achieved taking account the following conditions:

- a study for ore body „Borska Reka” mining without collapsing of the surface should be done;
- in the proposed study the mining should be performed in two stages as well;
- according to the supposed results of the both studies should be done a technical and economic analyses as the basic issues for a mining optimization- the selection of the most appropriate mining method for the ore body „Borska Reka”.

According to the above mentioned conclusion „The Study of the Ore Body »Borska Reka« Mining with Keeping the Surface”^[7], and in the study two new methods were considered to avoid potentially collapsing the surface. These methods are:

1. Room and Pillar Method with Backfill Mining and
2. Sublevel Stoping Method.

Room and Pillar Method with Backfill Mining

This method belongs in the group of mining methods which keep the solid rock massive around the ore body and do not cause collapsing of the surface above the ore body and the facilities on the surface^[7].

Mining layout for this method is consist of the 15 x 80 x 59 m blocks. Mining operations are going by blasting of longhole drill holes with diameter of 165 mm. Mined ore is coming down into the cutting level and then through ore passes is loading into the suitable mine loading equipment in the loading ore drives. The distance between ore passes is 7 m, oriented toward ore body lengthway.

For mine haulage it's proposed application of the trucks with 30 t capacity which are should be loaded direct form the ore passes. Oversize materials would be broken by secondary blasting or mechanical crushing.

Between the mining blocks 10 m width pillars would be left. The length of the pillars is the same as the length of the mining blocks. The height of the pillars is 69.5 m plus 10.5 m is the width of the roof plate pillar disposed above the blocks. On the Figure 6 is shown this mining method.

Development mining works are consist of the haulage drive on the level and tunneling the ore drives from the haulage drive, oriented rectangle of the ore body lenghtway. 10 m above of the loading level the cutting ore drives are tunneled. From the cutting ore drives, the blocks is cut of by the 7 m height bored tranches 59 m Above of the cutting level, in the middle of the blocks, are located the drilling ore drives. They are extended up to the edges of the blocks and then from the drilling ore dives start boring longohole drill holes down to the cutting level.

In the roofwall part of the ore body, from the drilling level is located the bacfill ore drives which are connect the drilling ore drives. The porposes of these ore drives is ventilation and the supplying of the backfill materials up to the stopes. The loading, cutting, caving control and drilling levels are connected by an incline with 20 % inclination which one should be used for vetilation and servis issues.

Sublevel Stopping Method

Subelev stoping method was considered just ones. The reality of the application of this methods is doubtfull, because it is not expect that the pillars are able to persist the stress for a long time. The existence of the faults and shears in the ore body could be affected the pillars and certainly soon or later some sort of backfilling would have to be provided to fullfil the remained stopes. One of the solution could be backfilling with the tailing waste, expecially taking account the problems in the surface about the tailing waste disposal.

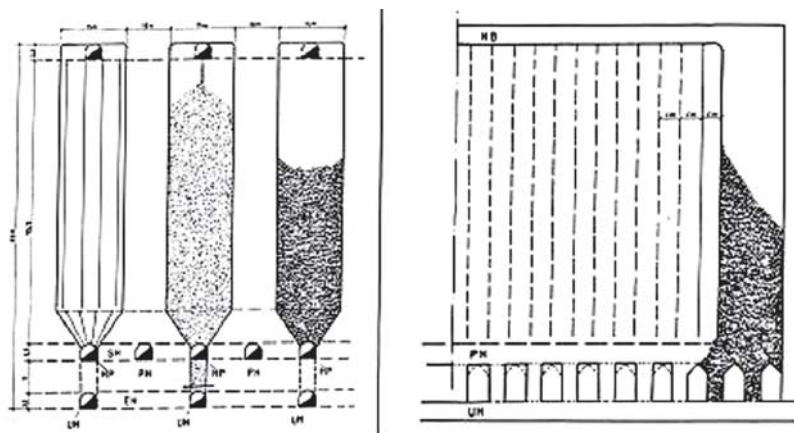


Figure 6. Room and Pillar Method with Backfill Mining^[7]

The proposed method is consist of simply solutions for development and mining works. Development works are consist of the ore drives at the bottom and the top of the rooms. The longhole parallel drill holes are bored from the top ore drives, and the bottom drives are used for bogging. Because the boggars should be bogging the row materials into the unsupported area, they should be remote controlled. On the Figure 7. is shown the layout of the method which is very similar with previous described method.

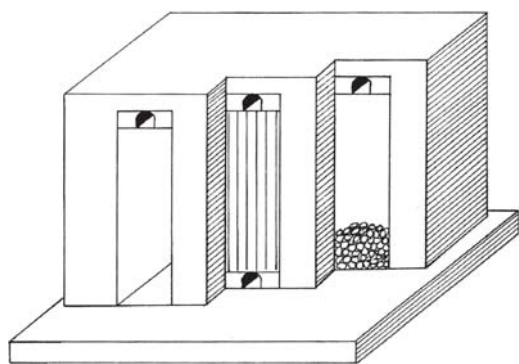


Figure 7. Sublevel Stopping Method

The IInd Researching Stage

In the second researching stage some other opportunities were considered , priority focused to find out the possibilities for cut the operation cost and provide the economical and profitable exploitation of the ore body „Borska Reka”. In this stage all previously described methods of the first stage were considered but this time with the electrical powered equipment. This is because previously researchings determined that for the high capacities (e.g. 4-10 million tones per year) ventilation costs would be too high as well as some technical

problems related with intakeing the fresh air throught the existing mining infrastructure could be occure. These researchings have shown the opportunities for cutting off the ventilation costs as well as the necessity to take account variable solutions and opportunities for the further researchings. Except already above desribed methods, some other methods were designed, as would be shown.

Sublevel Caving in Compressed Environment with Shrinkage Mining

Sublevel Caving methods had not been seriously considered previously because the longyears of experience with sublevel caving in Bor Mine. Althought some researching have shown some opportunities to change some parameters of the method related with the following issues:

- to increase the distance between the levels which would decrease the amount of development works per tonne of ore,
- to find out the possibilities to decrease the ore dilution by applying the ore mining in the wider ore belts.

These suppositions were considered in a few paper works^[8]. The basic for researching was a designed Sublevel Caving method as it is shown at the Figure 8. This is a proposed method with some combinations of Sublevel Caving and some variants of ore bogging. In odd ore blocks the ore is mined in a wider ore belts(15 - 20 m) and bogging from the lateral ore drives tunneled from the subsequent coupled ore blocks. In these blocks ore is mined in the shorter ore belts (3 - 4 m) and bogged from the drawpoint in the pre drivea to the haulage drive.

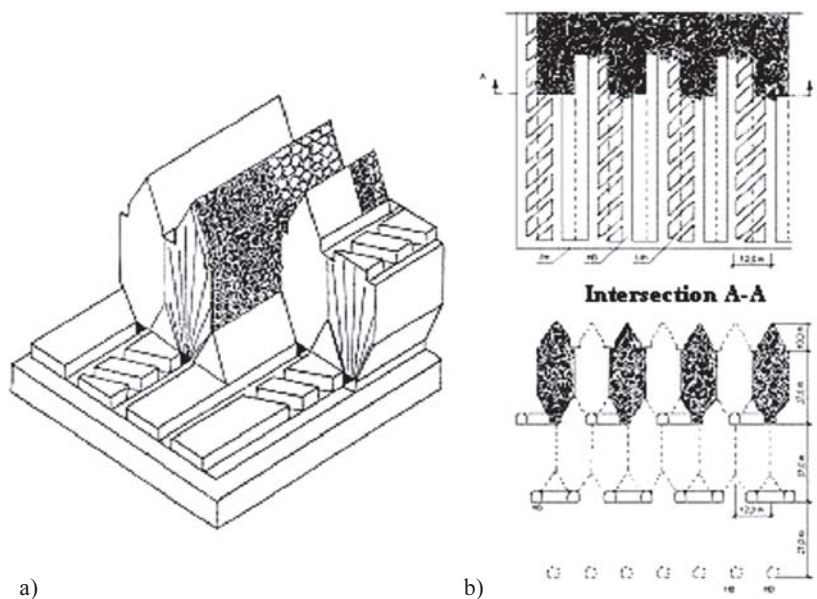


Figure 8. Sublevel Caving in Compressed Environment with Shrinkage Mining: a) axonometric Plan; b) horizontal and vertical sectionplanes oh the method^[8]

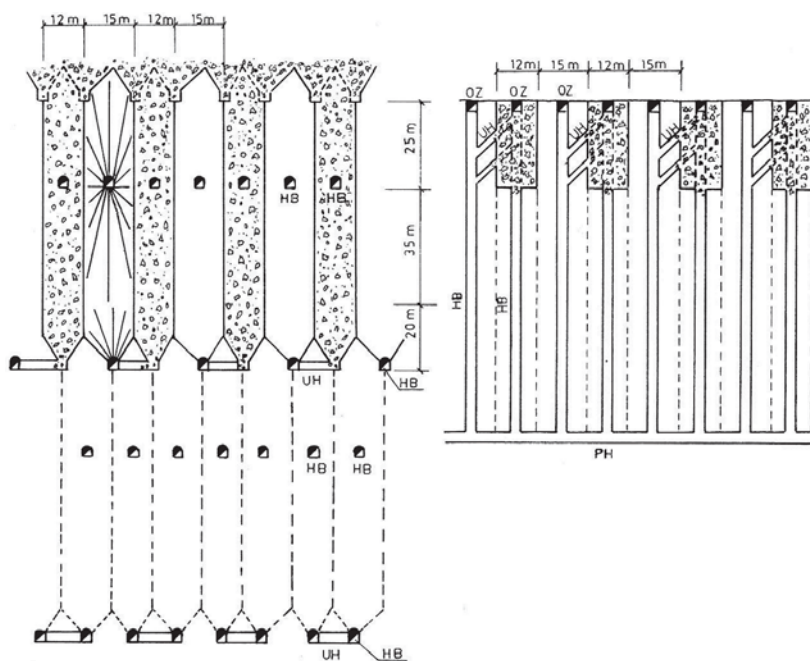


Figure 9. The proposed method of longhole block mining coming form the method shown in the Figure 8.

As can be seen, in the researchings the start distance between the levels was 27 m although during the some Lab. analyses that the height of the levels can be increased. Demonstration model was done for the distance up to the 50 m between the levels, and the caving process shown that there are possibilities for further increasing the distance which was done in some furthermore proposed solutions. One of them is shown on the Figure 9.

In this method the mining layout consist of the blocks 80 m height and 12 – 15 m width. The mining blocks are oriented with rect angle to the ore body lengthway. Development works are located on the basic level and in the sublevel where are located the ore drives.

There is a combination of mining works. In one block the ore is mined in the wider belt and the bogging is going from the sides, and in the next block the ore is mined in the shorter belt and bogging is going from the face. The researchings which are done to prove applicability of this method have shown that better results could be achieved with mining in the wider ore belts. In this case could be expected better ore granulation as well, what is expected for blasting in the compressed environment.

The last one mining method has a significant advantages compare with the previous considered methods. These are the following advantages:

- less development works;
- better blasted ore granulation;
- less consumption of explosive and rock supporting materials;
- increasing the ore recovery;

- decreasing the ore dilution;
- improvement of the work safety;
- better efficiency and mining capacity;
- less mining costs.

From the furthermore researchings come some new proposed variants for longhole block mining:

- the block longhole mining methods with ore blasting in the compressed environment;
- the semilevel caving methods with the lateral ore bogging from one side;
- the semilevel caving methods with the lateral ore bogging from two sided.

The block longhole mining method with ore blasting in the compressed environment

The mining layout and designed solutions of previously described mining method had not provided appropriate solutions for effectively the ore body Borska Reka mining. The designed blocks bottoms could not been able to provide effective ore loading. It was expected that the ore should be bogged by LHD, then dump into the ore passes to the lower haulage level. However some researching ^[23] have shown that proposed solution is not economical. Therefore some other solution were proposed, with the block – bottoms level just above of the haulage level, as can be seen on Figure 10.

This method belongs of longhole groups of method, with a excessive blasting works in the wider ore belts and the proposed design should provide a high capacity of the method, and as a result reduction of the operating costs, which is very important due to relatively low ore grade in the considered ore body.

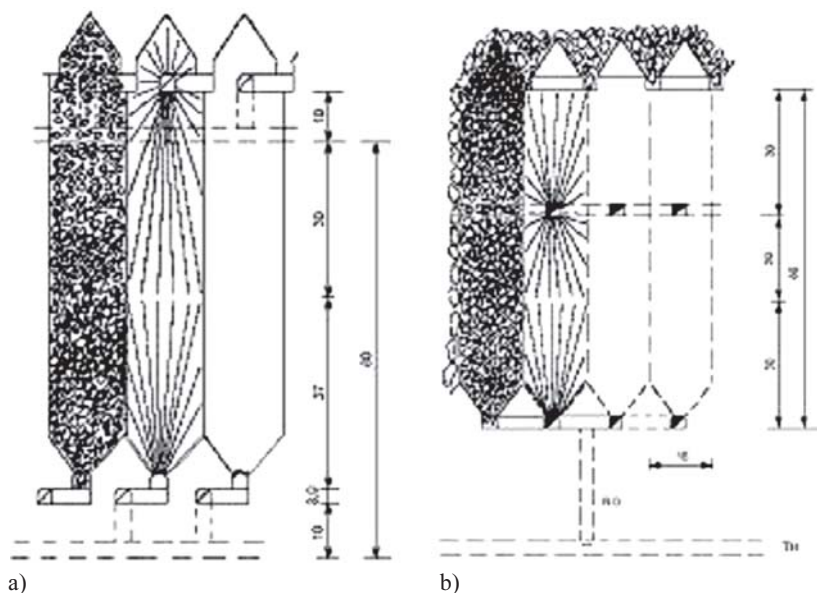


Figure 10. Two variants of the longhole block mining in the compressed environment

As a results of researchings on the demonstration models outcome the following geometrical pattern:

- the width of the mining blocks: 12 m;
- the height of the mining blocks: 80 m;
- the length of the mining blocks: 100 ÷ 120 m.

On the Figure 10 two variants of the proposed method are shown. The difference is related with the orientation of the ore drives. From these ore drives would be bored longholes. Also, it is different disposition of the blocks and haulage drive. In the first case a block is 10 m above of the haulage drive and the ore is blasted from the upper production level. In the second case drilling and blasting works are going from the ore drives on the same level as the haulage drive, 30 m below of the blocks.

The Semi-Level Caving Method with One and Duble Side Lateral Boggging

In Time, the various researchings led to the chose of the loghhole groups of methods, and that was a focus to find out the appropriate method and layout design. That issue leads to the Semi-Level Caving Methods proposal, which ones were the greatest modification compare with previously conisedred grops of mining methods. Two variants were been considered:

- The Semi-Level Caving Method with One Side Lateral Boggging (Figure 11);
- The Semi-Level Caving Method with Duble Side Lateral Boggging (Figure 12).

The methods have the specific position of the mining blocks, because the neigburing blocks are relocated for the half – level distance, up to the middle of the block height. That mining layout should be ensure a lower ore dillution.

In the both variants the ore should be blasted in the mining blocks 80 m height, and the width of the blocks is 12 m in the first variant and 24 m in the second one. The ore would be mined in the belts at least 10 – 16 m width and the height equail with the distance between the levels (80 m)^[11, 12]. By manyfold ore mining and preiviosly bogging a certain amount of ore, the ore could be mined in the even wider belts and the bogging could be done from a lot of drawpoin.

On the basis of the researchings on the demonstration models the following parameters of the mining method were suggested:

- the level
 $H = 80 \text{ m}$;
- the semi – level height
 $h = 40 \text{ m}$;
- the maximal drilling height
 $H_b = 40 \text{ m}$;

- the distance between the bogging and drilling ore drives
 $S = 12 \text{ m}$;
- the ore drives width
 $b = 4 \text{ m}$;
- the ore drives height
 $h = 3.5 \text{ m}$;
- the cros section area
 $P_{OH} = 12.7 \text{ m}^2$;
- the ore burden
 $W = 2 \text{ m}$;
- the length of the mining belt ($6 \times W$)
 $l_{p.m.} = 12 \text{ m}$.

These methods is because of the double – function of the ore drives. E.g. the ore drives used for bogging from the neighboring blocks later would be used for drilling upper level of the block. In the lower level of the block drilling and blasting works are going on from the tranches ore drives and at the same time that mine the development of the lower block level by tranche shaped excavations.

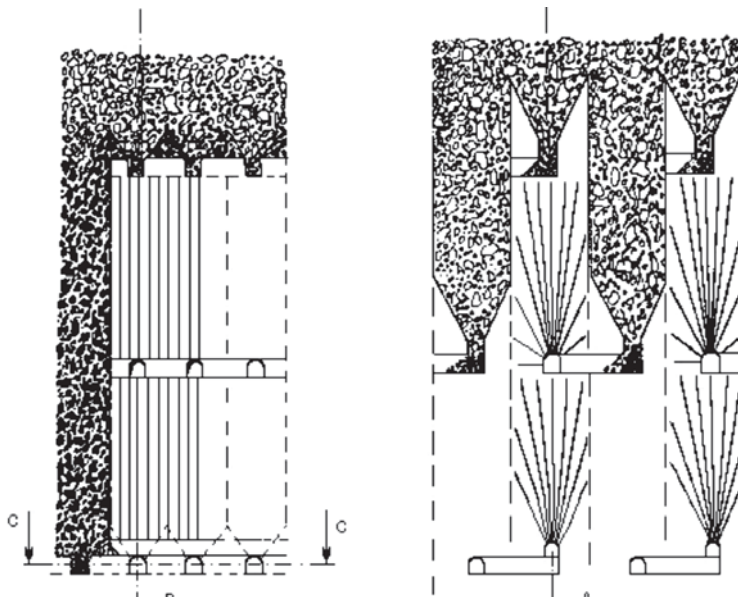


Figure 11. The Semi-Level Caving Method with One Side Lateral Bogging

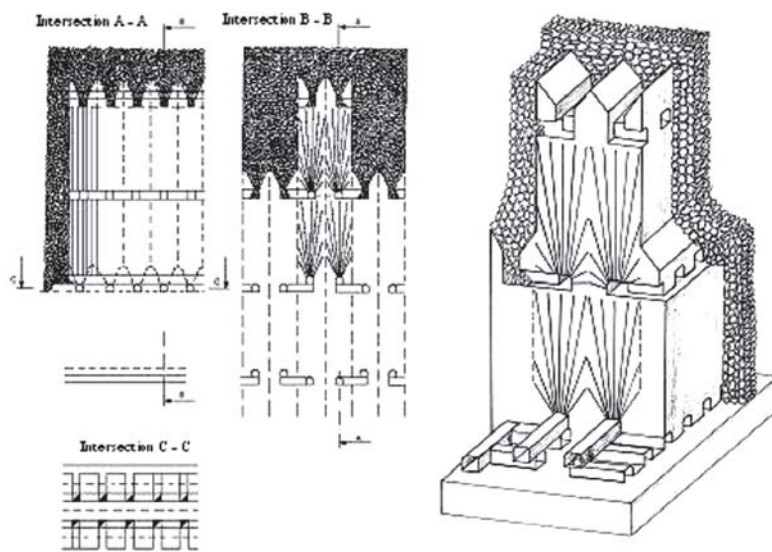


Figure 12. The Semi-Level Caving Method with Double Side Lateral Boggie

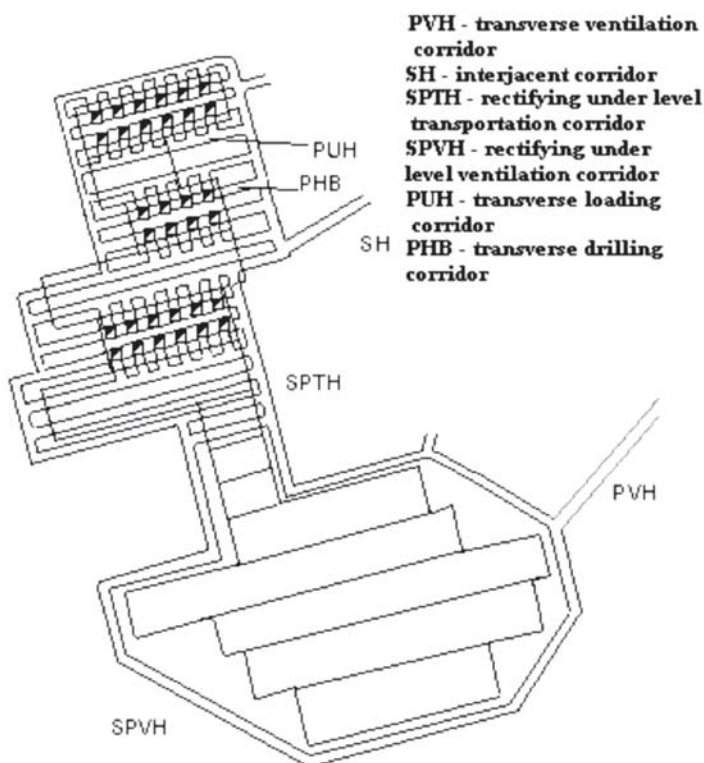


Figure 13. The mining layout at the haulage level

Ore drives are located on the basic level of mining blocks. On the sides of the ore drives are located the excavations which are used for bogging. The distance between the excavations is 10 – 12 m. In the first variant the excavations are located in just one ore drive, and in the second variant in two ore drives. Simultaneously bogging from the several excavations (drawpoints) should provide lower ore dilution level and better ore recovery.

The mining development layout is consist of the some other excavations as well: connecting ore drives, ventilation drives, slot ore rises, haulage drives, ore passes etc. The mining block are located transverse to the ore body, as can be seen on the Figure 13. Figure 13 is shown development layout for the highest part of the ore body where is relatively small the width of the ore body. Also, it is proposed that the ore should be loaded up to the ore passes, then should be dump into the ore passes and from there direct to mobile crushers as a primary crushers. After primary crushing the ore would be haulage further by belt conveyors.

Room and Pillar, VCR and Backfilling Mining Methods

This researching stage was related to find out an appropriate method which should be keep the surface of collapsing. The layout for these methods are the similar with the previous ones, but the development works are a bit different. The rooms are located transverse to the ore body and the rooms and pillars width were taken using rules of thumb (the rooms width 15 m and the pillars width 10 m). But the width of the rooms are a bit bigger in the higher levels compere with the roms width in the lower levels. And on the other side , the pillars width is bigger in the lower levels then in the upper ones. This is related to the underground stress and necessity of the disposal of the pillars because they should be strict located ones above of the others. The proposed rooms disposition is shown on the Figure 14. The length of the rooms is limited to the 80 – 100 m maximum.

The Rooms have tranches at the bottoms located 20 m above of the haulage level. That kind of layout provides a certain number of

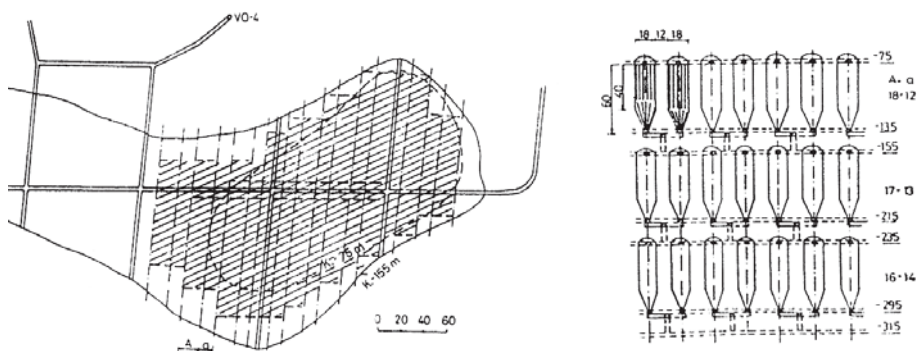


Figure 14. The mining layout in the ore body , horizontal and vertical sectionplane (K -155)

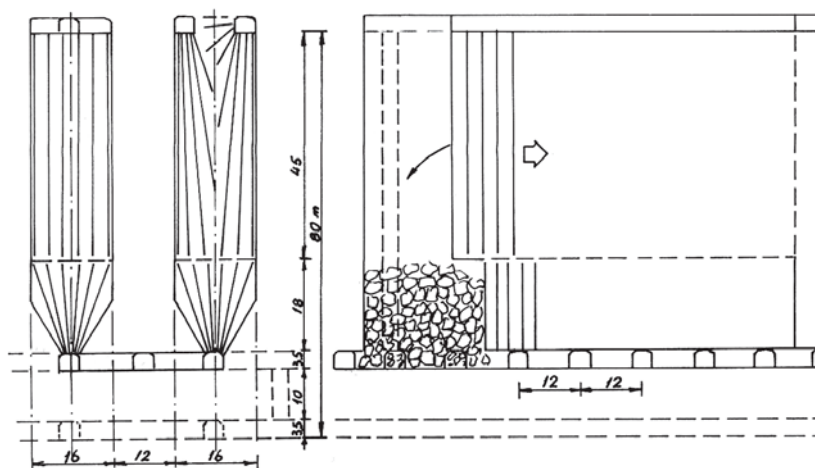


Figure 15. The sublevel stoping longhole mining in the vertical belts (here are shown two different drilling patterns)

ore passes with enough volumetric space to stockpile the ore and at the same time this part of mining block remained unmined serving as a roof pillar for the next downward level. That means that the ore from a lower level rooms would be mined from an upper level ore drives.

The ore recovery depends of the ration between rooms width and pillars width but usually is no more than 30 – 35 % (exceptionally up to the 40 %).

The mining pricip in the rooms can be different, so there are proposed three different variants of the mining method:

- the sublevel stoping longhole mining in the vertical belts (Figure 15.);
- the VCR mining in the horizontal belts(Figure 16.);
- room and pillar mining with simultaneoulsy mining on two levels, where the ore from the upper coming down on the previously mined lower level.

For the purposes of the designing this method it had been chosen the previously considered 80 m height levels, but the height of the blocks bottom is shorten to 13.5 m (it is distance between haulage and cutting ore drives).

Tecnical and economical analyses shown that the third one variant had the best performance, but the preliminary geomechanical researchings shown that could be a problem with the pillars stability due to the their height and big underground stress deeper in the ore body^[15]. Due to fulfill the requirements for the rooms height decreasing, in the paper work ^[15] had been performed the third variant of the lognhole methods as a part of preliminary researchings. It was proposed the two – stage room and pillar mining method as it shown on the Figure 17.

The Method is specific because of a horizontal pillar in the middle of the rooms with the ore passes for the purposes of ore caving

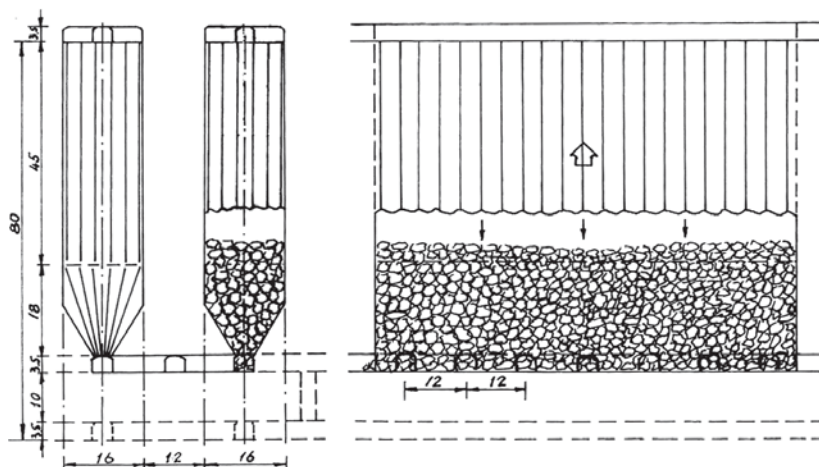


Figure 16. VCR mining method

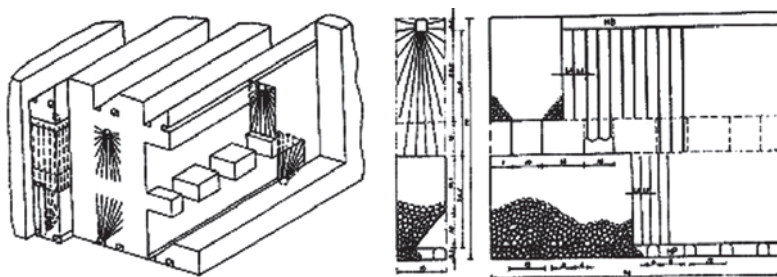


Figure 17. The plan of the two – stage room and pillar method with the basic parameters of the method^[15]

from the upper to the lower part of the room. Drilling and blasting works are going on simultaneously in the both part of the room taking account the mining front is 10 – 15 m in advance in the lower level compare with the upper level front. Development pattern of the bottom of the lower level consist of two parallel ore drives: a trench one (for the ore drilling purposes) and an ore drive for bogging. The detailed design of the method outcome the following parameters:

- the room and pillar width
16 + 16 m;
- the room length
96 m;
- the upper and lower room height
30 m;
- the intensity of the ore body mining
71.3 t/m².

The proposed mining methods have not been excepted due to the following reasons:

- low level of ore recovery (30 % , 40 %);
- impossibility to keep stable the open spaces (rooms) higher then 30 m without backfilling and consequently.

The IIIrd Researching Stage

The third researching stage has been going on during the last few years, since mining software Gemcom had been supplied and since the starting work of the new Laboratory for Rock and Soil Mechanic at the Copper Institute Bor.

Once again were analyzed all previously considered methods but this time using mining software Gemcom. Finally, the Caving group of methods were accepted as the better solutions compare with others groups of mining methods. The researchings was focused to the following method:

Sublevel Caving – Swedish Variant^[16]

At the first production stage it was suggested „Super Scale Sublevel Caving”. By this method is proposed to be mined the upper level of the ore body (downward by the level K -295)^[16]. To Determine the mining layout and the basic parameters of the method the most important issue is to determine the

height between the levels which is related to the drill equipment performances. Also very important issue is the width of the ore drives and the distance between them due to achieved as more as possible parallel ring drill holes pattern. The distance between the ore drives is related with the width of the drawpoints. The mining layout would be consist of ore drives and haulage drives. The distance between the ore drives would be 18 m, and they would be located in the alternate – “Chess” pattern. The distance between the levels is 30 m. Ore drives are fully arch shaped 6 m width and 4 m height, and haulage drives fully arch shaped as well but 5m width and 3.5 m height.

The Super Scale Sublevel Caving method has the following parameters:

- $H = 40$ m - the drilling height;
- $h_p = 30$ m - the level height;
- $B = 18$ m - the distance between the axles
for the ore drives;
- $b = 6$ m - the ore drive width;
- $h = 4$ m - the ore drive height;
- $W = 4$ m - the burden.

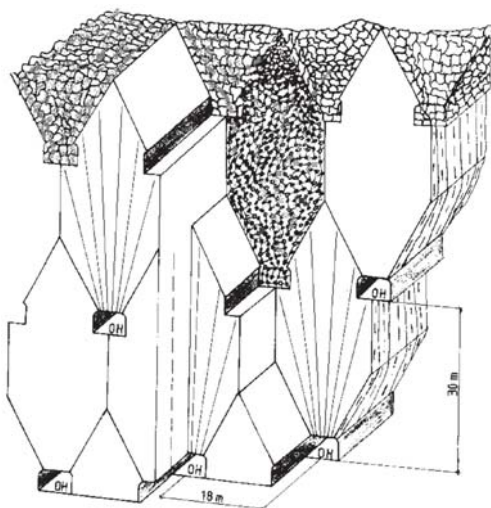


Figure 18. Sublevel caving, mining layout

RESULTS

The Ist Researching Stage

For all three caving methods as well as to – keep – surface method of the first researching stage some model researchings have been done due to gain some parameters about of ore dilution and recovery. The reselts are shown in the Table 1. as well as the develop-ment works coefficient.

Table 1. The Mining Methods Parameters from the I Researching Stage

	Parameters of the Methods	Mining Methods			
		The Longhole Block Method with the Compensation Room	The Longhole Block Mining Method with Srinkage Mining without Pillars	The Longhole Block Mining with Shrinkage Mining and Post-Mining of the Remained Pillars	Room and Pillar Method with Backfill Mining
1.	Ore Recovery (%)	92.4	67	73	62.5
2.	Ore Dillution (%)	6	15	6	0
3.	Development Works Coefficient (mm/t)	3.75	1.48	1.5	2.44

The IInd Researching Stage

Like in the previous researching stage, in the second stage researchings were done by some demonstration models. The parameters related to the ore recovery and ore dilution as well as the developent works coefficient are shown in the Table 2.

Table 2. The Mining Methods Parameters from the II Researching Stage

	Parameters of the Methods	Mining Methods			
		Sublevel Caving in Compressed Environment with Shrinkage Mining	The block longhole mining method with ore blasting in the compressed environment	The Semi-Level Caving Method with One and Duble Side Lateral Boggig	Room and Pillar Method with Backfill Mining
1.	Ore Recovery (%)	80	84.89	88	39.24
2.	Ore Dillution (%)	15	10	12	0
3.	Development Works Coefficient (mm/t)	1.94	1.37	1.312	2.36

The IIIrd Researching Stage

The parameters related to the ore recovery and ore dilution as well as the development works coefficient from the third researching stage are shown in the Table 3.

Table 3. The Mining Methods Parameters from the III Researching Stage

	Parameters of the Methods	Mining Methods
		Sublevel Caving – Swedish Variant
1.	Ore Recovery (%)	80.2
2.	Ore Dillution (%)	10.5
3.	Development Works Coefficient (mm/t)	1.24

DISCUSSION

The Ist Researching Stage

Analysing the achieved results from the first researching stage it is concluded that the best solution is to select The Longhole Block Mining with Shrinkage Mining and Post-Mining of the Remained Pillars. By this method could be reached 77 % of the primary ore recovery. After the second exploatio stage, after the stage of post – mining of the remained pillars, total ore recovery would be 73 %, and ore dilution 6 %. Furthermore, this method can ensure good Safety aspects of mining works, good ground conditions control especially related with the pillars stability, and effective secondary blasting of over – sized materials.

„The Study of Techno – Economical Feasibilty for the Ore baody »Borska Reka« Mining by Caving Methods”^[19] has proved that this method is the best and the most applicable compare with therest two methods, with the best economical effects.

Further, in the Copper Insitute Bor was done „The Study for Ore Body »Borska Reka« Mining by Keep – The Surface Methods - The Economy of Investment-”^[20]. In this stady were considered the economical point of view for the methods without collapsing the surface, like Room and Pillar method etc. for the mining ore body „Borska Reka”. To compare with the previously considered caving methods, in the study had been taken account the same parameters for economical assessment. From the Study outcame the investment level and costs, and expected economical effects (profit) for the exploitation for each method in the first and second exploitation stage.

ON the basis of the achieved results, the Study concluded that under that time available circumstancies the profitable mining was impossible and that therefore future researchigs should be focused on the cost reduction of the mining.

The II and III Researching Stage

The second Researching stage was focused of the cost reduction analyses to find out the possibilities and solutions for profitable mining of the ore body „Borska Reka”. The ways for cost reduction were based on the change the power supply of the mining equipment e.g. from diesel change into the electrical powered loaders, furthermore applying vibro – feeders and belt conveyers.

These attempts did not gave appropriate results due to the decreasing trend of the copper price in the world market at the time. The decreasing copper price trendline was continuing during the III researching stage as well. In the third stage only caving group of methods were analysed. Due to the base and precious metals prices downward trendlines, it was selected the Sublevel Caving – Swedish Variant for ore body „Borska Reka” mining. Then The Main Mining Project was designed but only for the upper part of the ore body so – called „The Hat” of the ore body. According to the Main Mining Project the profitable mining was ensure but in the case without collapsing of the surface and facilities above of the ore body. But some later researchings shown that by applying the Sublevel Caving or any other caving method, it is sure that the surface and facilities would be collapsed, and The Main Mining Project has been dropped out.

CONCLUSIONS

As can be seen above, the final decision about the ore body „Borska Reka” mining have not done yet. To make a final decision would be

necessary furthermore technical and technological researching works and the market researching as well which should provide more trusty data for a future investment programme.

But should be emphasized one good think. Last a few years the copper price has a upward trend. Current price is such that is certainly stimulative to continue further researching. Therefore in the work ^[13] a researching was done to find out applicability of the Caving group of methods in the ore body „Borska Reka” taking account current opward trends in the copper market place. It was considered a profitable applicability for the two mining methods already already designed during the previous researching stages:

1. the possibilities for the profitable ore body „Borska Reka” mining applying The Super Scale Sublevel Caving in the first exploitation stage, but taking account the investment costs to relocate the facilities which would be affected by mining works, these costs have not been considered in the previously so – called GRP Mining Project;
2. the possibilities for the profitable ore body „Borska Reka” mining applying The Semilevel Caving method.

The both method can ensure profitable mining and good economic results. Those results shown that further researching should be focused to the Caving group of method, and related to this statement should be mentioned that currently they are thinking about applicability of Block Caving method.

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**Pregled dosedanjih raziskovalnih
spoznanj v eksploataciji rudnega telesa
“Borska reka”, Bor**

Rudno telo “Borska reka” je največje najdeno v metalogenetski coni Bor. V nasprotju z drugimi, prej odkritimi bogatimi rudnimi telesi, je “Borska reka” manj bogata in je najgloblja v regiji. Zato bo možna samo jamska eksploatacija, ker so v krovlini le siromašne zmogljivosti, ki so bile ustavljene v obdobju nizke cene bakra. Od odkritja rudnega telesa pa so bile opravljene raziskave mnogih strokovnjakov iz različnih institucij v Srbiji, ki sedaj omogočajo razmislek o ekonomsko upravičenem izkoriščanju ležišča. V tem prispevku je podan pregled raziskav, ki obravnavajo možne jamske metode. (vsebinski prevod, J.Pezdič)