НАУЧНО-ТЕХНИЧЕСКИ СЪЮЗ
ПО МИННО ДЕЛО, ГЕОЛОГИЯ
И МЕТАЛУРГИЯ

SCIENTIFIC AND TECHNICAL
UNION OF MINING, GEOLOGY
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Шеста национална научно-техническа конференция с международно участие

PROCEEDINGS

of
Sixth National Scientific and Technical Conference with International Participation

Технологии и практики при подземен добив и минно строителство

Technologies and Practices in Underground Mining and Mine Construction

1 – 4 октомври 2018
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Научно – технически съюз по минно дело, геология и металургия

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Уважаеми дами и господа,
Уважаеми колеги,

От името на Организационния комитет ви поздравяваме за участието ви в **Шестата национална научно-техническа конференция с международно участие на тема "Технологии и практики при подземен добив и минно строителство**", 1 - 4 октомври 2018 г., гр. Девин.

Провеждането на това научно събитие за шести пореден път доказва авторитета и значението му.

Успехът на последната конференция и предизвиканият професионален интерес ни провокира да разширим този форум на по-голямо международно ниво.

И в тазгодишния форум всички ще имат възможност да се запознаят, както с постиженията, така и с възможностите за решаването на проблеми в подземния добив и минното строителство.

Надяваме се, че тематичните направления ще предизвикат отново Вашия интерес и ще провокират Вашия интелект за нови решения на поставените проблеми.

С Вашето участие във форума ще допринесете за повишаване на научното ниво и укрепването на бизнес и лични контакти.

Добре дошли!

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Б. Тунелно и метро строителство.

В. Маркшайдерско осигуряване на технологичните процеси при подземния добив и строителството.

Г. Геомеханични решения при подземни минни работи и минно строителство.

Д. Технологии и практики при взривните работи. Специални методи на взривяване. Производство на взривни материали за индустрията и строителството.

Е. Безопасност на труда. Вентилация и климатизация. Социално-икономически аспекти при управление и експлоатация на подземни рудници.

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З. Квалификация и реализация на кадри в подземния добив и минното строителство.

СЪДЪРЖАНИЕ

TECHNOLOGIES FOR UNDERGROUND EXPLOITATION APPLIED IN THE MINE FOR LEAD AND ZINC "ZLETOVO" - PROBISHTIP

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ABSTRACT
The application of an appropriate mining exploitation method is of great importance for any mine. In some cases, there are opportunities to use more mining exploitation methods in one single mine. Such is the case with the underground mine for lead and zinc "Zletovo", where four mining exploitation methods and several sub-variants have been applied so far.
This paper presents a brief description of the mining exploitation methods applied in the mine "Zletovo", and also a description of the parameters that have been successfully accomplished in the application of the exploitation methods.
Keywords: *underground exploitation, mining exploitation methods, filling, caving, shrinkage, stoping.*

INTRODUCTION

The mine for lead and zinc "Zletovo" from Probishtip started with active production in the distant 1928. After the Second World War, the mine was restarted with an initial annual production of 50000 t. Over the years, its production has been steadily increasing, so in 1960, reached over 260000 tons per year. Maximum production was reached in 1989 from 482146 tons of ore [1].
The mine "Zletovo" has been uninterrupted for about 60 years, except for one interruption of about 4 years due to the transformation of ownership from social to private.
In 2006, the mine "Zletovo" was privatized by the company "Binary Industry" and they registered the company named "Indo Minerals and Metals", which operated with the Mine. The company "Indo Minerals and Metals" from September 24, ceased production, and from 19.11.2015. went bankrupt.
The Government of the Republic of Macedonia in 2016 awarded the existing concession to a new company named "BULMAK 2016" DOOEL-Probishtip, which successfully works and achieves excellent results, fulfilling the planned annual capacity of 250000 tons of ore [3].
The mine "Zletovo" is a vein ore deposit of lead and zinc, where several ore vein with a thickness of 0.10 to 7.00 m are exploited. A smaller number of these veins are completely vertical and the rest are with a drop of 40^0 to 90^0. The ore is medium-sized and does not create problems in the exploitation [1, 3].
This paper presents a brief overview of the mining exploitation methods used in the mine "Zletovo", depending on the available mining and geological conditions during the exploitation of the respective ore block, as well as experimentally obtained parameters with these exploitation methods.

APPLIED MINING METHODS IN THE MINE FOR LEAD AND ZINC "ZLETOVO"

Mining exploitation methods that have been successfully applied for a longer period of time in the mine "Zletovo", and which could continue to be applied depending on the conditions encountered [6], are the following: method for horizontal hanging wall excavation with filling the excavated areas with dry filling material (the so-called classical method), a more detailed method for sublevel caving of ore and adjacent rocks, shrinkage mining method, sublevel stoping mining method.
In this paper, for each of these exploitation methods are listed the conditions for its application, preparatory work, details of excavation through drilling, mining, loading and haulage of ore, ventilation and organization of work. Also, the technical and economic parameters of the exploitation methods are analyzed, among which

are: coefficient of ore recovery, coefficient of ore dilution, coefficient of preparation, capacity and performance, as well as the consumption of materials [2, 4, 8].

In this present day in the mine "Zletovo" for excavation of all ore veins, on all horizons, the more detailed method for sublevel caving of ore and adjacent rocks is applied. This exploitation method gives satisfactory results with excavation, high safety at work, etc. [3].

About 10 years ago, the mining exploitation method was applied by filling the excavated areas with dry filling material, for excavating the ore vein 3 and 6. Nowadays that method is not applicable because it has a very small amount of excavated efficiency and requires a larger number of labor, and also a workforce for haulage the waste rock to fill the excavated space. The remaining mining exploitation methods have been used long time ago, i.e. while the mine was state-owned.

In this present day in the mine, 5 ore veins are excavated, which are named as ore vein 1B, 2, 3, 6 and 12. Exploitation is done on 3 horizons, i.e., horizon 450, horizon 400 and horizon 350.

On the horizon 450, excavation of the ore vein number 12 has been done, which has a falling angle of about 80÷85°, and has continuity in the stretching with an average thickness of about 1.8 m. On the horizon 450, excavation is also carried out on the ore vein number 3, which has a falling angle of about 55 ÷ 60° and has continuity in the stretching with an average thickness of about 1.7 m.

On the horizon 400/350, an ore vein number 2 is excavated, which has a falling angle of about 55 ÷ 60° and has a continuity of stretching with an average thickness of about 1.8 m. On the horizon 400/350, excavation is also carried out on the ore vein number 6, which has a falling angle of about 60 ÷ 65 ° and has a continuity after stretching, with an average thickness of about 1.4 m.

The surrounding rocks in the hanging wall and footwall of the ore veins are mostly dacite - andesite rocks and kaolin.

The excavated ore from the horizons 450, 400 and 350 is transported with the help of accumulator locomotives to the main bunker on the horizon 350/320, from where through the shaft 1 is transported by skip (vertical transport) to the main bunker on the horizon 580 - 560, where the ore is leached and transported with a 14t trolley-locomotive through a adit with a length of 3.6 km to the flotation plant. Shaft number 1 in the mine "Zletovo" is intended for haulage of ore from horizons 450 and 350 to the bunker of horizon 560, and from there the ore is transported by locomotive through the main adit to the flotation plant. This shaft is also intended for the transport of workers and raw materials to the above mentioned horizons and also to serve the mine with power, water drainage and ventilation [3].

The horizontal transport of the waste rock obtained during the preparation of the mining objects on the horizons: 450, 400 and 350 is carried out with 4.5 ton's accumulator locomotives and BPO wagons with a volume of 1.7 m^3. The waste rock of the horizons 450 and 350 are transported to the two-sided station in the shaft recette on the same horizons, which are connected to the service-ventilation shaft number 3, through which it is exported to the surface via adit 2 on horizon 675 [3].

DESCRIPTION OF THE EXPLOITATION METHODS AND THEIR PARAMETERS

1. Method for horizontal hanging wall excavation with filling the excavated areas with dry filling material

Depending on the thickness of the ore veins and their other local characteristics, this exploitation method can be applied in two variants, which differ in each other mainly according to the scope of the detailed preparation and the applied mechanization in the excavations, and accordingly they also differ in the basic technical-economic indicators [5]. The first variant applies if the ore vein thickness is up to 2 meters, and the second variant if the ore vein thickness is over 2 meters. For both variants, all preparatory objects (transport drift-IH, ventilation and fill rise-UVZ, passageways and service rises-UMS, ore pass-RS, scrapper chambers-SK) are made in the ore veins, i.e. in the ore or in the fill (Figure 1).

The excavated space, according to this exploitation method, is filled with sterile material which is obtained in a pit or on the surface, and through the rise for fill is delivered in the excavations areas. The filling is carried out with the advance of the excavations in the segments upwards, so that in the excavations it never has a bigger

height of 2.5 m before the fill, and a smaller height of 1.0 m after the fill (from the upper level of the fill to the ore). In the both variants of this method, after the completion of the preparatory work, the height of the stope begins to rise. In the first variant, no protective plate is left on the lower transport drift, and in the second variant, such plate is left. In the second phase, this protective plate is excavated and most of that ore is utilized.

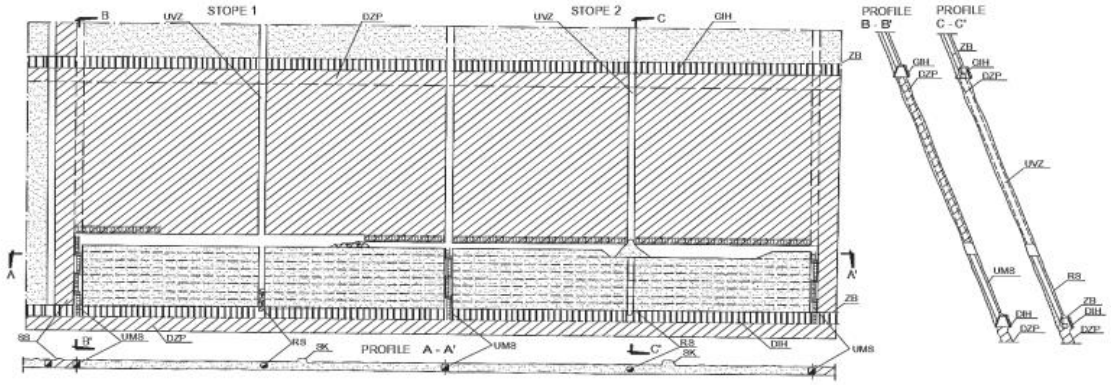

Figure 1. Preparatory work and excavation according to the fill method

In the both variants of this method, a protective plate is left underneath the upper transport drift, but this plate remains unearthed. The boundaries of the height increment are determined by the horizons (about 50m), while the length depends on the applied variant, i.e. mechanization (from 60 to 100m).

The demolishing of the ore in the excavations, in both of the variants, is carried out with blasting holes, which follow the fall of the ore vein, drilled in segments from below upwards at right angles to the stretching of the ore vein, thus achieving systematic and planar demolishing of the ore.

The transportation of ore at the first variant is done with scrapers, while in the second variant this operation is carried out by LHD.

The laying of the fill material in the stope, is delivered from the upper horizon through the rise for fill, and in the both variants is done with scrapers. From the ore pass, the ore is loaded in a wagons and transported further for processing.

The technical indicators for the two variants of this method are different and are shown in Table 1. These indicators were obtained on the basis of the practical experience gained from the long-term application of this exploitation method (variant 1 and 2) in the mine "Zletovo" [1].

Table 1. Technical indicators for the exploitation method by filling the excavated areas

Technical indicators	Variant 1	Variant 2
Ore recovery %	93	92
Ore loses, %	7	8
Ore dilution, %	8 ÷ 10	8 ÷ 10
Coefficient of preparatory work, mm/t ore	22,08	9,89
Coefficient of preparatory work, m^3/t ore	0,051	0,027
Capacity of two stopes, t/shift	56,00	78,00
Intensity of excavations, t/shift	28,00	39,00
Effect on preparatory objects and excavation, t/wage	4,88	7,14
Effect of excavations, t/wage	5,85	7,65

The advantages of this exploitation method are: The sides in the excavations of the stopes are retained, so the work in them is safe, and the surface above the excavations is secured; The morphological instability of the

ore veins is easily overcome; If quality fill material is obtained with this exploitation method, high utilization of the ore and slight dilution of the ore can be achieved.
Disadvantages of this exploitation method are: In comparison with other exploitation methods (shrinkage mining method, sublevel open stoping mining, etc.) the costs of this method are higher; Obtaining the fill material and its placement in the stopes, apart from being one of the most significant items in the exploitation costs, creates many operational and technical problems, engages work force, and thus directly reduces the effects; The consumption of wood is high, which is also not just an economic problem.

2. Sublevel caving method of ore and adjacent rocks

In this exploitation method, the following preparatory objects should be prepared: footwall transport drift-PH, footwall cross-cut-PP, transport drift in ore vein-IH, ore pass-RS, passageway, ventilation and service rises-UMVS (Figure 2).

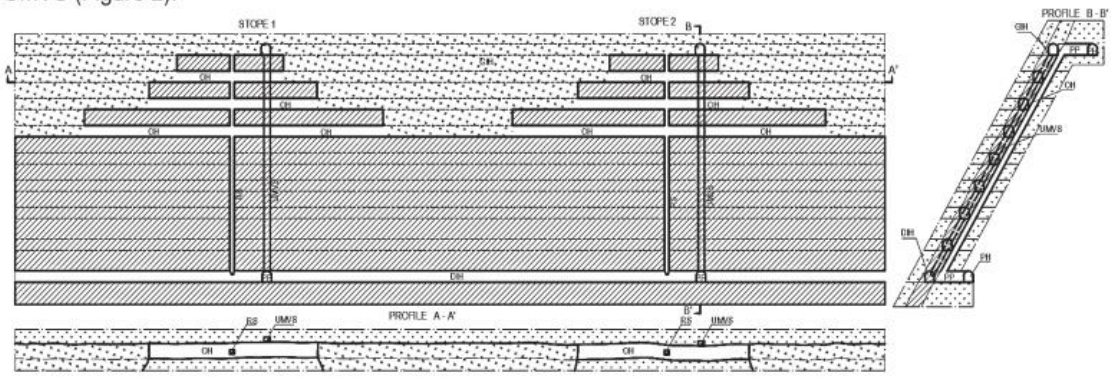

Figure 2. Preparatory work and excavation, with ore thickness up to 5 m, according to the sublevel caving method of ore and adjacent rocks

This exploitation method is used for the excavation of ore veins, where hydrothermal processes created such conditions in adjacent rocks (more pronounced in the hanging wall), which makes them particularly unstable and prone to self-demolition.
The possibility of self-demolition of the adjacent rocks in the hanging wall is used as a factor in this exploitation method, which, with controlled caving, has a positive effect on the results of excavation the ore. The excavation of the ore is done in segments (sublevels) according to the height of the stope, in principle at a vertical distance of 6 m.
On the sublevels the ore is excavated in two phases. In the first phase, the ore is excavated with drifts for excavation, and in the second phase the ore is excavated between the sublevel drifts, in which with withdrawal the material in the hanging wall naturally breaks down and fills the excavated space. This means that excavation can take place only from top to bottom and from the boundaries of the stope to its ore pass and the passageway, ventilation and service rises. This means that the application of this exploitation method is conditioned by the possibility of caving down the space above the stopes.
The boundaries of the stopes by height are determined by the horizons and inter-horizons, while the length may depend on the thickness of the ore vein, i.e. the width of the stope, which makes the application of different mechanization for loading and transporting the ore to the ore passes. From the ore passes, the ore is loaded into wagons and transported to the receiving bunker of the shaft with number 1.
The technical parameters of this exploitation method are shown in Table 2. These indicators were obtained on the basis of the practical experience gained from the long-term application of this exploitation method in the mine "Zletovo", as well as from the model investigations of this method which was carried out by the Faculty of Mining and Geology of Belgrade in 1977, (R. Serbia), in which the coefficient for ore recovery and ore dilution for different thickness of the ore vein and for different other technical conditions are processed in detail [1].

The advantages of this exploitation method are: With good organization and good work safety, compared with the method with filling the excavated space, it is possible to achieve significantly greater capacity in excavating and higher effects in the stopes; Low participation in the preparatory work, in relation to the total volume of works; Provides high safety.
Disadvantages of this exploitation method are: Relatively higher ore losses and ore dilution; While this is partially possible, selective excavation is not always ensured, in cases where the ore vein has interruptions; The ventilation in the development headings is not always good which usually requires auxiliary ventilation.

Table 2. Technical indicators of the sublevel caving method of ore and adjacent rocks

Technical indicators	Exploitation method
Ore recovery %	80 ÷ 85
Ore loses, %	15 ÷ 20
Ore dilution, %	20 ÷ 25
Coefficient of preparatory work for thickness from 2 m and fall of 70^0, mm/t ore	8,22
Coefficient of preparatory work for thickness from 3 m and fall of 60^0, mm/t ore	4,67
Coefficient of preparatory work for thickness from 5 m and fall of 60^0, mm/t ore	2,79
Capacity of stopes with thickness of 2 m, t/shift	40,00
Capacity of stopes with thickness of 3 m, t/shift	60,00
Capacity of stopes with thickness of 5 m, t/shift	65,00
Effect of excavation for thickness of 2 m, t/wage	5,14
Effect of excavation for thickness of 3 m, t/wage	7,29
Effect of excavation for thickness of 5 m, t/wage	7,89

3. Shrinkage mining method

Depending on the local characteristics of the ore veins and adjacent rocks, this exploitation method can be applied in two variants, which differ in each other according to the detailed preparation of the stope, and with some technical-economic indicator [5]. The first variant applies to ore veins with thickness up to 2 meters, and the second variant for ore veins with thickness over 2 meters.
In the first variant of this exploitation method it is necessary to prepare the following preparatory objects: transport drift-IH, passageway and ventilation rise-UMV, cross-cuts-PH, ore pass-RS, sublevel drifts-EH (Figure 3), and the second variant requires the preparation of the following preparatory objects: research drift-IH, footwall transport drift-PIH, loading drifts-TH, passageway and ventilation rise-UMV, cross-cuts-PH (Figure 3).

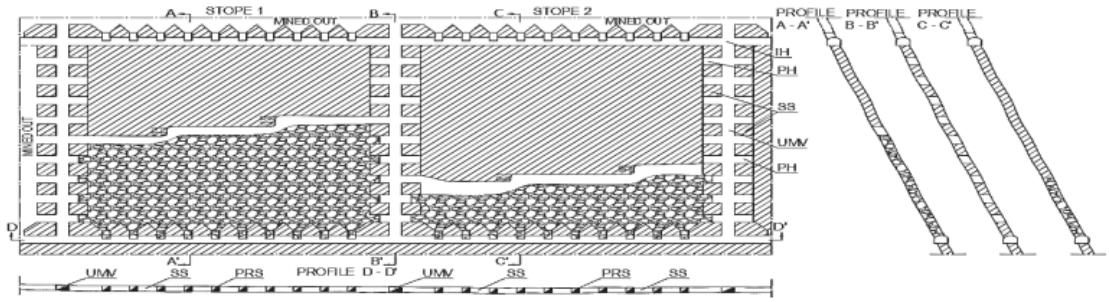

Figure 3. Preparatory work and excavation with shrinkage mining method

With the two variants of the shrinkage mining method, after the completion of the preparatory work, the height increment of the stope begins to rise. The ore in the horizontal belts, collapses in the stope. The collapsed ore in the stope occupies a larger volume than the one that it had in a compact state. To provide the necessary working space in the excavation, this excess of ore is required to be discharged. When the ore collapses, the

miners stand on the ore, which also serves to secure the excavation at its height advance. For safety in the stope, serve the pillars on both sides of the rises, safety plates or safety pillars between the ore passes (dependent on the variant) as well as the additional insurance of the stope with the rock bolts.
The discharge of the stope is carried out after the entire ore is crushed inside it, between the two horizons, or the entire height of the stope.
Variants 1 and 2 differ in each other according to the method of loading the ore from the stope. According to the first variant, loading is carried out in the wagons directly from the ore pass, which are made above the transport drift, in the ore vein. According to the second variant, loading of the ore in the wagons is carried out through the loading drifts with mechanization.
The boundaries of the stopes are determined and limited according to local natural conditions, as well as from the location of the previously prepared research and preparatory facilities. In height they are limited according to the height of the horizons, and the length of the stopes are limited for technical and technological reasons up to 50 m. The width of the stope is determined most often with the thickness of the ore vein, but also for technical and technological reasons, it cannot be less than 1.2 m and it is necessary to be equal at all its height, with minor deviations. Larger changes in the width of the stope by its height can cause jamming and difficulties in releasing the ore from the stope. In order to reduce the possibility of jamming the ore in the stope, secondary blasting of the ore should be applied, as well as anchoring of the blocks from the adjacent rocks, in order to prevent them from causing this jamming. If the ore vein is of less thickness, it is excavated by planned dilution. The upper limit for the width of the stope is not determined and depends of the thickness of the ore vein.
Ground support of the preparatory facilities and in the stopes should in principle not be present, but it cannot be completely avoided and it should be expected that the preparatory facilities will be partially supported with a wooden support, and the stopes will be supported from the sides of the stope, in order to prevent the falling of larger blocks in it.
The safety pillars, along with rises, are excavated in the second phase. According to the first variant, to secure the stopes in the upper part serve the safety pillars between the ore passes. If there is no old stope above the active excavation or the upper transport drift needs to be preserved, then a safety plate is left on the upper part of the stope, which is needed according to the second variant.
The loading of the ore on the lower horizon, according to the second variant, can be from ore passes or by means of transport drifts, and depends on the manner in which the preparatory work will be carried out, which depends on the mining and geological characteristics of the ore vein.
Technical indicators for the two variants of the shrinkage mining method are different and are shown in Table 3. These indicators were obtained on the basis of the practical experience gained from the long-term application of this exploitation method (variant 1 and 2) in the mine "Zletovo" [7].

Table 3. Technical indicators of the shrinkage mining method

Technical indicators	Variant 1	Variant 2
Ore recovery, %	93	90
Ore loses, %	7	10
Ore dilution, %	≈ 10	≈ 10
Coefficient of preparatory work, mm/t ore	29,07	32,02
Coefficient of preparatory work, m^3/t ore	0,10	0,13
Capacity of two stopes, t/shift	48,00	48,00
Effect of excavation, t/wage	8,38	8,06

The advantages of this exploitation method are: Exploitation of the ore is particularly inexpensive; With good organization and control, it is a very reliable method; Manual loading is completely avoided; Provides high effects; High utilization of the ore substance; Good ventilation in the stope.

Disadvantages of this exploitation method are: Much of the ore stands for a long time in the warehouse as a closed capital; Selective excavation is not possible; A large number of active stopes is required in order to continuously provide the planned capacity.

4. Sublevel stoping mining method

Characteristic of this exploitation method is that it is highly productive with low production costs, good ventilation, low dilution and work safety is at satisfactory level. This exploitation method has been applied for more than 20 years in the mine "Zletovo", where several variants have been applied, i.e. modifications to various parts of the site and in various ore blocks of a large number of ore veins. Variants differed according to whether funnel shaped passes are made at one or two levels at the height of the stope, whether they are blasted with long or short blast holes, whether they are drilled vertically or oblique etc. Depending on the means of loading the ore and depending on the slope and the thickness of the ore vein, variants with scraper loading and variants with self-propelled shovels were applied.
In this exploitation method, it is necessary to prepare the following preparatory objects: transport drift-TH, ventilation drift-VH, transport rise-PTU, ore pass-RS, cut rise-UZ, sublevel drifts-PH, cut drifts-HP, auxiliary ore passes-PRS (Figure 4).

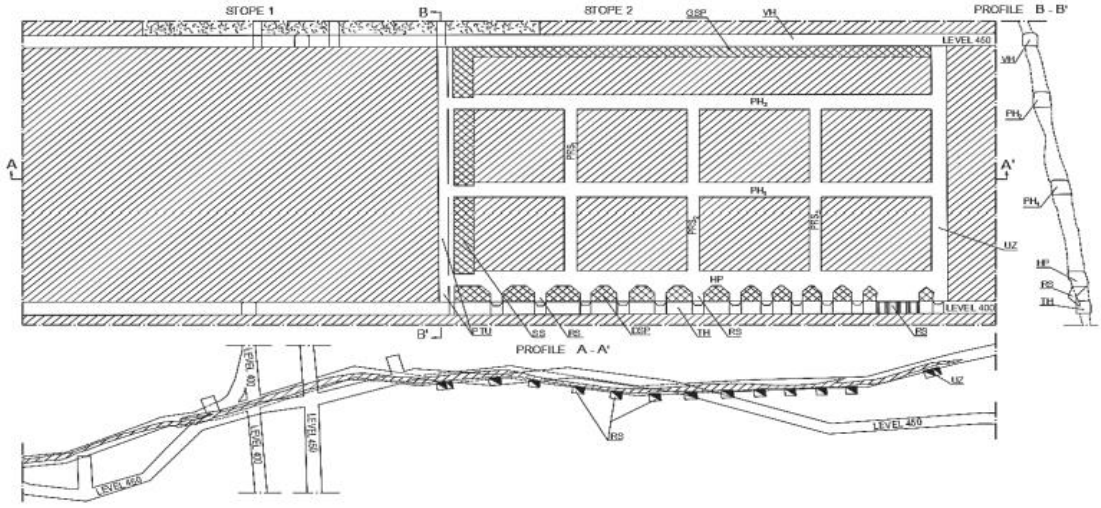

Figure 4. Preparatory work and excavation with sublevel stoping mining method

After the preparatory work, the excavation phase begins. It consists of drilling the blast holes from the sublevel drifts up and down, and from the cut drifts up. The blast holes are parallel to the fall of the ore vein and normal to it. They are drilled exclusively through the ore. After drilling a number of blast holes, they are blasted. The ore falls under the influence of gravity through the cut rise, and then by progressing the digging into the retreat to the transport rise through the open part of stope in the ore passes. Through the ore passes the ore is loaded inside wagons which are on the transport drift.
From the sublevel drifts is blasted half a pillar of ore in between the sublevel drifts. The same applies to the part of the ore between the cut drifts (HP) and the sublevel drifts PH_1, where one half of the pillar is blasted by holes which are drilled from the bottom upwards i.e. from the cut drift, and the second half of the pillar is blasted by holes made down from the sublevel drift PH_1. The part of the ore under the upper safety plate (GSP), which is left at the tip of the stope, just below the ventilation drift, is blasted by holes, which are made from sublevel drift PH_2 upwards.
The blasting of the ore, in fact the initiation of the blast holes, is done simultaneously with the use of time lighters.

The face of the stope, viewed in height, should be in the same plane. If this is not possible, the face of the stope should take the form of opposing scales, with the face at the lower levels leading in front of the working faces of the higher levels. The excavation is carried out in the specified manner up to the limits of the safety pillar of the transport rise.

Upon digging, the upper (GSP) and lower safety plates (DSP) are left. The upper safety plate, below the ventilation drift, is 2 m thick, which are provided by the favorable physical and mechanical properties of the ore and adjacent rocks. If during the excavation there is a need for leaving a plate with greater thickness, this will be accomplished by shortening the length of the blast holes, which are drilled from the sublevel drifts PH_2. The lower safety plate is 3 m thick.

The technical parameters of the sublevel stoping mining method are shown in Table 4 [7].

Table 4. Technical indicators of the sublevel stoping mining method

Technical indicators	Mining method
Ore recovery, %	85
Ore loses, %	15
Ore dilution, %	9
Coefficient of preparatory work, mm/t ore	53,8
Capacity of the stopes, t/shift	75
Intensities in excavation for advance in development heading, m'/day	0,51
Time intensity of excavation, day	142
Excavation effect, t/wage	12,5

CONCLUSION

A rich work experience of about 80 ÷ 90 years in the mine for lead and zinc "Zletovo", with occasional interruptions in production, contributed to the modification of certain mining exploitation methods and their improvement. Practical experience has led to the conclusion that the best results can be obtained by applying the previously considered four mining exploitation methods, depending on the conditions encountered.

In the last few years, the mining method with sublevel caving of ore and adjacent rocks, which gives satisfactory results in the excavation is proved to be the most suitable for the conditions in the mine "Zletovo". Using this method, the following average results are achieved: ore recovery of 90%, ore dilution of 35%, coefficient of preparatory work of 15%, capacity of stopes-120 t/day, excavation effect of 12 t/wage, high safety at work, etc.

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