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The first issue of the journal "Podzemni radovi" (Underground Mining Engineering) was published back in 1982. Its founders were: Business Association Rudis - Trbovlje and the Faculty of Mining and Geology Belgrade. After publishing only four issues, however, the publication of the journal ceased in the same year.

Ten years later, in 1992, on the initiative of the Chair for the Construction of Underground Roadways, the Faculty of mining and Geology as the publisher, has launched journal "Podzemni radovi". The initial concept of the journal was, primarily, to enable that experts in the field of underground works and disciplines directly connected with those activities get information and present their experiences and suggestions for solution of various problems in this scientific field.

Development of science and technique requires even larger multi-disciplinarity of underground works, but also of the entire mining as industrial sector as well. This has also determined the change in editorial policy of the journal. Today, papers in all fields of mining are published in the "Underground Mining Engineering", fields that are not so strictly in connection with underground works, such as: surface mining, mine surveying, mineral processing, mining machinery, environmental protection and safety at work, oil and gas engineering and many others.

Extended themes covered by this journal have resulted in higher quality of published papers, which have considerably added to the mining theory and practice in Serbia and which were very useful reading material for technical and scientific community.

A wish of editors is to extend themes being published in the "Underground Mining Engineering" even more and to include papers in the field of geology and other geo-sciences, but also in the field of other scientific and technical disciplines having direct or indirect application in mining.

The journal "Underground Mining Engineering" is published twice a year, in English language. Papers are subject to review.

This information represents the invitation for cooperation to all of those who have the need to publish their scientific, technical or research results in the field of mining, but also in the field of geology and other related scientific and technical disciplines having their application in mining.

Editors

TABLE OF CONTENTS

UNDERGROUND MINING ENGINEERING 26 (2015) 1-8 UDK 62
UNIVERSITY OF BELGRADE - FACULTY OF MINING AND GEOLOGY YU ISSN 03542904

Professional paper

DETERMINATION AND MONITORING OF ORE RECOVERY AND DILUTION COEFFICIENTS IN SASA LEAD AND ZINC MINE - M. KAMENICA, R. MACEDONIA

ODREĐIVANJE I PRAĆENJE KOEFICIJENATA ISKORIŠĆENJA I OSIROMAŠENJA RUDNE SUPSTANCE U RUDNIKU OLOVA I CINKA „SASA“ – M. KAMENICA, R. MAKEDONIJA

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Abstract: In this paper, proceeding of determination and monitoring of ore recovery and dilution coefficients in lead and zinc mine "Sasa" – M.Kamenica, will be presented. The calculation of these technical and economic excavation parameters were carried out by means of geodetic evaluations and measurements of the volume of excavated and non excavated ore for each stope in the pit.

Key words: recovery, dilution, sublevel caving, geodetic measurements

Apstrakt: U ovom radu prikazan je proces određivanja i praćenja koeficijenata iskorišćenja i razblaženja rude u procesu otkopavanja u rudniku olova i cinka „Sasa“ – M. Kamenica. Proračun ovih tehno-ekonomskih parametara eksploatacije je izrađen na osnovu geodetskih procena i merenja zapremina otkopane i neootkopane rude na svakom pojedinčnom otkopu – čelu radilišta u jami.

Ključne reči: iskorišćenje, osiromašenje, podetažna metoda sa zarušavanjem, geodetska merenja

1. INTRODUCTION

"Sasa" lead and zinc mine is situated in the north-eastern part of Republic of Macedonia, about 12 km north of Makedonska Kamenica. The mine was started with working activities in 1966., while during 2003. to 2006. the mine didn't work because of ownership changes.

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Lead-zinc ore excavation is performed using sublevel caving method (Гоцевски & Мијалковски, 2008). Using of this excavation method, ore recovery and dilution coefficient are in functional dependence, ie. with increasing of ore recovery, dilution also increasing and vice versa.
Considering the fact that the geological reserves of valuable mineral resources from day to day are gradually decreasing, as well as the fact of mineral resources` non-renewable, the problem of rational use of geological ore reserves during lead-zinc ore excavation never loses its meaning and always will be present.

In determining the recovery rate of geological reserves from ore deposit, the ratio of the excavated ore masses and ones contained in balance geological ore reserves is very important (Мијалковски, 2013).

In the past, classical methods (measuring surfaces using Planimeter, calculation of volumes through approximation of curved surfaces with a set of correct geometric objects, etc.) for determination of these masses have been applied. These do not enable the necessary accuracy so thus measurements have certain errors that indirectly affect the calculation accuracy of the recovery rate, during excavation of ore reserves.

The engagement of the large number of analysts and the increased number of working hours to perform the work also presents problem at classical methods.

In order faster and more accurate calculation of the excavated areas and volumes computer graphics is used today. Computer graphics is also very advantageous for visual image of ore bodies and mining objects in 3D, because it allows very well perceive the spatial distribution of all facilities and shaft into the mine. Therefore previously, in Sasa lead and zinc mine have been used "Promine", software package, while a year ago until today "Vulcan" software package is applied.

2. DETERMINATION AND MONITORING OF ORE RECOVERY AND DILUTION COEFFICIENTS ON WORKPLACES

This section will describe the manner of monitoring and determination of ore recovery and dilution coeficients for each workplace in Sasa lead and zinc mine - M. Kamenica. The calculation of these parameters is carried out by means of geodetic measurements of the volume of excavated and non-excavated ore for every position (Mijalkovski et al. 2013). Since ore recovery and dilution coefficient for each workplace is calculated separately, based on them average coefficient of ore recovery and dilution for each ore block, and then for each level is calculated. Finally the average coefficient of ore recovery and dilution for whole mine, for each month and in total for the whole year is calculated.

The measurement of the volume of excavated and non-excavated ore for each workplace is done with modern surveying instruments that present mini computers and their speed, accuracy and output data enable skiping and acceleration of many steps that lead to the final product of all procedure, ie maps and plans (Mijalkovski et al. 2013). One of such most modern instrument is Total Station Leica TCR 805 (Figure 1), which is used in "Sasa" mine and which fully meets all needs of the surveyor in performing geodetic measurements in the underground area.

Figure 1 - Application of Total Station LEICA TCR 805 in Sasa mine

Big advantage of this surveying instrument is that it did not need any trigonometric forms for registration of measured values (angles, lengths), because the same are stored and processed in the instrument and as output data are obtained coordinates and elevations of all measurement points. Then the measured data very quickly and easily converted into a computer and processed by the famous program for drawing AutoCAD.

The electronic display of maps or plans allows great accuracy and precision, which in the past has been complicated for many reasons, such as: the scale, type of paper, storage, deformations of the lining, geodetic drawing accessories etc). It is necessary to note that maps and plans in mining have very variable content, because of everyday changing situation of working activities, especially in the excavation area, so they must constantly be updated and amended, that is actually done in Sasa mine.

The final measurement after excavation of a sublevel is essential, if safety conditions allow it, for safety development of some future mining facilities near the excavated sublevel.

Thus has been calculated the amount of excavated ore from that sublevel and it compares with the value of geological projected ore amount, which determines the ore recovery or losses for the given sublevel.

Figure 3 shows three geological cross-sections, while Figure 2 shows Plan for specified location between these three geological profiles. The plan, as well as the geological profiles given projected geological loops for mining area and results from surveying record of mining activities. Figure 3 shows three geological cross-section profiles, while Figure 2 shows Plan for given location between these three geological profiles. The plan, as well as the geological profiles shows projected geological loops for orudnetata zone and results from surveying record of mining activities.

Thus we have been given graphical review of geological data before starting excavation and results of surveying recordings after excavation of a given part of mining area.

Once finished with the excavation of mining area parts, we compares geological ore reserves amounts with the amount of excavated ore. Also, the graphical attachments (geological profiles and plan) help us for easily calculation of the area or volume of excavated parts, and the parts where ore is not excavated due to certain technical reasons (leaving a protective pillars etc.). Comparing the amounts of geological reserves and quantities of excavated ore, ore losses have been calculated and are compared with projected losses according to mining project.

It is easy to determine the quantity of excavated ore without dilution, and quantity of excavated ore with dilution or unplanned dilution. Thus we can calculate the total ore dilution during excavation in the selected part and compare it to the planned dilution according to mining project. This procedure may help us to check the growth of geological ore reserves, or wheather are occupied some unconfirmed geological reserves.

Surveying records of mining activities during the excavation allows continous monitoring of ore dilution and losses. When ore dilution will increase over the planned according to mining project, excavation on that part will be stopped. After finishing excavation on one workplace, a final survey record of mining activities are performed and the amount of ore dilution and losses for that workplace are calculated and follow reporting. Table 1 shows results for excavation parameters for certain workplace in Sasa mine.

2.1. Example of calculating the coefficient of ore recovery and dilution for specific workplace

In addition to the text follows the example of calculating the coefficient of ore recovery and dilution for specific workplace:

Location:

- Sasa mine;
- Level XV;
- Mining Block 3;
- Sublevel XV – 14 (footwall ore body – north).

Horizontal distance: L = 50 m

- from geological profile 1400 to geological profile 1450.

Vertical distance: h = 7 m

- from sublevel -7 to sublevel -14.

Thickness of mining area:

- variable (from 5 m to 20 m).

Based on geological data and results of geodetic recordings of mining activities (Figure 2a), it was concluded that: Before starting preparatory mining activities and ore excavation for the above workplace, first, the realistic geological excavation reserves should be read $Q_{geol.} = 21.8$ t.

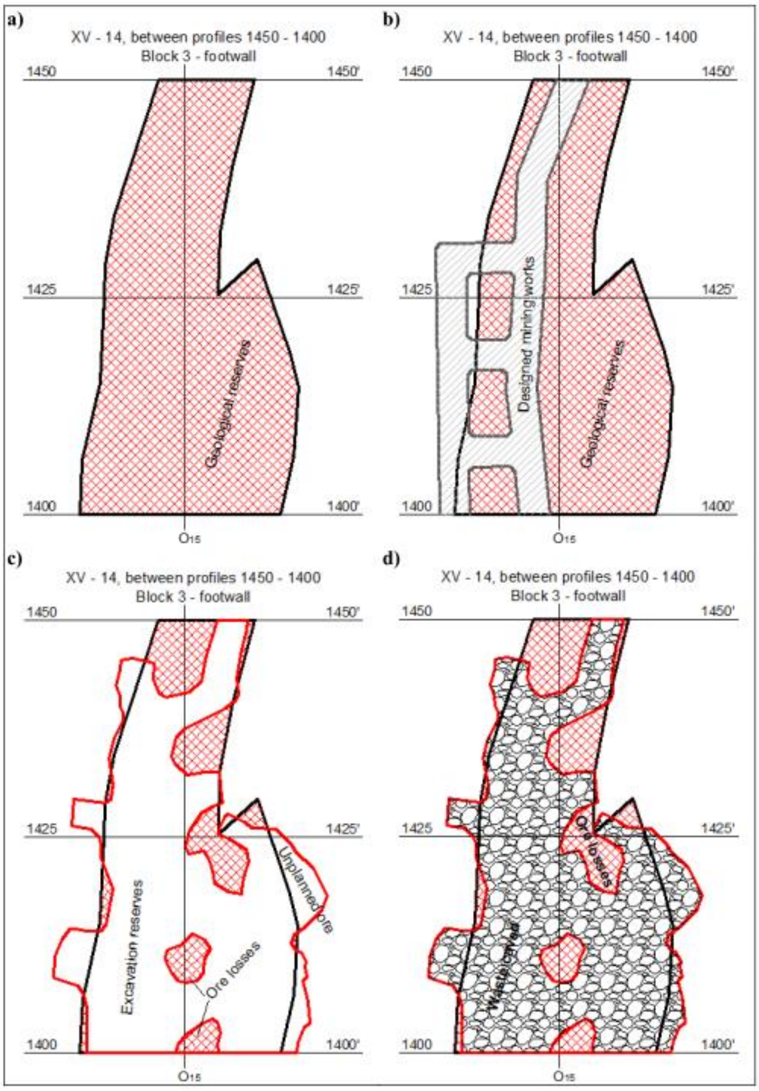

Figure 2 - Situation of working place Level XV, Block 3, Level XV-14 footwall, Profile 1450-1400, with excavation layout

After finishing ore excavation (Figure 2b, c) the situation is follows:

- Amount of excavated ore reserves without dilution $Q_1 = 18.2$ t (1.0 t of which is unconditioned ore);
- Amount of excavated ore reserves with dilution $Q_2 = 19.9$ t (0.7 t of which is rock waste).

Based on specific quantities of excavated ore reserves the ore dilution coefficient can be calculated (Gluščević, 1974):

$$o_r = \frac{Q_2 - Q_1}{Q_2} \cdot 100\% = \frac{19.9 - 18.2}{19.9} \cdot 100\% = 8.5\%$$

The projected average coefficient of dilution according the mining project for sublevel caving method is: $o_{r,rp.} = 18\%$.

Based on measurements of volumes quantities of other ore in the temporary protective pillars are specified (Figure 2c and 2d) and they amount $Q_{zs} = 3.8$ t. Well, knowing the geological reserves and these ore losses in pillars, we the ratio of ore losses can be calculated:

$$z_{zs} = \frac{Q_{zs}}{Q_{geol.}} \cdot 100\% = \frac{3.8}{21.8} \cdot 100\% = 17.3\%$$

Projected average coefficient of losses according to mining project for sublevel caving method is: $z_{zs,rp.} = 18\%$. The coefficient of ore recovery during excavation is:

$$i_r = 1 - z_{zs} = 1 - 0.173 = 0.827 \quad \rightarrow \quad 82.7\%$$

The total amount of excavated ore and other ores in protective pillars on this workplace is:

$$Q_{vk} = Q_1 + Q_{zs} = 18.2\text{t} + 3.8\text{t} = 22\text{t}$$

Table 1 - Data for excavation parameters of some workplaces in Sasa mine

Workplace	Profile	Read geological reserves Q_{geol} [t]	Total excavated ore without dilution Q_1 [t]	Total excavated ore with dilution Q_2 [t]	Total excavated rock waste Q_l [t]	Dilution o_r [%]	Ore in safety pillars Q_{zs} [t]	Total excavate run of mine ore Q_v [t]	Growth of geological reserves Q_{pr} [t]
XV B3-0p	1550-1500	10.2	9	9.4	0.4	4.3	1.8	10.8	0.6
XV B3-0p	1500-1450	9.2	9.8	10.2	0.4	3.9	2.3	12.1	2.9
XV B3-0p	1450-1400	13.3	8.6	10.4	1.8	17.3	5.2	13.8	0.5
XV B3-0p	1350-1300	12	10.7	13	2.3	17.7	2.6	13.3	1.3
XV B3+7p	1450-1400	14.5	15.5	17.1	1.6	9.4	1.7	17.2	2.7
XV B3+7p	1550-1500	6.4	9.8	10.7	0.9	8.4	0.4	10.2	3.8
XV B3+7p	1500-1450	12.1	16	16.9	0.9	5.3	3.6	19.6	7.5
XV B3+7p	1400-1350	18.1	15.8	17	1.2	7.1	2.7	18.5	0.4
XV B3-7p	1400-1350	19.5	17.6	19.7	2.1	10.7	2.3	19.9	0.4
XV B3-14p	1450-1400	21.8	18.2	19.9	1.7	8.5	3.8	22	0.2

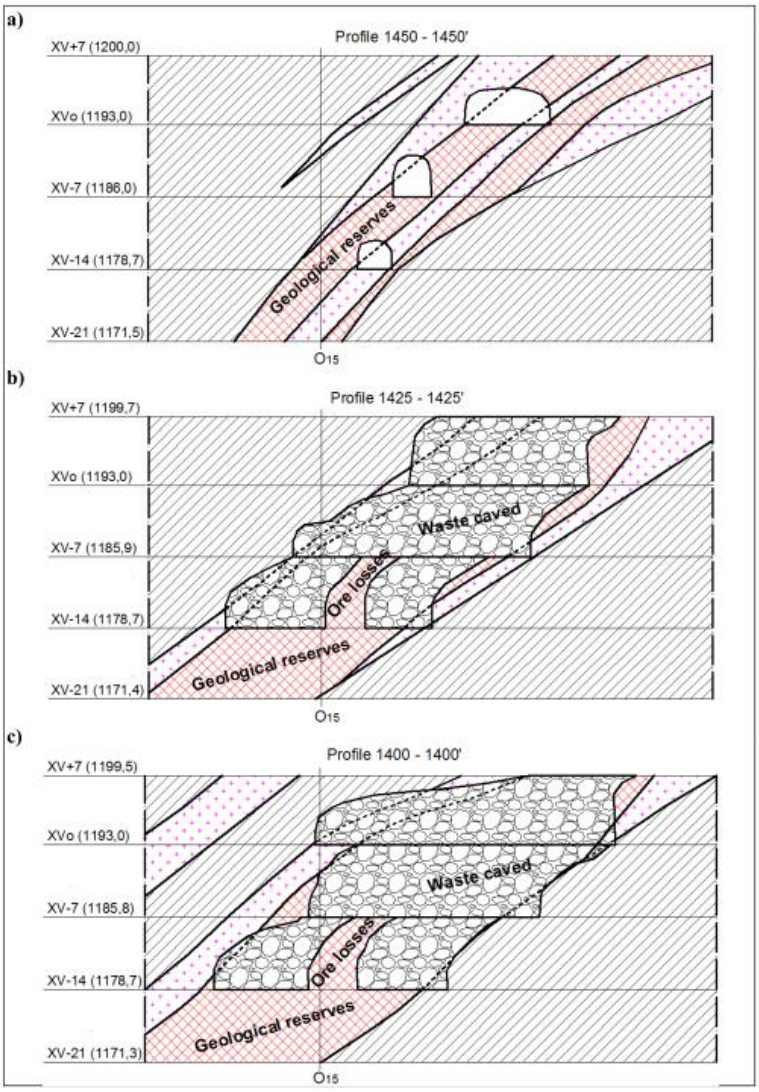

Figure 3 - Profiles for completed mining for working place:
Level XV, Block 3, Level XV-14 footwall, Profile 1450-1400

Now the ratio between total excavated run of mine ore and ore in geological reserves of this workplace can be calculated expressed in percentages:

$$\frac{Q_{vk}}{Q_{geol.}} \cdot 100\% = \frac{22}{21.8} \cdot 100\% = 101\%$$

The explanation for so high obtained ration during ore excavation for this workplace is proved by the following arguments:

- Growth of geological reserves: $Q_{pr} = Q_{vk} - Q_{geol.} = 22\text{t} - 21.8\text{t} = 0.2\text{t}$ or 1%;
- Unconfirmed geological reserves: 0 t or 0%;
- Non excavated because of technical reasons: 0 t or 0%,

which can be seen from the attached graphic articles of Figure 2 and 3.

3. CONCLUSION

The exercise of reasonable values for the ore recovery coefficient (losses) during ore reserves excavation is imperative for each mining company, having in mind the argument that mineral resources is non-renewable. Because of that, today more attention is paid to finding exact methods for its determination. In mining practice the ore recovery (losses) and dilution coefficient is determined with sufficient accuracy using surveying measurements of the volume of excavated and non - excavated ore.

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