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**“Gospodarjenje z odpadki - GzO’19  
Urbano rudarjenje”  
„Waste Management – GzO’19  
Urban Mining”**

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„46<sup>th</sup> Jump over the Leather Skin”**

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dr. Jože KORTNIK

Ljubljana,  
12. - 13. april 2019

Spoštovane udeleženke in udeleženci,

letos ponovno organiziramo 19. znanstveno posvetovanje z mednarodno udeležbo „Gospodarjenje z odpadki – GzO'19 urbano rudarjenje” hkrati z 14. znanstvenim posvetovanjem z mednarodno udeležbo „ob 46. Skoku čez kožo”, s čemer nadaljujemo tradicijo bienalnih srečanj domačih in tujih strokovnjakov s področja rudarstva, geotehnologije, okolja in gospodarjenja z odpadki. Udeležencem želim, da posvetovanji izkoristite predvsem z namenom širšega povezovanja, izboljšanja medsebojnega sodelovanja in izmenjave izkušenj strokovnjakov različnih strok na tako zahtevnem interdisciplinarnem področju.

Na obeh znanstvenih posvetovanjih z mednarodno udeležbo, bo po izboru znanstvenega odbora GzO svoje prispevke predstavilo 16 domačih in tujih predavateljev, strokovnjakov na področju rudarstva, geotehnologije in gospodarjenja z odpadki. Kot že v preteklih letih, nam bodo predstavljene novosti, uspešni pristopi k reševanju različnih problemov, primeri dobre prakse, rezultati raziskovalnih in razvojnih projektov. Za izmenjavo idej, mnenj in izkušenj glede stanja in možnosti nadaljnega trajnostnega razvoja bodo potekale tri tehnične sekcije ter drugi dan posvetovanja strokovno voden ogled kamnoloma Doline, podjetja Marmor Sežana d.d.. Zbornik člankov znanstvenega posvetovanja GzO'19 obsega 16 prispevkov, od tega 8 prispevkov iz tujine (Finske, Makedonije, Nemčije, Poljske in Južne Afrike).

Za pokroviteljstvo nad 19. znanstvenim posvetovanjem z mednarodno udeležbo „Gospodarjenje z odpadki – GzO'19 urbano rudarjenje” se želim zahvaliti Univerzi v Ljubljani, Naravoslovnotehniški fakulteti, Oddelku za geotehnologijo, rudarstvo in okolje, društvu SRDIT in pokroviteljema Ministrstvu za okolje in prostor ter Mestni občini Ljubljana. V imenu organizacijskega odbora se zahvaljujem dolgoletnim sponzorjem podjetju RIKO d.o.o, Marmor Sežana d.d., Geološkemu zavodu Slovenije, Inštitutu za rudarstvo, geotehnologijo in okolje – IRGO, podjetju Termit d.d., Moravče in podjetju Salonit Anhovo, Kamnolomi d.o.o., Deskle. Za organizacijo in izvedbo strokovno vodene ekskurzije v kamnolom Doline, se zahvaljujem podjetju Marmor Sežana d.d..

Organizacija in izvedba uspešnega znanstvenega posvetovanja z mednarodno udeležbo zahteva predano in timsko delo številnih posameznikov. Zahvaljujem se članom organizacijskega in znanstvenega odbora GzO, ki so pripomogli k uspešni izvedbi obeh posvetovanj „GzO'19 Urbano rudarjenje” in „ob 46. skoku čez kožo”.

Zahvalo za uspešno znanstveno posvetovanje dolgujem tudi vsem avtorjem člankov, ki ste pripravili in boste predstavili vaše znanstvene prispevke in vsem Vam, ki boste sodelovali z vprašanji, mnenji in pripombami v različnih znanstvenih in strokovnih razpravah.

Z rudarskim SREČNO!

doc.dr. Jože KORTNIK  
predsednik organizacijskega  
in znanstvenega odbora GzO





Dear conference participants,

we are organizing again, the 19<sup>th</sup> scientific conference with the international participation "Waste Management - GzO'19 Urban Mining" together with the 14<sup>th</sup> scientific conference with international participation "at 46<sup>th</sup> Jump over the Leather Skin". Thus continuing the tradition of biennial meetings of domestic and foreign experts from the fields of Mining, Geotechnology, Environment and Waste Management. I would like the participants to take advantage of the both conferences primarily with a view to broader connecting, improvement of mutual cooperation and exchange of experiences different professions in such demanding interdisciplinary fields.

At both scientific conferences, after the paper selection of the scientific GzO'19 committee, 16 domestic and foreign lecturers, experts in the fields of Mining, Geotechnology, Environment and Waste Management will be presented their contributions. As in previous years, will be presented novelties, successful regional approaches to addressing the topics of conferences, examples of good practice, the results of research and development projects. For the exchange of ideas, opinions and experiences regarding the state and possibilities of further development, three technical sections will be held and the second day of the conference will be also organized professionally guided technical excursion to the Doline dimension stone quarry, of the company Marmor Sežana d.d. The Proceedings of the GzO'19 conference comprises 16 papers of these 8 papers from the world (Finland, Northern Macedonia, Germany, Poland and South Africa).

I would like to thank the University of Ljubljana, the Faculty of Natural Sciences and Engineering, the Department of Geotechnology, Mining and Environment and the Slovenian Mining Association - SRDIT and patrons the Ministry of Environment and Spatial Planning and the Ljubljana City Municipality for sponsoring over the 19<sup>th</sup> Scientific Conference with the international participation "Waste Management GzO'19 - Urban Mining". On behalf of the organizing committee, I would like to thank the long-term sponsors RIKO d.o.o., Marmor Sežana d.d., Geological Survey of Slovenia, Institute for Mining, Geotechnology and Environment - IRGO, Termit d.d., Moravče and Salonit Anhovo, Kamnolomi d.o.o., Deskle. For organizing and conducting a professionally guided technical excursion in the Doline dimension stone quarry, I would like to thank the company Marmor Sežana d.d..

The organization and implementation of conference with international participation requires the demanding and teamwork of many individuals. I would like to thank the members of the organization and scientific GzO committee, which contributed to the successful performance of both conferences „GzO'19 Urban Mining” and „at 46<sup>th</sup> Jump over the Leather Skin”.

I also owe you the credit for a successful conference to all authors of the articles that you have prepared and will present your professional contributions and to all of you who will contribute with questions, opinions and comments in various expert discussions.

With mining Good luck!

Assist.prof.dr. Jože KORTNIK  
Chairman of the Organization and  
Scientific committee GzO



## Kazalo/Index

<b>ID 01</b>	doc.dr. Jože KORTNIK Zeleno urbano rudarjenje / <b>Green Urban Mining</b> ..... 1	<b>1</b>
<b>ID 02</b>	izr.prof.dr. Stojance MIJALKOVSKI, prof.dr. Zoran DESPODOV, prof.dr. Dejan MIRAKOVSKI, izr.prof.dr. Vancho ADJISKI, prof.dr. Nikolinka DONEVA Razvoj podzemnega izkoriščanja kovinskih mineralnih surovin v Republiki Makedoniji / <b>Development of the underground exploitation of metallic minerals in Republic of Macedonia</b> ..... 9	<b>9</b>
<b>ID 03</b>	Miha TAVČAR, Marijan KVARTIČ, doc.dr. Jože KORTNIK Širitev podzemnega izkoriščanja blokov naravnega kamna v kamnolomu Debela Griža / <b>Enlargement of underground dimension stone extraction at the Debela Griža quarry ...</b> 21	<b>21</b>
<b>ID 04</b>	dr. Łukasz GAWOR, dr. Marek MARCISZ, Diana TYRNA Vpliv izkoriščanja premoga na geomorfologijo premoškega bazena zgornje Šlezije na primeru saniranih jalovišč premoške jalovine / <b>The influence of the coal mining on the geomorphology of the area of Upper Silesian coal basin exemplified on post mining dumping grounds</b> ..... 30	<b>30</b>
<b>ID 05</b>	dr. Katarzyna STANIENDA-PILECKI Izbrane vrednosti kemijskih elementov v sledovih v Triasnem apnencu iz zgornje Šlezije na Poljskem / <b>Selected trace elements in the triassic limestones of the opole Silesia in Poland</b> ..... 38	<b>38</b>
<b>ID 06</b>	Jürgen KANITZ, prof.dr. Frank OTTO Raziskave 20 let starih odplinjevalnih sistemov na opuščenih odlagališčih odpadkov / <b>Investigation in 20 years old sucking systems on abandoned waste deposits</b> ..... 47	<b>47</b>
<b>ID 07</b>	dr. Jacek NOWAK, Magdalena KOKOWSKA-PAWLOWSKA Nevarnosti uporabe umetnih agregatov iz mineralnih odpadkov / <b>Threats coming from applying of artificial aggregates produced from mineral wastes ...</b> 56	<b>56</b>
<b>ID 08</b>	Andrej KOS, doc.dr. Jože KORTNIK Nova klasifikacija kompaktnosti blokov naravnega kamna – lipiški apnenec / <b>New dimension stone blocks compactness classification – Lipica limestone</b> ..... 64	<b>64</b>
<b>ID 09</b>	mag. Matej DRAKSLER, dr. Duška ROKAVEC, Urša ŠOLC, Tina BENDA EIT RawMaterials projekt »RESEERVE« mineralni potenciali Jugovzhodne Evrope / <b>EIT RawMaterials »RESEERVE« project - mineral potential of the SE EU region</b> ..... 73	<b>73</b>

<b>ID 10</b>	<p>Ana BURGER, Andreja SENEGAČNIK, dr. Duška ROKAVEC  Rudarska javna služba /  <b>Public mining service in Slovenia</b> .....</p>	78
<b>ID 11</b>	<p>dr. Gregor JEROMEL  Optimizacija prezračevalnega sistema jam Premogovnika Velenje /  <b>Optimization of the Coal mine Velenje ventilation system</b> .....</p>	81
<b>ID 12</b>	<p>dr. Janez ROŠER  Uporaba mobilnega ročnega laserskega skenerja v premogovništvu /  <b>Use of mobile hand-held laser scanner in coal mining industry</b> .....</p>	89
<b>ID 13</b>	<p>Marjana ŠULIGOJ, Mitja ŠULIGOJ, doc.dr. Jože KORTNIK  Miniranje z uporabo elektronskega inicialnega sistema  v kamnolomu tehničnega kamna Solkan /  <b>Blasting with use of electronic initiation system in Solkan technical stone quarry</b> .....</p>	99
<b>ID 14</b>	<p>Levis Alfred PARSONS, prof.dr. Sunday NWAUBANI  Uporaba odpadne električne in elektronske plastike za delno nadomeščanje  agregatov v betonih /  <b>The use of waste electrical and electronic plastic as partial replacement  for aggregates in concrete</b> .....</p>	107
<b>ID 15</b>	<p>adjunc.prof.dr. Jouko SAARELA  Raziskave in razvoj ter novi trendi v finskem rudarskem sektorju /  <b>Strong R&amp;D development and new initiatives in Finnish mining sector</b> .....</p>	116
<b>ID 16</b>	<p>prof.dr. Zoran PANOV, doc.dr. Radmila KARANAKOVA STEFANOVSKA,  izr.prof.dr. Risto POPOVSKI  Pristop k optimiranju kamionskega transporta pri površinskem izkoriščanju kovin  z namenom zmanjševanja stroškov /  <b>Approach towards optimising on truck transportation during surface exploitation  on metals in function of minimising the costs of exploitation</b> .....</p>	117
	<b>Seznam avtorjev / Author's index</b> .....	124





## Razvoj podzemnega izkoriščanja kovinskih mineralnih surovin v Republiki Makedoniji

### Development of the Underground Exploitation of metallic minerals in Republic of Macedonia

ID 02

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#### Povzetek

Podzemno izkoriščanje kovinskih mineralnih surovin ima v R. Makedoniji daljšo tradicijo, ki traja okoli devetdeset let. R. Makedonija ima tri aktivne podzemne rudnike svinca in cinka. Najstarejši rudnik za podzemno izkoriščanje svinčeve in cinkove rude je rudnik "Zletovo", malo mlajši je rudnik "Sasa" in najmlajši rudnik "Toranica". Vsi rudniki se nahajajo v severovzhodnem delu R. Makedonije. Članek obsega kratek opis treh rudnikov za podzemno izkoriščanje svinčeve in cinkove rude, tj. kratko zgodovino od odprtja do danes. Nadalje je opisan način rudarjenja, ki se je uporabljal v preteklosti in danes, v katerem so se skozi leta spreminjale proizvodne zmogljivosti. Nazadnje je predstavljeno trenutno stanje treh rudnikov in prikazana načrtovana posodobitev treh rudnikov.

**Ključne besede:** rudnik, podzemno izkoriščanje, rudarske odkopne metode, kapaciteta proizvodnje.

#### Abstract

Underground exploitation of metallic minerals in R. Macedonia has great tradition, which has been around for ninety years. R. Macedonia has three active mines for underground exploration of lead and zinc. The oldest mine for underground exploitation of lead and zinc ore is the mine "Zletovo", then the mine "Sasa", and the youngest mine is "Toranica". All these three mines are located in the north-eastern part of the R. Macedonia. This paper presents a brief description of the three mines for underground exploitation of lead and zinc ore, ie a short history from their opening to the present day. A further description is given of the mining excavation methods that have been applied in the past and in this present day and in which limits the production capacity was moving over the years. Finally, the current state of the three mines is described and a comparison is made regarding the modernization of the three mines.

**Key words:** mine, underground exploitation, mining excavation methods, production capacity.

## 1. INTRODUCTION

The Osogovo mountain massif, in which are situated the three mines for underground exploitation ("Zletovo", "Sasa" and "Toranica"), is located in the north-eastern part of the R. Macedonia. The Osogovo mountain massif in the Old century, and especially in the Middle century, was an object of particularly intense mining and smelting activity. This is evidenced by the numerous remains of old tools and slag found in the Kratovo-Zletovo area, in the area of the Sasa mine and elsewhere in R. Macedonia [1, 2, 3].



To date, some old mining facilities, tools, coins, etc., have been preserved, as well as traces of smelting activities.

In parallel with the evidence of the mining activity in this area, there are archaeological evidence of the miners' places of residence, the conditions in which they lived, their habits and beliefs.

Mining in these areas with different intensities existed even earlier. There are appropriate traces and assumptions that the roots of mining in this region date from the time of the Roman Empire. However, with the arrival of the Sases on the Balkan Peninsula (around 1250), mining has gained more momentum. This is understandable, because the Sases came to this area in order to encourage the development of mining.

Today these three mines operated by mining companies are responsible for the economic development not only of the local municipality in which they are located, but also for the state of R. Macedonia.

## **2. UNDERGROUND MINE FOR LEAD AND ZINC "ZLETOVO"**

The mine "Zletovo" is located about 7 km northeast from the town of Probishtip. The mine has good communication links, and it is connected with the national road Shtip - Kratovo and the local road Dobrevo-Probistip-Zletovo. The mine "Zletovo" is spread in the western regions of the Osogovo mountain range [3]. The area is typically mountainous, with the most significant mountain peaks: Plavica - 1298m, Bukovec -1424m, Gola Chuka - 1222m, Ilin Krst - 1118m, Gradiste, Chuka and others. There are occasional watercourses in this part, which make up the confluence of Zletovska and Kratovska river.

The ore bodies are in the form of ore vein, vein-impregnation ore zones and stockwork-veins. As adjacent rocks, the following occur most often: dacite, andesite, quartz-laties, tuffs and sediments.

### **2.1 Brief history of the "Zletovo" mine**

The mine for lead and zinc "Zletovo" from Probishtip, started with active production in the distant 1928. The UK company "Selection mines Limited" based in London, during the period from 1927 to 1941, took concessions and carried out research on the wider area of the ore, where on the basis of the positive results, ore exploitation and processing was carried out with a capacity of 120000 t per year.

Due to the state of war, in the period from 1939 to 1943, the mine was exploited by the Germans. After the Second World War, the mine was restarted with an initial annual production of 50000 t. Over the years, its production has steadily increased, so in 1960, reached 260000 t per year. Maximum production was achieved in 1989, from 482146 t of ore [3, 5].

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 24.09.2015, 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 t of ore [3,5].

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. Some ore veins span at a length of more than 3000 m. A smaller number of these veins are completely vertical and the rest are with a drop of 40<sup>0</sup> to 90<sup>0</sup>. The "Zletovo" ore deposit consists of a system of more than 16 main and "secondary" ore veins. The ore is medium-sized and does

not create problems in the exploitation [3, 5].

Since the restart of the mine "Zletovo", to date, better and better results are being reached, and production has not been stopped.

## **2.2 The "Zletovo" mine today**

Today's mine "Zletovo" is a very modern underground mine for exploitation of lead and zinc ore, whereby funds are continually invested for procurement of modern equipment and mechanization. The current annual production of the mine is about 250000 t of ore, and it is planned that this production capacity will be maintained in the following years. Capital objects (corridors, ramps and raises) are being constructed for opening and preparation to the currently lowest horizon 350, which provides conditions for smooth operation in the future. Investigation drilling is constantly carried out in order to discover new ore bodies [3, 5].

In the last 2 to 3 years, additional funds have been invested in equipping and replacing the old with relatively new equipment (loaders, drilling equipment, auxiliary equipment) that meets the highest safety standards. The maintenance of the equipment is performed by a service team within the mine itself.

The temporary ground support of the stopes in the mine "Zletovo" is done with bolts or a wooden support, in places where it is necessary. For blasting is used patronized powder and plastic explosives, as well as electric detonators. The flotation plant for concentration of lead-zinc ore allows selective flotation of lead and zinc minerals. The hydro tailings that was built during the opening of the mine has sufficient storage capacity for the waste slag which will be obtained from the processing the mineral resources in the future.

## **2.3 Mining methods applied in the "Zletovo" mine**

The mine "Zletovo" has been open in combination, with adit and with sloping and vertical shafts. The first pit of the mine "Zletovo" was opened with a sloping shaft in the footwall of the ore vein 1, which reached to the horizon 400 and the horizon 350. In this way, the ore reserves of ore vein 1, under horizon 625 were covered. The pit 2 and 3 were opened with adit number 2, in the immediate vicinity of the sloping shaft at the level of the horizon 625, and with this are covered the ore reserves above this horizon. This adit at the same time was the main transport path for the entire ore that was obtained over this horizon. The area "Lakacevac" is the southeastern part of the ore deposit where the veins with number 1, 3, 4 and 5 are located. "Lakacevac" was also opened with a adit at the level of the horizon 765 and a local shaft that reached the horizon 715. The ore veins 13 and 14, located at the far northwestern portion of the ore deposit, were opened with adit number 8 at the level of the horizon 750, and with it the entire ore from these ore veins to the surface was covered. The adit number 8 is connected through an ore pass with horizon 625, through which the ore was transported to the bunker on the surface. The area of the pits 2 and 3 below the horizon 625 was opened with a blind shaft from the horizon 625 to the horizon 535 in the central part of the area of the pit number 2. The ore below this horizon were covered with corridors at the level of the horizon 450 of the blind shaft. The additional connections of all three areas of the pit through the adit 14 at the level of the horizon 450, and the increase in the concentration of transport at that level, posed a problem for the transport capacity through the blind shaft, since the amount of ore exceeded its capacity. For this reason, as well as the increase in the production of the pit at 300000 t annually, construction of a new vertical transport shaft from the surface to the horizon 350 (planned to horizon 150) was started. The shaft is located in the immediate vicinity of the slope shaft, in the footwall of the area of pit 1. Since the existing cableway could not accept production of 300000 t annually, it was decided that the connection between the Mine and the flotation in Probishtip should be accomplished by building a adit to the level of horizon 560 (at elevation 580), which was done [3]. After the construction of these capital facilities (the transport shaft number 1 and the main transport adit at the level of the horizon 560), a new investment program for reconstruction of the mine and an increase in production of 500000 t per year was started. On the basis of the idea for the reconstruction of shaft number 2, a decision was made to depart from the idea of reconstruction of this shaft and build a new shaft number 3 (from

elevation 730 to 150) in the footwall of the area of the pit 3, from horizon 625 to the horizon 150 as a service-ventilation shaft. However, this shaft was made up to horizon 250 (elevation 285).

From the shaft number 3, the horizons: 625; 580; 560; 535; 490; 450; 400; 350; 300 and 250 were opened. From it were made crosscuts to the ore veins at a height distance of 40 to 100 m, and after that were made draft corridors in the footwall that follow the direction of the ore veins, which in some way represented also facilities for the development of the site.

The previously mentioned high altitude was dictated by the excavated technology. As auxiliary facilities for opening the mine "Zletovo" can be listed the following: North-west ventilation shaft, South-eastern ventilation shaft, Central ore pass, Pumping chambers on the horizons 350, 450 and 535, as well as other facilities that have served for a longer period of time.

Mining methods that have been successfully applied for a longer period of time in the mine "Zletovo", and which could be applied in the future, depending on the conditions encountered [3, 5], 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 open stoping mining.

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, 4, 7, 8, 9].

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.

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 (Figure 1).



**Figure 1.:** Longitudinal section of the "Zletovo" mine.

On the horizon 450, excavation of the ore vein number 12 has been done, which has a falling angle of about  $80 \div 85^\circ$ , 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  $55 \div 60^\circ$  and has continuity in the stretching with an average thickness of about 1.7m.

On the horizon 400/350, an ore vein number 2 is excavated, which has a falling angle of about  $55 \div 60^\circ$  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  $60 \div 65^\circ$  and

has a continuity after stretching, with an average thickness of about 1.4 m [3]. 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, from where through the Shaft 1 is transported by skip to the main bunker on the horizon 560, where the ore is leached and transported with a 14t trolley-locomotive with a 2,3 m<sup>3</sup> wagons, 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. 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<sup>3</sup>. The waste rock from the horizons 450 and 350 are transported to the two-sided station 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].

### **3. UNDERGROUND MINE FOR LEAD AND ZINC "SASA"**

The "Sasa" mine is located about 12 km north of the city of Makedonska Kamenica. The relief of the area of the mine is explicitly mountainous, which is why the surrounding area was poorly populated [2]. The area and the immediate surroundings are very rich in water. Rivers "Svinja River", "Kozja River" and "Golema River" spring from the site of the ore deposit, which is why the ore deposit itself is divided into areas that bearing their name, and further these rivers flow into Kamenicka River.

The ore bodies are in the form of lenses or slope ore pillars around the faults with great vertical and small horizontal consistency. As adjacent rocks most commonly occur: quartz-graphite schist, cipoline, dacite and gneiss.

#### **3.1 Brief history of the "Sasa" mine**

The idea of opening a lead and zinc mine, under the highest peak Ruen, was publicly announced in mid-1952.

The mine "Zletovo" gave its contribution to the opening of the "Sasa" mine, which with its operation was the carrier of the research. The first geological exploration of the site was started on June 14, 1954, where in the same year the first Elaborate for the geological ore reserves in the Osogovo region was prepared. In the period from 1960 to 1961, a decision was made to build and open the mine for underground exploitation of lead and zinc "Sasa", which lasted until 29.11.1966, when the mine was put into operation [2].

In the first production year (1967), the mine had annual production and processing of 300000 tons of lead-zinc ore. Twenty years later (by the end of 1978), the "Sasa" mine began to produce selective concentrates of lead and zinc, and from 1979 to 2003 a collective concentrate was produced.

There were two major investments in the modernization of mining machinery and equipment in flotation. This happened in the 1970s and 1980s, and with those investment an annual production of 625000 tons of wet ore was reached, which at the time was a record production. The average production of "Sasa" mine in the period of 37 years of fruitful work until the moment of bankruptcy that took place in 2003 was 450000 tons per year.

In 2003, "Sasa" mine was placed under forced control and a bankruptcy proceeding was initiated. In mid-2005, the "Sasa" mine was privately owned by the Russian company "Romtrejd" (later renamed into "Solvej"), and the following year it was restarted and started production again. The recovery of the mine lasted about eight months, and a lot of money and efforts were made to reach the desired goal.



Contracts for procurement of basic mining machines were signed immediately, with the world famous mining equipment company "Atlas Copco" and a completely new flotation plant division with the world-known manufacturer of the appropriate equipment "Metso Minerals". Training of the workers began for which foreign experts were engaged, the existing equipment was removed, the new equipment was installed, new facilities were built that were necessary for the normal functioning of the the mine and all the projects that had been started before the re-start of the mine was realized [2].

Upon completion of the restoration of the mine (by the end of 2006), the mine began to exploit and process 650000 tons of ore annually. Since the re-launch of Sasa, so far, very good production results have been achieved.

In the last four years, production has stabilized at around 770000 t of dry ore annually.

In 2016, the "Sasa" mine got a new owner. The new owner, the US investment fund "Orion", through the management company "Lunx Resources Ltd", paid special attention to the high level of corporate social responsibility of the company for cooperation with all relevant institutions at the local and central level, comprehensive development of employees and health and safety at work.

At the end of 2017, the ownership of the "Sasa" mine was changed again, but nothing changed in terms of the production philosophy, that is, every next calendar year was written with new success in every field. Today the owner of the Sasa mine is the company "Central Asia Metals, AIM: CALM".

### **3.2 The "Sasa" mine today**

Today's "Sasa" is a modern mine for underground exploitation and is among the five largest lead and zinc mines in Europe.

The current annual production of the mine is 770000 t of dry ore and it is planned to maintain this production capacity for the next ten years. Capital objects (drifts, ramps and raises) are being built for the opening and preparation of a new production horizon 750, which speaks for the operation in the future. Investigation drillings are constantly being carried out in order to discover new ore bodies [2, 7].

In the last 5 to 6 years, additional investment have been made to replace the old (purchased in the period 2006-2007) with the new equipment (loading machines, mine trucks, drilling equipment, auxiliary equipment).

The maintenance of the mining equipment is carried out by the company "Atlas Copco", which is the main supplier of the equipment. In the mine also is used special purpose equipment, manufactured by the German company "PAUS" (service vehicles "Minka" - for the transportation of workers, "Scaler" platforms, "Grader" machine - for maintenance of the roads in the mine, large block crushing machine), specialized Boltek equipment for ground support [2].

In the "Sasa" mine, for the first time in Macedonia, special raises were built using "Rais Boring" machines, (in the period from 2013 to 2015).

A new transport horizon 830 was developed, fully equipped with a new system for transportation of ore and waste rock - trolley locomotives.

Restoration is done on a vertical shaft in the area "Golema Reka" and replacement of an old skip-basket with a new one, which serves for transportation of ore and workers.

The process of ground support in the "Sasa" mine is modernized and improved with more qualitative bolts, steel mesh and sprayed concrete, and the use of wood support has been minimized.

In the process of blasting, a replacement of electric detonators with a nonel blasting system was done, and the powdery explosive was replaced by emulsion patronized explosives.

With the re-launch of the “Sasa” mine in 2006, the flotation equipment was completely replaced by a new one from the world-renowned manufacturer “Metso Minerals”. By equipping the flotation plant with modern equipment, the utilization of metals in the ore increased, a selective concentrate with increased quality was obtained and the harmful effect on the environment was reduced [2].

Recultivation of the old hydro tailings has been carried out and a new hydro tailings for storing technological waste has been built.

The “Sasa” mine has obtained and maintains several important ISO standards (ISO 9001, ISO 14001, OHSAS 18001), and also has international accreditation for the mine laboratory according to ISO 17025.

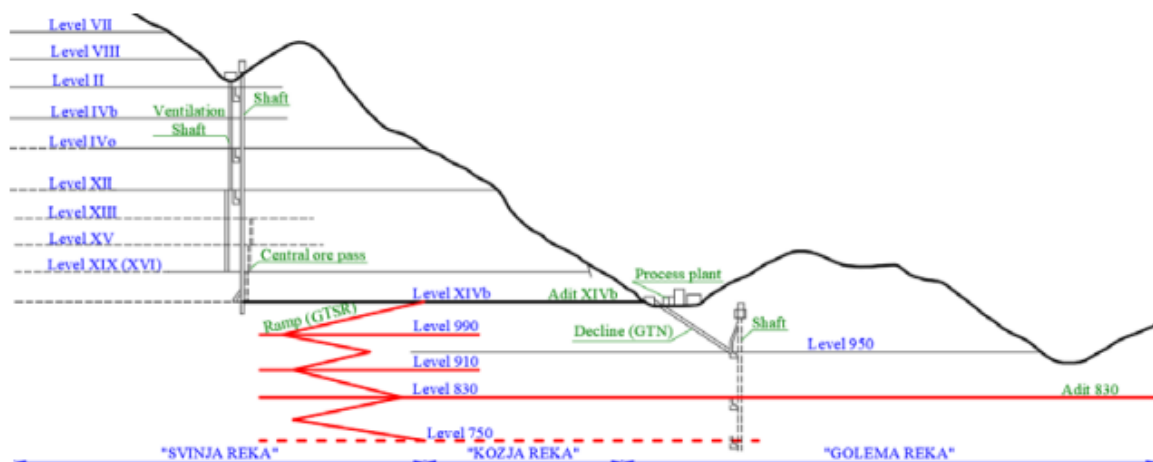
### 3.3 Mining methods applied in the “Sasa” mine

The mine “Sasa” was initially opened with adit and vertical hoist shaft in the northern part of the site (“Svinja Reka” and “Kozja Reka”), and the southern part of the site (“Golema Reka” and “Kozja Reka”) was opened with adit and slope hoist shaft [2].

In the past period, several mining methods have been applied, which have yielded satisfactory results, such as:

- Sublevel stoping with short blasting holes (in the area “Svinja Reka”)
- Sublevel caving (Swedish method - in the area “Svinja Reka”);
- Sublevel caving along the longitudinal section of the ore body (in the area “Golema Reka”);
- Sublevel caving with open stopes (in the area “Kozja Reka”);
- Frontal excavation following the dipping of ore bodies with open stopes (in the area “Golema Reka”);
- Raise excavation with open stopes (in the area “Kozja Reka”);
- Horizontal roof stoping with filling the stopes with hydrofill (in the area “Golema Reka”);

Today, the mining of the ore is done by applying the more detailed sublevel caving with blasting of the ore and adjacent rocks in two variants: sublevel caving along the direction of stretching of the ore bodies and a more detailed method with a sublevel caving, normal of the stretching of the ore bodies [2, 4, 6, 7, 8, 9].



**Figure 2.:** Longitudinal section of the “Sasa” mine.

Today, mining activities are performed only in the area “Svinja Reka”, where access to the ore deposit is accomplished with the help of a adit located on the highest horizon XIVb and a adit located on

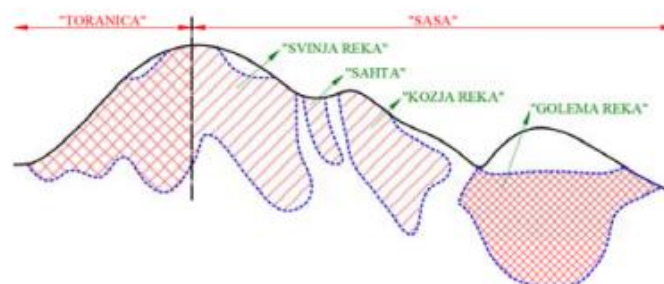
the lowest horizon 830, which are interconnected with the main export service ramp (Figure 2).

On the basis of the mining and geological conditions, mining methods, the planned production capacity, the volume of excavation and the performance of transport mechanization, in the deeper parts of the "Svinja River" (horizons XIVb-830) three independent production horizons are developed, as follows: production horizon XIVb-990; production horizon 990-910 and production horizon 910-830 [2, 6]. An intensive research is being carried out to open a new horizon 750.

Loading and transporting the ore from the stopes to the ore pass is carried out by diesel-powered loaders. When loading, it is necessary to strictly take into account the amount of blasted ore, in order to avoid big ore dilution. The ore is transported to an ore pass and unloaded in it, and then with help of gravity, falls to the level of the horizon 990 and further with trucks is transported through the main export service ramp to the flotation bunker on the surface. From the last two areas (Figure 2), the ore with help of gravity descends to the level of the horizon 830 and then with the help of railway it is transported to the vertical shaft, from where with skip-baskets is transported to the horizon 950, and from there with help of conveyor belt is transported to the primary crushing plant [2, 7].

#### 4. UNDERGROUND MINE FOR LEAD AND ZINC "TORANICA"

The mine "Toranica" is located about 24 km south-east of the city Kriva Palanka. The mine is located adjacent to the Macedonian-Bulgarian border, which is about 6 km away from the international road Skopje-Kriva Palanka-Bulgarian border [1]. The ore deposit "Toranica" is widespread in the Osogovo mountain massif and is a continuation of the ore deposit "Sasa" from Makedonska Kamenica (Figure 3). The area is typically mountainous, with the highest mountain peaks: Ruen - 2252 m, Tsarev vrh - Sultan Tepe - 2085 m, Sokol - 2038 m, which make up the ridge of the Osogovo Mountains in a length of 3 to 4 km.



**Figure 3.:** Outline of the "Toranica" and "Sasa" ore deposits.

The ore bodies are in the form of layers, layered-lens or vein-impregnation ore bodies. As adjacent rocks most commonly occur: quartz-graphite schist, cipoline, gneiss and quartz-latite.

##### 4.1 Brief history of the "Toranica" mine

The beginnings of the research in the area "Toranica" started in 1954, when teams of the Geological Institute from Skopje and the Geological service of the mine "Zletovo" from Probishtip began to conduct detailed geological mapping of the terrain and detailed research of the sites: "Toranica", "Sasa" and "Petrova Reka"[1].

At the end of 1958 due to poor results, the research in "Toranica" and "Petrova Reka" was stopped. Due to the positive results in "Sasa" deposit, the intensity of the research was increased. In 1974, researches started on the "Toranica" ore body as a result of the positive research at the area "Svinja Reka" in the ore body "Sasa", where the ore body "Sokol" from the "Toranica" mine is connected geographically and geologically. The results of those surveys were positive, so in 1976 a decision was made to establish

the company "Toranica". Since then, a more intense research into the lead-zinc deposits in the locality "Toranica" has begun, and detailed researches were carried out for the quantitative and qualitative proof of the ore reserves, which lasted until 1979. Based on the results from the research in December 1979, an Elaborate for mine reserves was prepared for the mine deposit, and then a Project for opening the mine "Toranica" (1980). In 1981, a decision was made for the investor of the project "Toranica" to be the "Zletovo" and "Sasa" mines, this decision was accepted in 1982 and then preparations were made for the construction of the mine "Toranica". In 1984, a positive report and assessment was given for the project "Toranica" from the Institute of economics and investments from Ljubljanska Bank, which resulted in a decision on acceptance for financing the construction of the mine "Toranica". Investors for the opening of the mine were the mines "Zletovo" and "Sasa" with 75% and "Cinkarna Celje" and "Mezice" from Slovenia with 25% [13].

The mine "Toranica" was designed as a modern mine with a capacity of 700000 t of ore per year, using modern mechanization in all technological phases of mining and production of selective lead and zinc concentrates. The mine "Toranica" with active production started in 1987, with an initial annual capacity of 41232 t and represents the youngest mine with underground exploitation for lead and zinc in R. Macedonia. Over the years, its production has steadily increased, so in 1990, reached 314210 t of ore annually [1]. The mine "Toranica" has been working for 32 years, with only two interruptions. The first interruption lasted about 5 years due to the transformation of ownership from social to private. While the second interruption lasted about 1 year, due to the change of the concessionaire.

In 2006, the mine "Toranica" was privatized by the foreign company "Binani industry" and the company "Indo Minerals and Metals" - Skopje was established. In November 2015, the company "IMM" went bankrupt, and in April 2016, the concession for exploitation of the mine "Toranica" was given to the company "Bulmak 2016" DOOEL- Probistip [1].

#### **4.2 The "Toranica" mine today**

Today's mine "Toranica" is a very modern mine for underground exploitation of lead and zinc, whereby funds are continually invested for procurement of modern equipment and mechanization. The current annual production of the mine is about 250000 t of ore and it is planned to reach production capacity of 268000 t of ore, which is planned to be held in the coming years. Capital objects are constructed (corridors, ramps and raises) for opening and preparation of the currently lowest horizon I, which indicates for smooth operation in the future. Investigative drilling are being carried out in order to discover new ore bodies [1]. In the last 2-3 years, additional investments have been made in equipping and replacing the old with relatively new equipment (loading machines, drilling equipment, auxiliary equipment) that meets the highest safety standards.

The maintenance of the mining equipment is carried out by a mechanical service within the mine itself, the drilling equipment was purchased from the company "Sandvik", and the loading and transport diesel equipment was purchased by the German company "Man GHH" [1]. Also in the mine is used a special purpose equipment (Minka) - for the transport of workers in the pit, produced by the German company "PAUS". Remediation of the vertical central ore pass 2 has been made (from horizon IIIa to the main transport adit) and also this ore pass was made for gravitational transportation of the ore to the main transport adit. Regarding the ground support in the mine "Toranica", an improved system has been adopted with bolts, steel mesh and sprayed concrete, and the use of wood support has been minimized. Electric detonators, as well as patronized powder and plastic explosives are used for blasting of ore and adjacent rocks.

The flotation plant for lead - zinc ore was completed at the end of 1986 and it is quite modern. The flotation equipment was imported from the former USSR company "Tsvetmetpromexport". The procedure for flotation concentration of useful minerals can be carried out in one of the following ways: selective flotation of parts of the lead minerals, collective flotation of lead-zinc minerals and selective flotation of the pyrite. Due to market demands, in the past years the procedure for selective flotation of lead minerals and selective flotation of zinc minerals was applied [1]. The hydro tailings that was built during the opening of the mine has sufficient storage capacity for the waste slag which will be obtained



from the processing of the mineral resources in the next ten years if the mine's capacity remains unchanged.

### 4.3 Mining methods applied in the “Toranica” mine

The ore deposit area "Sokol" - "Toranica" is spatially located at an altitude of 1250 to 1815 m with a northwest-southeast direction. In the southeast, this ore deposit is bordered by the "Sasa" ore deposit, which represents geographically and geologically one ore deposit. This ore deposit is investigated with length of about 1500 m with thickness of the ore zone of about 100 m.

The "Toranica" mine is open with the main transport adit at elevation of 1250 m, main service ramp, two central ore passes and several levels (horizontal), which are on mutual height of 40 to 50 m. The access to the ore bodies is through the adits: I, II, IIa, III, IIIa, VI VIa, IV, IVa and V. The adits I, IIa and IIIa are transport horizons, while adit: II, III, IV, VI and V serve for the development of the site in vertical, that is, serve for water drainage, ventilation and similar [1].

For gravitational transport of the ore from the stopes at the level of the main transport adit, two central ore passes with a height of about 360 m and a diameter of about 2 m are made, at a distance of 50 m each. The service of the pit is done through a main service ramp, which is about 3000 m long.

In mine "Toranitsa", two mining methods were used:

- sublevel caving;
- sublevel caving with open stopes.

Today, the excavation of the ore is done by applying the sublevel caving method with blasting the ore and adjacent rocks, because the geomechanical conditions of the ore and the surrounding rocks enable this method [1, 4, 7, 8, 9]. Today's mining activities are performed only in the part between horizon I and horizon III (Figure 4). The access to the ore deposit can be accomplished through adit I, II, IIa and III, while the Main transport adit serves to transport the ores from the Central ore passes to the receiving bunker at the mineral processing plant.

The main service ramp has the function to connect all the basic horizons, to provide two approaches to the mining facilities, to provide servicing of the pit with the necessary repro materials (electricity, compressed air, technological water for drilling) to enable movement of the overall mechanization and transport of workers from the surface to the main horizons [1].

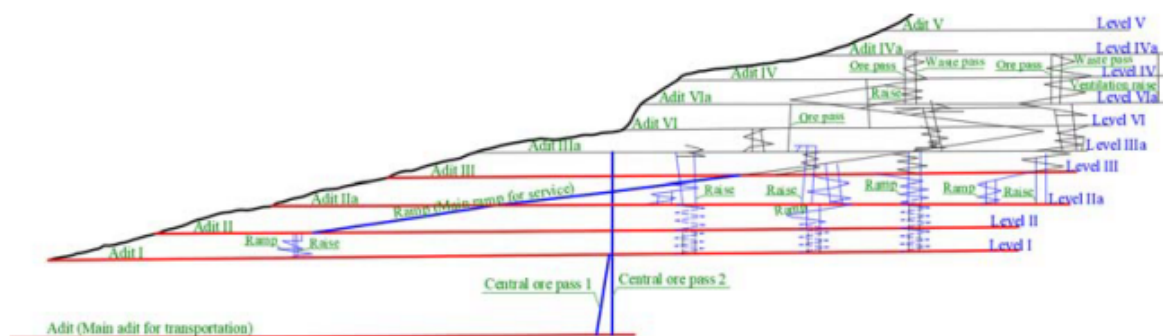


Figure 4.: Longitudinal section of the “Toranica” mine.

Loading and transporting the ore from the stopes to the ore passes is carried out by diesel-powered loaders. When loading, it is necessary to take into account the amount of loaded ore, in order to avoid greater dilution of the ore substance. The transport of ore along the horizons I and IIa from the ore passes to the central ore pass is carried out with trolley locomotives and wagons, while the waste rock is transported from the waste rock passes to the surface with acu-locomotives and heglund wagons [1].

## 5. CONCLUSIONS

The good mining tradition of the three mines for underground exploitation of lead and zinc, with small interruption breaks in production, contributed to the improvement of the underground mining technology of metallic mineral resources for specific mining and geological conditions. This is achieved by following and applying the latest technological advances in transport and drilling mechanization for underground exploitation.

In the last few years, in all three underground mines for exploitation of lead and zinc ore, sublevel caving method with blasting the ore and adjacent rocks is applied, where satisfactory production results are achieved (Table 1), good safety at work and low production costs.

**Table 1.:** Technical indicators for the sublevel caving method, which is applied in the three mines for underground exploitation of lead and zinc.

Parameter	Mine		
	Mine "Zletovo"	Mine "Sasa"	Mine "Toranica"
Ore recovery, %	80 ÷ 85	75 ÷ 80	75 ÷ 80
Ore loses, %	15 ÷ 20	20 ÷ 25	20 ÷ 25
Ore dilution, %	20 ÷ 25	20 ÷ 30	20 ÷ 30
Coefficient of preparatory work, mm/t ore	8,22 ÷ 2,79	1,45 ÷ 9,25	1,32 ÷ 3,18
Excavation effect, t/wage	5,14 ÷ 7,89	≈ 14	22,72 ÷ 33,33
Capacity of stopes, t / shift	40 ÷ 65	≈ 845,10	283,40 ÷ 334,58
Production of the mine, t / year	≈ 250000	≈ 770000	≈ 250000
Content of lead in the ore (Pb), %	≈ 6,74	≈ 5,04	≈ 3,99
Content of zinc in the ore (Zn), %	≈ 2,60	≈ 4,28	≈ 2,77

Macedonian underground mines for lead and zinc have a significant role in the macedonian economy and represent a good source of foreign currency assets. They have continuity in their development by investing in sophisticated equipment, training staff and constantly researching for new ore reserves, which is a good indicator of their future operations.

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