9th International Conference

MINING AND ENVIRONMENTAL PROTECTION

24. – 27. May 2023., Sokobanja, Serbia

MINING AND ENVIRONMENTAL PROTECTION

PROCEEDINGS

Editor
Prof. dr Ivica Ristović

Sokobanja

24-27th May 2023.

FOREWORD

After the consultations with business entities in the field of mining and environmental protection, faculties and scientific institutes, an initiative for organizing a scientific meeting on mining and environmental protection was taken in 1996. The Faculty of Mining and Geology in Belgrade, CENTER FOR ENVIRONMENTAL ENGINEERING, have organized the First Yugoslav Conference with International participants held from 25 to 27 April 1996. in Belgrade, Serbia. The second International Symposium was held in Belgrade from 25 to 27 May 1998. The third Symposium was held in Vrdnik from 21 to 23 May 2001. The fourth International Symposium was held in Vrdnik from 23 to 25 June 2003. Due to the large number of subjective and objective reasons organization of the symposium was discontinued in 2003. Fifth International Symposium was held in Vrdnik from 10 to 13 June 2015. The sixth International Symposium was held in Vrdnik from 21 to 24 June 2017. The seventh International Symposium was held in Vrdnik from 25 to 28 September 2019. and the eighth International Conference was held in Soko Banja from 22 to 25 September 2021.

On the basis of the conclusions made at the 8th Conference MEP 2021 and great interest of domestic and foreign scientific and professional public, the Faculty of Mining and Geology in Belgrade, in cooperation with co-organizers (Berg Faculty TU Košice, Slovakia, University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia, Goce Delčev University in Štip. N. Macedonia, Geological Survey of Slovenia, Ljubljana, Slovenia, University in Banja Luka. Faculty of Mining, Prijedor, Republic of Srpska, Bosnia & Herzegovina and Association of Mining and Geology Engineers), shall organize the 9th International Conference Mining and Environmental Protection – MEP 2023.

The previous Symposium, were very successful and scientist and companies from many countries gathered to exchange information and research results. The objective of this Conference is to bring together engineers, scientists and managers working in mining industry, research organizations and government organizations, on development and application of best practice in mining industry in the respect of environment protection.

At the Book of Proceedings of 9th International Conference on Mining and Environmental Protection are 56 Papers. Almost half is from abroad, or their authors is from different countries. At least 166 authors and co-authors took part in the preparation of these papers. The papers were reviewed by Reviewers. Only high-quality papers were selected, from two side, one from the scientific basis and the second from point of view of applicability in resolving problems at the development of mining.

We are very grateful to the authors of the papers, who contributed to a great extent to the success of this meeting by having sent enough number of high-quality papers, and thereby made the work of the reviewers a pleasant one in respect of selecting the best quality papers. Also, we would like to thank all of the participants in the Conference, as well as the sponsors who helped and enabled us to hold such a great meeting.

Editor

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Publisher: *University of Belgrade, Faculty of Mining and Geology, Belgrade, Serbia*

For publisher: *Prof. dr Biljana Abolmasov, Dean*

Technical design: *M.Sc. Emilija Širadović*

Printed by: *SaTCIP, Vrnjacka Banja, 2023.*

Copies: *200*

ISBN 978-86-7352-389-7

The publication of this Proceedings approved by the Council of Faculty of Mining and Geology, University of Belgrade.

All Papers in Proceedings are reviewed.

This Proceedings was published with the financial assistance of the Ministry of Science, Technological Development and Innovation of Republic of Serbia.

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CONTENTS:

PLENARY SESSION

WORKS SESSIONS

9th International Conference
MINING AND ENVIRONMENTAL PROTECTION
May 2023, Serbia

SOME TECHNICAL SOLUTIONS IN MACEDONIAN MINING WITH A HIGH DEGREE OF ENVIRONMENTAL PROTECTION

Zoran Despodov, Stojanče Mijalkovski, Bojan Despodov
University Goce Delčev, Štip, Faculty of Natural and Technical Sciences, Štip, North Macedonia
zoran.despodov@ugd.edu.mk; stojance.mijalkovski@ugd.edu.mk; despodovbojan@gmail.com

Abstract: *The paper presents some projected or in-phase technical solutions in Macedonian mining, which have a high degree of environmental protection. These technical solutions are: the storage and external curvilinear transport system of copper ore in the Borov Dol Mine, the technology of underground excavation and filling with paste in the Sasa lead and zinc mine, as well as the technology of dry disposal of flotation tailings in the Sasa Mine.*

Keywords: *mining, technical solution, curved conveyor, mining method, disposal*

1. INTRODUCTION

In the Law on the Environment, (Official Gazette of the Republic of N. Macedonia No.53/2005), Chapter XI – Assessment of the impacts of certain projects on the environment, Article 76 paragraph 2 states that: The assessment of the impact on the environment is carried out through the determination, description and assessment of the impacts that the specific project has or could have during its performance, operation and cessation of work on:

- people and biodiversity,
- soil, water, air and other natural resources, as well as the climate,
- the historical and cultural heritage, as well as on the mutual influences of the previously mentioned elements.

According to Chapter XII, Integrated environmental permits for the operation of installations that affect the environment, Article 95 of this Law: The activities of the new installations or significant changes to the existing ones, which are determined by the Government of the Republic of Macedonia, can only be carried out after a previously obtained integrated environmental permit. The permit is issued as an A-integrated environmental permit, which is issued by the state administration authority responsible for environmental affairs (Ministry of Eenvironment and Physical Planning- MOEPP) or B-integrated environmental permit, which is issued by the municipalities.

The A-integrated environmental permit is based on the application of the best available techniques, and it contains in particular: data on the operator and the installation, as well as mandatory conditions relating to emission limit values, measures to protect individual media and areas of the environment and the way of performing monitoring by the operator of the installation.

In Article 120 of the previously cited Law on the Environment, the obligations to return the environment to a satisfactory state are specified, after the termination of the installation work:

1) The operator of the installation with an A-integrated environmental permit is obliged to notify the state administration authority responsible for environmental affairs (MOEPP) of the intention to stop work at the installation and is obliged to propose a plan with measures for remediation of the location where the installation is located,
2) MOEPP approves the previously mentioned plan if it assesses that the proposed measures will ensure the return of the environment to a satisfactory state,
3) The operator is obliged to implement the measures in the manner and within the time limit determined in the plan,
4) If the operator restores the environment to a satisfactory condition MOEPP decides to return part of the compensation, taking into account the costs of remediation of the site, the condition of the site and the approved plan,
5) If the operator does not restore the environment to a satisfactory state, the state administration authority responsible for environmental affairs will do so with the funds from the compensation.

The operators of the installations are obliged to pay compensation:

- when submitting a request for an A-integrated environmental permit,
- when submitting a request for changes or transfer of an A-integrated environmental permit,
- for the possession of an A-integrated environmental permit, which is paid annually, and
- for regular supervision of the installation, in accordance with the conditions in the A-integrated environmental permit.

Borov Dol and Sasa mines as holders of A-integrated environmental permits in their technological processes have applied or will apply in the near future the best available practices, some of which will be addressed in the further text of this paper.

2. TECHNICAL SOLUTION FOR STORAGE AND EXTERNAL TRANSPORTATION OF CRUSHED COPPER ORE IN BOROV DOL MINE

2.1 Brief description of the Borov Dol Mine

Based on the received concession for detailed geological surveys from the Ministry of Economy, and detailed geological surveys carried out, DPTU "BOROV DOL" DOOEL Radovish concluded a concession agreement for the exploitation of mineral raw materials - copper at the "Borov Dol" locality with the Government of the Republic of North Macedonia. According to the agreement, DPTU "BOROV DOL" DOOEL Radovish, as an investor, built a mine installation for surface mining of copper ore on the given concession area. The projected exploitation period is at least 10 years. The project envisages the mining of copper ore at the mentioned locality Borov Dol, with the method of surface exploitation and transport of the run-of ore mine to the installations of the already existing mine "BUCHIM" for further processing and production of copper concentrate as a finished product. The concession area occupies an area of the territories of the municipalities of Konche, Radovish and Shtip with a total area of 4.72 km2, and is located in the southeastern part of the Republic of North Macedonia, on the northwestern slopes of Smrdesh Mountain. According to the basic concept for the exploitation and development of surface mine Borov Dol, according to floor bloks surface mining method, and a limit grade of 0.15% Cu, the exploitation will involve about 40 million tons of ore [3].

The technological process of mining and tailings at the surface mine "Borov Dol" consists in mining copper ore and gold ore, as well as an appropriate amount of tailings. The open pit "Borov Dol" is a height-depth mine with a total of 22 floors, from E675/660 to E360/345. The adopted height of the floors is 15 m. The opening and development of the open pit "Borov Dol" goes in two phases:

- Phase I (small open pit) - starts with the opening of E660/645 and further the remaining 9 floors are opened and developed, i.e. up to E525/510 and
- Phase II (completed widened and deepened open pit) - parallel to the first phase of E675/660.

2.2 Storage and external transport of the copper ore

The broken ore from the floors of the Borov Dol open pit is transported by KOMATSU HD785 type dumpers with a load capacity of 91 tons to the METSO Nordberg C160 primary crusher, from where it is transported by a short belt conveyor to a closed warehouse, fig. 1. The closed warehouse is intended for temporary storage of crushed ore with a maximum size of pieces of 355 mm, and leveling the capacities of the primary crushing and the main external belt conveyor.

Figure 1. Closed crushed ore warehouse - interior view

From the closed warehouse, the copper ore is transported with an external belt conveyor system to the open warehouse of the Processing Plant in the former Buchim mine.

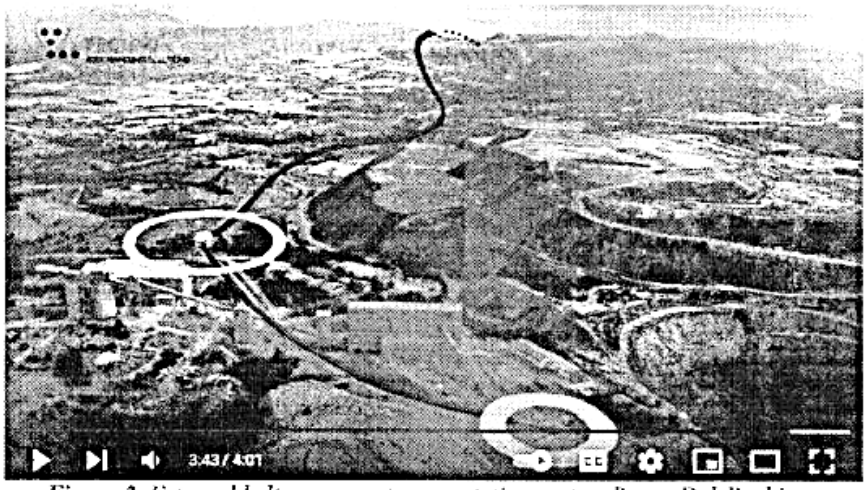


Figure 2. External belt conveyor transportation system Borov Dol-Buchim

The external belt conveyor system, Fig. 2. has a total length of 6333 m, and it is the first installed belt conveyor system in RNM with curvilinear belt conveyors. The technical characteristics of the external belt conveyor transportation system are shown in table 2.2.1.

Table 2.2.1 Technical characteristics of external belt conveyor system Borov Dol – Buchim

Parameter	First conveyor	Second conveyor	Third conveyor	Total
Power, kW	250	3 x 400	2 x 250	1950
Belt speed, m/s	3.4	4.5	3.4	
Belt width, mm	1200	1200	1200	
Length, m	820	4856	657	6333
Denivelation, m	+37/-80	-166/+167		
Radius of curve, m		R_1=2300; R_2=1000	R=500	
Flow rate, t/h				1100
Size, mm				0 ÷ 355
Density, t/m^3				1.59
Temperature, °C				-25 ÷+40

A service road has been built along the entire route from the transporter, the transporter is covered and a bridge has been built at the point of crossing over the Shtip – Radovish main road, fig. 3.

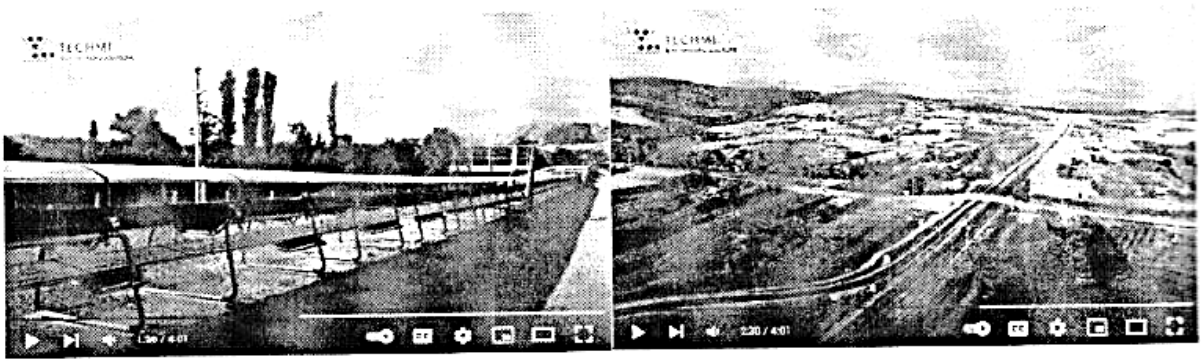


Figure 3 View of the transporter with the service road and the bridge for crossing over the main road

2.3 Benefits of the technical solution from the aspect of reducing harmful impacts on the environment

With the construction of the closed warehouse of crushed ore, the following benefits have been achieved:

- the emission of dust in the surrounding environment is eliminated,
- the loss of fine mineral raw material is eliminated,
- the mineral raw material is protected from external atmospheric influences.

The construction of the external belt conveyor transportation system contributed to the following:

- the curvilinear route of the transport system has reduced the number of spill places where dust emission occurs and increases the reliability of the system,
- the curvilinear route made it possible to overcome various obstacles, both of natural and artificial character, and improved the visual effect of the plant,
- the roof construction also contributes to the reduction of dust emissions and protection of the mineral raw material from external influences,
- the construction of a bridge over the main road represents the protection of the vehicles from possible falling out of pieces of ore from the transporter, etc.

3. TECHNICAL SOLUTION FOR UNDERGROUND EXCAVATION AND FILLING WITH PASTE, AND DRY STACK DISPOSAL OF THE REST OF THE FLOTATION TAILINGS IN THE SASA MINE

3.1 A brief description of the Sasa Mine

The "Sasa" mine is located in the eastern part of the Republic of North Macedonia, on the slopes of the mountain massif Osogovo - Besna Kobila (2.252 m above sea level) close to the border with R. Bulgaria. The "SASA" lead and zinc mine is located about 12 km north of Makedonska Kamenica, about 5 km west of the Bulgarian border.

The Sasa mine began active production of lead - zinc ore in 1966, with an initial annual production capacity of 300,000 tons. Production gradually increased so that during the period when the mine was in state ownership, it reached 600,000 tons. Since November 2017, the owner of the "Sasa" Mine is the English company/group Central Asia Metals (CAML). This company made certain investments in the technological process of underground exploitation of lead-zinc ore, so that already in 2019, the production capacity of the mine increased to 838,152 tons. The total grade of lead and zinc is about 7%. The mine annually produces 44,000 tons of lead concentrate and 52,500 tons of zinc concentrate. From the process of processing mineral raw materials as waste, flotation tailings are created, which until now have been deposited downstream in several landfills built along the valley of the Kamenicka Reka. CAML's management team decided to change the sublevel caving method by cut and fill mining method with paste backfill and replace the wet disposal of the flotation tailings with dry disposal as a much more effective method.

3.2. Description of technical solution for Underground Cut and Fill Mining with paste and Dry Stack Disposal of Flotation waste

The excavation of the ore bodies with an average width of 17.5 m and an average angle of inclination of (37.5)° between the horizons 990 and 750 will be performed with "Cut and Fill Mining Method with paste backfill" [1]. The mining ore zone will be divided into three excavation blocks with dimensions 300 x 50 m, fig. 4.

3.2.1 Development works

The preparation of the excavation block with a length of 300 m is envisaged with the following mining facilities:

1) Excavation service ramp located in the foot wall shale, at a distance of 20 to 30 m, with a slope of 15% and a cross section 4 x 4 m. Its purpose is to open the horizontal segments at a height of 20 m, servicing the excavation, access with mechanization, etc.
2) Access drifts, fig.3.3.2, located in the foot wall of the mining ore zone and they are the connection of the excavation ramp with the excavations, the ore pit and the ventilation shaft.
3) Ventilation raises also located in the foot wall central to the excavation block in the waste rocks, with a cross section of 2 x 2 m, slope 60° and length 56 m.
4) Ore pass located in the foot wall, central to the excavation block and directly connected to the access drifts / crossings. Their length is 56 m, the slope is 60° and the dimensions of the cross section are 2 x 2 m.

3.2.2 Details of the excavation process

The excavation starts from horizon 750 with the construction of the access drift, and crosscut that intersects the thickness of the ore body. Thus, the excavation block is divided into two semi-blocks with dimensions of 150 m. Then ore drift in strike is made in the hanging wall of the mining ore zone to the border of the excavation block. The dimensions of the excavation drifts are 4 x 4 m. If it is a matter of thin ore bodies up to 8 m thick, then an ore drift in strike is made, and the rest of the ore is excavated on the retreat access drift. In case of thicker ore bodies, with a thickness of over 8 m, in that case three or more drifts in strike are made, with the

excavation being done through one drift, in which way a protective pillar is left. A barricade is made at the crosscut and ore drift in hanging wall is filled with paste fill.

For exploitation drilling, drills of electro-hydraulic drive are provided, with a length of mine holes of 3 m during the construction of the excavation drifts.

Blasting: In the current practice, powdered emulsion explosives normative by 0.43 kg/t have been used, and the initiation is done with nonel detonators.

Loading and haulage in stopes: Diesel load machines (LHD), produced by the company Epiroc, with a shovel capacity of 2.8 m3 are envisaged.

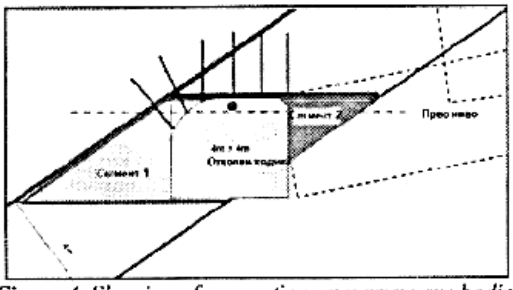
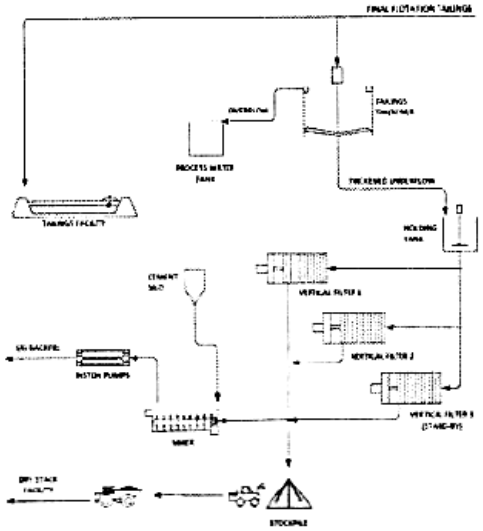


Figure 4. Showing of excavation on narrow ore bodies

3.2.3 Backfilling

The backfilling of the excavated spaces will be done with filled material in the form of paste-slurry, which is composed of the following components: flotation tailings, cement, and fly ash-product of the thermal power plants. A special plant is built for the production of the paste. The paste production plant is located on the plateau near the entrance of the old Adit XIVo, south of the ore body. The location was chosen due to proximity of the entrance of Adit XIVb through which the route of the paste pipeline and the available space will be guided. The tailings obtained from flotation will thicken and must first be drained before being filtered, [3]. The filtered mixture will go either to the tailings dump or to the paste production plant. The mixture that will enter the paste production plant will be mixed with water and binder (cement and fly ash) to make a paste, [4]. The paste will be pumped into the pit by means of positive displacement pumps. The conceptual sketch of the technological process is shown in Figure. 5. To fill all excavation zone where Cut and Fill Mining Method will be applied it is necessary to install about 7.5 km of pipeline and 1 km of borcholes. The productivity of the excavations is 8.37 t/wage-shift and there should be four ore blocks in simultaneous operation.



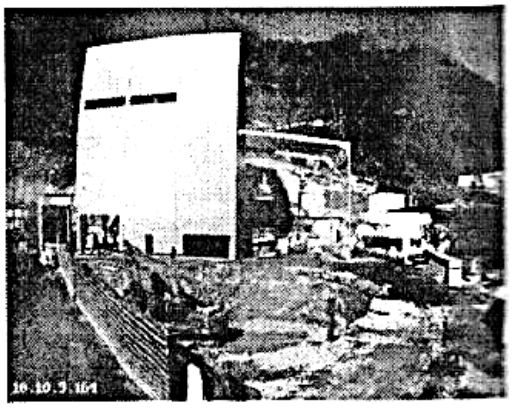


Figure 5. Conceptual scheme for flotation tailings management (P&C) and appearance of the Backfill Plant

3.2.4 Dry disposal of flotation tailings

The dry disposal installation serves to deposit the pre-drained flotation tailings, which is achieved by using a thickener and a filter press. Dewatering the flotation tailings to a higher degree than the paste is used to produce a filtered wet (saturated) and dry (unsaturated) cake which can no longer be piped due to low moisture content. The tailings filtered in this way are transported by conveyor belt or truck to the location intended for dry disposal, deposited, spread and compacted to form an unsaturated deposit, forming a stable/solid body of the landfill. As a result of this technological process, the flotation tailings are brought into a form safe for dry disposal, which has greater geomechanical stability, especially over a longer period of time. Therefore, with this technical solution of disposal of the material, there is no need for additional activities for the long-term stability of the object, as in the case of embankment dams, nor measures for further maintenance after its complete closure. A moisture content of less than 20% is achieved by using a combination of thickener and filter press. A schematic view of the process of dewatering the flotation tailings and transporting it to the dry disposal site is shown in fig. 6.

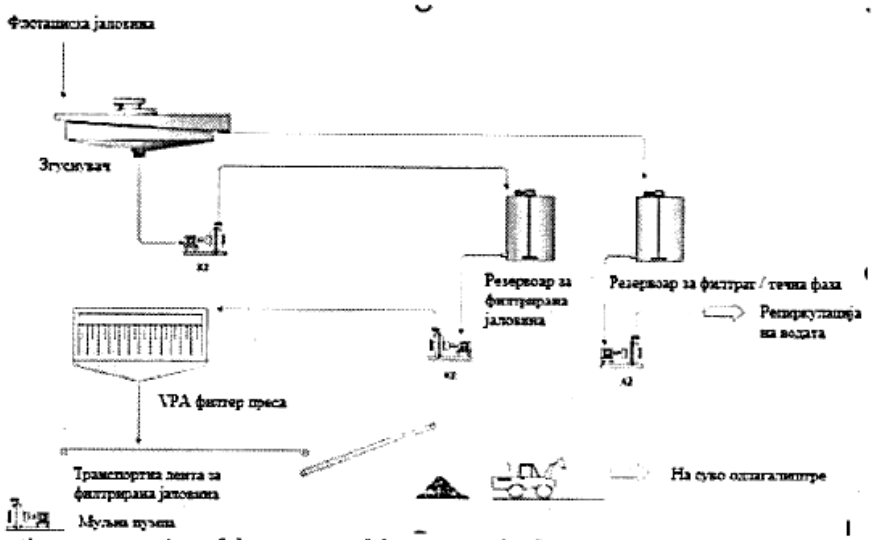


Figure 6. Schematic representation of the process of dewatering the flotation tailings and transport to the dry disposal site

The dry landfill, fig. 7., will be formed in compacted layers of filtered tailings with a nominal thickness of 30 cm. Initial perimeter berms will be formed with mine tailings with a maximum slope of 1:3 (1:2.5 at maximum floor slopes) in order to increase the stability of the landfill and minimize the potential for erosion, as well as to allow simultaneous coverage of the landfill along the perimeter of the external slopes during the operation phase.

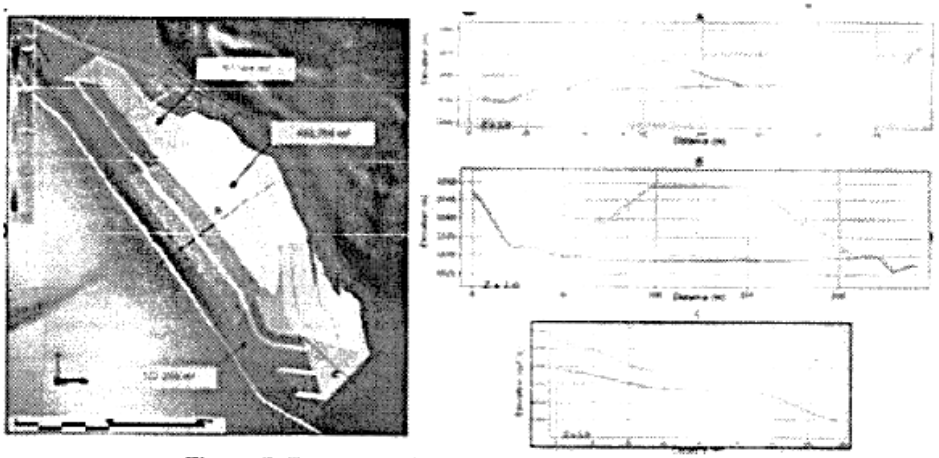


Figure 7. Formation plan and cross-sections of the dry landfill

4. CONCLUSION

From the previously presented text, it can be concluded that the era of introducing technologies with a high degree of environmental protection has begun in Macedonian mining. These technical solutions should be an example for the introduction of similar technologies in other mines in the Republic of North Macedonia.

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