

ANALYSIS OF THE ENVIRONMENTAL IMPACT AND POSSIBILITIES OF ITS REDUCTION IN THE CASE OF THE BLASTING WORKS AT ROȘIA POIENI OPEN PIT

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Abstract: *The drilling and blasting operation represents an important component of the whole complex of operations specific to the activity of exploitation of mineral resources through explosives blasting, both economically and in terms of environmental impact. The extraction activity requires the preparation of a complex document called drilling and blasting monograph that includes the elements of the drilling design with the geometric characteristics of the location and the diameter of the boreholes, respectively the choice of the explosive and the sequencing method. The present paper represents a synthesis of the extensive works carried out as part of the Horizon 2020 - Goldeneye European project, through Grant Agreement 869398.*

Keywords: *blasting, explosives, environmental impact, Goldeneye*

1. Introduction

For a relevant analysis of the execution of the drilling- blasting works, the data are correlated with the geo-mechanical, elastic and acoustic characteristics of the rock massif where the extraction is carried out. In this paper, an analysis is made of the environmental impact generated by the blasting works at Roșia Poieni quarry. In the context of the energy crisis, the problems related to explosives have become more acute due to the price and supply possibilities. Due to these impediments, the explosive used is the simple mixture of ammonium nitrate NH_4NO_3 with diesel fuel $C_{14}H_{32}$ for all types of massive rock structures encountered within the mining perimeter. Visual analysis of blast gases shows a problem given by the chemical reactions that occur during the detonation of the explosive. The predominant red- brown/orange color of the explosion gases shows the presence of nitrogen oxides NO_x that have an impact on the environment and the effects of the explosion.

2. The problems of shooting – the formation of explosive gases

The analysis carried out within the Roșia Poieni mining perimeter starts from the hypothesis of the detonation of the explosive consisting of ammonium nitrate NH_4NO_3 and diesel fuel $C_{14}H_{32}$ in different scenarios of the formation of chemical reactions at the time of the explosion.

In the **first hypothesis**, it is considered that the oxidation reaction is complete. The use of NH_4NO_3 + diesel generates explosive gases (NO_x , CO_2 , H_2O , N_2) with minimum impact and maximum knockdown effect. For the reaction of ammonium nitrate, gases consisting of water, nitrogen and oxygen result [1]. The calculation of the volume of gases and their type allows an analysis of a complete reaction:



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Thus: 1 mol $\rightarrow$ 22.4 l gas

$2 + 1 + 0.5 = 3.5$ moles

$3.5 \times 22.4 \text{ l} = 78.4 \text{ l}$

Molar mass of $\text{NH}_4\text{NO}_3 = 80 \text{ g}$

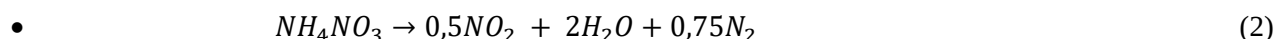
80 g 78.4 l

1000 g 980 l gas

1 kg of NH_4NO_3 with complete oxidation produces 980 l of white colored gases consisting of water vapor, nitrogen, oxygen and dust. The excess oxygen must enter into the reaction by adding diesel to obtain a zero oxygen balance.

In **the second hypothesis**, the analysis starts from the fact that red-brown (predominant) gases result from the blasting, proving the presence of nitrogen dioxide NO_2 , a toxic and water-soluble gas, where nitrogen has a valence of 4 (N^{4+}).

The oxidation reaction can take place in two forms:



Thus: $0.5 + 2 + 0.75 = 3.25$ moles

$3.25 \times 22.4 = 72.8 \text{ l gas}$

80 g 72.8

1000 g x

$x = 910 \text{ l of gas instead of } 980 \text{ l}$

The volume of nitrogen dioxide resulting from 1 kg of ammonium nitrate:

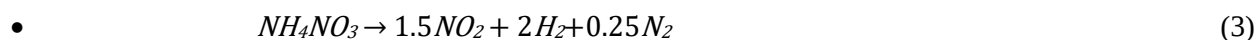
$\text{NH}_4\text{NO}_3 \rightarrow 0.5 \times 22.4 \text{ l NO}_2 = 11.2 \text{ l}$

80g 11.2

1000g x_1

$x_1 = 140 \text{ l NO}_2$

Thus, from this reaction, 1 kg of explosive generates 140 l of NO_2



Thus: $1.5 + 2 + 0.25 = 3.75$ moles

The volume of nitrogen dioxide for 1 kg of explosive is: $1.5 \times 22.4 \text{ l} = 33.6 \text{ l gas}$

80 g 33.6

1000 g x_2

$x_2 = 420 \text{ l NO}_2 \text{ gas (the volume of nitrogen dioxide resulting from one kilogram of ammonium nitrate)}$

The total volume of gases is the same as in the first reaction 910 l.

Theoretically, the volume of NO_2 produced by 1 kg of ammonium nitrate is between 140 l and 420 l, depending on the mode of oxidation and formation of the explosion gases. In practice, the gas volume is not significantly modified (reduced) to reduce the effects of the explosion, but it has an environmental impact. In these assumptions, diesel does not react to form CO_2 .

The presence of this gas (NO_2) in the atmosphere contributes to the formation of another pollutant called bad ozone (O_3) under the action of the sun's rays, after the reaction:



$\text{O} + \text{O}_2 \rightarrow \text{O}_3$ - "bad" ozone present in the lower layer of the atmosphere - troposphere (8...15km), considered a pollutant and contributing to urban smog.

An analysis of the existing information in the database of the European Environment Agency regarding greenhouse gases and especially ozone, but also dust, certifies the fact that these gases resulting from shooting belong to the group of greenhouse gases and can influence the state of health of the population [1].

Thus, through the European Goldeneye project, several measures have been identified that can be applied in the shot drilling process, thus reducing the environmental impact of this operation. Since Romania is part of the European Ecological Pact - Green Deal [2] CUPRUMIN SA Abrud company can contribute to achieving Romania's goal of improving the quality of life and reducing the negative environmental impact [3].

In the case of Roşia Poieni pilot test, an example calculation is of the form: for the extraction of 3 million t of ore/year, respectively 1.2 million m^3 of ore/year [4] a quantity of 600,000 kg of explosives is required, for a specific consumption of 0.5 kg/m^3 [1]. If the amount of material extracted for overburden is added, the increase is proportional.

Table 1. Air pollution – Romania profile [1]

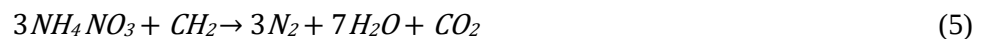
Exposure - Romania		2016	2017	2018	2019	2020
The table below shows the percentage of urban population exposed to concentrations above EU standards for selected air pollutants such as PM10, PM2.5, O3, NO2 and BaP for the years 2016-2020.						
BaP	annual mean			0.0	0.0	0.0
NO2	annual mean	0.0	1.0	1.5	2.5	0.3
O3	percentile 93.15	0.0	36.0	1.3	0.0	0.0
PM2.5	annual mean	0.0	12.8	8.7	0.0	0.0
PM10	annual mean	0.0	0.3	0.2	0.0	0.0
	percentile 90.41	0.0	24.3	7.0	11.0	0.3

Note: the production of NO_x and especially NO_2 from incorrect blasting generates a large environmental impact especially when there are explosions with large quantities at significant mining productions.

Table 2. Air pollution - Effects on the health status of the population - Profile of Romania [1]

Country	Population (x1000)	Annual mean (PM2.5)	Premature Deaths (PM2.5)	Annual mean (NO2)	Premature Deaths (NO2)	Annual mean (O3)	Premature Deaths (O3)
Romania	19,328	15.20	21,556	15.20	3,110	2,955	1,001
EU27	442,850	11.20	237,810	14.10	48,555	4,182	24,109
Total	530,892	11.40	274,673	15.70	64,312	4,229	28,337

The explosive used for extraction at Roşia Poieni open pit is a mixture of ammonium nitrate NH_4NO_3 with diesel $C_{14}H_{32}$. To obtain a zero oxygen balance, 95.3% NH_4NO_3 + 5.7% $C_{14}H_{32}$ or 3.7 l of diesel per 50 kg of ammonium nitrate is required. In this case the ideal chemical reaction is of the form:



obtaining an energy of 920 kcal/kg explosive and 970 l gas/kg explosive [4].

These gases do not result in a toxic component such as NO_x and CO , but only greenhouse effect CO_2 .

In reality, due to some imperfections in the structure of the mixture, commissioning, etc., following the blasting at Roşia Poieni, a significant percentage of gases with a red-brown, reddish, orange color result, which proves the presence of NO_2 (fig. 1).



Figure 1. Gas resulting from the shooting – Roşia Poieni

3. The choice of the explosive for the conditions at Roşia Poieni with the criterion of impedance

In the choice of explosives, there are numerous criteria that allow the efficiency of the explosive effect, both economically and to reduce the environmental impact.

One criterion is the ratio of the acoustic impedance of the rocks to the impedance of the explosive.

$$I = \frac{C \cdot \rho_{rock}}{D \cdot \rho_{explosive}} \quad (6)$$

where:

$$C \cdot \rho_{rock} - \text{rock acoustic impedance, m/s and kg/m}^3 \quad (7)$$

C – longitudinal wave propagation speed in rock, m/s

ρ_{rock} – density of rock, kg/m³

$D \cdot \rho_{explosive}$ – rock acoustic impedance

D – explosive detonation speed, m/s

$\rho_{explosive}$ – density of explosive, kg/m³

The optimal ratio is between 0.8 and 1.5 for which approximately 90% of the energy released by the explosive is transmitted to the rock massif.

In order to transmit energy and break the rocks as efficiently as possible, it is necessary to correlate the type of explosive with the physical -mechanical and acoustic characteristics of the rocks in which the demolition is performed. This criterion explained a paradox in the mining experience where it was found that if a high explosive - high detonation velocity (dynamite type) is used in soft rocks, no effective breaking occurs. Conversely, if weak explosive is used - with low detonation speed in hard rocks, the effect is reduced.

As part of the Goldeneye project [5], [6], on the AI platform developed especially for the mining industry, the latest technologies in the Remote Sensing field were tested and applied in 5 pilot sites: Germany, Bulgaria, Finland, Romania and Kosovo.

Physical-mechanical characteristics of the rocks can be identified, from Poieni andesite (with high characteristics) – silicified and chloritized or Fundoia andesite to altered andesite (with reduced characteristics) [7], [8]. These data were processed based on an information flow using (fig. 2) a hardware / software architecture tailored for the mining industry (fig. 3).

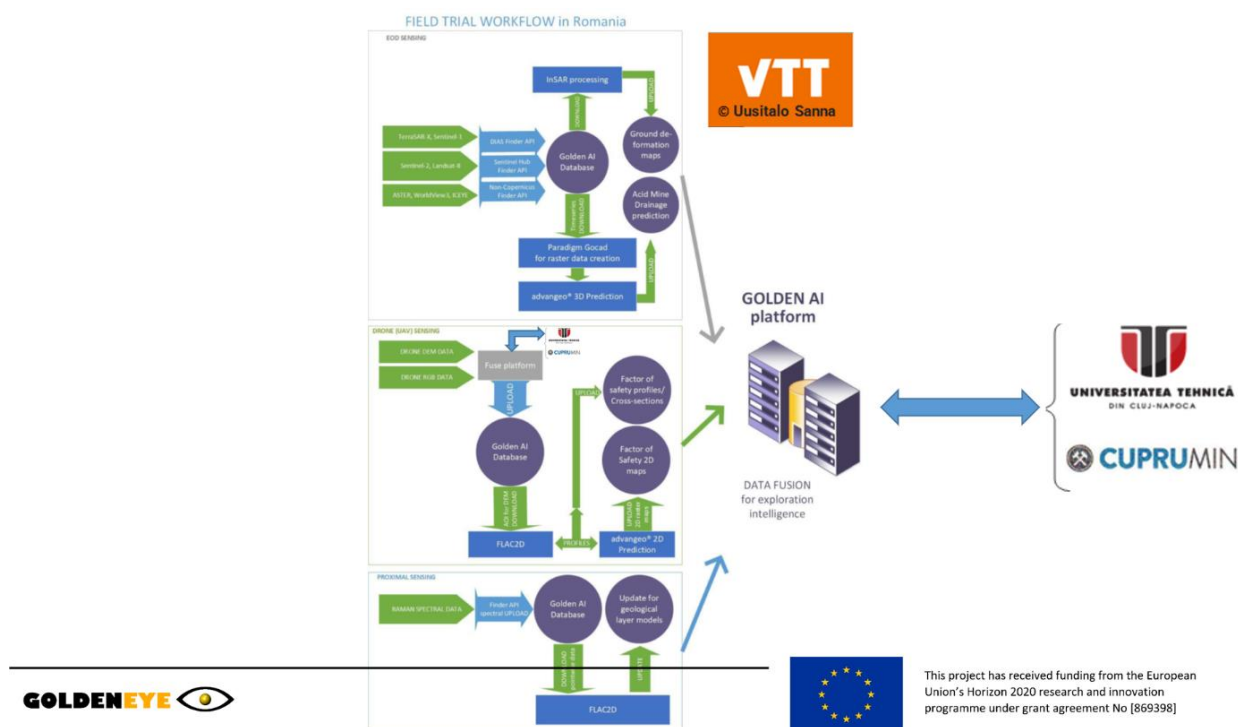


Figure 2. Informational data flow for Roşia Poieni

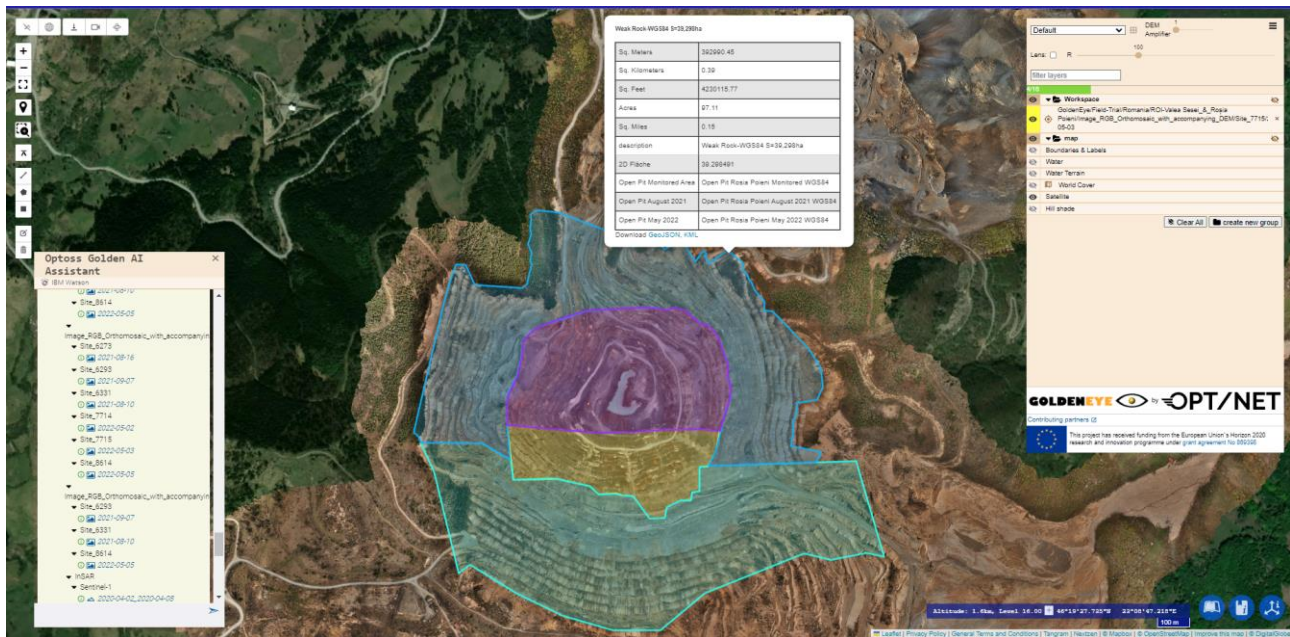


Figure 3. Extracting the 4 types of rocks from the GoldenAI platform [6]

The use of only one type of drilling-blasting monograph (fig. 4): hole diameter, distance between holes, explosive consisting of ammonium nitrate and diesel fuel is ineffective and environmentally impactful.

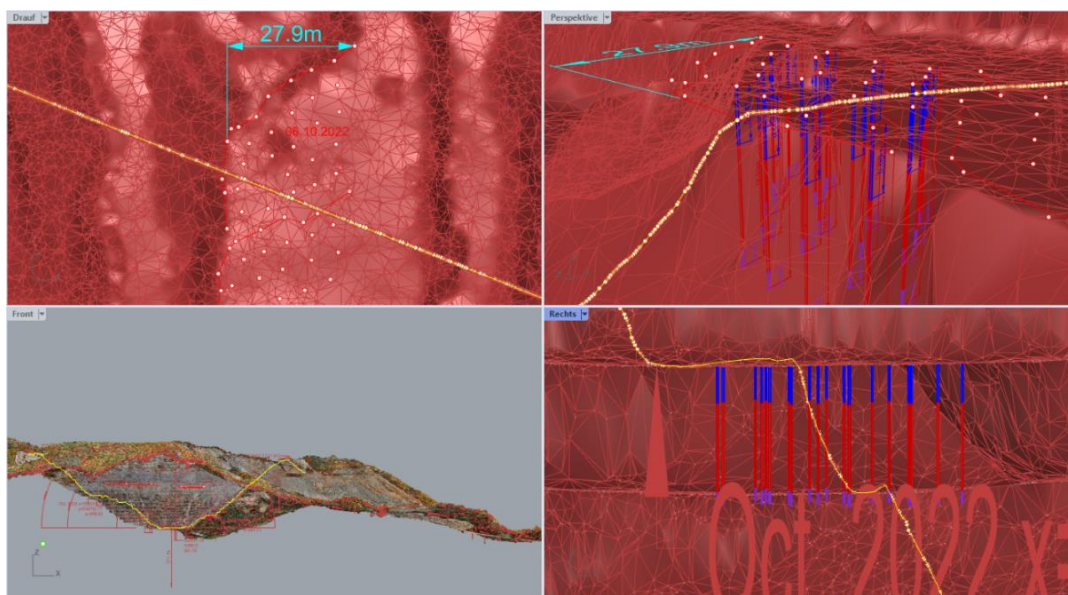


Figure 4. Accurate Drilling Positioning on Working Bench (October 2022)

The calculation of the parameter I for the Roșia Poieni quarry in different scenarios of rocks and explosives showed very different values, from 0.13...0.15 to 6...8 [4].

E.g.:

Nitramon – mixture of ammonium with diesel fuel $\rho_{explosive} = 0.8 \text{ kg/m}^3$ and $D = 2000 \text{ m/s}$

Dynamite RA-with 41% sensitizers (nitroglycerine and nitroglycol) has $\rho_{explosive} = 1.5 \text{ kg/m}^3$ and $D = 6150 \text{ m/s}$ [7].

Rocks can have the speed of acoustic waves C with values between 2500 and 6000 m/s.

In this way, if there is no correlation between these parameters, the breaking efficiency cannot be achieved. In the case of Roșia Poieni Open Pit, it is necessary to draw up at least 4 types of drilling and blasting monographs for both the drilling parameters and the choice of the blasting and sequencing. Succession involves obtaining free surfaces and sequencing implies delay between loads. These aspects have an important role in the efficiency of the derailment and the reduction of oversized blocks.

4. Choice of stemming

Dusting – is an important component in controlling the explosion gases during detonation and reducing the entrainment of dust into the atmosphere. The purpose of the stemming is to prevent the rapid evacuation of gases in the direction of the borehole. In most cases the drilling is done with the detritus obtained from the perforation and the detritus cone is located next to the borehole (fig. 5).

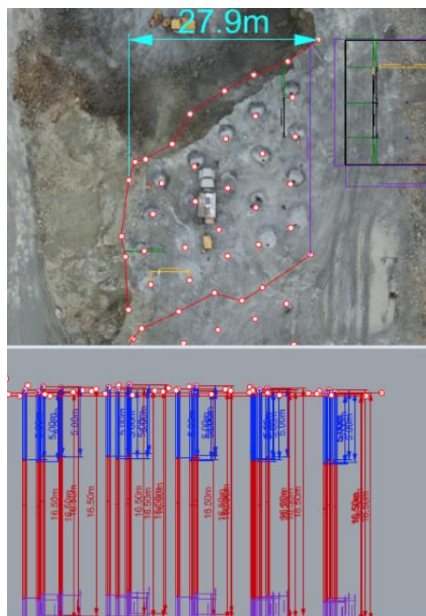


Figure 5. Cone-shaped detritus on firing stage (October 2022)

This material consists mainly of fine particles that will be carried during the explosion easily into the atmosphere amplifying the dust in the perimeter and around Roșia Poieni open pit. Regarding the role of stemming, this material has little effect.

The material that will create an optimal stemming must consist of granules obtained by crushing with a rough shape with dimensions of 4-9mm according to Atlas- Copco recommendations [9], or with dimensions of 8-12 mm according to prof. Fodor's recommendations [4]. Experience has shown that broken stone with sharp corners is the best for drilling, having a silting effect to oppose the action of the blast from being thrown out of the borehole.

Note: in the case of Roșia Poieni, we recommend the use of the granulometry obtained in the stone quarries of CUPRUMIN SA Abrud company located near Rosia Poieni open pit and which fall within the range of values from the two situations.

5. Conclusions

The reduction of the environmental impact and the efficiency of the blasting work requires a broad analysis and requires a complex database: the mechanical and acoustic characteristics of the rock massif, the structure of the massif (the presence of discontinuities, their characteristics, the presence of water), the drilling monograph and the diversity of types of explosives available on the market with the related prices. In the conditions in Romania, there is a problem of supply with explosives, although there is experience and domestic production capacity. Over time, the mining activity had numerous setbacks, but through the involvement of the state authorities, this activity was boosted, including in the field of explosives. To support mining in Apuseni, the state intervenes through several means during the interwar period (the purchase of gold by the National Bank, the use of state galleries by individuals, etc.). In 1930, the Azotin black powder factory was put back into operation, an explosive sold to private individuals at a reduced [10]. These lessons can be repeated with beneficial economic, social and environmental effects. For the conditions at Roșia Poieni, at least 4 explosive recipes with different ballistic characteristics are needed, which respond to the conditions in the field. For hard rocks, explosives with the prevailing parameters are required explosive - with shock effect, high detonation speed. For weaker rocks, the gas effect must prevail, lower detonation speed. Also, the most homogeneous mixture of ammonium nitrate and diesel fuel causes carbon to enter the reaction and avoid the formation of nitrogen oxides.

The development of explosives production capacities with a varied range is becoming a necessity for Romania and Europe both for civil purposes (mining, road and railway construction, slope stabilization, demolitions, etc.) and for military purposes, especially in today's context. Also, the distribution of production according to the criteria of forming a network of explosives factories and initiation systems at the European level is a necessity for optimizing the transport of explosive products due to the special safety conditions. The high costs of blasting works (explosive materials, transport, security assurance, lack of qualified personnel) put great pressure on the production capacities of mining products and spoils from other fields. Realization of a strategy in this sector, at the national level and European needs to be carried out for a better correlation between the needs in the civil and military fields in order to optimize costs and stocks. The production, storage and transport of explosive materials require special conditions and qualified personnel in this regard.

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References

- [1] **Bud I.**, 2006
Pollutants in the mining industry (in Romanian), Risoprint Publishing House, Cluj Napoca, ISBN 973-751-102-6
- [2] * * *
<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019DC0640&qid=1634801571885>
- [3] * * *
<https://www.eea.europa.eu/themes/air/country-fact-sheets/2022-country-fact-sheets/romania-air-pollution-country>
- [4] * * *
Technical Documentation CUPRUMIN SA
- [5] **Paavola M., Bogdanov K., Matselyukh T., Knobloch A., Uusitalo S., Guşat D., Sobrecueva A., Mänttari M.**, 2020
Goldeneye Project: Earth observation and Earth GNSS data acquisition and processing platform for safe, sustainable and cost- efficient mining operations. Proceeding in REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY. vol. 81, part 3, 2020, p. 281. Bulgarian Academy of Sciences
- [6] * * *
<https://next-gui.goldenai.opt-net.eu/>
- [7] **Fodor D.**, 2007
Blasting Engineering (in Romanian), Namaste Publishing House Timisoara, Corvin Deva Publishing House, ISBN: 978-973-87855-0-2.
- [8] **Guşat D., Bud I., Goia M.**, 2021
Analysis of the possibilities of geometry of Rosia Poieni mining field. SIMPRO 2021. MATEC Web of Conferences 342, 02010 (2021). University of Petrosani. 10.1051/ mateconf /202134202010
- [9] **Fernberg H.**, 2008
Surface Drilling / Principle of Rock Blasting. 4th Edition 2008. Printed by Atlas Copco Rock Drills AB, Örebro, Sweden
- [10] **Popa A.**, 2000
Gold Mining from Apuseni (in Romanian), Infomin Deva Publishing House, ISBN: 973-98552-7-X
- [11] * * *
<http://www.goldeneye-project.eu/>



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