

# GOLD AND ENVIRONMENT AT ROȘIA MONTANĂ. REALITIES AND PERSPECTIVES

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The gold ore from Roșia Montană has been extracted since ancient times up to the present. While the ancient extracting and processing traditional techniques had a minimum impact upon the environment, the modern techniques have affected all the components of the natural environment.

If the ore is treated according to the program issued by the Canadian company Gold Corporation, the geographic space of the area will turn into an industrial desert. The environmental problems are related both to the specific of such an industrial activity and to the use of huge quantities of sodium cyanide directly on the preparation flow from the plant. There are very few similar cases in the world. Cyanides are mostly used to treat gold ore, an operation which needs maximum security, closed spaces in isolated areas and the neutralization (detoxifying) is made on the spot. The use of cyanides in open spaces, including the flow of preparation plants, has always raised environmental problems. In fact, the neutralization technologies do not entirely eliminate the toxic effect of the cyanides; usually less toxic chemical products are obtained (cyanites, sulphuric acid, ammonia, nitrates etc.).

In order to avoid an ecologic disaster and for the preservation of the local patrimony values, several recommendations should be considered, because they allow both the use of the ore – a socio-economic necessity for the area - and the ecologic reconstruction of the geographic area that has been affected.

**Key words:** gold, Roșia Montană, mining activity, ecological impact, risks.

## 1. Short History of the Mining Activity in Roșia Montană

The history of Roșia Montană is closely connected to the exploitation of gold resources and has undergone three significant periods: Antiquity, with the vast system of Roman exploitations; Middle Ages, with the traditional exploitation type, and the modern period, characterized by the technologic development.

In Antiquity, at Roșia Montană (Alburnus Maior), mining works started in 131 A.D. 24 km of galleries and mining spaces have remained since the Roman times and partly they have now electric power which enables visitors to get acquainted with that period. The historians wrote about mining in the famous wax tiles which state the rights of the miners and of their masters and about a loan contract issued by a local money lender called Iulius Alexander.

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The most important Roman mines were built in Cetatea Mare, Cetatea Mică, Orlea, Letea-Sf. Cruce, Igren, Scamnița, Cârnicul Mare and Cârnicel. Hard rock ore extraction was made by using fire (fire+water=cooling and removal of the rock), chisel, holes filled with water and covered with a wooden plug which was hammered so eventually the pressure caused the cracking of the ore; it was then processed through comminution and amalgamation (Abrudeanu Rusu, 2006).

Mining is mentioned in the Middle Ages in 1238 and is said to have been organized by German colonists. By then, the place was called Rubeo Flumine (Red River) and afterwards was called Rotseifen and Rotbach. The holes were still made by chisel, but the rocks were removed with black powder (gun powder) techniques which lasted until the Modern Age (Sântimbreanu and Bedeleian, 2002).

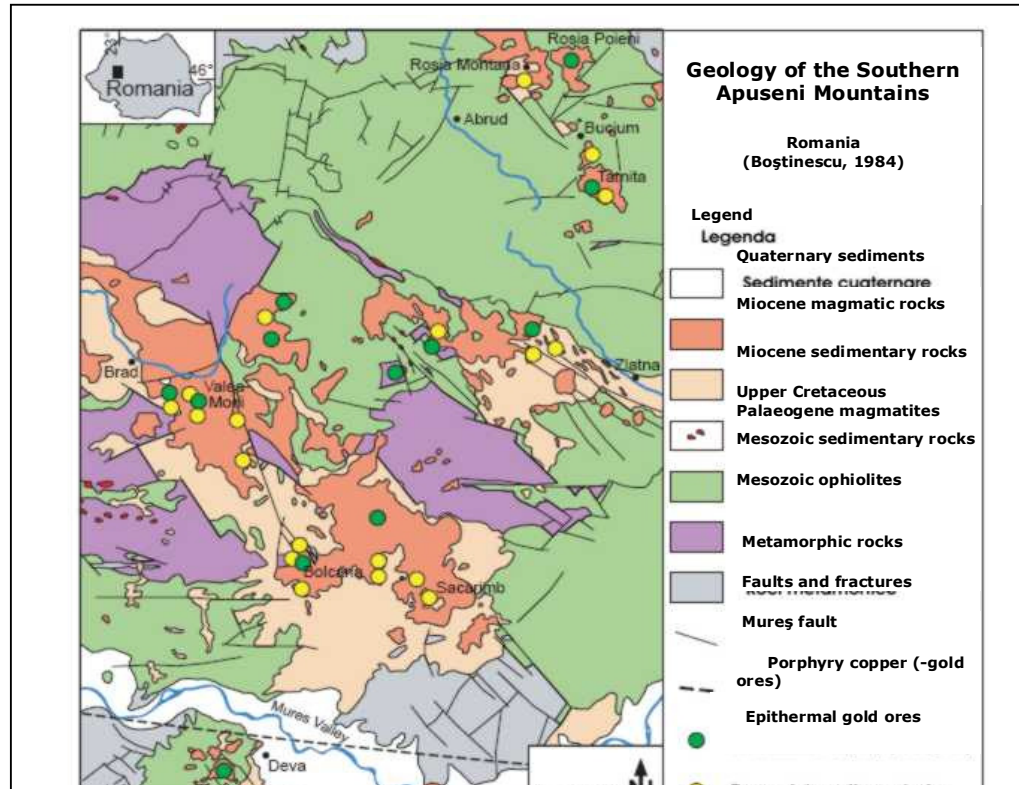
During the Modern Age, characterized by the Industrial Revolution, the State (The Habsburg Empire) and the private owners started major mining works. Artificial lakes systems are created for grinding the gold ore (1,200 grinding devices). At the end of the 19th century and beginning of the 20th century gold mining develops significantly and Roșia Montană evolves economically and thus becomes a separate territory with its own administration, apart from Abrud. After the Unification from the 1st of December 1918 the Romanian State encourages the private mining sector that thrives spectacularly until the Nationalization Act in 1948.

During the Communist period planned mining develops, initially in order to pay for the war damages (until 1963) and then in order to pay for the debts of the State. The stamping mills were destroyed, as well as the water canals and other components of the traditional mining. New highly productive underground mining technologies fail to work, so in 1970 they start work at the Cetate opencast pit. Out-of-date technologies and frequent flux interruptions in the preparation plant led to significant losses, therefore that gold can be found today in the separation ponds for the plant waste.

After 1990, in spite of the social economic turmoil, the activity continued until 2005-2006 and then it ceased. Thus, privatization seemed the appropriate solution and the only participant at the acquisition auction was the Canadian Company Gold Corporation. The public debate about the perspective of giving this company the right to start mining for gold reserves led to the formation of two opposite groups, pointing out the pros and cons for such a decision. The Zonal Urban Plan was elaborated; the main issues of the debate were related to the destruction of the Roșia Montană historic site and to the use of large quantities of sodium cyanide during the ore processing.

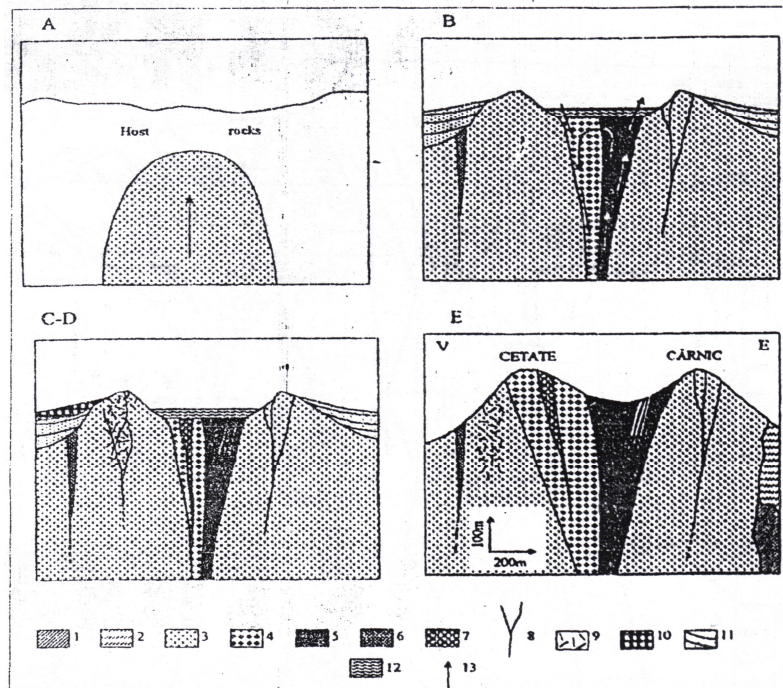
## **2. Geology of the ore body**

The gold ore in Roșia Montană belongs to the „Gold Quadrilateral” of the Metaliferi Mountains from the chain of Southern Apuseni Mountains. Their geologic structure is made of metamorphic rocks, Mesozoic ophiolites, Cretaceous magmatites (Upper Paleogene), Neogene igneous rocks, Mesozoic and Miocene sedimentary rocks, Quaternary sediments (*fig. 1*).



*Fig. 1. Geological map of the Metaliferi Mountains from the Southern Apuseni Mountains with the distribution of auri-argentiferous ores and porphyry copper (according to Boştinescu (1984), quoted by Popescu *et al.*, (2007))*

The deposit lies in the NE part of Metaliferi Mountains and belongs to the morphostructural subunit of the Roşia Montană Mountains the metallogenetic District Roşia-Bucium. The geologic structure and the metallogenetic evolution of the main ore body Cetate Cârnic are presented in *fig. 2*.



*Fig. 2.* Roşia Montană Metalliferous Field, Cetate-Cârnic mineralized structure, Metaliferi Mountains (Southern Apuseni Mountains): A. Formation of the Cetate dacite; B. Genesis of the Cetate Phreatomagmatic breccia – fluidisation circuit is functional (Glamm Formation and Cetate breccia in the classic sense); C and D. Au-Ag mineralizations (impregnations, Phreatic breccia, tectonic breccia, lodes, cavity fillings, stockworks, placers, etc.); E. Present image of the Cetate-Cârnic structure; 1-2 Host rocks (1. Cretaceous, 2. Neogene); 3 – Cetate dacite; 4 – Cetate breccia (classic sense); 5 – Glamm formations – fluidization canal; 6 – Tectonic breccias; 7 – Phreatic breccias (superposed on the phreatomagmatic breccia column); 8 – Crack; 9 – Stockworks; 10 – Auriferous placers; 11 – Talus deposits; 12 – Sediments of Maar type; 13 – Direction of transport (according to Vlad, 2005; quoted by Duma, 2007)

The mineralization is mainly auriferous and all the other elements associated under the form of sulphides are subordinated; it presents as lodes, stockworks and impregnation areas.

The mineral areas vary, the medium length of the lodes is 100-200m. The stockworks are 100-450m high and horizontally 300-1,500 m, representing about 90% from the present gold ore reserve.

The combination of minerals in these ores is: gold (Au), blende (ZnS), galena (PbS), alabandine (MnS), pyrite (FeS<sub>2</sub>), marcasite (FeS<sub>2</sub>), mispickel (FeAsS), calcopyrite (CuFeS<sub>2</sub>), rhodochrosite (MnCO<sub>3</sub>).

There are several deposits of gold ore in the area: Carpen-Orlea-Țarina, Cetate, Cârnic, Cârnicel, Fioeș-Igre-Văidoaia. The opencast pit mining is restricted to gold ore from Cetate in the dacitic peak and is found in stockworks and lodes. The most important stockworks are Roșețe-Ștefan-Contact, Juho, Ierusalim, Borașai, Afiniș, Bakoși, Mangan and Cetate. The lodes are small – 50-150 m length and 0.1-0.5 m width. The mineralization of stockworks and of lodes consists of gold, pyrite, calcopyrite, blende and galena inside a quartz and rhodochrosite gangue (Duma, 2007).

The bodies of gold ore are estimated at about 215 million tons with an average content of gold which proves the mining process is worth starting. Much gold is also to be found in the waste from the processed tailings settling ponds.

It must also be added that the lodes have largely been processed, so the present reserve lies mostly in the impregnations and stockworks.

### 3. The Impact of Mining upon the Environment

The gold ore reserve remained from the underground works has still been processed from the underground waters in the Cetate opencast pit, because significant quantities have been lost there (over 70%). The old underground fittings (galleries, raising shafts) create great technical, technological, safety and environmental problems (*fig. 3*).



*Fig. 3.* Roșia Montană. Cetate opencast pit

The relief around Cetate opencast pit and around the waste dumps has been severely affected by the transfer of ore which led to the modification of the area morphometry and morphology also due to opencast pit excavations and waste deposits. In the opencast pit, because of the old fittings, (galleries, raising shafts, pillars) it's impossible to achieve a correct geometry of the steps.

The 16 mining waste dumps, as positive relief microforms cover about 13-14 ha and only two of them are recent: Valea Verde and Hop.

Valea Verde waste dump (*fig. 4*) covers 3.8 ha and has 2 levels. The first one at elevation + 875 m and the second at elevation + 900 m; it is about 80 m high.



*Fig. 4.* Roșia Montană. Valea Verde waste dump

Hop waste dump is smaller; it covers 3.8 ha and the deposits are made on one platform at elevation + 900 m.

Both of them are slope waste dumps and present a relative degree of stability; under the Valea Verde waste dump, at a distance of 500 m is situated the village Corna.

The processed tailings settling ponds cover about 35.92 ha, out of which 11 ha are covered by the Valea Săliștei settling pond and 24.92 ha by the three settling ponds from Gura Roșiei; intense erosion processes started on all their taluses (*fig. 5*).



Fig. 5. Roșia Montană. Gura Roșiei tailings settling pond – Erosion processes

The main noxes to be found in the industrial areas are different forms of dust, usually containing silicon, nitrogen oxides and aerosols from the flotation area. The fine sands are windborne and the smell of almonds, typical to the sodium cyanide is frequently felt around Valea Săliștei pond. The cyanides emitted in the air under the form of gaseous hydrocyanic acid attach to the dust particles and remain in the atmosphere for about 1-3 years (Witt *et al.*, 2004).

The perforation works, blasting, loading and transport, as well as crushing operations generate air pollution with silicogenous dusts. *Table 1* presents the level of pollution with  $\text{SiO}_2$  in each area and working place with major concentrations of  $\text{SiO}_2$  above the admitted limit in all the places where samples were prelevated.

#### The Quality of Air at Roșia Montană Mining Objective

Table 1

Zone (site) of sample collection	Measured concentration of $\text{SiO}_2$	Admitted D.W.P.R. (MMOG, 1988)
Cetate opencast pit, tailings loading, Elevation: 880 m	14.2	4.8
Cetate, tailings loading, Elevation: 894 m	16.6	4.8
Pre-crushing	10.7	3.5
Grinding hall	6.6	3.0
Gyratory crusher	15.4	3.0

Source: Duma (2008).

Silicon dust produces silicosis and other diseases such as pneumonia, bronchitis, emphysema and lung cancer (Buia and Rădulescu, 1999).

The main water collector in the mining area at Roşia Montană is the Valea Roşiei creek and the opencast pit Cetate lies in the same retention basin. This is the only place in the country where lakes for ore washing have remained. These are: Tăul Mare between Cârnic and Dealul Cuibarului; Tăul Țarina near Văidoaiei Peak; Tăul Brazilor and Tăul Anghel above Roşia Montană (near Cârnic hill); Tăul Țapului upstream Săliște Valley (upstream the tailings settling pond) and Tăul Cornii upstream Corna. The only lake affected by pollution is Tăul Mare (fig. 6), where a part of the waters near the waste dumps Cuibaru in Roşia Poieni flow (Duma, 1998).



Fig. 6. Roşia Montană. Tăul Mare

In the area of the opencast pit Cetate the hydrographic network has been totally disorganized. The rain waters infiltrated underground in the old mining works, washing away the mineralization. They are collected in the main gallery and then they are discharged into Valea Roşie as acid drainage, locally known as „galiță”, a phenomenon manifested through formation of sulphuric acid from mineral sulphides in contact with air and water. The process is directly and indirectly accelerated by the presence of some bacteria (*Tiobacillus ferroxidans*, *T. thiooxidans*, *Leptospirillum ferrooxidans*) and it generally takes place naturally in areas with pyriteous polymetallic mineralization. Its presence is noticed due to the brown-reddish colour of the water, containing  $Fe^{3+}$  in suspension and to brown-reddish or intense red silt deposits containing iron oxy-hydroxide and other precipitation minerals. The acid drainage also implies heavy metal ions with potential direct and synergic effects upon the aquatic environment. The reddish colour of the waters in the main water collector of the area determined its name (Valea Roşiei – Red Valley), the old name of the locality, *Rubeo Flumine* (Red River) and the present name of the locality, Roşia Montană (Duma, 2008).

In the mining waters almost all indicatives are beyond limits, including toxic elements such as: lead, zinc and copper; the pH is also alarming (*table 2*).

**The Quality of Waters in Cetate Mine**

*Table 2*

Quality Indicators mg/L	Mine water	Admitted Values for the Water of the Roșia Creek, Downstream the Mine Water Discharge (Authorisation No. 10/1991)
pH	2.6	6.5-8.5
Suspensions	40.0	25
Fixed residuum	6,130.0	1,200
CCO-Mn	80.0	25
Calcium	338.0	150
Magnesium	67.0	200
Chlorines	35.5	300
Copper	1.50	0.3
Lead	1.0	0.05
Zinc	43.6	1.0
Manganese	261.9	0.3

Source: Duma (2008).

The more acid the waters, the higher the metal content. Acid pH has direct negative effects upon the flora and water fauna and secondary effects such as: lower oxygen levels, higher pressure of the carbon dioxide, higher osmotic pressure due to the high concentration of mineral salts and also synergetic effects of the ions, all of the above contributing to the high toxic level of these waters (Postel and Richter, 2003). As a consequence, life in the waters of Valea Roșia has completely disappeared and because of the pollution of phreatic waters from the small meadow, the wells have been partially abandoned. With humans, lead impregnated water leads to memory disorder, hands numbness, insomnia, anaemia and cancer; children's metabolic and immune systems are attacked; it also affects their intelligence level. Zinc produces epigastric and cardiovascular pain, diarrhoea, trembling and paralysis (Taitner, 1988). Animals present digestive disorder (diarrhoea), salivation, seizures, paralysis of the muscles and of the larynx, swollen joints (Coman, 1991).

The industrial water for the processing plant Gura Roșiei flows into Abrudel stream at 300m upstream from the plant, but downstream the flowing of the clarifying waters from Valea Săliștei.

The quality of the technologic waters is affected by large amounts of toxins: suspensions, CCO-Mn, sulphates, iron, magnesium, zinc, copper and cyanides (*table 3*).

**The Quality of Industrial Water and of the Valea Săliștei Settling Pond Water***Table 3*

Quality indicators mg/L	Abrudel Valley industrial water	Cleared Water, Valea Săliștei Settling Pond	Admitted Values, According to C.G.A. M.11/88; STAS 4706/88
pH	6.0	5.5	6.5-85
Suspensions	75.0	58	25
Fixed residuum	612	980	1,200
CCO-Mn	253	49.1	25
Magnesium	12.2	206	200
Chlorides	28.4	28.4	300
Sulphides	3,194	485	400
Cyanides	0.014	0.018	0.02
Copper	0.17	0.11	0.2
Lead	0	0.16	0.2
Zinc	126	1.95	0.2
Manganese	7.5	335	02
Calcium	116	145	150

Source: Duma (2008).

Industrial water which practically has the qualities of the Abrudel creek waters is also impurifier – laden water; this explains the disappearance of aquatic biota and to the poisoning of the phreatic levels in Abrudel flood plain. The fish are most affected by the cyanides because contents of 0.03 mg/L HCN in the waters are fatal for them (Witt *et al.*, 2004). Drinking the water with cyanides leads to headaches, vomiting, respiratory distress, tachycardia, coma and at levels over 300 mg/L HCN it leads to death (Taitner, 1988). It is worth mentioning that the level of cyanides in Abrudel waters is close to the level in the cleared waters coming from Valea Săliștei pond. Moreover, the Abrudel flow is at least 20 times bigger than Valea Săliștei (clarified water). Under these circumstances, the cyanide level in Abrudel water, due to dilution, should be 20 times lower. Elementary logics leads to a reversed calculation which gives the result of 0.36 mg/L of cyanides in cleared water, much above the admitted one (0.02 mg/L) (Duma, 2008).

The soil cover from the mining perimeter Roșia-Montană has acid brown soils, argillic brown soils, cambic podzols, albic luvisols, usually eroded down to the level B horizon and undeveloped soils (alluvial proto soils) in Abrudel floodplain and in the small floodplain of Valea Roșie creek.

In the area Cetate opencast pit the soils were removed when the ore was uncovered and around the waste dumps and tailings settling ponds they were covered with mining and plant waste.

The severe erosion on the hills Cărnic and Cărnicele also led to the removal of soil cover. The texture of the soils in Abrudel flood plain was also affected due to flotation sand flow from the mining process; this sand was mixed with them during the agricultural works.

As far as their chemical contents are concerned, they were impregnated with toxic elements such as lead, zinc and copper.

Lead usually accumulates on the soil surface and is easily assimilated by the plants with a developed radicular system at the level of the biologic horizon. The negative effects of lead in soil result in the slowing down or blockage of the fermentation processes and consequently to smaller crops. Lead accumulates in plants (leaves, straws, grains, tubers) and then into the consumers' bodies. Lead reduces the oxidation and photosynthesis processes and fastens biochemical processing. It also induces a smaller absorption of water and a more acute need of oxygen, slowing down the growth of plants and ultimately causing their death. The plants that are most exposed to lead are barley, clover and potatoes and among the animals the ruminants should be mentioned, because lead remains for a long time in their digestive tube and the absorption is enhanced. The accumulation of lead in the human body produces saturnism, encephalopathy, degeneration of the peripheral nerves, venous stasis, pulmonary sclerosis, heart hypertrophy, liver jaundice and kidney sclerosis (Ionescu, 1973).

Zinc diminishes the biologic activity, slows down the fermentation processes in the soil and reduces the barley, beans, carrots, potatoes crops; the beans production is reduced with 15% at a content of 17ppm Zn. It mainly accumulates in the green organs of the plants. When eaten, the plants containing zinc affect the human body similarly to water containing zinc. Copper reduces the gas exchange in plants, slows down the chlorophyll formation, stops the activity of microorganisms and reduces the activity of some fermentation elements (Duma, 2006).

The forestry vegetation in the area, mainly oak and mixtures of oak and beech has been cut from the very beginning of mining (the Daco-Roman period) and the wood has been used in underground works or in other purposes. Nowadays, the forests around the opencast pit are smaller and the clusters of trees and shrub that have remained grow slowly because of the white deposits on their leaves, which slowed down photosynthesis through stoma obstruction. There is also very little grass on the secondary meadows. The fruit trees near the opencast pit are no longer pollinated by bees, so fruit are scarce. The biota in the waters has totally disappeared and the wild animals took refuge from the detonation areas.

The industrial mining perimeter is very close to the built-up area in Roșia Montană, thus representing an element of landscape aggressiveness (Duma, 2008).

#### **4. Perspectives of valorizing the ore in Roșia Montană and environmental issues**

The ore exploitation programme issued by Gold Corporation has in view to extract and process 13 million tons annually. This is conceived as a 17 year project, which means over 220 million tons of gold ore extracted and processed, 240 tons of gold and 1,100 tons of silver. There will be used 240,000 tons of cyanide and the processed tailings deposit on Valea Cornii will cover 600 ha

and will be 178 m high. With regard to the safety of tailings settling ponds, numerous accidents due to cyanide that flooded the hydrographic network should be mentioned. In 1992 in the USA, the Alamosa – a Colorado affluent plant waste containing cyanide – flooded and destroyed life on a surface of 25 km, provoking damages amounting to 170 mil dollars (Egan, 2000). 130 mil. L of cyanide solutions flowed into the Tisa affluents from the ponds Bozânta and Novăț near Baia Mare in 2000 (Duma, 2007). A catastrophic accident happened at Certej in 1971 (October 30<sup>th</sup>, at 4 a.m.) when the old tailings settling pond fell causing the death of 99 people; hundreds of people were hurt and many were permanently disabled. There has also been significant damage (two blocks of flats and dozens of houses were demolished, hundreds of hectares of agriculture land were covered in mud). The damage produced to the environment has never been quantified, although cyanides existed in the pond (Duma, 1998).

The total area affected by mining works will cover 24 km<sup>2</sup>, including four mountains: Cetate, Cârnic, Jig-Văidoaia and Orlea and the impact surface of mining upon the environment will cover about 100 km<sup>2</sup>. 975 houses will disappear, out of which 41 belong to the patrimony, 7 churches (2 Greco-Catholic, 2 Orthodox, one Romano-Catholic, one Unitarian and one Calvin) and 11 churchyards – this is the richest archaeological site in Europe. They will destroy the Roman road, the Roman galleries (24 km), the Roman castrum and the Roman city from 130-140 A.D. Natural monuments will be destroyed too: Piatra Despicață – 0.3 ha, and Piatra Corbului – 5 ha, and the artificial lakes: Brazi, Anghel, Țarina, Corna, Țapului, Găuri, and Lacu Mare. Only 1/20 out of the entire historical site will remain and it will be surrounded by opencast pits, mining waste dumps, tailings ponds etc. Everything will turn into a desert. Only a small part from the historical centre will remain – some old buildings and a few newly built ones which have nothing in common with the local traditional architecture (Duma, 2008).

In case the Roșia Montană ore is accepted to be valorised, the following recommendations must be made:

- re-evaluation of the quality of the deposits made by Romanian institutes;
- priority in processing the tailings from Gura Roșiei and Valea Săliștei settling ponds, depositing of the tailings in the same locations and cancelling the building of Valea Cornii settling pond;
- keeping the archaeological site and the historic site and processing of the ore bodies that do not affect them;
- starting of the mining processing from Cetate body (Cetate opencast pit);
- using a processing technology that does not imply sodium cyanide. Among the technologies suitable for processing gold ore in Roșia Montană and for other deposits in Metaliferi Mountains leach treatment with thiourea and thiosulphate is recommended; these chemical agents are more efficient technologically, but they cost more. The chloride gas treatment is another tested leaching method; through seepage of the crushed ore, soluble gold chlorides are formed and they can be removed with water; the dissolved gold can be extracted from the solution using iron sulphate;

- depositing of the processed tailings resulted from processing the ore coming from the Valea Săliștei settling pond by superelevating it (the morphologic profile of the valley allows it); while the ore is extracted from Cetate opencast pit, the remaining gap should be filled with processed tailings;
- building of spillway channels around the Valea Săliștei pond, facilitating the flow of rain waters upstream the pond dam, into Valea Săliștei bed. Spillway channels should also be built around the future pond in Cetate opencast pit;
- building of emergency ponds upstream the main ponds for cases of technical or technological break-downs and mostly in case accidents should happen (leakage, collapses) at the main pond;
- neutralization of the acid drainage and proofing of the bottom of the processed tailings settling ponds with natural materials (concrete, clay and bentonite). The neutralization of acid drainage takes place all along the extraction and processing flux. Ex.: removal of pyrite, adding of neutralizing substances such as lime during grinding; alternation of neutralizing materials such as limestone within the strata of waste etc.;
- achievement of final ecologic reconstruction that includes fertile soil to cover the mining waste dumps and the processed tailings settling ponds, followed by afforestation (with acacia, birch tree, box thorn).

This would allow both the processing of the ore – which is a socio-economic priority for the area – and a relative preservation of the natural and anthropic environment that eventually could transform this area into a valuable cultural-historical and tourist attraction.

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