RISK FACTORS CAUSED BY MINING ACTIVITIES IN BAIA MARE

S. ZAHARIA[1], B. DRIGA[2], D. ISTVAN, L.MĂGUŢ

Abstract. - risk factors caused by mining activities in Baia Mare. In order to prevent major unbalances in the geographical area, as a consequence of mining activities, to avoid and reduce the consequence of heavy metal pollution, we identified and analyzed the main areas and locations affected. Also, we will present the conclusions that we reached and the measures that need to be taken.

Key words: pollution risks, mining activities, caved galleries and wells, sterile and concentrate dumping sites

Location.

The precious metals extraction activity has determined the establishing of the medieval settlement on the location of the present day municipality. Throughout the centuries, various diggings have been exploited, situated on the territory of the municipality of Baia Mare. Nowadays, four different types of mineralites can be found:

-*The Săsar-Roşiei Valley mining field,* constituted by the lode groups Aurum, Adam- Cremenea, Ţigher-Sofia, Iojica-Bartoşa-Wilhelm (all on the Borcut Valley), the gold stuck structure Borzaş (Borcut Valley) and the metallogenetic structure Roşiei Valley (Baia Mare)

-*The metallogenetic structure Dealul Crucii* (Baia Mare)

-*The metallogenetic structure Herja* (Ferneziu)

-*The metallogenetic structure Firiza*

All these structures and lode groups are situated to the north of the municipality's incorporated areas, in the woodland. In the mining galleries situated in the Baia Mare municipality, minerals have been researched and exploited which belong to the *Metallogenetic district Baia Mare, the metallogenetic sub-province associated to the neogene magmatism from the Oriental Carpathians.* This metallogenetic district is the most important metallogenetic accumulation from the Oriental Carpathians and from Europe.

[1] Geoproiect, Baia Mare, Romania, e-mail: geobaiamare@yahoo.com
[2] Institute of Geography, Romanian Academy, Bucharest, e-mail: driga_basarab@yahoo.com

Within this metallogenetic district, there are several metallogenetic fields (Racşa-Ilba-Băiţa, Săsar- Crucii Hill, Herja- Poiana Botizii). The greatest part of the galleries investigated on the territory of the Baia Mare municipality, is situated between the Băiţei and Firizei Valleys, presenting the following structures:

The Sofia Structure- presents a group of lodes, length of 700-1500 m, thickness 0,1-3,5 m direction NNE- SSW and a vertical depth of 500 m.

The Roşiei Valley Structure- presents several main lodes with NNE-SSW direction, length of 1200-1500 m, thickness of 0,5- 2,5 m.

Borzaş Structure (Borcut Valley)- formed by dispersed minerals of the stokwork type, with the dimension of 250 x 75 m, in the space of gold lodes.

The Wilhelm Structure (Borcut Valley) developed in the Ulmoasa dalcite, on the superior course of the Borcut Valley. It is formed by 2 lode groups: Wilhelm and Complex (lodes with length of 100-600 m, thickness of 0,3- 0,5 m, with a lead-zinc mineralization)

The Aurum Structure (Borcut Valley) formed by the main Aurum lode (length of 700 m, average thickness of 0,2 m, total level of mineralization of 700 m and several secondary lodes)

The Simion- Trei Stejari Structure (Borcut Valley) formed by 2 lode groups: Bartoş-Iojica to the north, which has approximately 30 lead-zinc lodes, developed on a surface of 0,6 x 0,3 km.

The Adam-Cremenea Structure (Borcut Valley) situated to the west of the Borzaş structure and to the south of the Aurum structure. It comprises several short lodes (length of 150-200 m), directing NNW-SSE, formed in a discontinued lode formation with a length of 1 km.

The Dealul Crucii Structure- formed by the main lode, with a thickness of 1-8 m, exploited length of 800 m, which presents several bedding and roof branches

The Firiza Structure (Firiza-Neagră Valley) The minerals in this structure have 3 lode groups: Seicina- Roşie Valley with a reef level of 50-80 m, the Neagră Valley with lead, zinc, coper+/- gold, silver mineralized lodes and Jobodi Valley

The metallogenetic field Herja-Poiana Botizii. Within the territory of the Baia Mare municipality it is only represented by the **Herja Structure,** a tectonic unit raised on paleogen flysch crossed by magmatic intrusions. The main intrusive body has a dimension of 250 x 300 m. The Herja deposit comprises approximately 250 lodes and secondary branches, developed in a limited space (1,0 x 0,75 km). The minerals from the Herja structure are lead and zinc, with high concentrations of silver and stibium on its superior part.

Documented for centuries, mining activities in the Maramureş region and its connected activities (metallurgy, constructions, mechanical engineering, transportation, services etc), have been for centuries a very important income and

subsistence source for the county population, but also the most important risk factor and pollution source for the environment. Simultaneously with the development of the mining industry, several areas of Maramureş County emerged as mining centers, such as: Baia Mare, Baia Sprie, Cavnic, Borşa, Ilba, Nistru, Băiuţ, Răzoare. After successive restructuring processes, of which the most important took place in 1997 and 2006, the activity of extraction and reprocessing of base and precious metals has been ceased at the end of 2006.

Although, serious problems concerning the risk factors and environment impact have been presented, little has been done to change this situation. The ecological disaster at the sterile sludge pond "AURUL Baia Mare" – Bozânta Mare (January 30th, 2000), had a huge media impact, emphasizing again that unusual meteorological phenomena can create major risks, which can lead to accidental pollution with a regional or even trans-border impact.

After the closing down of the extraction and processing activity led by the *National Company for Precious and Base Metals* REMIN SA Baia Mare, at the end of 2006, the impact on the environment, population and deposits safety has been major. Due to the restructuring of mining activities, some people entered old mining works or destroyed dams made of prefabricated blocks. Some have entered in the underground galleries, from where they stole scrap, cables or other materials (piping, railway tracks, airing tubes, electrical equipment etc) actions which even caused the death of some of these people.

Due to the stopping of mining water pumping, the inferior spaces have been flooded, and the mining water will be released soon or has already started to flow through the adit. Because of the economic collapse within CNMPN REMIN SA Baia Mare, beginning with 2008, the mining perimeters intended for closing down and greening have been transferred to CONVERSMIN SA Bucureşti.

The main risk phenomena identified as a consequence of mining activities are: *underground holes which reach the surface, caving-in caused by underground holes, uncontrolled groundwater accumulations, with possible flooding, corrosive mining waters, sterile dumping sites with possible release and slide caused by the pronounced acclivity; corrosive mining concentrates dumping sites; mining installations.*

Case studies.

Underground holes which reach the surface. The several such holes identified pose great falling danger for people and animals and represent old ventilation raises, exploiting units, surface wells (older or newer), presenting an urgent need to be appropriately organized (warning signs, fencing). For example, on the right slope of the Antoca valley, belonging to the Sofia (Săsar) mining perimeter, one can find a caving-in with a 30 m diameter, the raise well having a

depth of 50 m, while the ventilation raise of the lode 3, Alexandru, has a depth of 104 m (figura 1)

Fig. 1 Deep caving-in of the Antoca, left-side. ventilation raise of the lode 3 Alexandru

On the same slope, the bank line of lode 10 presents a seriously dangerous caving-in, with a length of 25 m, width of 15 m and depth of 40 m, without having a warning sign or being fenced. (figure 2)

Fig. 2 Caving-in of the lode 10 Sofia bank line Fig. 3 IPEG well- Dealul Crucii

Similarly, the IPEG well on the Dealul Crucii (figure 3), on the right slope of the Vicleanului Valley, is not covered, having a diameter of approximately 5 m and a depth of 60 m; in the caved-in raise of the well, with a depth of 15 m, in 2010 a car has fallen with 2 people in it.

On an old road, within 300 m distance from the IPEG well, the so-called New Well, dating back to the 16th century and manually dug, is uncovered and having a depth of 62 m; similarly to many other caving-ins it is uncovered and unfenced (figure 4)

Fig. 4 The Nou well manually dug in the 16th century, 62 m deep, unprotected today

The closing down of some surface-related mining activities from the "Dealul Crucii" mining perimeter (phase I underground) have been executed with an Environment Permit and Notice of Water Management in 2004. However, several adits and vertical mining activities have been left unfenced in these mining perimeters.

Caving-in areas caused by underground activities. There are over 200 galleries in the Săsar and Herja mines, the IPEG galleries, from the adjacent areas of the Săsar and Herja mines, underground holes exposed to phenomena of mining pressing, uncontrolled accumulations of mining waters, acidifying caused by the washing of minerals by infiltration waters. The mining exploitation areas are usually situated in the unincorporated areas and due to the fact that they are located in compact, eruptive rocks, they are not affected by caving-ins. Obviously, there are also identified exceptions.

Thus, the Borzaş mining perimeter, part of the SĂSAR Baia Mare Mine is situated in the north-western part of the Baia Mare municipality; by a road corresponding to the Borcut Valley and then on the Borzaş Valley (in the old Borzaş mining perimeter) and the Neamţului Valley one can reach the caving-in mine crater, of which the biggest has a diameter of approximately 150 m and a depth of approximately 40 m; in these caving-in mine craters great quantities of infiltration water accumulate, which then flow into the underground and are evacuated through the Săsar gallery. This area is not fenced either.

The Incorporated area Săsar-Valea Roşie-Dealul Crucii

An area of possible extensive caving-ins in the incorporated areas, is situated to the north of the Minerilor-Victor Babeş-Nucului streets, a sector from which 3 main galleries spring; the three were used in the exploitation of minerals situated further north (figure 5) On the several meters long section in which the tree go through brittle sedimentary rocks or through rocks with a possible volume variation, a risk of caving-in is present, caused by the destruction in time of the underground timbering system present there.

Fig. 5 Săsar Gallery-mining premises and the Săsar mining water pumping station

The Săsar Gallery was active until 2006 and is for the most part cemented, also having a paralel conjuncted gallery. There is no short and medium term caving hazard, but in the case of the caving-in of the other two main galleries (Valea Rosie and Dealul Crucii), this gallery becomes the main mining water delivering gallery; the water is evacuated from the gallery through an internal sewer that crosses the enclosure of the Săsar mine then through a sewer in the ditch on Nucului street, in the the Victoria Street sewer and into the Sasar river. In the event of heavy rainfall, the sewer cannot sustain the entire debit, which causes the flooding of the old pumping station of the Săsar Processing Plant, and of the Nucului and Victoriei streets as well as several other lots in the area.

The Valea Roşie Gallery (formerly dubbed Svajczer, then Cuza Voda). The mining premises here was closed at the same time the Săsar quarter construction halted. After the closing of the gallery, in short timeframe, a 1.5 meter mud layer had formed, making the gallery inaccesible as of now. It is situated in the city of Baia Mare, at the corner of Iuliu Maniu and Victor Babes streets (figure 6). A debit of approx. 5 litres/sec comes out of the gallery, and flows into Baia Mare's sewer system. Following a series of rainfalls in the months of may and june 2010 there have been sightings of exfiltered mining waters on a several lots found above the Cuza Voda gallery.

The Dealul Crucii gallery (formerly dubbed Inaltarea Sfintei Cruci, Lobkowitz or 23 August) was dug between 1765-1795 and used as EM Săsar access until 2006 (figure 7). The section that goes through the sedimentary is affected by pressure phenomena, the gallery having sectors that are reinforced with cemented rock masonry.

Fig. 6 Cuza Vodă Gallery, Baia Mare, Iuliu Maniu Street

The cement is degradable, favoring caving-ins. Such a collapse took place in 2008, underlined by a surface collapse cone formed in the backyard of a home.

Fig. 7 Lobkowicz (23 August) gallery, mud-filled

Mining waters from the Lobkowicz gallery flow with a 7l/sec debit into the the Baia Mare sewer system.

Corrosive mining waters. The corrosive character of mining waters is given by the alterations of the sulphur foud not only in deposits but also in surrounding rocks and the presence of sulphurous and sulphuric acids. Some of these waters are partially treated and neutralised, before being shed into the sewage system (Herja, Sasar), others are still ignored (those in Valea Rosie and Dealul Crucii galleries).

The evacuations of acid mining waters, directly into the emitter, posess variable debits (0-150 litres/sec) or even larger in the case of heavy rainfall or quick snow-melts (ex. The Sasar, Cuza Voda, Lobkowitz and Herja galleries).

The most vulnerable locations that provide mining waters are:

- The Sofia gallery situated on the Antonca Valley at about 200 m upstream from the Valea Borcutului Street.
- The Valea Lunga IPEG dumping site and gallery. The dumping site is situated on the Valea Lunga riverbed, 800 upstream from the confluence of the Valuea Lunga and the Valea Pietroasal; dowsntream , the dumping site is exfiltered.
- The Herja Mine (Ioachim gallery). Activity at the Herja mine was stopped in 2006. Infiltration waters at the surface and in the mining holes are accumulated underground and are evacuated by means of well pumping, fromwhere they are gravitationally evacuated on a distance of approx. 1 km to the main premises of the Herja mine (figure 8). The Herja mining waters are directed though an inner sewer to the Herja mining water treatment station where they are neutralised with lime (figure 9).

Fig. 8 Entrance of the Herja UP Flotaţia Centrală gallery

Fig. 9 Herja mining water treatment station

Sterile dumping sites with possible scaling and landslides. There are over 100 sterile dumping sites in the Baia Mare area, the great majority of them presenting mechanical instability caused by the large acclivity angle, through the creation of cloughs, washings of the dumping sites basis, as well as phenomena

characterized by the downstream migration of pollutants (heavy metals) due to ex-filtering activities or to ore leaching phenomena.

- *The Simion- Trei Stejari gallery dumping site (Bartoşa)* situated to the left of the Bartoşa Valley, downstream from the entrance in the Bartoşa gallery, the dumping site has a length of approximately 30 m, medium width of 10 m and a height of approximately 3 m, the acclivity angle of 60º, comprising a volume of approximately 500 mc; it does not have anti-erosion protection, the basis of the dumping site being in direct contact with the water of Bartoşa valley.
- *The Simion- Trei Stejari gallery dumping site (Bartoşa)* situated to the left of the Bartoşa valley; it has a length of approximately 150 m, medium width of 5 m and an estimated volume of sterile deposited of approximately 10 000 mc; the water of the Bartoşa valley, under-crosses the dumping site through a sewer, with a diameter of 1600 mm
- *The IPEG Lungă Valley dumping site (Roşie Valley)* situated on the riverbed of the Lungă valley, approximately 800 m downstream from the confluence with Pietroasa Valley; it has a surface of approximately 0,60 ha and a value of deposited material of approximately 44 300 mc; downstream the dumping site has exfiltration, probably due to mining water infiltration through the IPEG galleries and also due to the under-crossing by the Lungă Valley water; downstream from the dumping site, material has been excavated which created a physical instability of the material deposited, together with the migration of geochemical elements downstream, both on terrain and in surface waters;
- *The Adam Veta (Ventilator) dumping site (Roşie Valley)-Borzaş,* situated on the right slope of the Borzaş Valley (left affluent for the Borcut Valley); the dumping site has a surface of 0, 82 ha, and a volume of 65 000 mc and a an interior sewer which is partially blocked
- *Herja dumping sites.* Two dumping sites can be found in the main premises, namely (fig.):

-the old sterile dumping site from within the Herja mine (surface of 0,45 ha, volume of approximately 112 000 m^3);

-the new sterile dumping site from within the Herja mine (surface of the dumping site area 0,52 ha, surface of the dumping site basis: 0,62 ha, volume of approximately 525 000 m^3);

-both dumping sites have a high acclivity angle, and here and there instability phenomena can be noticed due to material excavations carried out at its basis;

- *Corrosive mining concentrates dumping sites.* At UP Flotaţia Centrală no processing activities are being carried out, that is no mining processing, the activity being ceased in December 2006. The existing pyrite concentrates are being deposited in several areas, in 7 pyrite deposits. In the area of these deposits,

accumulations of rainwater are present which have a brown-reddish color, have acid characteristics and contain metallic ions (fig.) These waters affect the area's soil, phreatic waters and surface waters.

The acid waters that leak from the pyrite deposit (located between the railway tracks and Oborului Street), affect the soil along the street to the railway and then reaching SC CUPROM SA. In the area of the power-line towers, next to the Oborului street, the acid waters have corroded the foundation and the metallic brace, the risk of collapsing being present.

Mining installations (plants, toxic substances hydro-transportation piping).

The hydro-transportation piping between the Processing Plant and the Bozânta Pond are currently being taken apart. The 350 mm piping line belongs to SC ROMALTYN MINING SRL, a company which intends to process the flotation sterile deposited in the Central Pond, together with the pyrite concentrate from the deposits near the UP Flotaţia Centrală.

The processing installation of SC ROMALTYN SRL is intended to be reintroduced for the processing of sterile from the UP Flotaţia Centrală pond and also of its pyrite deposits. The hydro-transportation piping may present risks in the case of any malfunctions, even if it is currently being replaced, on a route which avoids the central area of the town. Also, the processing installation which uses a high quantity of sodium cyanide presents risks in the case of any malfunctions. Actually, through the Zonal Urban Plan, recently drafted, *the use of cyanided will be strictly prohibited in that sector of the town.*

Risks are also present in the case of the sterile transportation pipe to the Bozânta pond, because the sterile has a high content of sodium cyanide, the cyanide neutralizer being organized at the pond and not at the plant.

Conclusions

For the closing of the mining perimeters a sectorial approach was preferred to the global one of the environmental and risk area problematic, in the technical projects regarding the ceasement of mining activities only the beneficiary (CNMPN REMIN SA Baia Mare) was considered, and not the prospecting processes, geological explorations or openings executed by IPEG Maramureş or other mining operators. We believe that a prioritization regarding risk areas, the safety of mining work, people and animals as well as environmental factors is in order.

The impact of underground mining work on the surface terrain

- Vertical mining operations (raises, bank line caving in mine craters) represent a real danger to people and wildlife (falling risks, collapsing etc.); these operations are neither properly signaled nor fenced (exceptions are constituted by a few older works in Dealul Crucii);

- Through the caving in mine craters or landslides from the surface, water from the surface infiltrates and washes the minerals, dissolves ions of heavy metals, they acidify, increasing the debit of the evacuated mining waters.
- The largest caving in mine craters are in the Borzas (Sasar) mining perimeters, the surface affected by cavings being of approx 7 ha, the largest having a diameter of 150 m and a depth of about 40m, and the above surface being under constant movement..
- The terrain above the mines is affected in all perimeters, but significant cavings are present in mining perimeters: Borzaş, Aurum, Sofia, Valea Roşie, Dealul Crucii.

The safety of mining operations and the environmental impact

- Unsealed adit mines represent a real danger in the case of entering these locations.
- In the caving-in mine craters where water has accumulated, there is the risk that the pressure from the water would defeat the base material's resistence and massive and sudden water infiltrations would take place in the underground, with unpredictable consequences, especially in populated areas.
- Eloquent examples of underground waters: powerful flooding in the month of march 2001 in the Câmpurele – Băiţa galleries (a 2 m3/sec recorded debit) and Valea Colbului – Ilba (station flooded by a stream), massive mining water evacuation (of approximately 20 times larger than the normal debit) in the Tyuzosa gallery (March 5th 2008), the causes of the evacuation of such a large debit, may be the massive water infiltration from the Tyuzosa stream owed to heavy rainfall, or the formation of a peg, that is shattered by the high pressure of water accumulated in the back of this dam, and recently (2010) massive mining water evacuations from the underground into the Purcăret gallery inferior (Ilba), waters that have destroyed the access route and have flooded several households downstream of the dumping sites.
- Material has been exacavated from many dumping sites in order to be subsequently treated in processing plants, road repairs or the sealing of backfill galleries, as a result, the elevation of water floors has been accentuated, increasing the mechanical instability of dumping sites
- Sewers underneath dumping sites are half-blocked in the majority of mining perimeters, with instances where sewer tubes have been removed, the material in the dumping sites being moved downstream (ex. Valea Roşie, Valea Bartoşa etc.)
- Because of deforestationm on cliffs and the course of some valleys, logs and branches have remained, in the case of heavy flooding increasing the risk of

blockage of the sewers under the dumping sites (ex. The Bartoşa, Lunga Valley dumping sites and the Aurum well etc.)

Necessary measures

1. monitoring of all mining perimeters after sealing.
2. the making of maps of risk areas in all mining perimeters, through a global approach of the area.
3. ceasing all mining works that are concerned with the surface (galleries, raises, extraction and ventilation wells, caving in mine craters on bank lines) by finding appropriate technical solutions.
4. Executing stabilization works, water protection and greening of all dumping sites in all mining perimeters.
5. the fencing of all raises, mine craters, surface unevenness in order to prevent the access and fall of people and/or wildlife in these extremely dangerous areas.
6. cartographing and marking on topographic or tourist maps, the making of risk maps for all mining operations linked to the surface or surface adjacent (galleries, raises, wells).

REFERENCES

1. Budai C. (1988), *Relieful antropic din regiunea minieră Baia Mare*, Stud. Cerc. Geol, Geof., Geogr., ser. Geogr., vol XXXX, Bucuresti
2. Chendeş, V., Driga, B , Niculescu, Gh., Zaharia, S., *Landslides in Maramureş County (1998)*, Documentation of Mountain Disaster, Proceedings of the Third International DOMODIS Workshop, Editor D. Bălteanu, Ed. Ars Docendi, Bucureşti
3. Gotiu D, Surdeanu V. (2007), *Notiuni fundamentale în studiul hazardelor naturale*, Ed.Presa Universitară Clujeană, Cluj-Napoca.
4. Macklin Mark,G., Brewer Paul A., Basarab Driga, Zaharia Sorin, *The long term fate and environmental significance of contaminant metals released by January and March 2000 mining tailings dam failures in Maramureş County, upper Tisa Basin, Romania*, Applied Geochemistry, 18(2003), pag. 241-257.
5. Petrea D., Petrea R. (2005), *Mining, Anthropic landsforms and environmental threatening in the urban area of Baia Mare (Romania)*, in vol. "The 10-th Romanian-Italian-Franco-Belgian geomorphological Meeting: Geomorphology and Environment, Mangalia.
6. Sorocovschi, V., (2003), *Complexitatea teritorială a riscurilor şi catastrofelor,* Casa Cărţii de Ştiinţă Cluj Napoca
7. *** *Geografia Romaniei*, (1983-2005), Ed. Academiei Romane
8. *** *Atlasul R.S.Romania* (1972-1979), Ed. Academiei Romane