CORRELATIONS BETWEEN SURFACE-WATER CHARACTERISTICS AND GEOLOGICAL SUBSTRATUM IN AGHIRES MINING AREA, ROMANIA

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ABSTRACT. – Correlations between surface-water characteristics and geological substratum in Aghires mining area, Romania. The exploitation activities from Aghireş generated a series of lakes, drainage ditches and creeks, specific for mining. In this paper, the physical and chemical parameters of the mining lakes are presented, the results being then correlated with the characteristics of the geological substratum. For the physico-chemical testing, three different water samples have been collected for each of the ten mining lakes. The samples where then analyzed in the field, by using a portable multi-parameter measuring instrument. The final results confirm the initial premise that the water quality is influenced by the geological substratum. The parameters that stand out the most are the pH, electric conductivity, and salinity, which vary quite significantly between the collected samples. The pH parameter is the most illustrative in this respect, given that three of the mining lakes have an extremely acidic water environment (with pH levels lower than 4.0), while the rest of the lakes have neutral pH levels. This difference can be explained by the presence of pyrite, associated with coal deposits in the underlying formations of acidic lakes.

Keywords: surface-waters, mining lakes, geological substratum, quartz-kaolin, Aghireş.

1. INTRODUCTION

In recent years, several research studies have been conducted in Aghireş area, most of which focused on the artificial lakes resulting from former or current mining activities (e.g. Şerban et al., 2009; Pandi et al., 2009, 2010; Sorocovschi & Şerban, 2010; Măcicăşan et al., 2012). Based on these studies it has been determined that the mining lakes offer a great potential for rehabilitation, with positive effects on all the environmental or anthropogenic components. It must however be noted that although these studies have approached many of the lakes features (e.g. genesis, evolution, morphometric aspects, water quality), and also the existing external influences on the mining lakes (e.g. the mining activity), one of these factors, otherwise a very important one, has been very little addressed to. This is represented by the geological substratum, an environmental factor with strong influences on all the characteristics of mining lakes. From the cited papers, only Pandi et al. (2009) make some observations on the geological substratum of Aghireş area, but in a broader context which will be updated and further detailed in the present paper.

Therefore, this research paper intends to provide some contributions related to the above, but does not claim to address these issues exhaustively, but

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rather to propose several possible explanations and open a new arena of discussions regarding the influence of geological substratum on surface-waters. In correlation with the already investigated factors, fulfilling this desideratum will also facilitate the development process of the most appropriate rehabilitation measures for the existing mining lakes, in the overall geo-environmental context.

In short, the present study aims at identifying the main physical and chemical characteristics of existing mining lakes, and determining the influence of geological substratum on them. In this respect, considering that the substratum conditions differ from one mining field to another, several differences are expected regarding the characteristics of analyzed water-bodies.

2. STUDY AREA

The quartz-kaolin mining perimeter investigated in this paper is situated in the northwestern part of Transylvanian Depression, at the boundary of Cluj and Sălaj counties, and lying on the administrative territories of Aghireşu, Cuzăplac and Gârbău townships (Figure 1).

The perimeter is generally referred to as „Aghireş mining area", and is divided in two sectors, within which all the quarries are located (Figure 2).

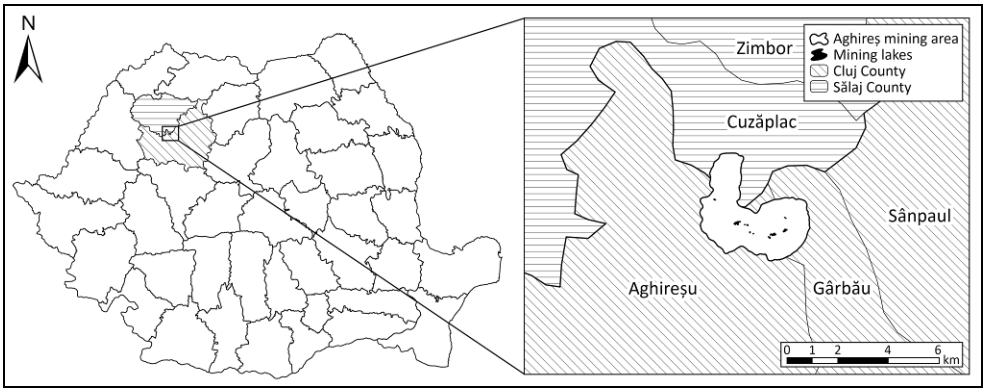

Figure 1. ***Geographical location of Aghireş mining area***

3. GEOLOGICAL CONTEXT

The geological formations developed in Aghireş area belong to the Cenozoic sequence of the northwestern sector of Transylvanian Basin. In this region, Rusu (1970) and Popescu (1976) have separated three sedimentation areas, completely individualized during the Oligocene: *Gilău* (in the South), *Meseş* (in the West), and *Preluca* (in the North) (Baciu, 2003). The geological system of beds from Aghires is included in Gilău area and has been sedimented during the Paleogene period, from Eocene to Oligocene.

In Gilău area, the Eocene-Oligocene interval evolved under a succession of transgressive-regressive cycles (Kovacs & Arnaud-Vannau, 2004), which clearly influenced the sedimentation process. As a result, the geological formations from Aghireş have been sedimented under a continental-lacustrine and marine regime, with shallow waters, more precisely in an epicontinental shelf area (Petrescu et al., 1997). Noteworthy that Petrescu, Givulescu & Barbu conducted several paleobotanical research studies in the area, from which one of the richest Oligocene flora of Romania has been collected, the final results being published in 1997, under a detailed research paper.

The lithostratigraphic formations that occur in Aghireş mining perimeter are represented by *Moigrad Beds* (Rusu, 1970), *Dâncu Beds* (Rusu, 1972), *Gruia Sandstone* (Rusu, 1989), *Var Sandstone* (Răileanu & Saulea, 1955) and *Cuzăplac Beds* (Moisescu, 1972) (Petrescu et al., 1997; Baciu, 2003) (Figure 2).

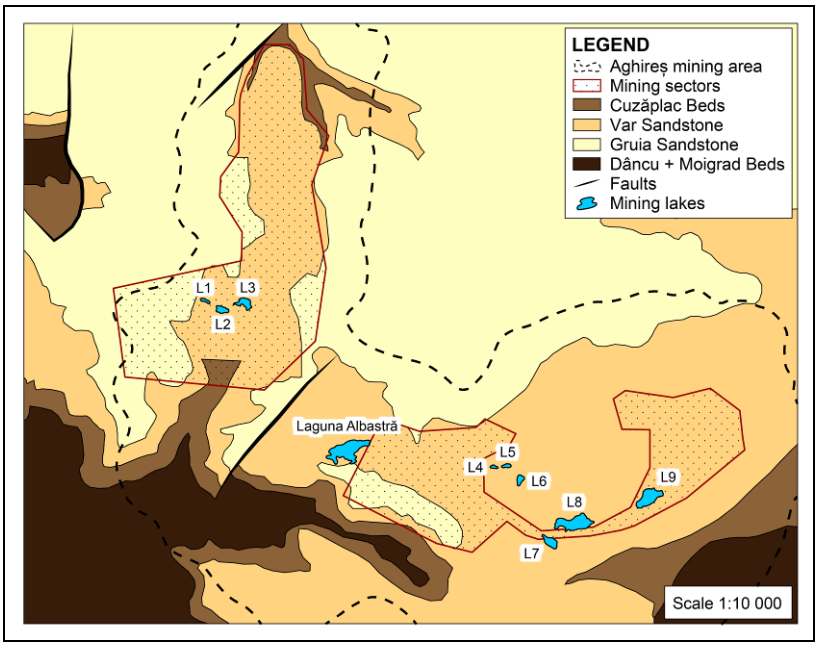

Figure 2. ***Geological map of Aghireş mining area (modified after SC Belevion Impex SRL, 2006)***

The quartz-kaolin sands deposit belongs to the *Var Sandstone*, which is discordantly disposed over the *Gruia Sandstone* and below the red clays of *Cuzăplac Beds,* for a total thickness of 45 m (Petrescu et al., 1997; SC Belevion Impex SRL, 2006).

Regarding the *Var Sandstone*, the geological research studies conducted at Aghireş Quarry revealed a total number of five layers of sands, stronger or weaker cemented, with different petrographic and technological characteristics (Baciu, 2003). These were numbered *I* to *V*, from top to bottom (Petrescu et al., 1997).

At the bottom, a layer of 10-20 m of gray-greenish sands occurs *(layer V)*, over which a coal shale layer is disposed, for a thickness of 4 m. The rest of the layers *(IV* to *I)* are disposed above the coal shale layer, for a total thickness of 20 m. This last sequence of layers consists of white and gray sand deposits, (SC Belevion Impex SRL, 2006) within which thinner or thicker shale breaks can be found (Petrescu et al., 1997).

During the Oligocene, a major change of the sedimentation process occurred in the northern sector of Transylvanian Basin, the *carbonaceous* deposits being replaced by the *siliciclastic* ones (Huismans et al., 1997). Therefore, from a mineralogical and petrographic point of view, the current quartz-kaolin sands from Aghireş are composed of: *quartz, kaolin, rock fragments, alkali feldspars, mica, montmorillonite, haloysite, small amounts of heavy minerals* and *limonitic concretions* (Petrescu et al., 1997). They originated from the alteration of *granitic rocks, pegmatites,* and *crystalline feldspar schists* from Apuseni Mountains, in a propitious climate for hydrolysis processes (Petrescu et al., 1997; SC Belevion Impex SRL, 2006).

Pandi et al. (2009) bring some additional information regarding the quartz-kaolin deposit developed in Aghireş area, stating that the mineralogical study presented the following dominant minerals: *quartz, kaolinite, muscovite, sericite, biotite, chlorite, limonit, pyrite, oligist, ilmenite* etc. Among these minerals, the quartz is the predominant one, representing about 80-85% from the total useful formation, while the kaolin appears to be in a much smaller proportion, of about 8-18% from the useful formation (Pandi et al., 2009).

In Aghireş area, the mineral resources have initially been exploited through underground workings, but after a few years, due to the low productivity, high costs, and unsafe geological structure, the company operating in the area opted for quarrying, a method ensuring minimal losses of useful minerals and a higher productivity (Şerban et al., 2009).

Over time, given that the useful minerals were unevenly distributed within the area, new mining fields have been opened while the older ones were abandoned. Consequently, the abandoned open-pits and associated mining dumps favored the formation of several water-bodies specific for mining, like mining lakes, drainage ditches, and creeks. However, despite the fact that most of the mining lakes resulted after the cessation of open-cast mining and infilling of mine pits by rising groundwater and precipitation, given that the exploitations began through underground workings, in certain cases the mining lakes have emerged after former galleries collapsed and were afterward flooded by precipitation and re-ascending groundwater (Măcicăşan et al., 2012).

4. METHODOLOGY

Considering that the areas occupied by surface-waters vary significantly from one year to another in the investigated mining perimeter, the present study began by performing a new and up to date inventory of existing water-bodies, and

also by digitizing and updating them on the thematic maps. Even though the study intended to examine not only the mining lakes but also the existing drainage ditches and creeks, this is not altogether possible given that the latter were mostly drained during the investigations, and the results are not consistent enough. For this reason, they will be thoroughly addressed in a future paper.

However, regarding the surface hydrographic network it is worth mentioning that this consists of valleys with torrential character and streams with irregular flow, determined by the variations of annual rainfall. Thus, in the quartz-kaolin mining perimeter there are no permanent sources of water (e.g. streams), which could constantly fill the mining lakes (Măcicăşan et al., 2012).

As regard to the mining lakes, we mention that the most notable is Laguna Albastră Lake (Blue Lagoon), both in terms of dimensions and color, from the latter actually deriving its toponym (Figure 3). This interesting color is given by the water's rich chemical cargo in dissolute compounds, resulting from the exploited rocks (Şerban et al., 2009). At the time of writing, several analyses are being performed in order to precisely determine which chemicals are responsible for the lake's unique color, the final results following to be published in a future paper.

Fig. 3. ***Blue Lagoon Lake (photo V. Măcicăşan)***

Alongside with Laguna Albastră Lake, nine more permanent mining lakes have been identified (see Figure 2), each having particular features given by the geological substratum. The water from these lakes accumulates over the banks and layers of quartz-kaolin sands, creating a unique landscape.

In order to determine the physico-chemical characteristics of the mining lakes, a number of three samples have been collected from each of the ten lakes, which were then analyzed in the field by using a portable multi-parameter measuring kit *(inoLab pH/cond 720 Series)*, capable of determining six different parameters: temperature, pH, redox voltage (ORP), electric conductivity (CE), total dissolved solids (TDS) and salinity.

The samples were taken a few inches below the surface of the water, in different characteristic spots. The average for each parameter was then calculated, the results being presented in Table 1.

5. RESULTS AND DISCUSSIONS

After reviewing the final results, the first parameter that stands out is the pH, which in the case of Lake 1, Lake 2 and Lake 3, indicates an extremely acidic water environment. The rest of the lakes have a neutral pH, which is suitable for aquatic ecosystems that have already started developing.

The next parameters that show significant differences between the mining lakes are the salinity and electric conductivity, which present the highest values for the same lakes (1, 2 and 3). It is not surprising that the Lakes 1-3, which have the lowest pH (highest concentration of hydrogen ions), have also the highest salinity and conductivity concentrations.

Table 1. ***Physical and chemical parameters of mining lakes***

Lake	pH	ORP (mV)	CE (µS/cm)	TDS (mg/l)	Salinity (‰)
Laguna Albastră	7.44	-29.5	928	928	0.2
Lake 1	2.91	238	4756	OFL	2.5
Lake 2	3.39	211	3983	OFL	2
Lake 3	3.59	597	2613	OFL	1.2
Lake 4	7.80	-42	2020	OFL	0.9
Lake 5	7.53	-31	2050	OFL	0.9
Lake 6	7.75	-43	2360	OFL	1.1
Lake 7	7.09	-1.5	1197	1197	0.4
Lake 8	8.16	-69	695	695	0.1
Lake 9	7.98	-59	593	593	0

Comparing the present results with that from previous studies (e.g. Pandi et al., 2009, 2010), the primarily noticed aspect is the one related to the pH levels of Lakes 1-3. In past studies, these lakes were merged in a single, much bigger lake, with a pH value of 5.72 in the hot season, and 7.44 in the cold season (Pandi et al., 2009). Although the study presented in this paper does not allow us to make comparisons between the hot and cold seasons, the difference between the pH levels can be easily observed, comparing present study with the previous one.

In attempting to explain the strong difference in the pH levels, we started by analyzing the other similar studies (e.g. Pandi et al., 2009, 2010) and trying to correlate them with the present one. It is worth mentioning that in the previous studies it has been noted that the water characteristics of the mining lakes vary mainly due to the natural agents like the climate, the geological substratum, the geomorphologic and the vegetation conditions, which directly influence the hydrologic regime of the water (Pandi et al., 2009).

However, from the present study it can be deducted that the geological substratum is actually playing the major role in this respect, by constituting a direct provider of chemicals that dissolve in the water.

By analyzing the geological map (see Figure 2) it can be observed that the geological formation where all the mining lakes have developed is represented by

the *Var Sandstone*. This fact is perfectly explicable, considering that it represents the useful deposit, namely the one that has been exploited through mining. However, in the field it has been found that the current underlying substratum – resulted after the excavations – differs between the acidic lakes and the neutral ones. Hence, in the area where Lakes 1-3 are located, the exploitation activities have depleted the *Var Sandstone* deposits, thus uncovering the subjacent layer of *Gruia Sandstone*. In consequence, the mentioned lakes have a completely different substratum than the rest of the lakes, herby the difference in the pH levels.

Acidic waters are quite frequent in areas with underground coal resources. The mechanism of building up acidity consists in bacterial oxidation of the sulphite content that usually accompanies coal deposits (Singh, 1988). The bedrock of Aghireş area consists of several sandstone layers deposited over a shallow layer of low quality coal, previously exploited in several locations of the area. By exploiting the quartz-kaolin mineral resources, the coal shale layer might be exposed, and hence sulphur containing materials being exposed to atmosphere. The differences in pH values between the studied lakes can be explained by the various degrees of exposure of the organic layer, and the processes of isolation of the exposed coal layers by the clay present in the lakes cuvettes. As acidic waters have a greater potential to solubilize various materials present in the lake bedrock, hence the greater content of TDS of the lower pH acidic waters compared to the other lakes.

Fig. 4. ***The reddish color of Lake 1 (photo V. Măcicăşan)***

6. CONCLUSIONS

In Aghireş area, the mining activities led to the formation of several artificial water-bodies, like mining lakes, drainage ditches and creeks, which may offer a great potential for the whole mining area in case of rehabilitation. For example, thanks to the mining lakes, and especially to Laguna Albastră Lake, which has been seen as a perfect place for recreation, during the last ten years the whole area became a touristic attraction for local community.

In the present paper, the physical and chemical characteristics of the mining lakes have been investigated, in direct relation with the geological substratum, and all of these in order to determine the influence of the substratum over the water's main parameters.

The results showed that the geological substratum plays a major role on the mining lakes characteristics, especially regarding the dissolute compounds and the concentration of hydrogen ions. The implication of the acidic waters presence in some lakes poses new challenges in the case of the environmental rehabilitation of the former mining areas.

However, further research studies are necessary in order determine the whole influence of the substratum over the mining lakes, and which minerals give the distinctive features of the mining lakes, such as for example their unique colors.

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