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AN INTEGRATED GEOMORPHOLOGICAL APPROACH FOR QUARRY REHABILITATION (AGHIREȘ MINING AREA, ROMANIA)

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Abstract: In Aghireș area, the environmental effects induced by mining need to be mitigated through appropriate rehabilitation planning. In this paper, by using an integrated geomorphological approach, two rehabilitation alternatives are proposed. The entire process is supported by USLE tool, physicochemical testing of soil and water, and GIS analysis. The final results should be separately addressed depending on the targeted component. Regarding the soil, the erosion risk indicated a maximum erosion rate of 10.94 tons/ha/year, and an average of 0.11 tons, on a background terrain stability of five different classes. The correlations suggest that the associated geomorphological processes are directly related to the uncovered land surfaces and the presence of mine dumps, on which the soils are in emerging state. By analyzing the newly formed soils it has been observed that several parameters (e.g. granulometry, plasticity and humus content), differ very much between the rehabilitated and the non-rehabilitated areas, suggesting different pedogenesis conditions. In addition to soils, the mining lakes have also been investigated, as support for rehabilitation. From the morphometric features it has been observed that the lakes surfaces vary quite significant during the year, depending on the recorded annual precipitation. It is also worth mentioning that three mining lakes have an extremely acidic water environment (with pH levels lower than 4.0), while the rest of the lakes have a neutral pH. Based on the obtained data, two possible environmental rehabilitation alternatives are proposed, complying with the requirements of SLOSS concept.

Key words: Aghireș mining area, quarry rehabilitation, mine dumps, Universal Soil Loss Equation (USLE), Geographic Information System (GIS), Single Large or Several Small (SLOSS)

1. INTRODUCTION

The rehabilitation process of quarries and related mine dumps requires a thorough understanding of the territorial context. Thus, for a successful rehabilitation process, regardless of the methods approached, the necessity of understanding the preexisting and the future quarry-generated landforms stands out from the beginning. Such matters are also specific for the quartz-kaolin sands exploitation from Aghireșu, where excessive anthropogenic activity specific for the last 40 years generated significant changes in the evolution of landforms and associated geomorphological processes, which are clearly influenced and restricted by the human activity.

In the study area, the superficial treatment of environmental conflicts generated by mining, eventually resulted in a heavily visual impacted area and an ecological and economical dysfunctional system. Considering this, appropriate rehabilitation measures must be selected and implemented in the mining perimeter. And in order for the selection process to be most effective, a profound knowledge and understanding of the geomorphological, pedological and hydrological context is compulsory.

Regarding the geomorphology, the slope drainage processes and land-slides have been investigated, considering that knowing these types of landforms and understanding their dynamics will constitute a support tool for the decision making process and will provide objective rehabilitation alternatives for the current situation. Also, the erosion rate for the territories affected by mining has been calculated, by applying a USLE model using the GIS technique.

In addition, the soil and water quality has been investigated, a study-case for each being presented in the following.

The alternatives proposed in this paper fulfill the current needs of rehabilitation for the anthropogenic induced landforms, and also the minimal legal requirements regarding the quarry restoration procedure.

2. TERRITORIAL CONTEXT

Aghireş mining area is located in the northwestern part of Transylvanian Depression, in its regional subdivision known as the Someșan Plateau, a hilly unit with average heights between 400 and 600 m. The surroundings consist of pastures, farmlands and meadows of poor quality.

The mining perimeter is situated approximately 3 km north-east of Aghireș Fabrici industrial village, 1 km west of Cornești village, and 27 km north-west of Cluj-Napoca Municipality. Regionally, it is located at the boundary of Cluj and Sălaj counties, lying on the administrative territories of Aghireșu and Gârbău (Cluj county) and Cuzăplac (Sălaj county) (Fig. 1).

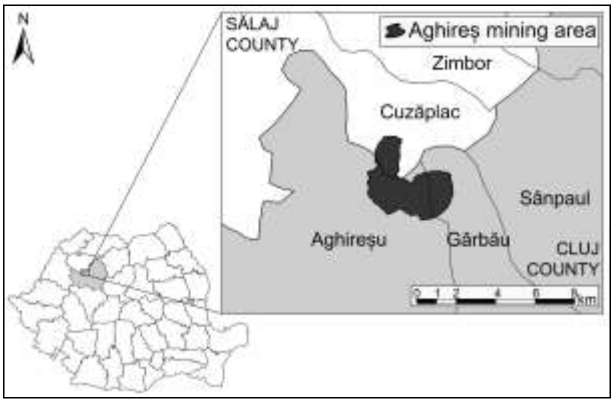

Figure 1. Geographical location of the study area

At Aghireșu, the mining activity started as underground exploitation but due to the high costs, low productivity and unsafe geological structure it was soon replaced by open-pit mining, an exploitation method which ensures high productivity and minimal losses of useful minerals (Șerban et al., 2009). Currently, the exploitation method for the quartz-kaolin sands deposit is quarrying, on stages with downward progress, dislocation through drilling-blasting, and inner or outer tailing dumping.

The mining perimeter has two sectors, namely *Aghireș-Cornești* and *Stoguri* (Fig. 2), but currently the exploitation activities are being carried out only in Aghireș-Cornești sector.

Regarding the geological system of beds, in the region we can find Eocene and Oligocene formations, the deposit of quartz-kaolin sands – which corresponds to our study area – belonging to the Oligocene sequence on the western side of Transylvanian Basin (Petrescu et al., 1997).

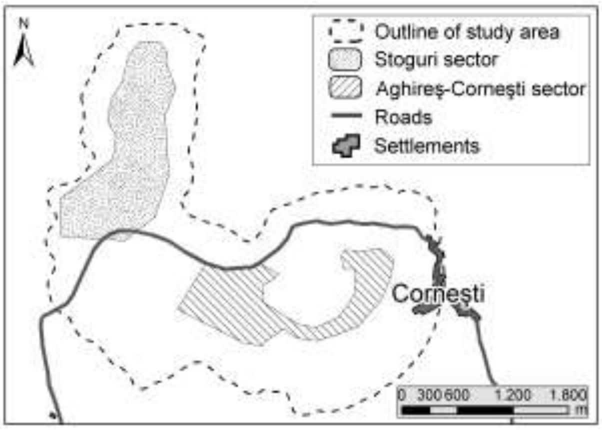

Figure 2. Mining sectors of Aghireș area

3. MATERIALS AND METHODS

3.1. The geomorphologic support for rehabilitation

3.1.1. Erosion risk assessment

The actual sheet erosion rate was determined using the Universal Soil Loss Equation (USLE) adapted by Moțoc et al., (1975) after Wischmeier & Smith (1965). The model is based on the following formula:

$$E = K \times Ls \times S \times C \times Cs \quad (1)$$

where,

- E is the average annual surface erosion rate, in tons/ha/year;
- K is a correction coefficient for rain aggressivity (rainfall erodibility index);
- Ls (slope length and slope degree coefficient) defined as a function of both slope and length (Kinnell, 2005);
- S represents the correction coefficient for soil erodibility and is based on soil or rock resistance to rain;
- C is a correction coefficient for land use and vegetation cover characteristics;
- Cs represents the coefficient for the effect of erosion control measurements.

For the present study, several researches covering the NW of Romania were analyzed and compared, such as the studies of Bilaşco et al., (2009) which covered the Șomeșan Plateau and determined erosion rate values as high as 37.35 tons/ha/year, although such values are rare (79.8% of the total area had an erosion rate between 0 and 0.5 tons/ha/year). Another study covering

Codrului Ridge and Piedmont (Arghiuș & Arghiuș, 2011), and using USLE based ROMSEM model, registered average values for the annual surface erosion rate of 0.575 tons/ha/year.

Covering a much smaller area, the results of the present study indicate a maximum erosion rate of 10.94tons/ha/year, and an average of 0.11 tons/ha/year for the investigated perimeter. However, these values are unevenly distributed, with the highest erosion rates being found in the quarry area, and the rate in the surrounding (forested) area approaching the null value (Fig. 3).

For the GIS model, different data sources and layers have been used starting from a *digital elevation model* with a spatial resolution of 25 m. Based on this model and using the formula developed by Mitasova et al., (1996), the *Ls* was determined.

The soil erodibility coefficient was determined on the basis of vectorized soil type data using both the soil map of Romania (scale 1:200000) and the detailed map of Aghireș mining area (scale 1:5000) developed according to the in situ mapping.

The *C* coefficient was determined using CORINE 2006 as background data, and introduced in the formula according to the values stated by Moţoc & Sevastel (2002), based on the studies conducted in Perieni (Vaslui county), Aldeni (Buzău county), Bâlceşti (Argeş county), Valea Călugărească (Prahova county) and Câmpia Turzii (Cluj county). The same values were also used for the *S* factor.

The climatic aggressivity coefficient was introduced in the model as a unique numeric value, of 0.120 (Stănescu et al., 1969; Moţoc & Sevastel, 2002). Thus, the value for the *Cs* factor was introduced following the same methodology developed by Moţoc & Sevastel (2002).

The USLE model represents a very important component for the present study, considering that the proposed rehabilitation measures depend in a great extent on the erodibility.

3.1.2. Slopes declivity and terrain stability

The introduction of geomorphological criteria in environmental rehabilitation enables such matters to be considered from a long-term viewpoint, based on the evolution of natural and anthropic slopes.

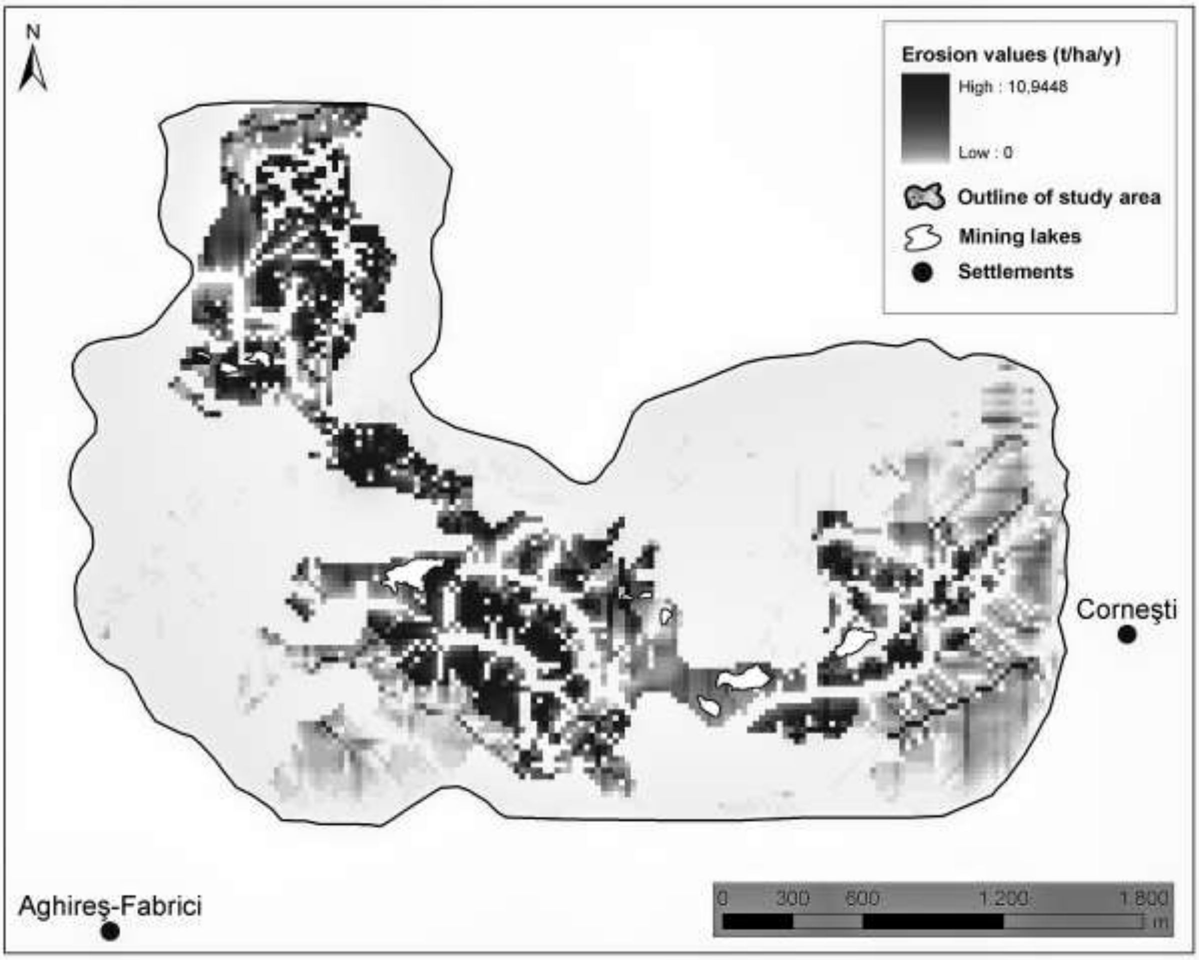

Figure 3. Soil erosion map of Aghireş area

It is preferable to give priority to land shifting in order to generate morphology and a substratum suited to the geomorphological, hydrological, and edaphic system (Martín Duque et al., 1998).

In addition to the erosion coefficient, the proposed rehabilitation alternatives will also take into account the slopes declivity values and the geomorphological processes specific to each terrain stability class; we consider that the slopes declivity represents an important land feature for rehabilitation plan.

Within the mining area, the slopes declivity values range between 0 and 48°, being divided in five classes (Fig. 4).

All these classes have geomorphological significance and can be described as follows:

a. *Quasi-horizontal surfaces (0 to 2°),* covering small areas which include interfluves and river beds.These values occur in the anthropogenic micro-relief forms, especially at the top of stabilized mine-dumps.
b. *Slightly inclined surfaces (2.1 to 5°),* specific for the slopes connecting the interfluves with the river beds, and for the areas situated at the bottom of mine dumps. The geomorphological processes affecting these slopes are those specific for gully erosion.
c. *Moderately inclined surfaces (5.1 to 8°)* appear on excavated areas and on stabilized dump slopes. These morphological surfaces are mainly affected by gully erosion and superficial landslides.
d. *Highly inclined surfaces (8.1 to 15°),* covering small areas and being prominent in the mining sectors (e.g. open-pit slope walls and mine dump embankments). Among the geomorphological processes specific for these surfaces, the superficial landslides and rolling blocks are the most frequent.
e. *Extremely inclined surfaces (15.1 to 48°),* covering very small areas and being prominent in the active mining sectors (e.g. open-pit slope walls). Among the specific geomorphological processes, the rolling blocks, rockfalls, and wall cavings are the most frequent.

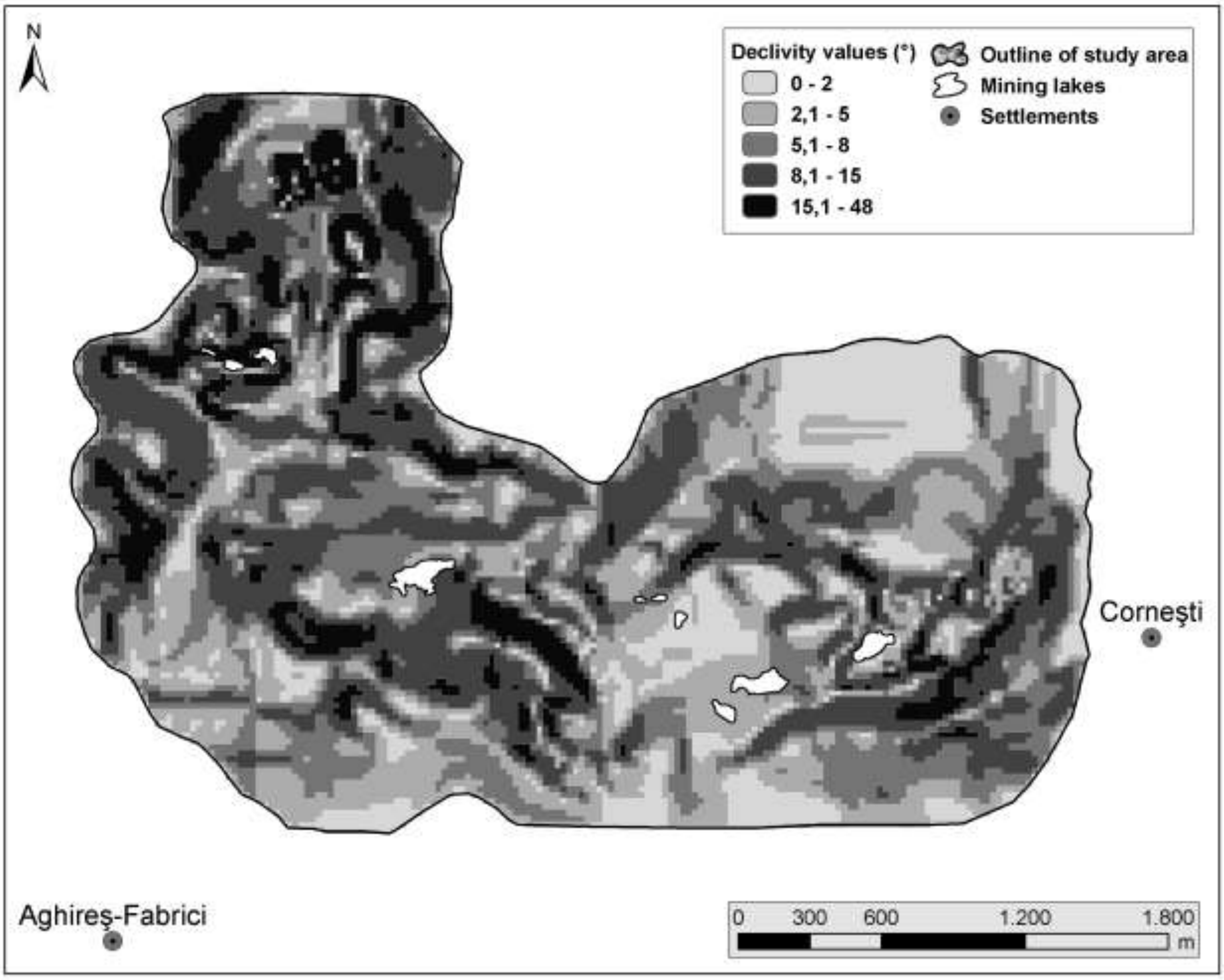

Figure 4. Slopes declivity map

Among the landforms, together with those characteristic for interfluvial ridges, slopes and river beds, unaffected by mining, the ones that stand out are those induced by anthropic activities (e.g.gullies, landslides, rockfalls, wall cavings, creep) and those generated by anthropic activities (e.g. slope walls, open-pit benches, mine dumps).

The terrain stability classes are prerequisites for subsequent rehabilitation measures, as presented in table 1.

Table 1. The relationship between slope angle and land use (modified after Roşian, 2011)

Slope category	Declivity nature	Land use possibilities
0-2°	Quasi-horizontal	Suitable for any type of land use
2.1-5°	Slightly inclined	Suitable for revegetation with herbaceous species and shrubs
5.1-8°	Moderately inclined	Artificial terracing is recommended
8.1-15°	Highly inclined	Artificial terracing is recommended
15.1-48°	Extremely inclined	Afforestation is recommended

3.2. Soil properties as support for rehabilitation

For the present study, the attention was focused on the newly formed soils, more precisely the soils formed on mine dumps, which have very particular features depending on how the dumps were managed through anthropogenic activities. The investigations were aimed towards determining the soils physical features.

In this respect, several soil samples have been collected from the mining area, the sampling points being chosen by taking into consideration the age of investigated mine dumps and their remedial stage, the magnitude of geomorphological processes, and the proximity to the mining sectors.

The first sample has been collected from an old mine dump (already rehabilitated through forest plantations), the second sample from a dump slope (adjacent to Laguna Albastră mining lake and affected by gully erosion), the third sample from a site located between the mine dumps, and the fourth sample from a dump affected by a landslide. The control sample was located in a natural forest, unaffected by mining.

The laboratory analyses were conducted in accordance with the following standards: STAS 1913/1-82 (humidity determination), STAS 1913/4-86 (plasticity limits determination), STAS 1913/3-76 (soil density determination), STAS 1913/12-88 (soil absorption capacity determination), STAS 1913/5-85 (granulometry determination), and STAS 7107/1-76 (organic matter determination).

From the results, the following can be highlighted:

- Sample 1 presents a moderate-to-high content of humus and a low content of clay, which is not surprising considering that the dump has been rehabilitated through forest plantations.
- Samples 2 and 4, corresponding to the non-rehabilitated dumps, show a low content of humus and a moderate-to-high content of clay, the latter being also reflected by the plasticity, these two being the only samples that allowed the plasticity limits determination. In both cases, the spontaneous vegetation is poorly represented.
- Sample 3, corresponding to the site located between dumps, has a high content of humus and a low content of clay, these features reflecting the basic characteristics of underlying soils unaffected by mining.
- Sample 5 (the control sample), shows a high content of humus, the lowest content of clay and the highest content of sand, also specific for the zonal soils surrounding the mining area.

The development state of investigated soils differs depending on how the dumps were managed, in the sense that some were planted with forest vegetation while others were left to evolve in the absence of a protective vegetation cover. The latter are affected by geomorphological processes like the gully erosion and landslides.

Table 2. Physical features of soil samples

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Humidity (%)	19.70	15.79	22.31	23.66	18.26
Upper plasticity limit (%)	-	24	-	38.89	-
Lower plasticity limit (%)	-	10	-	12.5	-
Plasticity index (%)	-	14	-	26,39	-
Density (g/cm^3)	2.12	1.84	1.80	1.86	1.54
Absorption capacity (%)	128	110	65	115	90

Table 3. Lithology, granulometry and organic matter of soil samples

		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Lithology		sandy-siltic clay	sandy clay	sandy-siltic clay	siltic clay	clayey sand
Granulo-metry (%)	*clay*	17.18	23.62	17.18	39.67	11.56
	silt	25.56	31.97	52.48	37.99	12.78
	sand	44	39	30.04	18.18	74.45
	gravel	13.26	5.42	0.3	4.16	1.21
Organic matter	*color*	dark yellow	colorless	dark brown	light yellow	dark brown
	humus	2 - 5%	0 - 1%	> 5%	1 - 2%	> 5%

Considering all the above and depending on the specific pedogenetic conditions of each mine dump, the following recommendations can be outlined:

- For the mine dump corresponding to sample 1, further rehabilitation measures aren't necessary since the initial measures have yielded good results and the soil started to regain its original properties;
- For the site situated between the mine dumps (corresponding to sample 3), the rehabilitation measures are not required yet, but the situation will be soon reviewed depending on how the exploitations will expand in the near future;
- For the mine dumps corresponding to samples 2 and 4, in order to prevent and combat the gully erosion and landslides, a series of rehabilitation measures and strategies are required, such as the stabilization of mine dumps and soil cover, the prevention and control of slope drainage processes by water discharge workings and revegetation (with herbaceous species and shrubs), the waterproofing of dump platforms by cylinder compaction, maintenance and monitoring (Fodor & Băican, 2001; Roşian, 2011).

By extrapolation, it can be established that the above measures are applicable to all dumps that have similar characteristics to those investigated in this paper.

Furthermore, by correlating the obtained results with the geomorphological studies conducted on site location, and considering that the soil constitutes a prerequisite for future vegetation development, it can be outlined that the investigated dump soils require further adequate pedogenesis conditions in order to increase their function as protective cover for the substrate and support for the vegetation. For this reason, for the future-generated mine dumps, a minimum of 30 cm of soil cover must be brought-in and deposited, in such a way as the pedogenesis process to be completed in a shorter period of time.

3.3. The hydrologic support: mining lakes

In the mining perimeter, once the underground exploitations have been replaced by open-pit mining, certain galleries collapsed and were afterwards flooded by precipitation and re-ascending groundwater. This led to the formation of permanent or ephemeral lacustrine units (Măcicăşan et al., 2012). According to the above mentioned authors, the abandoned quarries have later undergone the same flooding process, which resulted in the formation of other similar units, referred to as mining lakes.

By applying the GIS technique and by performing on-site analyses, the morphometric features and the current characteristics of these mining lakes have been determined, the results being presented this paper.

Regarding the morphometry, it can be noted that the investigated mining lakes have irregular shaped depressions and due to the extremely friable substrate and the surrounding unconsolidated sterile dumps, these have a special dynamics in space and time, which may lead, in a relatively short period of time, to the disappearance of certain lakes and the emergence of others (Sorocovschi & Şerban, 2010).

Among the investigated mining lakes, the lake known as Laguna Albastră (Blue Lagoon) is primarily noticed, this having a unique color – from which derives its toponym – that is given by the water's rich chemical cargo in dissolute compounds from the exploited rocks (Pandi et al., 2009, 2010; Şerban et al., 2009).

Alongside with Laguna Albastră, nine more permanent mining lakes have been identified (see Fig. 5).

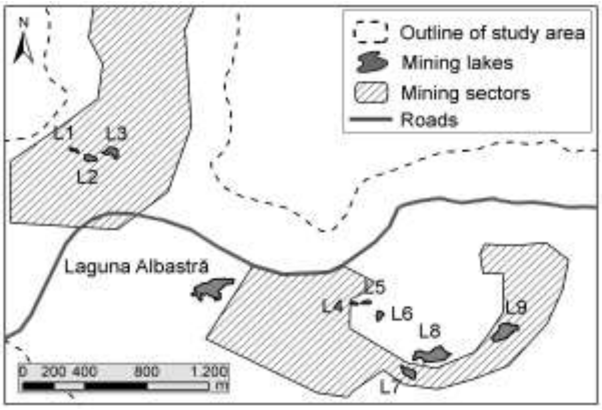

Figure 5. Distribution of mining lakes

From the numerous morphometric features of the investigated mining lakes, in this paper will be presented only the length and surface area (Table 4), which have been determined by applying the GIS technique, as it was mentioned earlier. This involved using particular software for digitizing the mining lakes and calculating their lengths and surface areas.

As shown in table 4, three of the mining lakes have medium-sized areas and lengths (e.g. Laguna Albastră, Lake 7 and Lake 8) while the others have small-sized morphometric features. This denotes that the morphometric features are in a close relationship with recorded precipitation during the year, which means that the lakes surfaces vary quite significant.

In addition to the morphometric features, the physical and chemical properties were analyzed covering the permanent mining lakes, using a portable multi-parameter measuring instrument *(inoLab pH/cond 720 Series, WTW GmbH)*. For each lake the samples were taken from three different locations, the average for every parameter being then calculated. The results are presented in table 5.

The results highlight that Lake 1, Lake 2 and Lake 3 have a very low pH, indicating an extremely acidic water environment which require immediate remedial measures, while the rest of the lakes have a neutral pH, suitable for aquatic ecosystems, which in fact have already started developing.

Hence, it can be concluded that through adequate rehabilitation strategies the area could be well emphasized, giving to the whole region a new value, with effects beyond its borders.

Table 4. Morphometric features of Aghireş mining lakes

Lake	Area (m^2)	Length (m)
Laguna Albastră	19859	292
Lake 1	901	65
Lake 2	2624	84
Lake 3	4019	112
Lake 4	721	50
Lake 5	1171	61
Lake 6	2027	67
Lake 7	4523	123
Lake 8	14646	250
Lake 9	11373	191

Table 5. Physical and chemical properties 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	4756	2.5
Lake 2	3.39	211	3983	3983	2
Lake 3	3.59	597	2613	2613	1.2
Lake 4	7.80	-42	2020	2020	0.9
Lake 5	7.53	-31	2050	2050	0.9
Lake 6	7.75	-43	2360	2360	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

4. QUARRY REHABILITATION ALTERNATIVES

Rehabilitation, in the case of quarry exploitations, represents the land treatment after aggregate extraction so that the use or condition of the territory is restored to its former use/condition, or is changed to another use/condition that is or will be compatible with the use of the adjacent territories.

The development and execution of a rehabilitation plan is affected by several factors such as natural environment, legislative environment (national legislation frameworks and specific provisions for quarry rehabilitation), internal (e.g. employees, shareholders) or external stakeholders (e.g. land owners, local communities, authorities, NGOs), company operating in the area and site objectives (World Business Council for Sustainable Development, 2011).

Romanian legislation sets out the minimum rehabilitation requirements, but lately the mining companies are committed to realize higher quality rehabilitation with objectives such as integrating and blending the rehabilitated perimeter with the surrounding landscape and enhancing the biodiversity.

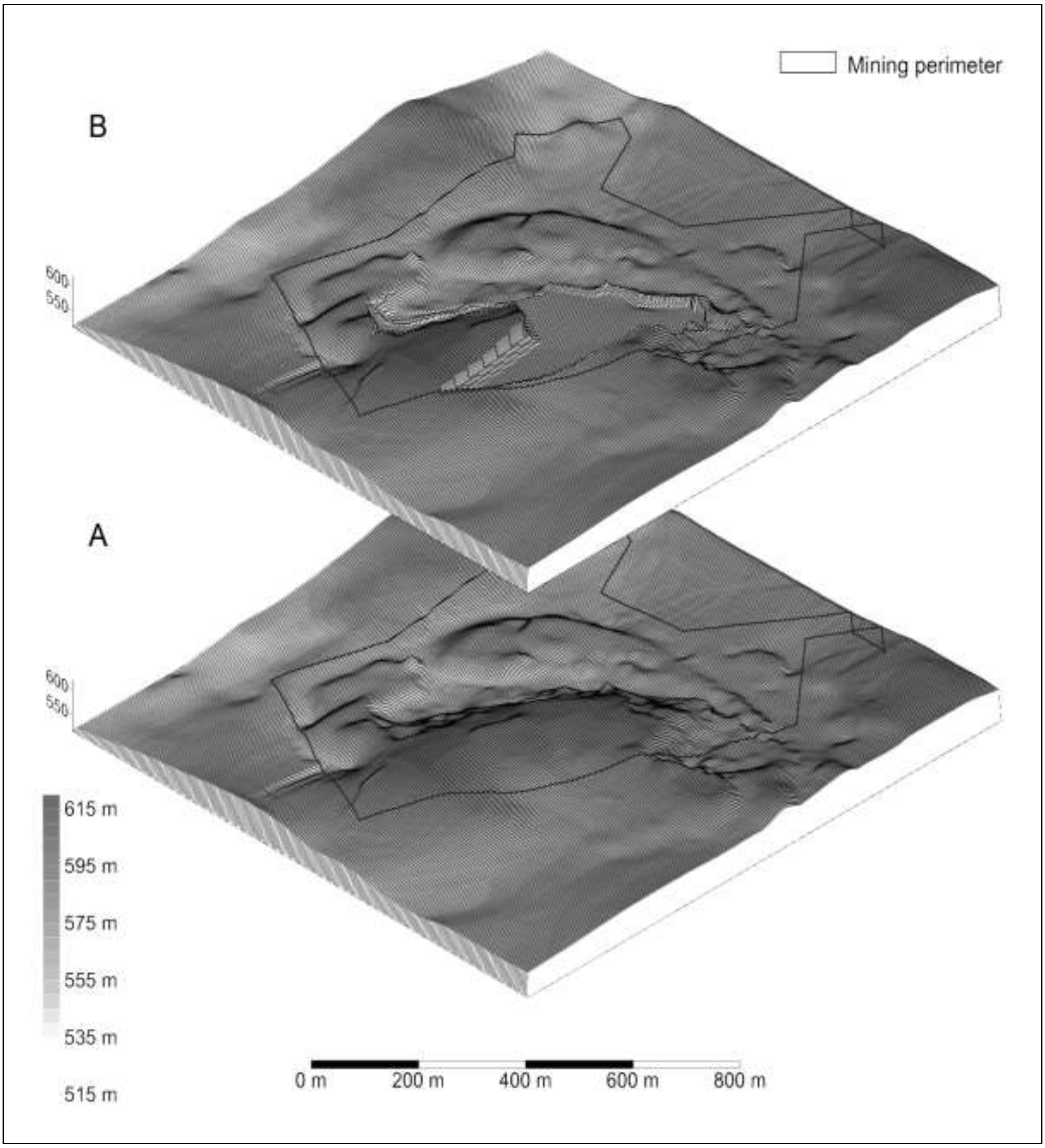

Figure 6. Block diagrams showing the terrain evolution in the western part of Aghireș-Cornești sector.
A – current configuration; B – final configuration. The block diagrams are seen from the SW.

Aghiresu Quarry dates from a period when rehabilitation measures did not represent a priority in mining, and therefore some of the former works were not performed according to restoration designed strategy. Recently, legal requirements determined the company operating in the area to plan a restoration strategy, based on a strict schedule. But in order for the territory reclamation strategy to be most adequate, the landscaping compatibility with the surrounding ecosystems must be ensured and especially the stability of the ecological rehabilitated system.

Therefore, in determining the necessary measures for environmental restoration, the following features have been considered:

- the biogeographic features of the region;
- the pre-mining features of the territory (at a local scale);
- the effects arising from the exploitation activity over time;
- the morphological features of the bedding and the applied mining method.

As far as the active mining sectors are concerned, as aggregate is removed and the terrain is stripped of its cover, the affected areas can be progressively rehabilitated. Thus, by applying a good planning strategy for the stripping process and overburden replacement, the subsoil and topsoil will facilitate the vegetation establishment as restoration moves forward following extraction.

During the final rehabilitation stage, all equipment, stockpiles and buildings are removed, this allowing additional tree planting and completion of all vegetation requirements in order for the site rehabilitation to be properly finalized.

Thus, the rehabilitation approach shall be developed taking into account information such as local landscape conservation activities, land uses, pre-mining landforms, biodiversity aspects, soils, hydrology, and geological aspects, relevant to rehabilitation.

The process of environmental rehabilitation of the mining area can be implemented in several ways, among which two possible alternatives are presented in in this paper. We adapted the idea of SLOSS ("single large or several small") concept, provided by ecology and conservation biology, to our study area and rehabilitation planning. The quarry rehabilitation planning is based in this case on several strategies, such as: to reintegrate exhausted parts of a quarry into the landscape; to make the site safe and stable for future land use; to return land to a beneficial post-quarrying use, balancing environmental, social and economic factors; and to minimize adverse long-term environmental, social and economic impacts after quarry closure. Thus, the two alternatives are based on two different approaches which can be summarized as following:

a. *The "Single Large" approach – the classic rehabilitation alternative,* based on minimal legal intervention and consisting in whole terrain reconfiguration, including the removal of existing mining lakes;
b. *The "Several Small" approach – the ecological rehabilitation alternative,* based on landscape integration and biodiversity enhancement, with special focus on ecological valorization of existing mining lakes and land units.

For the implementation of "Several Small" concept, the quarry structure and the nature of exploited minerals (quartz-kaolin sands) allow a rehabilitation and ecological reconstruction scenario approach based on a complex system of wetlands (e.g. polders, temporary and permanent ponds, swamps). For the entire complex, several branched forest belts that penetrate through created wetlands will be necessary, favoring colonization of fauna and local landscape fragmentation. The implementation of this comprehensive ecological restoration scenario could illustrate the ecological value of a former mining area.

Thus, the mining area will become a focal point for biodiversity (hot-spot) and will have significantly higher biodiversity indices compared to neighboring habitats that are subject to natural succession of vegetation.

For both rehabilitation alternatives, the intervention measures are proposed in accordance with the final terrain configuration resulted after the quarry closure.

An example regarding the terrain evolution and its final configuration for the western part of Aghireș-Cornești sector is presented in figure 6.

4.1. Classic alternative

The alternative is based on developing structures that are connected to the environmental matrix, thus obtaining dimensionally significant categories of block habitats (e.g. compact forests). The effect achieved by this method underlies the "Single Large" strategy objectives.

After the mining license expires, the areas that need to be rehabilitated are:

- Aghireș-Cornești sector: 24.4 ha;
- Stoguri sector: 22.2 ha.

Depending on the targeted component, the rehabilitation measures will consist of:

a. For the quarry floor: bringing in soil (minimum 30 cm), revegetation (with herbaceous and arbustive species), maintenance activities and monitoring;

b. For the natural slopes and embankments: remodeling works and embankment stabilization, revegetation with species from the spontaneous flora (e.g. *Festuca rubra, Crataegus monogyna, Corylus avellana, Prunus spinosa, Rosa canina, Salix caprea* etc.), maintenance activities and monitoring of natural slopes and final embankments;
c. For the mine dumps: stabilization, soil deposition (minimum 30 cm), revegetation (with herbaceous species and shrubs), maintenance activities and monitoring;
d. For the mining lakes: drainage, infilling with residual materials resulted from demolitions, bringing in soil, revegetation, maintenance activities and monitoring;
e. Finally, the organization and maintenance of the access roads shall be added.

4.2. Landscape integration and biodiversity enhancement

The second alternative will capitalize on the importance of the mining lakes, which are established already as important environmental assets at local scale.

With the exception of Lake 1, Lake 2 and Lake 3, which have very low pH levels (Table 5), the physical and chemical properties of the existing mining lakes allow their restoration as biodiversity reservoirs, with an important recreational value. Thus, the sustainable management of the mining lakes constitutes an important ecological and socio-economical factor for the Aghireş area.

For the ecological restoration process, the following principles shall be considered:

- Integration of mining perimeter in the local environmental matrix;
- Landscape integration;
- Increase of local biodiversity indices;
- Conferring an increased potential toward supporting alternative activities.

The intention is to provide a framed perimeter in the existing natural matrix, but which to emphasize the structural features (embankments, platforms etc.), by installing a variety of habitats, complementary to each other and able to increase the biodiversity and to ensure a structural and functional stability from an ecological point of view.

This scenario of ecological restoration is oriented to the conceptual elements of the "Several Small" approach, to which the intention of delivering large areas of eco-tone and intergradation is furthermore added.

In this respect, the following actions are required:

a. Quarry floor reconfiguration, with the preservation of existing cuvette type structures (mining lakes);
b. Bringing in soil and developing a soil cover layer;
c. Reconfiguration of slopes and embankments in order to ensure the land stability;
d. Construction of reception areas, routing and discharge areas in order for the pluvial water to be redirected towards the mining lakes (as water basins);
e. Developing terrestrial microhabitat networks (in dry areas) and water networks (in areas with lakes);
f. Revegetation with species from the spontaneous flora (e.g. grasses: *Festuca rubra, Lolium perene*, shrubs: *Crataegus monogyna, Corylus avellana, Prunus spinosa,* and trees: *Acer campestre, Fraxinus excelsior, Populus nigra, Quercus robur, Salix caprea);*
g. Feature detail – on the mining perimeter limit, a curtain of trees will be planted (e.g. *Acer campestre, Cornus mas, Fraxinus excelsior, Prunus spinosa).*

The scenario will supplementary include clay lining of the lake cuvette and construction of communication roads.

Regarding the microhabitat networks, these may include: wetlands, boulder piles, stacks of dead wood, shelters, feeders etc., which can be located adjacent to a wooden area at the quarry floor level.

The effect achieved by this method represents the core of the "Several Small" strategy thus providing a great diversity of ecological niches which will contribute to an increase in the ecological stability of rehabilitated areas. This will provide a high stability to the whole ecological restoration project.

Both alternatives fulfill the requirements and the recommendations of national and European legislation and comply with the current necessities regarding the sustainable use of reclaimed lands, at all levels.

5. CONCLUSIONS AND PERSPECTIVES

A geomorphological approach based on the landform architecture (prior to and derived from exploitation) can contribute to the environmental rehabilitation of the site affected by a quartz-kaolin sands quarry. The rehabilitation procedure based on this approach gives importance to geomorphological criteria (e.g. morphographic, morphodynamic and terrain stability classes), soil erosion and soil properties. The outcomes of this study (e.g. USLE model and thematic maps) are useful tools in quarry rehabilitation and they complete the methodologies applied in environmental restorations, by incorporating aspects of soil erosion, slopes declivity and stability of terrain.

As a result of open-pit workings on a friable lithology background, the landforms from Aghireş mining area had undergone a mutation process from a fluvial type to an anthropogenic one, while the absence of geo-environmental strategies and rehabilitation measures for degraded lands, led to activation of specific geomorphological processes like the gully erosion and landslides.

In order to remediate the existing geo-environmental problems and to prevent future deterioration of environmental factors, a detailed research study was initiated in Aghireş mining area, which has been finalized and materialized by developing of two possible and appropriate rehabilitation alternatives (SLOSS: "Single Large" and "Several Small").

Considering that a profound knowledge and understanding of the geomorphological context underlies the selection process of the most appropriate restoration measures, the erosion risk has been assessed and the declivity values were investigated. And in order for the proposed remediation planning to be most adequate for existing territory situation, the description of Aghireșu dump soils has been performed and the investigation of the existing mining lakes has also been undertaken.

Geomorphological features are components of a local design which facilitate the implementation of two rehabilitation alternatives (classical and ecological). In this case, the landscape integration and biodiversity enhancement is the most appropriate alternative to ensure that the environmental rehabilitation will be progressively implemented during the next years.

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