# THE PROCESS OF PEDOGENESIS ON MINE DUMPS (A CASE STUDY: AGHIREŞ MINING AREA, ROMANIA)

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***ABSTRACT: - The process of pedogenesis on mine dumps (a case study: Aghireş mining area, Romania).*** *The presence of mining, with all its specific activities carried on for decades, leads to an inevitable change in the evolution of environmental factors. Among these, and especially in the conditions of open-cast mining, the soil is definitely affected. The present study examines the soils developed on mine dumps in Aghireş mining area. It is noted that depending on how the mine dumps were managed, a differentially pedogenesis process started on their surface. Under these conditions, in order to determine the physical characteristics of soils in question, four sampling points were chosen, plus a fifth one with the role of control sample. The final results show clear differences between the physical parameters of investigated soil samples depending on the pedogenesis conditions, differing between the planted dumps and those without a protective vegetation cover.*

**Key words:** pedogenesis, mine dumps, soil samples, physical parameters, Aghireşu.



## 1. Territorial context

Aghireş mining area is located in the northwestern part of Transylvanian Depression, in its regional subunit known as the Someşan Plateau, a hilly unit with average heights between 400 and 600 m. Regionally, it is located in Cluj County (about 3 km north-east from Aghireş Fabrici industrial village, 1 km west of Corneşti village, and about 27 km north-west of Cluj-Napoca Municipality), on the administrative territories of Aghireşu and Gârbău (from Cluj County) and Cuzăplac (from Sălaj County) [Fig.1.].

In the process of establishing the territory limits for this study, which are much wider than the limits corresponding to the mining sectors in the area, it was started from the premise that the limits, among other functions they perform, have the ability to define a geo-environmental system from a temporal-spatial point of view. Therefore, the limits considered were the three watershed boundaries in which the exploitations develop. The first of these is the one associated to Valea Ruginoasa (with north-drainage unto Bohozelnicu creek, a right tributary of Almaşu river), the second one is that of Valea Caolinel (Valea Hărastului), a tributary of Nadăş, and the third one is that of Valea Mare (tributary of Şomtelec, which itself is a left tributary of Nadăş).

Regarding the natural environment in the area, this is quite well structured, but the natural factor which caused the biggest economic changes was the geology of the region. In this respect, in terms of geological system of beds, in Aghireş area we can find Eocene and Oligocene formations, within which a deposit of quartz-kaolin sands has developed (Măcicăşan et al., 2012). This deposit belongs to the Oligocene sequence on the western side of Transylvanian Depression, and was sedimented under continental-lacustrine or marine conditions, in shallow waters, more precisely in an epicontinental shelf area (Petrescu et al., 1997; SC Belevion Impex SRL, 2006).

At Aghireşu, the sands in question were opened by quarrying, on stages with downward progress and inner or outer tailing dumping (SC MINESA ICPM SA, 2010). Hence, as a result of open-cast mining on a friable lithology background, the landforms had undergone a mutation process from a fluvial type (considered as natural) to an anthropogenic type (considered

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as a modified one). Thus, the current landscape is the result of anthropic activities on the substrate and also the effect of atmospheric factors' action (precipitation, dynamics of air masses, freeze-thaw process) on the remaining morphology after mining. The absence of geo-environmental strategies and rehabilitation measures for degraded lands, led to activation of specific geomorphological processes. In this regard, there can be noted the slope drainage and landslides, with all their specific landforms.

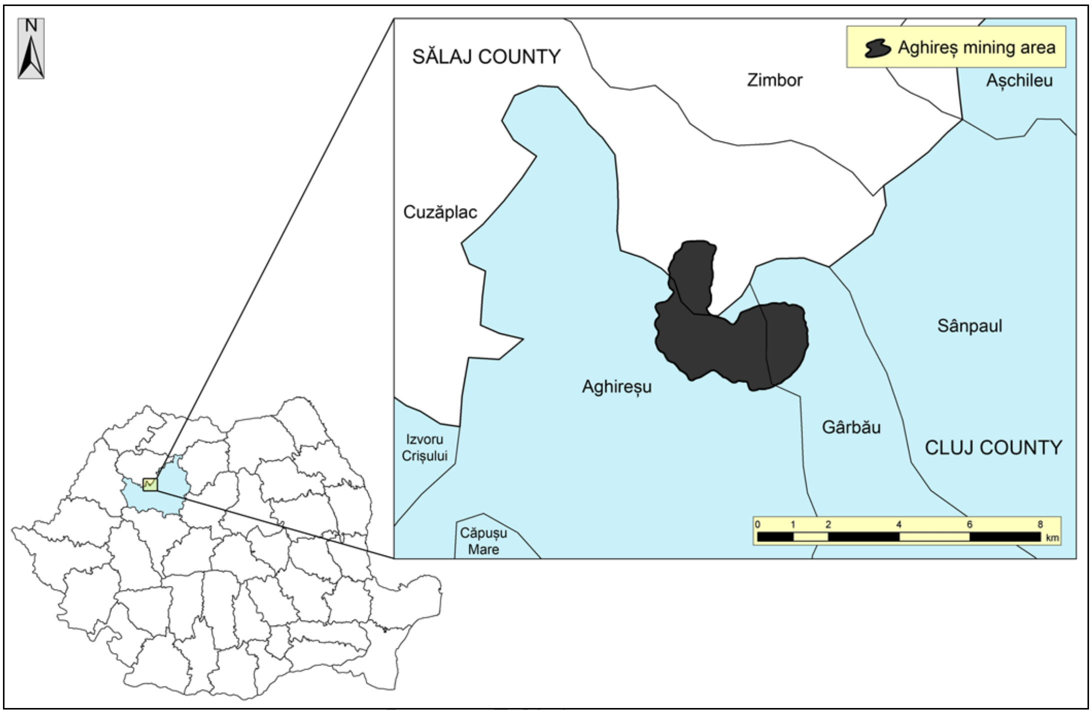


*Figure 1. Territorial framing of the mining area.*

In order to remedy existing geo-environmental problems and to prevent future deterioration of environmental factors, a detailed research study was initiated in Aghireş mining area, which will be finalized and materialized by developing possible and appropriate rehabilitation measures.

The research study began by investigating the environmental physical and chemical factors, like substrate, soil, groundwater and surface water.

This paper focuses on presenting and interpreting the main characteristics of 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 results will be very important for the future remediation planning and for the best land use measures.

## 2. Materials and methods

In order to identify the main characteristics of Aghireşu dump soils, several soil samples were collected from the mining area, the lab results being discussed in this paper. Furthermore, by correlating the obtained results with the geomorphological studies conducted on site location, the current situation in the territory was revealed and interpreted, a prerequisite for developing appropriate remediation strategies.

Regarding the sampling points, these were chosen 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 located on an old mine dump which has already been rehabilitated through forest plantations, and then the attention was directed toward dumps that have not been improved with plantations yet and also towards soils located between mine dumps.

Hence, the second sample has been located on a lake slope, affected in a greater extent by the geomorphological processes (in this case by the slope drainage process); the third sample has been located in an active mining sector, between the mine dumps; and the fourth sample on a dump affected by a landslide. Regarding the control sample, this was located in an area unaffected by mining, more precisely in a natural forest [see Fig.2. and Table.1.].

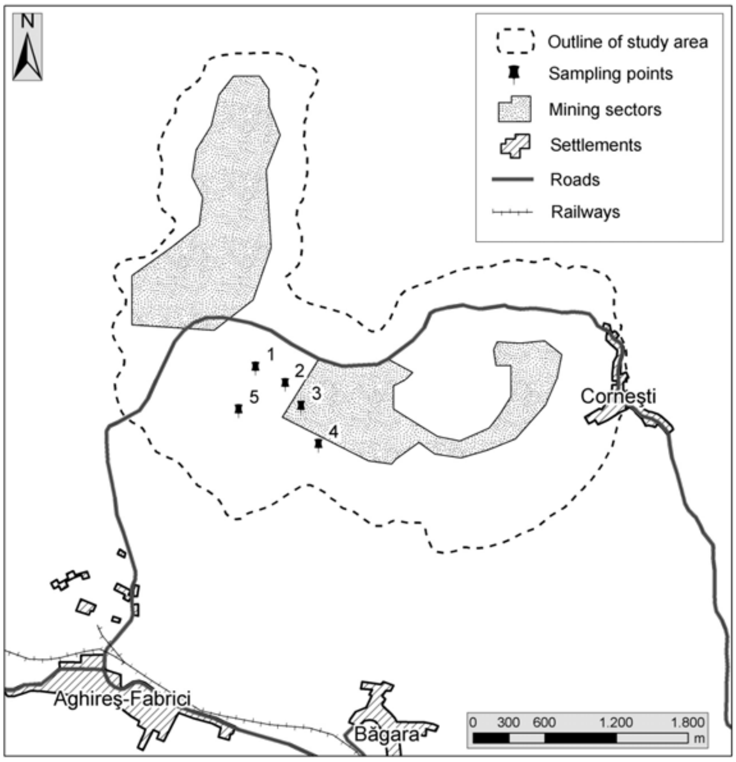


*Figure 2. The position of sampling points.*

*Table 1. GPS coordinates of sampling points*

| | *Sample 1* | *Sample 2* | *Sample 3* | *Sample 4* | *Sample 5* |
|---|---|---|---|---|---|
| Latitude | 46°53'26" N | 46°53'22" N | 46°53'16" N | 46°53'50" N | 46°53'14" N |
| Longitude | 23°17'19" E | 23°17'31" E | 23°17'38" E | 23°17'45" E | 23°17'13" E |
| Altitude | 591 m | 569 m | 619 m | 607 m | 538 m |

As an environmental factor, the soil from Aghireşu is characterized by some degree of tessellation, caused mainly by the variety and evolution of pre-existing topography, the geological conditions, hydrological conditions and old mining activities.

At the same time, the soil represents an accurate indicator for geo-environmental state changes in the various territories. Furthermore, the feasibility of a rehabilitation project depends on site topography, terrain conditions and soil properties (soil quality) (UTCB, 2002).

The process of *quality checking* consists in determining the main characteristics of the soil, which for the present study were analyzed 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 7107/1-76 – Organic matter determination
- STAS 1913/5-85 – Granulometry determination

**Humidity *(w)*.** The method consists in determining the mass of water lost from a known quantity of soil (assay-sample), by desiccation at 105 ± 2°C. The results are presented in Table 2.

**Upper plasticity limit *($w_L$)*.** This represents the maximum amount of humidity at which a soil sample behaves as a plastic body, highlighting the soil transition from plastic state to flowing state. In order to determine this parameter, we used the *cup method* [see Table.2.].

**Lower plasticity limit *($w_P$)*.** The method consists in determining the minimum amount of humidity at which a soil sample can be modeled as a cylinder, highlighting the soil transition from semisolid state to plastic state. For determining this parameter we used the *soil cylinders method* [see Table.2.].

By knowing the soil humidity, its upper and lower plasticity limits, we calculated the **plasticity index *(Ip)*** and **consistency index *(Ic)*** [see Table.2.].

The plasticity index quantitatively expresses the soil plasticity and is calculated by the following formula:

$$(1)\quad Ip = w_L - w_P$$

The consistency index expresses the physical state of a cohesive soil which depends on the humidity and is calculated by the following formula:

$$(2)\quad Ic = \frac{w_L - w}{w_L - w_P} = \frac{w_L - w}{Ip}$$

**Soil density *(ρ)*.** Given that the analyzed soil samples were characterized either by a hard-plastic consistency (the clayey ones) or by a stronger cementation (the sandy ones), being brittle and prone to rupture into pieces (lumps) of irregular shapes, in order to determine the density we applied the *hydrostatic weighting method*. The results are presented in Table 2.

**Absorption capacity of soil *($U_L$)*.** The method consists in determining the volume growth of a soil sample after all its pores have been filled with water. The results are presented in Table 2.

**Soil granulometry.** Given that the sampled soils have a broad range of granulometry, we used two methods of determining it: the sedimentation method and the sieving method [see Table.3.].

**Organic matter.** The method used for determining the organic matter consists in dissolving the humus from the soil sample in a sodium hydroxide solution, thus identifying its presence. The results are presented in Table 3.

## 3. Results and discussions

Based on the current situation in the investigated mining perimeter, where on the mine dumps the pedogenesis processes started a few decades ago, using the above mentioned methods the present study was aimed at finding and knowing the characteristics of soils that are in a developing process.

It is noteworthy that the development state of analyzed soils differs depending on how the dumps were used, 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, in the mentioned conditions, are affected by geomorphological processes in the category of torrential and material slope movement ones.

*Table 2. Physical features of soil samples*

| | *Sample 1* | *Sample 2* | *Sample 3* | *Sample 4* | *Sample 5* |
|---|---|---|---|---|---|
| Humidity *(w)* | 19.70 | 15.79 | 22.31 | 23.66 | 18.26 |
| Upper plasticity limit *($w_L$)* | - | 24 | - | 38.89 | - |
| Lower plasticity limit *($w_P$)* | - | 10 | - | 12.5 | - |
| Plasticity index *(Ip)* | - | 14 | - | 26,39 | - |
| Consistency index *(Ic)* | - | 0.307143 | - | 0.577113 | - |
| Density *(ρ)* | 2.12 | 1.84 | 1.80 | 1.86 | 1.54 |
| Absorption capacity *($U_L$)* | 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% |

The results highlight the following:

- Sample 1 presents high humus content and a low content of clay, which can be explained by the fact that the dump has been rehabilitated through forest plantations.
- Samples 2 and 4 have low humus and high content of clay (which is also reflected by the plasticity, these two samples being the only ones that allowed the determination of plasticity limits). These aspects can be explained, on the one hand, by the fact that through exploitation the sandy fraction of the deposit has been extracted in large proportion and the sterile material resulted with a high percentage of clay, and on the other hand by the fact that the dumps are not rehabilitated and the spontaneous vegetation is poorly represented in both cases.
- Sample 3, which has been taken from a site located between dumps, shows a high content of humus and a low content of clay, which actually reflect the basic characteristics of underlying soils affected only in a small extent by mining.
- Sample 5, namely the control sample, shows the highest content of sand and lowest content of clay, with high content of humus, which all reflect a long pedogenetic evolution that admits the zonal type soil placement.

Considering the above, several recommendations can be outlined, depending on the specific pedogenetic conditions of each mine dump. Thus, 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. Similarly, for the site situated between the mine dumps (from which sample 3 has been taken), 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, instead, in order to prevent and combat the landslides and slope drainage processes, a series of rehabilitation measures and strategies are required, such as (Fodor and Băican, 2001; Roşian, 2011):

- the execution of special geotechnical and construction workings in order to stabilize the mine dumps and to prevent the landslides;
- the stabilization of soils on mine dumps;
- the prevention and control of slope drainage processes, by water discharge workings and forest plantations;
- the waterproofing of dump platforms by cylinder compaction.

Moreover, being in an early development stage, further adequate pegogenesis conditions must be provided for investigated dump soils in order to increase their function as protective cover for the substrate and support for the vegetation.

Regarding the soil taxonomy, by correlating the lab results with the local pedogenesis conditions, it can be observed that instead of a typical soil model for the Someşan Plateau, in the form of preluvosols and luvisols (luvisols class), particular soils have been developed in the form of entiantrosols (protisols class). The entiantrosols are distinguished by the fact that they are emerging soils developed on anthropogenic parent materials (e.g. mine dumps), without diagnostic horizons except an Ao horizon.

## 4. Conclusions

The results of this study show that several of the physical parameters of investigated soil samples (e.g. granulometry, plasticity and humus content) present clear differences regarding the obtained values. After interpreting them, it has been observed that the main differences occur between the rehabilitated and the non-rehabilitated mine dumps.

Furthermore, after performing a comprehensive visual evaluation of the mining area it has been observed that most of the terrain is unstable, due to slope processes among which the landslides and torrential formations stand out. However, after correlating the visual analysis with the lab testing it was revealed that the non-rehabilitated mine dumps are much prone to geomorphological processes than the rehabilitated ones.

Hence, regarding the environmental restoration process, two types of areas can be highlighted: those that are heavily affected by mining and geomorphological processes, in which case rehabilitation measures are strictly necessary, and those less affected by nearby mining, which currently only need to be monitored.

Reclamation of abandoned mine dumps is a very complex process. In conjunction with forthcoming investigations, the outcomes of this study will be able to support a viable land use planning for the Aghireş mining area. The next challenge is to establish the main driving forces of pedogenesis in this area (e.g. water, sediments and chemical fluxes).

The desideratum for the future studies is to make use of the latest developments in the field, thus improving data and information related to soil quality and environmental components affected by mining activities. The results obtained from environmental analysis and assessment will make part of an integrated site remediation planning.

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