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GEOMORPHOLOGICAL SYSTEM'S VULNERABILITY OF THE EASTERN REGION OF PETROŞANI DEPRESSION AND GENERATION OF CRITICAL ENVIRONMENTS BY THE COAL EXPLOITATION ACTIVITY

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Abstract: Eastern Region of Petroşani Depression is a complex intensely modified by coal mining activity, an activity that has increased the vulnerability of the system and the formation of critical environments which evolution over time is difficult to establish. Critical environments, seen as the product of environmental system malfunction caused by human intervention, takes the form of thresholds, characterized by phenomena of disorganization of information and energy that reduce or make disappear entirely the internal capacity of the system to self-regulate and to ensure a dynamic balance.

Key words: vulnerability, coal exploitation, Petroşani Depression, anthropic relief.

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INTRODUCTION

Petroşani Depression is a lowered region of the Carpathians, limited to the North by the mountain ranges: Retezat and Şureanu, South and Southeast by Vâlcan and Parâng Mountains. It has an approximately guidance of NNE-SSW, stretching over a length of about 45 km and a width ranging from East to West to 9-12 km. In terms of morphometry, the region looks like a lowland area to frame the surrounding mountains. However, it is considered a high mountain depression with a bottomed hilly, with the lowest altitude of 556 m (at the confluence of the two Jiu Rivers) and the highest between 800 - 900 m, to the periphery in contact with the mountain frame (Pop, 2001; Ardeiu, 2004; Nimară, 2011). Working together for endogenous and exogenous factors have manifested in different forms from place to place, so the landscape was imposed by certain elements: structural, tectonic differential erosion etc. Within this perimeter regionalization, we distinguish a number of units and subunits, having both common elements and elements that differentiate them (Tufescu & Mocanu, 1964).

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The evolution of the diversification fund constituted according to which issues have become more complex morphological (Lupu, 1967). Looking at the ratio of the overall shape of the basin, its morphology and structure, including tectonics, we find separating the two regions of the depression: Eastern Region and Western Region. Mining, the main economic activity in Petroşani Depression was a vital necessity of the development community in this micro-region, but which *„products"* could be seen both in the natural environment and social policy. The natural environment is highlighted by technogenic morphology varied in size, shape and morphogenetic processes.

COAL MINING ACTIVITY AND GENERATION OF VULNERABLE AREAS

Anthropogenic modeling differs from the natural one by the degree of intensity of the expression, complexity and form of products, making irreversible changes to the territory by generating a high degree of vulnerability (Mac & Petrea, 2003; Mac, 1991, 2000, 2003; Anghel & Bilaşco, 2008; Anghel & Todică, 2008; Anghel, 2009; Irimuş et al., 2009, Creţu et al., 2013; Vlaicu et al., 2013).

The areas with positive relief, modeled by human activity have been converted from the original form to a horizontal form and flat surfaces were raised by tens of meters. Following this feedback it generates a new spatial dimensioning and planning, resulting finally a relief appearance by inversions and critical environments. Unpredictability, uncertainty, seemingly determination and surprising character in building and succession states, is undeniable traits of a system on risk. They are indecisive character and versatility both ways to solve energy imbalances that occur on the evolutionary path of the system. Natural geomorphological modeling processes are represented by the river, wind, glacial, marine or ocean, and the tectonic system modeling. Anthropogenic processes that have a transformative effect of the relief and printing a certain print to the landscape are: agricultural processes and techniques, construction (buildings, roads), extraction and preparation of minerals, military actions etc (Nimară, 2010).

A feature of the human impact is the layer with increased susceptibility to change, according to Hooke's theory, *„human activity directly affects land area only on a limited layer"*, which size varies according to the type of human activities, it being called *susceptible layer*. Also, anthropic pressure introduces in the dynamics of the landscape a new chronological scale namely *anthropic chronological scale*. Using this scale, the response of relief - landscape torque, affected by specific human activity, in this case: mining, may be of the order of minutes until the years. We could say that human activity is the same as weather; occurs every day, is widespread and is in continuous change, affecting both the natural environment and human society by its manifestations (Wang et al., 2001; Ilieş et al., 2010).

The social and economic evolution made by the transformations induced to the environmental components and its answer, can be seen by highlighting the relations between the environmental elements, seen in the field. As technological development and spatial extent of anthropogenic areas, there was an increase in conflicting relations with the natural environment. The type of occupied areas from different economic activities is shown in the following table 1.

Table 1. Type of occupied areas from different economic activities in Petroşani Depression

No. crt.	Indicatory	Occupied surface (ha)	Percentage in depression area (%)
1	Agricultural area	31326	31,59
2	Forests	57015	57,50
3	Rivers and ponds	338	0,34
4	Other areas	10484	10,57

The extraction of solids is done both in underground and at surface. Both methods give strong negative influences in relief in two forms:

a) underground holes of various sizes and orientations (vertical or inclined galleries, large cavities with different geometries);

b) surface cavities (craters, pits, excavation canals).

The adjacent area of underground mining area is destabilized by mining exploitation, surface water or groundwater seepage, vibration (caused by blasts), explosions, mining transport, that the chance of risk are effective.

Jiu Valley anthropogenic activity generates multiple and various changes in natural conditions, including high importance are those that adversely affect land (table 2). Inventory of economic activities generating such effects is the first step in the correct assessment of the types of the degradation which is supported by the land. A short list of these includes: coal mining extraction from underground and surface mining, tailings storage obtained from this, the land filling of household waste, forest logging activity.

Table 2. Affected are (ha) and percentage of it (%)

Activity	Area (ha)	Percentage (%)
Sterile dumps	207.84	46.0
Preparation dumps	66.70	15.0
Municipal waste	7.50	2.0
Trenches and ravines	21.50	5.0
Slag deposits	20.00	4.0
Coal pits	94.18	21.0
Fractures and collapses	29.10	7.0
Total	**446.82**	**100.0**

Land degradation depends of the layer's thickness. Exploiting the thin layers causes only slight incline surface diving without being affected the crops in the area. In case of thick layers, it manifests different stages of diving with intense layers rupture direction. It has been noticed the appearance of springs, drying up of lakes and wells and disappear of vegetal soil. The location of dumps and land deformations that occur have a direct consequence by burying topsoil.

Exhibition changes present deviations from the overall average. From the comparative situation (figure 1 a, b), it appears that the biggest differences is realized by the Western exhibitions, followed by Eastern and Northern. Significant differences are recorded in the Southern exhibitions (Nimară, 2010).

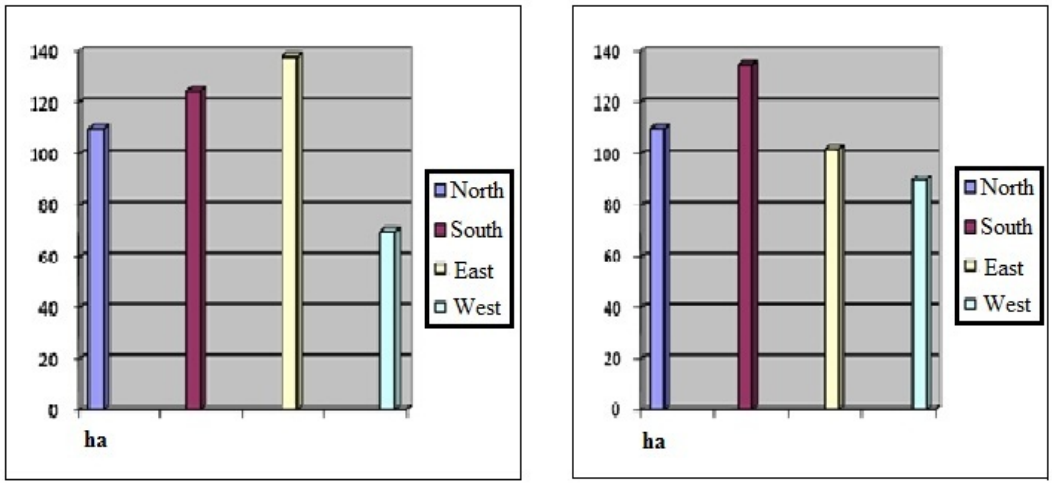

Figure 1. Slope exhibition in the past (a) and present day (b)

Underground coal mining has great repercussions on the land surface by causing subsidence, rupture or collapse. These phenomena not only allow normal use of the land, for the initial goals, but also seriously affect the construction's area (Hosu, 2003).

The severity of the surface deformation is dependent on assistance from the ground, the level of stress and deformations arising and always has the effect of destroying the stability of the surrounding rock. Fractured rocks on the excavation's perimeter are put in motion, moving into massive which is a function of their ability to fill the resulted gap. If it is very high, exceeding the capacity rock's fragments to fill it and stop such phenomenon rock's deformation, the movement can be transmitted to the ground surface (Nimară, 2010; Nimară, 2011).

Exploitation of thinner coal layers, cause only sinking of the surfaces without compromising crop land; exploitation of thicker layers, where occur different diving areas in the direction of rupture layers, the consequences on land are radically altering their total use.

Other undesirable consequences of this activity can be: the drying up of wells, the emergence of new springs, disturbance of groundwater or the formation of permanent lakes in the bottom of sinking areas. The affected areas by rupture and collapse of land because of the coal mining in Petroşani Mining Basin are presented in the following table (table 3).

Table 3. Areas affected by rupture and collapse of land because of the coal mining

Area	Surface (ha)	Volume (thousand m^3)	Surface of influenced area (ha)
Petroşani	5,5	8571,9	14,54
Petrila	4,3	6701,6	11,36
Aninoasa	4,0	6234,1	10,57
Total	**13,8**	**21507,6**	**36,47**

IDENTIFICATION OF AFFECTED GEOMORPHOLOGIC RESOURCES

In the anthropic mining relief following the triggered of geomorphologic processes are made relief microforms. The anthropic mining relief interests in duration of existence, typology, dispersion mode, surface modification complexity initial coverage of a complex, potential risk and induced effect. The affected areas with the highest vulnerability are:

- *Meadow and terrace of Maleia brook*

In the Northeast part of Petroşani Depression, in the vicinity of Petrila town, is located the dump perimeter (figure 2) which is being developed close to the mining premises and continues to the southern side of the Rusalin river and on the Northern side of Maleia brook. Both are tributary waters of East Jiu.

The 2 East dump occupies an area of 2.10 ha and the land on where it is located the dump, was initially a plateau with a slow morphology, with small slopes not exceeding 10°, generally with a direction from South to North slope (table 4).

The five branches of the dump are arranged from West to South in the following order: branch III, I, II, V and IV, with angles of 9^o, 14^o, 16^o and 24^o.

Table 4. Type of degraded land from the Petrila mining perimeter

No. crt.	Type of degraded land	Surface (ha)
1	Degraded land by subsidence phenomena	0.28
2	Degraded land by erosin phenomena (gullies and ravines)	0.10
3	Land with excessive surface erosion	7.01
4	Partly degraded land with grass surface	4.51
5	Submerged degraded land	6.21
6	Plateau	3.02
7	Degraded land with marsh phenomena	1.48

Figure 2. Structural and functional modification of geomorphologic environment in the area of Petrila town (Source: *www.google.com/earth*)

- *Arsului Valley*

In the Arsului Valley sector, related to Lonea mining area, there are frequent collapses, subsidence with negative influences on larger areas than the mine site (figure 4). The subsidence phenomenon is a physical-mechanical mechanism that occurs as a result of the generation of gaps in rocks deposits. Loose of sedimentary deposits induce a redistribution of masses and rearrangement of layers so it results the deformation of the original topographic surface. The process is manifested by the appearance of sinks with different amplitudes. In the adjacent areas of the new made small depression appear humps and cracks that portend the extension of settlement. The mechanism of this process is manifested differently, depending on the reservoir (thickness and inclination of the layers, the physical and mechanical properties of rocks, tectonic, hydrological and geological situation, local mining technologies etc.) In the sector of the valley (photo 2, 3), is visible the topographic surface deformation due to the collapse of the roof directly after mining extraction of mass blocks III, IV, VII, Layer 3.

- *Defor Valley*

The affected valley sector by mining is an area of 12.56 ha, located in the Eastern part of Jieţ River.

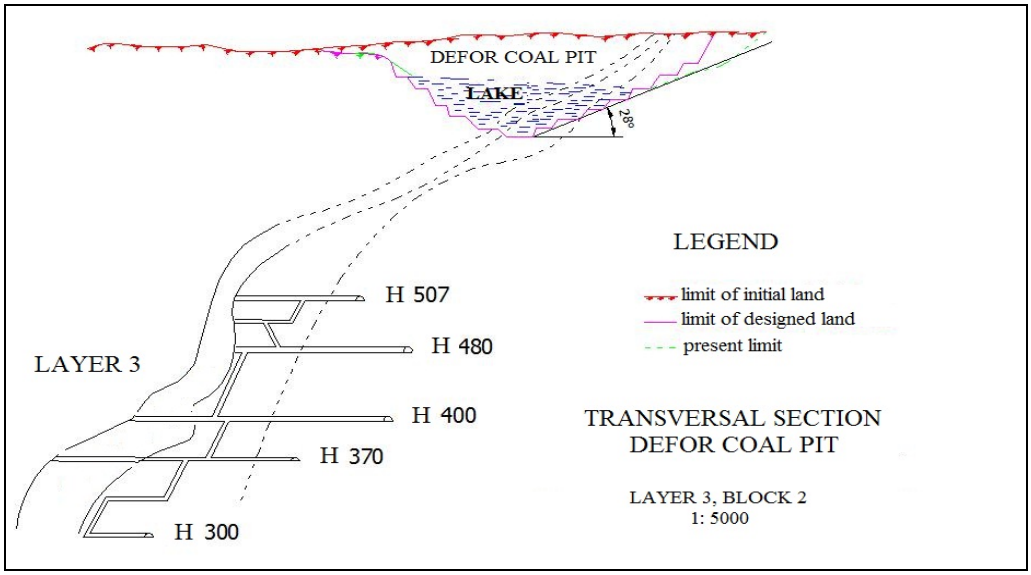

Figure 3. Transversal section through Defor coal pit

Following the discontinuation of mining in the coal pit in 1990, the Defor brook which was diverted during mining works, resumed the old course and the water accumulate in the coal pit, forming a lake with dimensions of 250/170 m, a depth of 20-25 m, water table elevation standing at 745,92 m (figure 3).

As a result of mining in the studied area, the main areas where land can trigger mass movements are Defor coal pit (figure 5) and Defor dump.

Factors that contribute to triggering of landslides in the area are:
- cracks and gullies formed by runoff water from precipitation;
- water accumulated in the coal pit;
- exploitation of groundwater.

Figure 4. Subsidence phenomena in Lonea area

Figure 5. Collapse at the Defor coal pit

Figure 6. Products of concentrated erosion, Defor coal pit

Due to concentrated flow of water from precipitation on the slopes of the coal pit, arise a series of gullies that lead to instability in the affected areas (figure 6).

CONCLUSIONS

Through the activities of mining and minerals processing, spaces in relative equilibrium, change their dynamics through a regressive acceleration, generating other landscapes which operate in a high degree of entropy. Geomorphologic elements are modified new superficial formations are created and accelerates the soil physicochemical processes. In the Eastern region of

Petroşani Depression, can be seen that the most active geomorphologic phenomena and the most important are the erosion and mass movement of materials, but which can be considered a destabilizing factor only in the case of gullies and ravines formed on the routes of sterile dumps and in the areas where the forest is cut.

Erosion appears due to rainwater after a mismanagement of anthropogenic relief find favorable conditions for development by focusing of leaks, poorly compacted substrates and steep slopes. These phenomena worsen over time if necessary measures are not taken, while other geomorphologic processes tend to a natural balance. The most vulnerable areas are: meadow and terrace of Maleia brook, Arsului Valley and Defor Valley.

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