Landscape changes induced by the mining activity at the contact between the Olteţ Piedmont and Gorj Subcarpathians. GIS applications

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ABSTRACT

In the northern part of the Olteţ Piedmont, there are important areas of opencast coal exploitation. This complex process implied uncovering, depositing and transportation of the material and led to drastic landscape changes. Some of the most important transformations regard the following aspects: within the uncovered and excavated areas there appeared depressions; the waste and soil depositing generated dumps located on the interfluves, on the slopes or in the alluvial plains; the transportation of the coal and of the waste imposed the construction of specific infrastructure and, particularly, of conveyer belts and access ways; settlements were displaced and important surfaces could not be used any more for agricultural or forest purposes. The study of landslides, some of them with catastrophic effects, as those from Seciurile and Mateeşti, required detailed analyses, as well as the identification of certain general and specific causes that triggered these phenomena or favour their periodical and more severe return. The studies were conducted mainly in order to better know and to fight against these phenomena. GIS-based cartographic materials were obtained and used in order to realise the complex analysis of landscape changes and to underline the transformations that occurred.

Keywords: landscape changes, mining exploitation, the Olteţ Piedmont, GIS

1. INTRODUCTION

The study area lies between the Gilort and Cerna Olteţului rivers, at the contact between the Olteţ Piedmont southwards and the Subcarpathians northwards. The perimeters of lignite exploitation belong to the Piedmont in the western part (in the area of Bustuchini, Seciurile, Poiana Seciurile and Stejaru settlements) and to the Subcarpathians in the East (the area of Ruget, Alunu, Berbeşti, Mateeşti, Bălteni, Ulmeni settlements).

The limit between the Piedmont and the Subcarpathians is sinuous within this sector (Fig. 1). Between the Gilort and the Olteţ rivers, the Piedmont advances northwards, while on the sector between the Olteţ and the Cerna it withdraws southwards, being at the contact between the Romanian-Quaternary formations, where a cuesta alignment formed (Badea L. 1967, pp. 26-27; Aur, N., 1996). During the Pliocene, the paleogeographic evolution of the region was characterized by periodical invasions of the water of the lake located in the Dacian Basin, followed by successive water withdrawals, leaving behind coal generator marshes and seacoast plains.

Therefore, starting with the Dacian, the paleogeographic conditions favoured the formation of coal layers (Boengiu S., Enache, C., 2002, pp. 70-71). During the Romanian, there are known only two short-period withdrawals of the lake water, followed by the formation of the Piedmont deposits, as indicated by the Tetoiu gravels. During the Villafranchian, in the Wallachian stage, there took place the rising of the Subcarpathians through the accentuation of the folding and fracturing of the Pliocene deposits and, at the same time, the rising of the Southern Carpathians with about 1,000 meters. Through the acceleration of the vertical ero-

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sion, these phenomena led to the removal of the piedmont deposits located between the mountain and the southern limit of the Getic Subcarpathians.

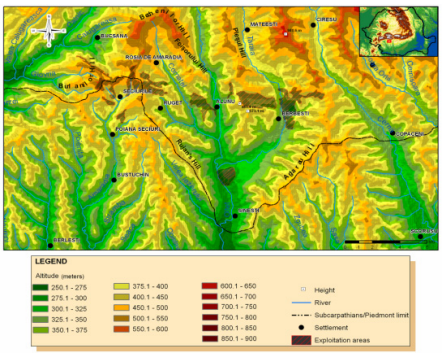

Figure 1: Morphometrical map and perimeters of the mining exploitations

Within the study area, the geological structure of the Plio-Quaternary deposits is represented by a pericline that slopes southwards and is affected by some transversal faults. Between the Gilort the Cerna Olteţului rivers, the exploration drilling contoured lignite deposits, the removal of the piedmont deposits located and capitalization of this resource starting with underground mines (Albeni, Alunu, Berbesti), which were closed or are in closing process because of the difficult exploitation conditions. On the other hand, the lignite exploitation developed in high capacity opencasts.

2. DISTRIBUTION OF THE COAL EXPLOITATIONS

The Seciuri – Bustuchini deposit includes the perimeters of Seciuri West, Seciuri East and Bustuchini opencasts, located on both sides of the Amaradia Valley. Within the perimeter of the opencasts there are to be found three litho-stratigraphic layers: the low sandy layer (Lower Dacian), the marl – sandy layer and the upper layer with coal (Fig. 2).

The Amaradia Valley – Tărâia Valley deposit is bordered by the two river valleys westwards, respectively eastwards, representing the continuance of the Seciuri – Bustuchini deposit towards East.

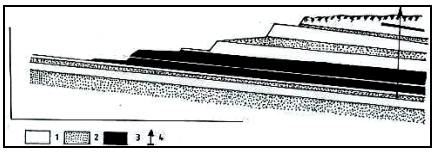

Figure 2: Cross-section through Seciuri opencast: 1- clays, 2- sand, 3- coal, 4- drill

The coal bearing formation starts with the Upper Dacian (Parscovian), in which six lignite layers were identified (the base layer is characterized by 3 - 4 meters exploitable thickness in opencast, the other coal layers being too thin). There follows the Romanian, which comprises only one coal layer (VII), also relatively thin (0.1 – 0.7 meters) and having lenticular development, as well as two thin, discontinuous intercalations (layers VIII and IX).

Ruget, Olteţ, Panga opencasts, the Alunu micro-quarry and Alunu and Berbeşti mines were opened within the perimeter of this deposit, the last two being in closeout process.

The Tărâia Valley – Cernişoara Valley deposit continues the Amaradia Valley – the Tărâia Valley deposit towards East, being transversally crossed by the Tărâia valley westwards and the Cerna and the Cernişoara eastwards, between the settlements of Dobreşti, Bălteni, Ulmeni, Armăşeşti and Groşi.

The Upper Dacian (Parscovian) is at the base of the stratigraphic bar of the productive formation, this stage being represented by a complex of clays, marls and sands, in which eight lignite layers are interposed. The entire sub-level is 100 meters thick. Small quarries were opened in this deposit: Cerna - Copăceni, Valea Mare, Roşioara - presently closed (Enache C., 2008, pp. 339-343).

As a general exploitation scheme, in the big lignite open pits there is firstly realized an opening ditch, the resulting waste being deposited in the exterior heap; once the excavation steps have sufficiently advanced, the waste is deposited in dumps into the bare space left behind.

Since the lignite layers belonging to these deposits are inclined from the outcrop southwards, the opencast exploitation is realised through descendant steps, down to the maximum depth that can be reached with the present technology. Thus, in this type of open pits it is

not possible to deposit the waste behind the work line, as the dump heap may slide towards these excavation steps. This being taken into account, in the open pits started later within the Gilort – the Cerna Olteţului sector, the opening trenches were realized following the inclination of the deposits (North - South), the excavation line advancing on the direction of the deposits. Thus, it was subsequently possible to proceed to the interior waste dump deposition.

This special situation in the above-mentioned opencasts led to the appearance of exterior waste dump that are much bigger than in other conditions. The exterior dump deposition surfaces are far from the exploitation area because of the relatively irregular relief.

3. DATA AND METHODS

In order to analyze the human intervention in the transformation of the landscape, there have been evaluated the morphological, morphometrical features, the evolution and the present distribution of the vegetation, as well as the technogene relief at the contact between the Piedmont area and the Subcarpathians. Under the influence of the human intervention, the dynamics of the natural support shows a clearer image of the present significance of the natural and man-induced hazards.

The analysis of the relief has been conducted based on the topographical maps scale 1:25,000, 1:50,000, 1:100,000 and SRTM DTM at 30 meters, the hypsometric map and the map of the present geomorphologic processes being obtained.

The spatial-temporal evolution of the vegetal landscape was analyzed using the above mentioned topographical maps for different periods of time, the forest arrangement maps, Corine Land Cover Data and a mosaic of Landsat 2000 satellite images in GIS environment, to which there were added the orthophotographs (scale 1:5,000) for the critical areas. Thus, it was possible to analyse the significant changes occurred in the land use and land cover structure, with implications in the landscape degradation. The statistical analysis allowed for a better understanding of the landscape transformations and of the dynamics of the main natural and man-induced elements. Terrain observations have been conducted in order clarify or to provide new details that were not observable on the maps (especially aspects concerning man-induced relief and the related hazards and risks).

4. RESULTS AND DISCUSSIONS

The characteristics of the landscape changes

The Subcarpathians - Piedmont contact between the Gilort and the Cerna Olteţului rivers represents an area that underwent long and significant human pressure, as a consequence of its inhabitation since ancient times (Cioacă, A. & Dinu Mihaela, 1998, 2001).

Until 1977, the human pressure took the form of deforestations for the extension of the pasture lands, the use of wood in constructions and as fuel; extension of the built-up area; increase of the cultivated surfaces; lignite exploitation in mines (started in 1970) etc.

All these processes took place slowly, on relatively small surfaces and the recover capacity of the environment was not irreversibly disturbed. Within this framework, the landsides and the torrential erosion were the most important, extended and frequent present geomorphologic processes and this situation was explained by the petrographic nature of the sector, mostly characterized by low resistance, to which the climatic regime is to be added.

After 1977, there begins the opencast lignite exploitation, with the inherent removal of the vegetation and of the overburden, excavation activities, appearance of the waste dumps and of the specific transportation ways (conveyer belts, access roads, electricity transportation etc.). These processes modify significantly all the components of the environment. The deforestation, the change of the natural modelling system, the soil destruction or its serious fertility reduction led to landscape transformations without immediate recovering possibilities.

Land use and land cover dynamics

The land use represents the concrete means of expressing the integration of human life and activity within landscape. It is a significant indicator of the man-induced stress exerted on the landscape

(Dumitraşcu Monica, 2006, p. 173; Evans, KG., Willgoose, GR., 2000b; Goudie, A. Viles, H., 1997).

The comparative analysis of the land use and land cover between 1960 and 2007 (Fig. 3) shows important structural changes. Generally speaking, there is registered a significant decrease of the agricultural surfaces, which were dominant in 1960 (7,108 hectares, as compared to 4,525 – the value of the non-agricultural surfaces), down to a level that is inferior to the non-agricultural surfaces in 2007 (respectively, 5,429 hectares agricultural versus 5,777 hectares non-agricultural) (Fig. 4). The most severe decrease regards the vineyards (from 37 hectares in 1960, down to 9 hectares in 2007, respectively 0.08%), the orchards (from 885 hectares to 290 hectares, representing only 2.59% in 2007) and the arable domain (from 2,830 hectares to 1,650 hectares, its part in the land fund reaching 14.72% in 2007).

Smaller reductions also register the forest surfaces (3,264 hectares in 1960 and 3,196 hectares, respectively 28. 53%, in 2007) and the water surfaces (80 hectares in 1960 and 54 hectares, respectively 0.48%, in 2007).

In the interval 1960-2007, the ascendant trend characterises the non-agricultural surfaces, respectively those occupied by various categories of transportation ways (from 208 hectares in 1960 to 267 hectares, respectively 2.38%, in 2007), constructions (190 hectares in 1960 and 694 hectares in 2007, respectively 6.19%), and unproductive surfaces (783 hectares in 1960 and 1,565 hectares in 2007, respectively 13.97%). Pastures and hay fields represent the only agricultural category that registers certain increase (from 3,356 hectares in 1960 to 3,480 hectares, respectively 31.05% in 2007).These important structural changes in the land use, with clear implications in the landscape transformation, can be explained through the conversion of extended agricultural surfaces into opencasts and deposition areas, as well as surfaces covered by the infrastructure necessary to such exploitation. Parallel with the development of the extractive sector within the area, the population number increased and the built-up area significantly expanded. On the other hand, the political, social, and economic changes that characterized the transition period manifested themselves also at the level of the landscape. From this viewpoint, an important element is represented by the cha nge of the type of land ownership, respectively passing from the collective and state properly to the private one (Dumitraşcu Monica, 2006, p. 179). The high costs implied by the good maintenance production means, the lack of interest from the part of the new owners, all these elements correlated with the relatively low productions and with the difficulties regarding the capitalization of the agricultural products contributed to the abandon of some arable lands.The same thing happened to certain surfaces occupied by vineyards and orchards, which were gradually cleared or abandoned, the resulting surface being used as arable land, pasture or hay field.

The technogene relief

The existence of lignite layers with thickness that favoured the surface exploitation led to the opening of large opencasts, by means of the giant rotor excavators that are able to dig on 20 – 25 meter high steps; there was also used high-speed transportation equipment endowed with

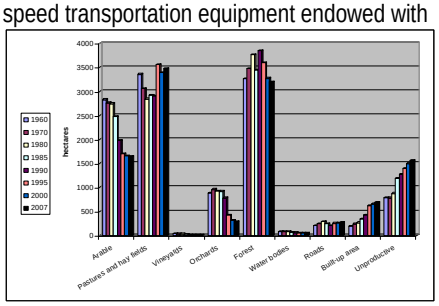

Figure 3: Land use dynamics between 1960 and 2007

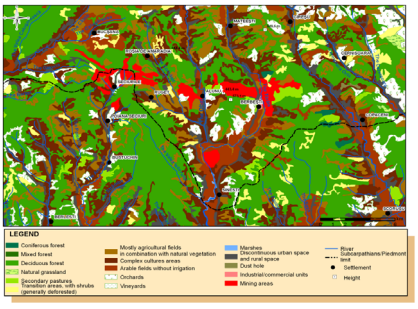

Figure 4: Land use and land cover

Photo.1: The Stejari – Seciurile opencast, May 2008

Table 1: Data regarding the exploitation areas

Mining perimeter	Surface of the exploited area (sq km)	Degraded surfaces (sq km)				Exterior dump (sq km)	Transporting bands (km)
		forest	orchards	unproductive	arable		
Bustuchini	5.2	2.4	-	0.1	2.7	2.9	0.55
Ruget	5.3	0.8	0.5	-	4.0	3.9	3.7
Olteţ	6.3	1.8	-	0.7	3.8	2.0	2.2
Berbeşti	4.8	-	-	1.8	3.0	2.7	1.8
Panga	4.3	1.5	-	-	2.8	1.2	4.2
TOTAL	25.9	6.5	0.5	2.6	16.3	12.7	12.45

rubber belts and rotary arm installations for waste dump deposition. Thus, Bustuchin, Ruget, Olteţ, Berbeşti, and Panga opencasts appeared.

The open pits are negative landforms that appear after the removal of the soil overburden, waste and lignite layers (Photo 1). They represent typical relief inversions and new local base levels for the modelling of the relief (Dinu M., Sandu M., Cioacă A., 1998). The Bustuchini, Ruget, Olteţ, Berbeşti and Panga opencasts sum up a stripped surface of 25.9 square km, a surface covered with exterior waste dumps of 12.7 square km, to which is to be added the surface occupied by the conveyer belts and the roads (Table 1).

The exterior waste dumps represent positive landforms generated by coal waste accumulation. They were placed at the origins of certain valleys, such as Valea Roşie (Red Valley), Valea Şoimului (Falcon's Valley), within floodplains - at Poiana Seciurile, on the terraces - at the confluence of the Olteţ with the Tărâia streams or on the slope, such as the one at Mateeşti. At the beginning of the exploitation in big opencasts, the coal waste was deposited in exterior dumps, and subsequently, following the development of the opencast, the dumps were placed at the interior.

The interior waste dumps contribute to the attenuation of the level variation induced by the opencast; they develop in steps and follow the advancement of the exploitation line. All opencasts in the study area display interior dumps, as the empty spaces created during 30 years of exploitation allow them such a placement (Photo 2).

Photo.2: The interior waste dump, the Ruget opencast, May 2008

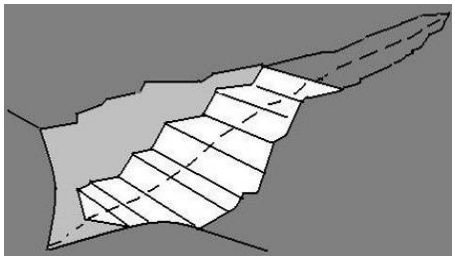

Figure 5: The scheme of a waste dump placed in the upper part of a valley

Photo.3: The Mateeşti landslide

The man-induced relief transformed certain valleys into plateaus, which led to an essential landscape change, the valley being sometimes filled up to the level of the watershed (the dumps on the Valea Şoimului, Valea Roşie) (Fig. 5).

The waste dumps that are located near these opencasts and continue to develop led to significant landscape changes and generated positive relief forms similar to hillocks. Thus, the coal waste dump located at the confluence between the Tărâia and the Olteţ rivers, placed on the 3 - 5 meters terrace, occupies a surface of about one square kilometre, being 500 meters long and rising 65 meters above the terrace.

The dumps often endanger the surrounding areas through the supplementary charging that they exert on the field, the imbalances thus generated leading to the sliding of the deposited material and, sometimes, of the natural components of the slope. Thus, the extensive landslide that took place in the area of Mateeşti settlement destroyed several households and still represents a potential danger, as it can block the Tăria stream (Photo 3). The most important causes of this phenomenon regard the following aspects: the waste dump was placed on a slope higher than 30º; the thickness of the deposited material exceeds 40 meters. Moreover, no specific arrangement work has been carried out on the dump.

The water stagnates on the slid mass, sometimes forming small water bodies and increasing the danger of a new landslide occurrence. The geomorphologic risk phenomena are also a present feature of the area of Seciurile settlement (Photos 4, 5, 6).

The complex and reactivated landslides in the area have as main causes: overcharging of the slope with overburden; change in the pluvial water flow; accumulation of pluvial water in the micro-depressions appeared on the surface of the dump; deforestation of the slope; the technological exploitation standards were not complied with.

The lignite opencasts are located in a hilly region; in these conditions, during the development of the exploitation works, they led to the lateral extension and the flattening of the valleys and subsequently it appeared a gradient in steps towards the watershed. The heights present within the opencast perimeter were cut off.

Photo 4: The landslide scarp at Seciurile

Photo 5: Building affected by the landslide, at Seciurile

Photo 6: Successive detachment scarps on the waste dump placed on the slope, at Seciurile

Photo 7: Lake formed through the blocking of the Amaradia river by the waste dump placed in the floodplain, at Poiana Seciurile

Photo. 8: Lake formed through the blocking of the tributaries of the Upper Amaradia valley

The *pits* left at the closing of the exploitation are one of the most relevant *negative man-induced relief forms.*

In certain cases, lakes appeared at the base of the waste dumps (Photos 7, 8).

5. CONCLUSIONS

Through the presence of marls and clays, the lithological complex favours the landslides and soil running, while the thick sand layers favour a very active relief dynamics through rain-wash, gully erosion, compaction and pipping. The 13 coal layers complicate the dynamics of the region because of the hardness differences, but most of all through the extensive surfaces that have been degraded as a consequence of mining activity. The morphological and climatic features present the study area as a region characterised by average and high geomorphologic risks, the presence of the areas highly exposed to gravitational and hydrologic processes being obvious. Along with the natural potential of geomorphologic risk, within this region, the human activity seriously influences the intensity of the relief modelling processes, through the rapid extension of the areas affected by erosion and mass movements, while the newly appeared relief forms are characterised by higher energy and instability.

The used technologies have not always been compatible with the supporting capacity of the environment and the relief reacted violently, the balance being disturbed. Thus, the geomorphologic risk is high near the mining exploitations and, starting from these instability cores, it propagates at various distances.

Besides the man-induced landforms that it generates, the lignite exploitation in opencasts leads to sliding processes affecting the material of the exterior dumps, rain-wash phenomena, with the appearance of gully erosion forms etc.

The landslides developed before opencast mining increased and became even more dangerous due to this type of exploitation. Among the damages is the destruction of settlements, of reinforced roads, of power pillars etc. (Cioacă, A. & Dinu Mihaela., 1995, 1996, Boengiu, S. et al., 2008).

Because of the important gaps between the deposition, arrangement and fertilization works, the waste dumps, both exterior and interior, present for decades a depressing moon-like aspect, to which there is to be added the dust pollution activated by the wind.

The opencast exploitations, with the stripping of the unproductive layers above, which

may be tens of meters thick, radically change the landscape, firstly destroying the fertile soil. Although the excavated space is gradually covered with the waste dump, finally still remains a lake or a dry depression of important dimensions and with moon-like aspect, the vegetation reappearing after a long time because of the absence of the fertile soil. This type of phenomena can be seen at Ruget and Panga.

Besides the relief and hydrography changes, the surface exploitation within the study area induced significant changes in the vegetation, as a consequence of the important deforestations that took place in the area of these opencasts; the place of the forests or of the natural grasslands has been taken by fields covered with *Botriochloa ischaemum* or simply by more and more extended lands that cannot be used in the present conditions.

The technogene landscape is completed by the excavators and waste dump machines, which appear above the fields, by the power pillars, by the transportation network that sinuate all over the area of the big open pits.

In these exploitation conditions, the changes that regard the human communities involve, on the one hand, the important destructions and displacements and, on the other hand, the increasing number of dwellings, their aspect and the appearance of the town of Berbeşti.

REFERENCES

Aur, N., 1996. *Piemontul Olteţului,* Universitaria Publishing House, Craiova.

Badea, L., 1967. *Subcarpaţii dintre Cerna Olteţului şi Olteţ. Studiu de geomorfologie,* The Publishing House of the Romanian Academy, Bucharest, pp. 26-27.

Boengiu, S., Enache, C., 2002. *On the Miocene-Pliocene geological evolution of the extra-Carpatian Oltenia,* Geographical Phorum – Geographical and Environmental Studies and Research, No.1., Universitaria Publishing House, Craiova, pp. 70-71.

Boengiu, S., Vlăduţ, Alina., Avram S., 2008. *Geomorphologic risks in the western part of the Getic Piedmont*, Proceedings - Fourth International Conference-Global Changes and Problems. Theory and Practice ”St. Kliment Ohridski University Press”, Sofia, pp. 485-488.

Cioacă, A., Dinu Mihaela., 1995. *Hazardele geomorfologice în regiunile de exploatare a lignitului din nordul Olteniei. Studiu de caz în câmpul minier Olteţ*, Analele Universităţii din Oradea, Seria Geografie, No. 5, Oradea, pp. 57-67.

Cioacă, A., Dinu, Mihaela., 1996. *Geomorphological hazards. Lignite mining and the newly-built relief in the North of Oltenia (Romania)*, Geografia fisica e Dinamica Quaternaria, Comitato Glaciologico Italiano, Torino, 18, 1995, pp. 3-6.

Cioacă, A., Dinu, Mihaela., 1998. *Restructuring lignite mining in Romania and its environmental effects with special references to landforms,* Revue roumaine de géographie, Tome 42, The Publishing House of the Romanian Academy, Bucharest.

Cioacă, A., Dinu Mihaela., 2001. Efectele activităţilor tehnologice asupra riscurilor geomorfologice, în regiunile de extracţie a resurselor naturale ale subsolului, Revista Geografică, Serie Nouă, No. VII (2000), Bucharest.

Dinu, Mihaela., Sandu, M., Cioacă, A., 1998. Modificări antropice ale reliefului în câmpul minier Alunu – Berbeşti, Studii şi comunicări de geografie, XLIV, Bucharest, p.110.

Dumitraşcu Monica, 2006. *Modificări ale peisajului în Câmpia Olteniei,* The Publishing House of the Romanian Academy, Bucharest, pp. 173-190.

Enache, C., 2008. *Geologia Olteniei,* Universitaria Publishing House, Craiova, pp. 339-343.

Evans, KG., Willgoose, GR., (2000b), Post-mining landform evolution modelling: 2. Effects of vegetation and surface ripping. Earth Surface Proces Landforms, Nr. 25(8), pp.803–823.

Goudie, A. Viles, H., (1997), The Earth Transformed: An Introduction to Human Impacts on the Environment, Oxford, UK: Blackwell.