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GEOMORPHOLOGICAL HAZARDS. LIGNITE MINING AND THE NEWLY-BUILT RELIEF IN THE NORTH OF OLTENIA (ROMANIA)

ABSTRACT: CIOACĂ A. & DINU M., *Geomorphological hazards. Lignite mining and newly-built relief in the North of Oltenia (Romania).* (IT ISSN 0391-9838, 1995).

The paper is about the new landscape born by digging works and dumping from the exploitation of lignite in the Oltenia area. Lignite mining began in the interwar period and covers 75 Km². The principal aspect of the newly-built landscape is the inversion of the relief, as diggings are situated in the hills of Southern Carpathians while dumpings in the lower terraces of Olteţ river.

The modelling processes of this newly-built relief have a sensible diversity and intensity of natural modelling and the present-day dynamics shows new geomorphological hazards, as rock and soil falls, debris flows, topples and down-sagging and even mud-flows, slidings and sheet erosion. The top of the hazard is localized in the slope of Subcarpathian: in the 1994 April 22 18,500 c.m. of sterile sands down to the foot of the hillslope.

To sum up, the newly-built reliefs of Oltenia are high by geomorphological hazards areas. In the future when the degraded landscape will be rehabilited, the attention will have to be focused on the stability of the slopes and on the rationalisation of the drainage network.

KEY WORDS: Geomorphological hazard, Man-made relief, Region of Oltenia (SW Romania).

RIASSUNTO: CIOACĂ A. & DINU M., *Rischi geomorfologici. La coltivazione della lignite e un nuovo rilievo nella regione di Oltenia (Romania).* (IT ISSN 0391-9838, 1995).

Si riferisce di un nuovo paesaggio nato dagli scavi e dai riporti di materiale nella regione di Oltenia nei Subcarpazi Getici e nel Pedemonte Getico in conseguenza della coltivazione della lignite iniziata fra le due guerre mondiali. L'area trasformata occupa 75 Km². La conseguenza più generale è una inversione del rilievo naturale, considerato che le escavazioni sono per la maggior parte situate in zone collinari e i riporti in aree vallive.

I processi di modellamento, essenzialmente di degradazione dei versanti, si sviluppano ad un ritmo superiore a quello naturale e tali da creare situazioni di rischio geomorfologico, quali frane di roccia sciolta, colate di terra e fango, erosione areale, collassi. Il maggior rischio è localizzato nei Subcarpazi, per le preesistenti più forti energie di rilievo naturali. Nel 1994 vi fu una discesa fino al piede delle colline di ben 18.500 m³ di sterile. Nelle zone depresse del Pedemonte Getico invece i riporti hanno per ora attutito il rischio di inondazione, ma hanno modificato la rete idrografica.

Considerata la situazione di rischio sono necessari interventi di sistemazione e bonifica, quali costruzioni di canali e di casse di espansione delle acque e un'opera di stabilizzazione dei pendii fino al rimboschimento. Comunque sia sarà sorto un nuovo paesaggio a un tempo artificiale e naturale.

TERMINI CHIAVE: Rischi geomorfologici, Paesaggio artificiale, Regione di Oltenia (Romania di SW).

Lignite mining in the hilly zone of Oltenia, which began in the interwar period, has been developing significantly over the last three decades. From the coal-strip mines in the Jiu Passageway, exploitations have extended to vast areas, from the hillocks, stretching between Luncavăţ in the East to the source area of the Bistriţa Valley in the West. The whole area belongs to two major relief units: the Western branch of the Getic Subcarpathians (named the Subcarpathians of Oltenia) and the *Getic Piedmont* (the piedmonts of the Motru, Jiu and Olteţ Valleys) (Fig. 1). The relief built by coal diggings and dumping covers 75 sq km, with diggings occupying 55 sq km (22 sq km of which have already been dump-filled to remake the degraded natural landscape). The man-made hills outside the mining area extend along 20 sq km (2 sq km in the source area of some valleys surrounding the mines and 18 sq km in the waterplains, or on the lower terraces). Unlike the *Central sector* (with hills on the Southern flank of an extended anticline of the Gorj Subcarpathians), or the *Eastern sector* (with hills extending both on folded and monocline structure), the *Western sector* shows a great morphological diversity (with the Motru Piedmont appearing like a succession of elongated hilly summits enlarging Southward and forming a kind of structural bridges that bespeak a monolithic structure divided by consequent valleys). A brief morphometrical and morphographical analysis indicates similar differences between the three sectors: higher altitudes in the Eastern sector (Chicera Mateeşti, 649 m), lower ones in the central sector (400-450 m), going down to 300-350 m in the Western sector. The relief itself is unevenly fragmented, decreasing from the East (3.0-6.0 km/sq km) to the West (0.2-3.6 km/sq km) and from the

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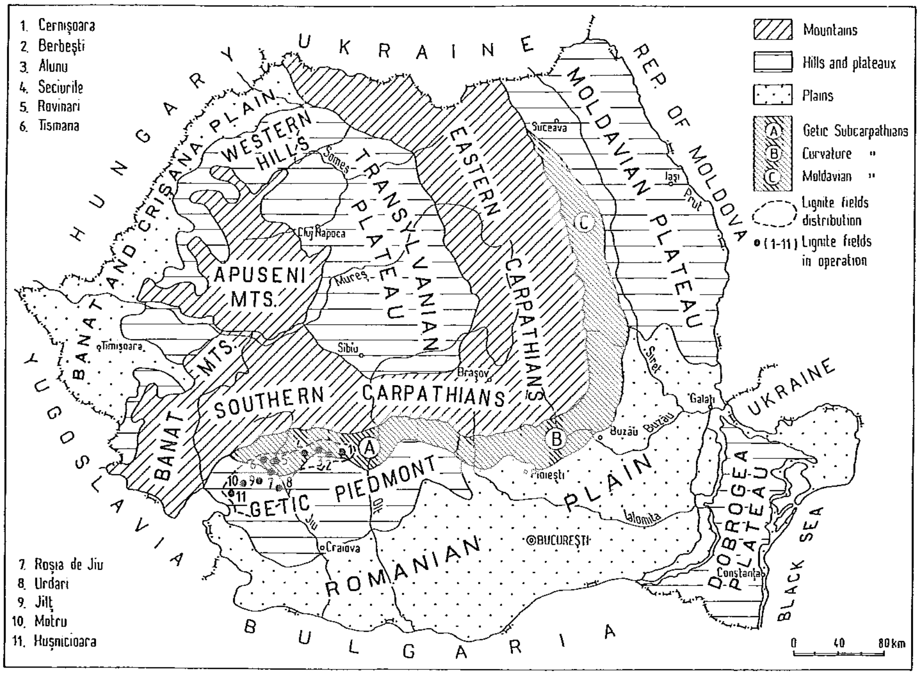


FIG. 1 - Location of mine fields in the North of Oltenia (Romania).

North (2.5-5.0 km/sq km) to the South (0.4-1.8 km/sq km). Discrepancies are obvious also in regard of relief energy (120-150 m in the East and North, 60-100 m in the central sector, and 40-60 m in the West and South).

If these early relief values correspond to a lasting evolution, the values of the relief newly-built in time by coal digging and dumping show spectacular inversions in many cases. Let us take, for example, the Olteţ man-made hills built on the lower terraces of the Tărâia River in the junction area with the Olteţ (an outside dump), which tops the terrace bridge today by nearly 40 m; previously, this terrace had been part of a 5-20 m relief-energy area; the mines of Ruget, Seciuri, Olteţ and Berbesti, dug in hills of 500-550 m alt. and relief energy of 120-150 m or even more, have depressed these values down to 80-100 m; the coal strip mines of Roşia de Jiu and Peşteana Nord were dug in the Jiu waterplain down to depths of 30-50 m; they lie in the vicinity of the Fàrcăşeşti, Cicani, and Beterega man-made mountains which, after having filled the old mines or formed directly on the alluvial plain, stand now by some 35 m higher than the waterplain of the lower terrace level. The upper level of the Fàrcàşeşti dump is scheduled to reach as high as 50 m. Natural relief declivity values are moderate to high (rounded interfluve slopes up to 15°, glacis and terrace bridges of 8°-10°, terrace fronts of 15°-25°, slope scarps, gullies and landslide valleys); excavations are bordered by 50°-75° slopes, while connection areas between dump levels are of only 8°-12°.

Considering that about 67% of the mine fields between Luncavăţ and Huşniţa are hills and slopes (the remaining 12% being depressionary source area and 21% waterplains, terraces and glacis), it is understandable why relief analysis focuses on slope dynamics responsible for the diversity and intensity of natural modelling processes and more recently of man-induced ones in the wake of lignite mining. The dynamics of present-day geomorphological processes is closely related to slope shape declivity in a homogeneous rock and structure substrate. Under natural conditions, the slope as a whole is regressing at a slower pace, while its particular forms created by rainfall and denudation, gully erosion and slow or sudden mass movements, are seen to accelerate and grow in intensity. Things have been complicated by digging works and the formation of man-made mountains, which have diversified the range of these processes, from a natural modelling system to one dependent upon new basic levels, upon new relief forms (BADEA & *alii*, 1994).

The relief newly built in the wake of lignite extraction in the hilly region of Oltenia falls into these two basic categories: forms engendered by excavation and forms built by dumping (smooth surfaces, edges, straight or curved connection surfaces, etc) similar to the naturally-developed relief on which they rely to a great extent, tending eventually to evolve along its lines (the moment when modelling progresses along natural lines, behaving like any landform generated by the action of natural agents).

The geomorphological hazards of a lignite-mining-built relief are distinct from those affecting a natural relief, in that it shows an accelerated evolution, reaching a state of equilibrium in a shorter time-interval, subsequently undergoing natural modelling, as shown by the present-day modelling of the older man-made mountains at Cicani, Beterega and Gârla; instead of mass movements there is now creeping and solifluxion, without however their having a notable effect on slope dynamics. Looking at the present condition of the relief, at the variety of events and, moreover, at the intensity and risk of geomorphological processes, we can distinguish two large groups of area where new relief forms have been excavated or built up: in the waterplains and on terraces, covering 20% of all thernine fields, and in the hilly Subcarpathian and piedmont zones, which are by far more extended. In the former case, the newly-built relief has developed in previously drained and embanked areas, fact that has almost completely reduced the risk of flooding and of change through fluviatile processes. On the other hand, new geomorphological hazard situations occur on dump slopes and coal-strip mine scarps, e.g. rock-and-soil falls, sinkings, slidings, mudflows, down-sagging and even sheet erosion. However, the highest geomorphological hazard is obvious in the Subcarpathian or piedmont hills (BĂLTEANU & *alii*, 1989), both on natural summits and slopes and on summits and slopes built by man through diggings, or dumping (in the source area of drainage basins or inside the mines).

— *Major and secondary summits, smooth or rounded*, are subjected, in principal, to rainfall and denudation. However, they can also be affected laterally by geomorphological processes occurring in the source area of secondary basins.

— *Slopes with low risk of erosion and sheet wash* are mainly deforested grounds marked by rainfall and denudation (from splash and sheet wash on mildly dipping surfaces to incipient forms of rill-wash or bush-or tree-covered slopes under which rock-related erosion progresses, leading to better-evolved rill-wash forms. Solifluxion and creeping are characteristic of mild slopes (5°-10°) on sliding coluvia. These slopes, which cover nearly 15° of all the mine fields, are largely affected by digging works and less so by outside dumping (except for some temporary dumping sites) consisting of the stripped fertile soil layer dumped up and then used for making the soil cover of some of the dumps cultivable;

— *Slopes with intermediate risk of mass erosion* have an average 8°-12° declivity angle propitious to gulling (400-600 m long and 1.0-1.5 m deep). Slow movements (creep and solifluxion) have a high incidence in deforested areas with moisture excedent, usually in deluvial formations. These slopes cover 17% of the mine fields in the hilly zone of Oltenia;

— *Slopes with high risk of erosion and mass movement* dip by 15°-25°. Dispersed especially in the East of the mine field region, they nevertheless cover more than 17% of the fields. The multitude of small fixed valleys and the very active landslide valleys causes headward erosion, with immediate impact on the decrease of interfluves. Besides, the risk of mass movements is particularly great here.

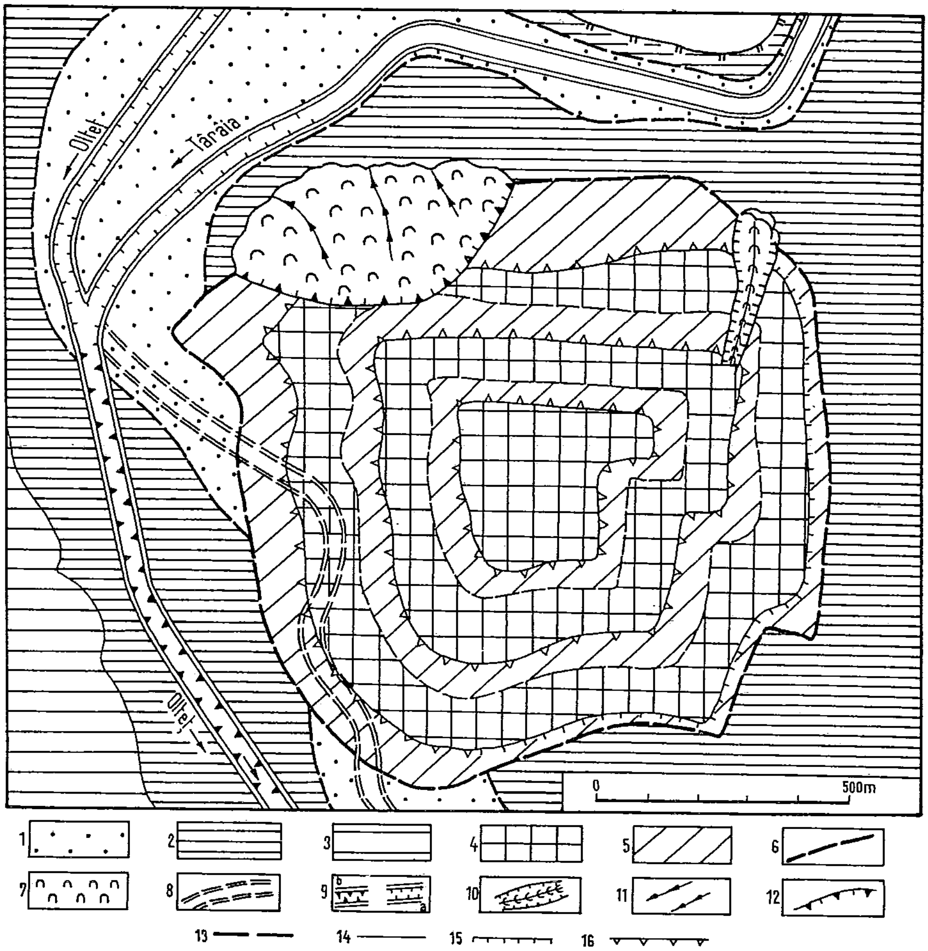
— *Slopes with high and very high risk of mass movement* are very steep, as a rule (35-45°), but cover small areas (4.45%). Whenever erosion cuts into stripped layer ends, there is a risk of layer 'curving', followed by short creep-induced corrosion up to the moment when soil-and-rock and boulders start falling.

Besides these geomorphological hazards of a naturally-modelled relief, new hazard forms, specific to coal strip mine slopes or man-made mountain slopes have emerged. In the first case, rockfall, debrisflow, topples and down-sagging which are characteristic of friable formations that lignite is dug out from. In the west mine field sector, the substrate consists of monocline Pliocene formations of the S-E-oriented piedmont — gravels, marls and sandy clays; in the central sector, between the Jiu and the Gilort rivers, the widely — folded sedimentary formations, lying in an anticline faulted on the Northern flank (BADEA & BĂLTEANU, 1982), belong to the Subcarpathians of the Gorj: in the Eastern sector, coal-digging goes on both in the formations folded on the Southern flank of the Gorj Subcarpathians and in the piedmont monocline formations leaning on them. The slopes dug out in coal-rich strata are fairly steep (65°-75°) and the technical studies made before stripping began assumed them to be stable. The vertical fissures, of mechanical origin, favour rock-and-soil falls by depleting the cohesion of stripped layer ends. These fissures are getting wider, especially if the slope cuts into underground sheets which permanently moist the friable rocks; freezing during the cold season, the stagnant water volume in the fissures increases (by some 10%) through lateral pressure. In this way, boulders easily fall at the foot of the slope, leading in time to the accumulation of some materials which, leaning on the slope, reduce its declivity. There is a high risk for such processes to develop, but as the mine is dump-filled the risk is diminished or eliminated altogether.

In the second case, however, the stability of the step-like slopes, built up by dumping, is calculated in terms of dominant rock composition and spread on the surface of the man-made hills. Technical studies usually suggest a 12-14° declivity gradient for slopes consisting of gravels and marly clays, and of 8-10° for the ones formed of sands and sandy clays. But exploration rates and the higher cost of sorting out the dump and storing what is technologically unfit for dumping increase the geomorphological risk for some large quantities to suddenly slide down to a lower level, or to the base itself. This was the case of the Olteţ man-made hills (an outside dump) on April 22, 1994 (Fig. 2). Substa ntive amounts of sands, thick of 0.8 m-1.2 m, being dumped on its North-Western flank caused changes in the circulation of the waters infiltrated in the mountain coluvia, entailing some 18,500 cm. of sterile down to its foot. In addition to such geomorphological hazards, there are minor risk situations of down-sagging due to moisture and stagnation of precipitation water at the foot of the mines and on the horizontal surfaces of the man-made mountains. Another contributing factor is, in many instances, the mechanical pressure put by excavation on the dumping equipment.

The type of landuse prior to digging and dumping works had played a secondary part in the evolution of natural slopes. Nowadays, however, when the landscapes degraded by such works are to be rehabilitated, the elements used to fix up and strengthen the newly-built relief are certain to bring about changes in the early landscape. Thus, the building of canals and dykes in the drainage network, of lakes in the area of waterplain mines, or on the lower terraces of embanked sites capable to take over and store the additional water volumes of disaster flows that can jeopardize lignite mining, together with afforestations and expansion of forest zones, as well as the limited recov-

FIG. 2 - The Olteţ external man-made hills. A geomorphological sketch. 1) Waterplain, 2) Waterplain terraces (1.0-2.0 m), 3) Lower terrace (3.5-5.0 m), 4) Flat surfaces on the dumping mass, 5) Dump slopes (5-8°), 6) External dump boundary, 7) Slided dump, 8) The former Olteţ Valley, 9) Embanked minor channel-bed sectors deepened by 1-2 m (a) and 2-3 m (b), 10) Mudflows, 11) Small fixed valleys, 12) Scarp, 13) Floodplain boundary, 14) Delevellings below 5 m, 15) Delevellings of 5-10 m, 16) Delevellings over 10 m.



ery of some agricultural grounds, are some of the major priorities. These works can effectively contribute to reducing destructive processes on slopes, at the same time ensuring their normal evolution by eliminating chaotic development hazards (BURTON & *alii*, 1978; HAGGET, 1979). To sum up, we would say that man-made hills built in the source area of some hilly slopes in the mine fields of Berbeşti and Jilţ are high geomorphological hazards. It is advisable, therefore, that landforms, in which water accumulation from heavy rainfalls can turn dumped materials into a muddy mass capable to sweep aside everything standing in the valley downstream the man-made hills, should be avoided. If such structures do already exist, drainage works must necessarily be undertaken if disaster flows are to be coped with.

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