

# Conditions of gully development within piedmont areas with examples from the western part of the Getic Piedmont, Romania

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## Abstract

Features of gully morphometry and associated relief characteristics emphasize that gully develop under a wide variety of rock conditions, rainfall regimes, geomorphic predisposition, and human influence. Consequently, many slopes within piedmont areas, in this case, the Getic Piedmont, are characterized by dense gully systems, as there occur excessive clearing, inappropriate land use, compaction of the soil caused by grazing, on the general background of a favourable climate. Both rainfall and runoff factors must be considered in assessing a water erosion problem. The erosional slope development within the Getic Piedmont was evaluated based on maps and field studies in the last 15 years, which emphasized that about 20 % of the total surface of the piedmont is affected by gully erosion. The results show that the factors leading to the strong gully erosion in this area include – the widely distributed friable rocks, the unique geomorphologic configuration, the strong and time-concentrated rainfall, the alternance of drought-humid periods that prepares the ground for the development of fissures in soils, the drought that influence the growth and recovery of vegetation, and the intense human activities. Gully erosion is one of the most visible forms of soil erosion, which affects its productivity, provides considerable material transport – torrential transports, debris flow, restricts land use, and threatens local communities.

## Key words

Gully erosion, Slopes, Torrential transport, Land use, Getic Piedmont

## Introduction

The monocline of the Getic Piedmont represents a transition unit between the folded region of the Southern Carpathians and Getic Subcarpathians in the north and the platform region of the Romanian plain in the south. This geographical unit genetically and structurally corresponds to the geological unit of the Getic Depression characterized by a sedimentation process occurring between Senonian and Pleistocene, which was enhanced by the development of the Carpathian foredeep.

The Getic Piedmont overlaps the surface occupied by the piedmont-like cover and corresponds to a particular type of humanized landscape, developing between the Danube river in the west and the Dambovită river in the east (Badea, 1973; Geografia României, 1992).

The relief of the piedmont is characterized by the presence of long summits, directed north-south and greatly fragmented by the river system tributary to the Danube, the Jiu, the Olt and the Arges rivers. The friable rocks – sands, gravels, argillaceous sands, marls, imposed a rapid evolution of valleys and favoured the development of intense geomorphologic processes.

Even if there is a relatively homogenous natural environment in the Getic Piedmont, there occurs a certain differentiation in the frequency and intensity of the gully erosion. The friable rocks, mean values of the drainage density and of the relief energy, torrential rainfalls, and different human activities favour the development of gully erosion. The present study aimed at analysing the control factors of gully processes – the lithological background, structure, climatic features, present evolution stage of

the relief, different human activities, such as deforestations, drainages or overgrazing.

### Materials and Methods

The causes that trigger the appearance and development of different forms of torrential erosion are extremely diversified and complex.

The relief analysis, namely the evaluation of morphological and morphometrical features, was made on the base of topographic maps at the scale 1: 25,000, 1: 50,000, 1: 100,000 m and photograms. The lithological background and role it plays in the development of gully processes was assessed on the base of different materials published in the literature, in the field, maps, and geological drillings, as well as through constant field trips in the monitored perimeters.

The climatic factor and its impact was determined by means of specific statistical data processing (mean precipitation and temperature values, intensity of rain showers, maximum amounts in 24 hr) of the values supplied by seven meteorological stations located within the perimeter of the piedmont or in the contact areas. The risk of gully appearance within a region was estimated starting from the calculation of mean available soil moisture:

$W_s = \frac{R - R'}{t}$ , where  $W_s$  is the moisture content,  $R$  annual precipitation amount,  $R'$  annual precipitation amount necessary for

the development of plants –  $R' = 30(t+7)$ ,  $t$  is the mean annual temperature (Rădoane et al., 1999).

The dynamics of the main anthropogenic elements, the induced transformations of the landscape were directly monitored during the field trips made by research team in last ten years, as well as through certain methods specific to statistical analysis.

The detailed monitoring of gullies took place in four main perimeters, two of them located west of the Jiu river – the perimeter Bistrita – Hinova (P1) and the perimeter of Drincea basin (P2), and other two east of the Jiu – the perimeter of Gilort basin (P3) and the perimeter of Amaradia basin (P4).

### Results and Discussion

#### Control factors of gully processes:

**Lithological background:** The crystalline basement of the depression was covered by thick layers of sedimentary formations (limestones, sandstones, marls, clays, sands, gravels) disposed horizontally or monocline-like, which means it had the features of a platform structure that was called *Getic* towards the Carpathians and *Moesic* towards the Balkans.

At surface, the sector developed between the Danube and the Jiu rivers displays deposits of different ages – Pliocene-Quaternary made up of sandstones, marls, clays, sands, gravels, and stratified sandy silts of varied thickness (Fig. 1, 2). For example,

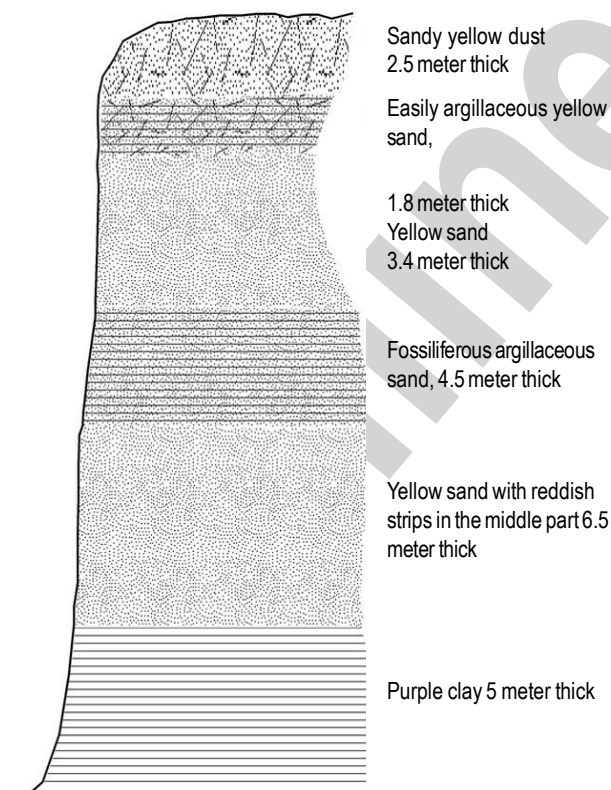


Fig. 1: Lithological profile at Valea Florilor (Boengiu, 2008)

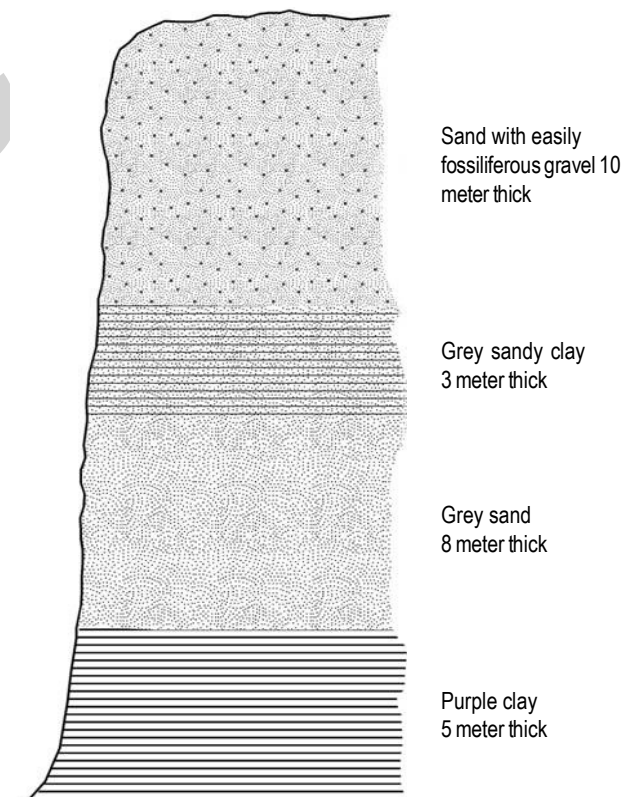


Fig. 2: Lithological profile at Valea Bisericii (Boengiu, 2008.)

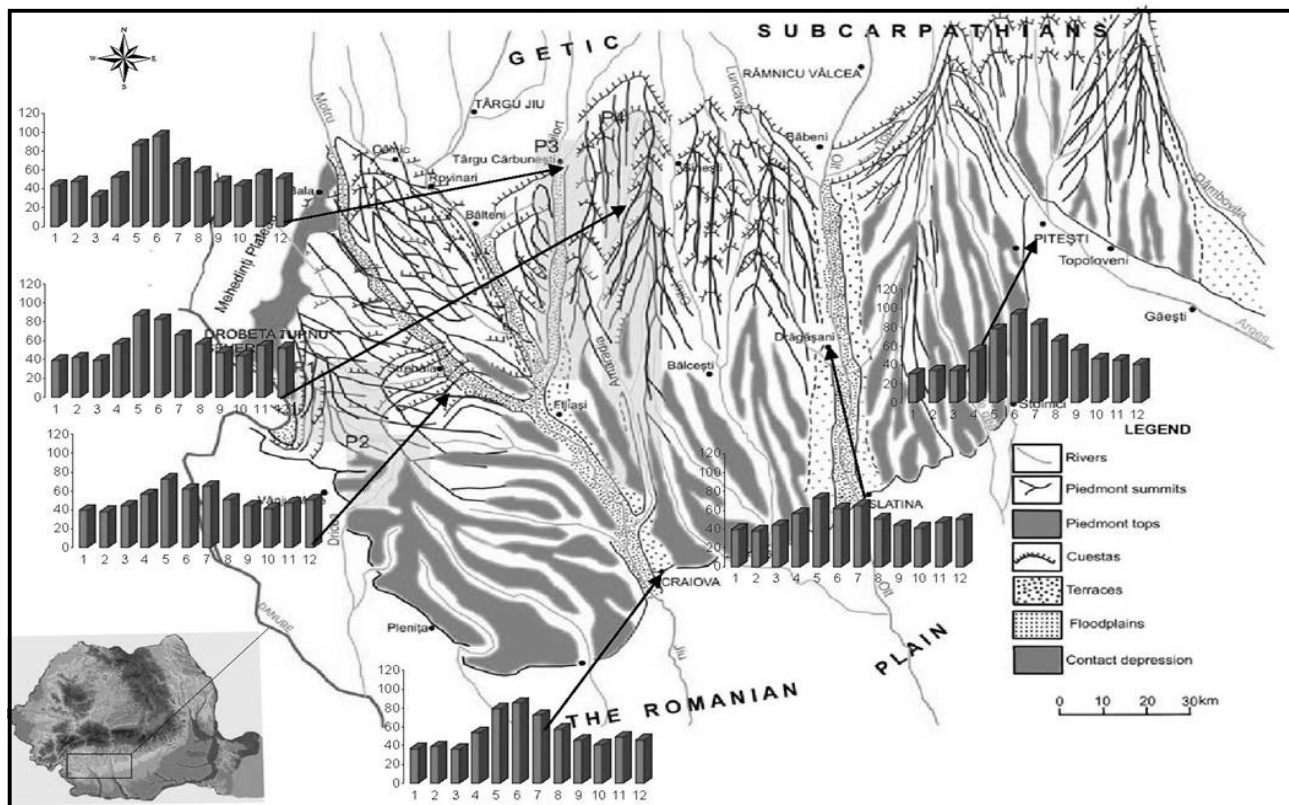


Fig. 3: Monthly distribution of the precipitation amounts (map processed after Geografia României, 1992)

the Pliocene clay deposits reach 600 m thickness in the south and 150 m in the north (Schiopoiu, 1982).

The sedimentary series of the sector located between the Jiu and Olt rivers displays at the upper part an alternance of clays, sands, marls, gravels, and boulders of about 100 m thickness (the deposits exceeded 100 m at Dragasani, about 70 m north of Craiova and decrease in thickness towards the north of the piedmont, where the Romanian and Dacian deposits predominate) (Aur, 1996).

These formations are covered by loess-like deposits and thick alteration mantle-rock, which appears as an almost continuous cover with varied thickness depending on the sector, according to the terrain slope and their genesis. The modelling is influenced by the stability of the superficial deposits that varies according to the local morphology and vegetation cover degree. The most fragile areas are those displaying superficial deposits resulted from Pliocene sands (the perimeter Bistrita – Hinova, Cosustea basin, Drincea basin and Amaradia basin), with steep slopes, which underwent rapid withdrawal due to these processes.

**Relief conditions:** The relief is characterized by the presence of long piedmont summits directed north-south. They resulted from fragmentation of the initial piedmont surface exerted by almost parallel river system. In the northern part, interfluvies display the form of rounded summits that gradually got larger southwards till they transformed in flat, less affected by erosion surfaces. In fact, they are

so even and smooth (the Oltet Piedmont between Amaradia and Olt rivers or extremities of the Cotmeana Piedmont) that certain geographers considered they represented a plateau resulted from a high fragmented plain (Fig. 1,2).

On continuous rising it underwent inducing different altitudes (700 m east of the Olt river, 600-650 m in the Oltet Piedmont, and 400 m west of the Gilort river), determined a gradual and relatively rapid deepening of the valleys and an intense relief fragmentation, which was also favoured by the friable component rocks – marls, clays, gravels etc. Thus, there developed a series of terraces that went along the main valleys. The number and relative altitude of the terraces decrease from north to south in accordance with the age of piedmont and intensity of neotectonic processes. According to the way terraces were distributed, it clearly results in the areas of river convergence – north of Filiasi and north of Craiova, on the Jiu river; from Balcesti on the Oltet river; south-east of Bals on the Olt river; north of Pitesti on the Arges river; here the extension and lower altitude of terraces proved the influence of negative neotectonic movements.

The non-consolidated sedimentary rocks favoured a rapid evolution of the slopes that are presently affected by numerous active processes, which however decrease in intensity from north to south as relief energy also decrease.

The drainage density and relief intensity decrease from north to south. In the west, they reach maximum values of 6.6 km km<sup>-2</sup> and



Fig. 4: The effect of overgrazing on inclined slopes – Amaradia basin



Fig. 5: Rills on wastes in the area of Vârtej, Amaradia basin

Table - 1: Main features of the monitored gullies

No.	Name	Length (km)	Mean depth (m)	Energy (m)	Mean width (m)
1	Hinova 1	2.8	5.54	156	45.42
2	Hinova 2	2.4	5.5	154	44.64
3	Brânistea	3.8	2.5	33	66.70
4	Pitulata	0.95	2.6	4	4.4
5	Berdincesti	1.3	6.4	62	9.4
6	Siglesu	3.2	3.1	12	6.3
7	Izvorălu de Jos	0.96	2.9	31	4.5
8	Plopi	0.052	7	13	9
9	Negoiesti 1	0.860	15	157	72.4
10	Negoiesti 2	0.740	14	150	64.5
11	Negoiesti 3	0.625	12	146	56.5

respectively 160 m in the Balăcita Piedmont (Boengiu *et al.*, 2008), while eastwards, they reached 1.05 km km<sup>-2</sup>, respectively 250 m in the north of the Oltet Piedmont (Aur *et al.*, 1996). In the eastern part of the Oltet Piedmont (the Gilort basin and the Amaradia hills), the drainage density generally oscillated between 2.75 and 3.25 km km<sup>-2</sup>, the maximum values being 4.75 km km<sup>-2</sup>, while the relief intensity displays mean values of 90-150 m, the maximum reaching 174 m (Marinescu *et al.*, 2006). In the northern sector, the rising movements imposed in the valleys features of young systems, which mean accelerated vertical erosion and high intensity of slope processes, while in the south, the fragmentation indexes decrease as there predominate flat interfluvies, terraces and floodplains.

**Climatic conditions:** Climatic conditions, especially the regime of atmospheric precipitation and the thermal regime, play an extremely important role in the genesis and evolution of gullies. The used data were supplied by seven meteorological stations located in different areas of the piedmont or along the contact area with plain region – Bicles, Craiova, Târgu Logresti, Târgu Cărbunesti, Drăgășani, Pitesti and Târgoviste. The data from the last two stations were used for comparison as the rainfall regime registered significant differences in the west and east part of the piedmont. The data chain was generally registered between 1984 and 2006, with some exceptions

(Tg. Logresti and Tg. Cărbunesti), where the meteorological stations stopped their activity before 2000.

The annual mean amounts of precipitation are homogenous and generally exceed 600 mm. However, they are higher in the north as compared to the south of the piedmont, mainly due to the differences of altitude, oscillating between 679 mm and 587.2 mm. During the year, the monthly amounts increase from January-February, which register less than 40 mm (mainly solid precipitations) till June, the month with maximum values within the entire piedmont (>70 mm). Starting with the interval July-August, the amounts decrease gradually, as cyclone activity and thermal convection reduce their intensity. In autumn and at the beginning of winter, there occur notable differences between the western and eastern parts of the piedmont, due to the exposure to air masses of different origins. Thus, in the western part, we mention the occurrence of a second period characterized by great precipitation amount in November-December, induced by the intensification of the cyclone activity in the basin of the Mediterranean Sea; while in the east, where the penetration of continental dry air masses is more frequent, the monthly precipitation amounts continue to decrease starting with July (Fig. 3). Consequently, west of the Jiu river, the amounts corresponding to the two semesters are more homogenous (55% in the warm semester, 45% in the cold semester) than east of the





Fig. 6: Stages of gullies evolution (a,b,c). Plesoi gully

aforementioned river, where the warm semester holds more than 65% of the annual amount.

The erodibility potential exerted by rainfalls directly depends on their intensity. The effect of rain shower increases when they occur after a prolonged drought period, which deteriorates the vegetation (Boengiu *et al.*, 2009). The Getic Piedmont displays medium intensities of the showers, 4-5 mm min<sup>-1</sup> (Vlăduț, 2002), more reduced than the ones calculated for the neighbouring relief units (plain and Subcarpathians regions).



Fig. 7: Gully with landslides within the Drincea basin, east of Pitulata hill

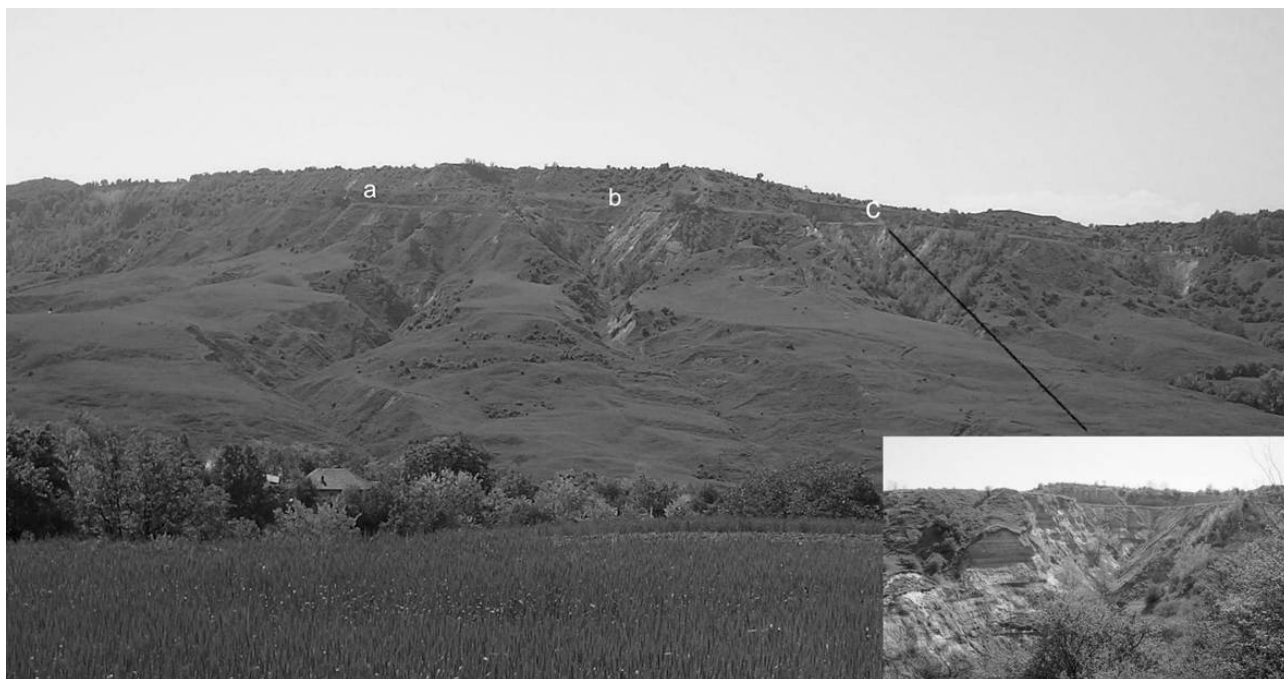


Fig. 8: Plopi gully

As distribution, the western part is more exposed to such phenomena compared to eastern part due to the more frequent penetration of humid tropical air masses in summer and sometimes even in autumn – Tg. Logresti – 3.6 mm min<sup>-1</sup>, Craiova – 4.5 mm min<sup>-1</sup> the mean of the first five highest intensities (Dragota and Balteanu, 2000). The most problematic months of the year are July and August, when numerous showers occur. Thus, we mention the showers registered on July 12, 1999, when about 150 mm/36 hours affected Strehaia Piedmont. Other showers occurred in July and August, 2004 within Strehaia Piedmont and the Jiu Hillocks. On July 1-2, 2005, we mention 101.7 mm at Bacles (215.9% higher than the normal amount of the month), 130 mm at Breasta, 103.5 mm at Filiasi etc. (Marinica, 2006).

By calculating the moisture content available in the soil in order to quantify the gully risks, it results that the lowest values occur in the western and eastern extremities of the piedmont, as well as in its central part, where it usually does not exceed the value 10 (Craiova – 3.98, Bacles – 9.39, Drăgășani – 9.27). In the northern part of the piedmont, the coefficient exceeded the threshold of 15 (16.9 at Tg. Cărbunesti, 17.29 at Tg. Loresti).

**Human control:** The human factor represents a key element for the appearance and development of gully processes. As the Getic Piedmont had numerous soil and subsoil resources, anthropogenic



**Fig. 9:** (a) Negoiesti 1, (b) Negoiesti 2, (c) Negoiesti 3

pressure upon environment increasing especially during the forceful industrialization that occurred in the communist period.

Thus, human factor acted especially through deforestation on extended surfaces and utilization of resulted fields in the agricultural circuit but, especially through underground and open pit lignite mining and development of oil and natural gas exploitations.

Deforestations were done mainly before 1970 for different purposes – utilization of wood as fuel, in constructions, for the extension of the pasture lands and arable plots etc.; however, such actions still occur till date, but at a lower scale (Stroe, 2003). Thus, rills formation and intensification of gully erosion was favoured within the entire surface of Getic Piedmont, the most affected being inclined slopes (15–20°) (Fig. 4). Even if we cannot ignore the role played by deforestation and, of course, by the change of land use in gully erosion processes, they did not affect irreversibly the natural balance of the analysed region. However, these phenomena reached their climax after 1970, when there developed many centers for lignite, oil and natural gas exploitations.

In the west of Getic Piedmont, lignite mining industry (mines and open pit exploitations) developed in the northern half of Jilt hills, in the north and west of Cosustea hills, as well as in the Motru basin. East of the Jiu river, in the Oltet Piedmont, lignite was exploited in the areas Alunu – Cucești and Seciurile – Amaradia.

Numerous localities of the piedmont dispose of oil and natural gas reserves that are found in Paleogene, Miocene, and Pliocene formations at Bogasi, Mosoia, Poiana Lacului, Vede, Oprelu, Cungea, Iancu Jianu, Mădulari etc.

Consequently, the landscape underwent drastic changes in the exploitation areas, positive relief forms being transformed in negative forms, and the negative ones (the valleys) in positive forms (waste), characterized by greater energy and instability. For example, in the case of Rosiuta open pit from the Motru basin, the surface covered by wastes reaches 1,489 ha, while the surface of the pit was about 500 ha. It would extend to 682.36 ha till 2020 and 410 ha presently covered by forest would be cleared (Tomescu, 2004; Tomescu *et al.*, 2007). Gully erosion processes affected most of the surface of these wastes because they were not covered by a layer of fertile soil and were not used as agricultural plots or planted with different species of trees (Fig. 5).

**Case studies:** The flow of rain water on slopes generates gully erosion processes, which are quite diverse, from the incipient forms (rills, furrows) to the most evolved (gullies and torrents in different evolution stages).

The highest frequency of gullies is registered on the slopes made up of detritic poorly consolidated rocks (gravels, sands, and poorly cemented sandstones); gully erosion processes also occur as secondary processes in the morphogenetic systems where landslides are predominant and, together, they represent slope morphodynamic complexes.

On the slopes, the distribution of gullies acquired different forms, starting from the simplest, which are frequent on the upper third, to the branched ones that resulted from gathering of simple segments located on the median and lower thirds of slope. The branching degree and dimensions of gullies depend on their stage of evolution. The greatest depths appear at the upper (head) or



Fig. 10: Dam built at Pitulata gully

middle parts of the slope. The slopes predominantly modelled through gully erosion processes cover relatively reduced surfaces compared to those where they are associated with mass movement processes, where the destructive effect is more efficient. The gullies are more numerous and displayed many branches, and predominated dry valleys compared to active valleys. They display an obvious vertical deepening tendency and at their mouth, there are deposited large quantities of sands and gravels resulted from the destroyed Samatian and Pliocene formations. The catchment basin of all these valleys is highly fragmented displaying a steep aspect.

Starting from the classification according to configuration, there can be identified many types (Boengiu *et al.*, 2008.): bifurcated gully (confluence gully); dendritic gully; composed gully (linear, bifurcated); composed gully (linear, dendritic); unilaterally latticed gully; composed gully (dendritic, bulb-like shaped); poorly dendritic gully; bulb-like gully spatulate at its apex; linear gullies resulting from the development of certain rills.

The configuration of gullies is greatly dominated by the type of surface flow, the presence of human activities on the slopes, and presence of small cracks in the soil that favour piping processes.

The evolution of gullies generally respect the model achieved by Bălteanu and Taloescu (1978):

- The incipient stage of discontinuous erosion, which starts when vertical erosion does no longer change its course from one rain shower to another and gullies cannot be filled up through ploughing (Fig. 6a). Compared to rills, in this case, it appears a succession of thresholds on the longitudinal profile.
- The stage of discontinuous gullies corresponding to the appearance of a catchment basin that contributes to the channeling of the rain water is shown in (Fig. 6b).
- The stage of transformation of discontinuous gullies in continuous gullies is shown in (Fig. 6c).

The most spectacular gullies in terms of length, depth, and shape, located in the area west of Jiu, were found on the left slope of Danube, upstream Hinova, on the right slope of Jiu between

Bralostita and Sfircea, within the Drincea basin (Fig. 7) and along the Slătinic valley, near Plopi settlement (Fig. 8).

The gullies located on the left slope of the Danube were greatly induced by the presence of thick sand deposits and the rapid deepening of the river together with intense lateral erosion it exerted, contributed to the maintenance of a very steep 230 m high slope. In the case of Hinova gully, its apex started at about 250 m; branched at 200 m and then, after a distance of two kilometers, it went 100 m down. The same mechanism acts in the case of the gullies located on the right bank of Jiu, where the river laterally eroded leading to increase of slope declivity, which, in its turn, favoured the appearance and further development of gully erosion processes.

S.A.C. Tâmba made some observations in the Cosustea Hills (Schipoiu, 1982) and it resulted that it was removed a quantity of 16 cubic meters of materials per hectare yearly due to geomorphologic processes. 7,700 ha were affected by sheet erosion, 270 ha by vertical erosion and 1,200 ha by settled and active landslides within the entire region of Cosustea Hills.

The gullies from Drincea and Slătinic basins developed on the background of sandy and loess-like deposits and they were mainly induced by the deterioration of the vegetal cover during summer and the contiguous action of rain showers with high intensity and frequency. We mention Plopi gully as a special case, as it appeared after the 'eruption of a suspended aquifer' that imposed high pressure on the slope, penetrated the covering deposits and, consequently, generated the gully in an extremely short time, about 10 hr (April, 2002).

Gully erosion within the perimeter located between the Jiu and Olt rivers mainly occurred Pliocene deposits (especially Meotian – sands, fine gravels, poorly cemented sandstones with thin intercalations of marls and clays). The erosional processes affect the cuesta areas and head of subsequent valleys in contact area between Subcarpathians and piedmont (Fig. 9). Thus, there appeared large gullies where the respective processes were associated with mass movements, which stressed and diversified them.

The gully erosion of the cuesta slopes was marked by an extremely intense regressive erosion in the head area (the destruction of the second and third scarps of the landslide from Negoiesti due to the development of an about 46 m high head escarpment), which occurred together with its deepening in the slid mass. Thus, there appeared a gully with two heads in the western sector, with regressive evolution, where the channels merged together 240 m away from the slope foot. The length of gully reached 860 m, with maximum width of 112 m. At its base, there developed small alluvial fans that sometimes blocked the riverbed of the stream. In the central part of the slope morphodynamic complex, there developed another two linear gullies, 14 m deep and 740 m long, respectively 625 m long, narrow at the lower part (14-19 m) and



very large in the head area (95-125 m). Due to the undermining of the gully banks, there appeared certain cracks in the slip wrinkles. In the eastern sector, five linear gullies that fragment the slide mass pushed their heads higher till they reached the escarpment. The length of the gullies oscillated between 470 and 560 m and the width between 12 and 74 m (Fig. 9, table 1).

Gully erosion within the Gilort perimeter occur both in Romanian (clays, sands, coal) and Pleistocene deposits (gravels and sands). The most developed gullies are located on the Boia and Mira valleys, while in the south, along the short torrential valleys that fragment the Amaradia hills, between Băcila and Tudoreasa valleys. Important torrential erosion forms also appeared on the right slope of the Gilort, in the catchment basins of Valea lui Căine, Sterpoaia, Daia.

The other area where torrential erosion acted on such deposits is larger and includes the strip of monocline hills from the Giovria and the Bârzei springs, Cărbunesti and Ștefănești hills. In this case we mention even a stronger correlation between torrential and landslide processes, according to the emergence of marl-clayey deposits. Consequently, erosion occurred in two distinct situations. In the first case, torrents deepened only in sands and gravels, while in the second, erosion affected areas characterized by a greater lithological diversity imposed by the alternance between sand-gravel and marl-clay horizons. Gully erosion affect the slopes of the Bârzei and the Ștefănești valleys.

When vegetation covers the banks and bottom of the gully, it transforms into a relatively stabilized form (dale, dry valley). If these conditions modify and the dynamic balance is disturbed, the respective gully will reactivate. Tectonics and relief features often impose the reactivation of certain torrential formations, active gullies being a frequent presence in the landscape of the piedmont.

The slopes affected by torrential erosion undergo certain typology (Badea, 1967).

In the first category, there are included the slopes of the valleys located at the contact with the Subcarpathians, such as the Giovria Valley. It displayed the most characteristic erosion forms holding the aspect of cirques at the head of certain more evolved torrential valleys as the ones tributary to the Giovria (the Bănea and the Fătul valleys). They appeared as circular or semicircular excavations, with diameters oscillating between several tens and hundreds meters, separated by steep, high, vertical slopes. Their development is due to both torrential erosion that undermines the base of the slope and to the almost vertical collapse of poorly or non-cemented sand and gravel deposits. The resulted materials are rapidly evacuated by streams and thus, slope undermining and withdrawal occurred quite rapidly. The appearance of these forms is also conditioned by the monocline structure, as one may notice they are mainly located especially in the areas where the cut off of the deposits occurs.

A comparison between the configuration of the head of these torrential valleys registered forty years ago (Badea, 1967) and presently (field observations and mapping, 2002-2009) reveals that most of the head cirques were relatively stabilized by means of afforestation or dams (Fig. 10).

Presently, modelling action occur more intensely within the middle sectors of the basins, where large landslides are associated with gully erosion. This situation is induced by the change of land use (deforestation for the extension of pasture lands on the slopes of the Giovria and the Cioiana streams), as well as by high intensity or prolonged rains that occurred quite frequently in the last decades and they represent triggering factors for the aforementioned processes.

Another category of slopes display a step profile and they seem more evolved due to the occurrence of small dimension landslides. The head basins displayed lower relief intensity and are less affected by these processes. Torrential accumulations resulted from the discharge of the materials towards depressions (proluviums) and their depositing as alluvial fans or as real strips at the contact with the hills mainly led to the rising of the floodplains and lower terraces.

Gully erosion represents one of the most visible erosion forms, which presently affects extended surfaces of the Getic Piedmont. They are generated by the concomitant action of the lithological, structural (mainly slope inclination and relief intensity), climatic, and human factors. Incipiently, depending on the area, the triggering factor is represented by the climatic conditions (periods of drought and dryness that strongly deteriorate vegetation, followed by rain showers within intensity greater than  $3 \text{ mm min}^{-1}$ ), on the background of a lithological structure made up mostly of friable rocks – sand, gravel, loess. This situation is often noticed in the case of many gully systems from the Drincea basin – Pitulata, Izvorălu de Jos and the Blăhnița basin – Berdincești.

However, there are areas where gully erosion was mainly induced by the slope increased inclination – the scarp of the cuestas from the Danube (Hinova 1, Hinova 2) and from the north of piedmont at contact with the Subcarpathians (Negoiesti 1, 2, 3). These are the most spectacular gullies, reaching more than one kilometre in length and tens of meters in width. They are extremely active and hard to stabilize due to the area structure and lithology, as well as to the climatic features.

Human factor acts especially within the perimeter of lignite and oil exploitation – the Motru, the Amaradia, the Oltet basins, where wastes are affected by intense gully erosion associated with landslides. In this case, slope and lack of vegetation represent the triggering factor. These areas were extremely vulnerable due to the complete lack of natural balance. At a lower scale, the entire surface of the piedmont was affected by gully processes induced by deforestation, overgrazing, building of slope roads (Plesoi, Busu, Corzu), inadequate use of terrains (Podu Grosului) etc. This



represent the triggering factor of gully erosion, but the subsequent evolution of these processes was equally influenced by all the other mentioned factors. However, most of these gully systems are shallow, reaching only an initial stage. Under these circumstances, an adequate management of the affected surfaces would clearly reduce the impact of the processes.

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