LANDFORMS OF ROMANIA – THE SYSTEM OF GEOCHRONOLOGIC EVOLUTION

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Abstract

The corroborationof geomorphological, tectonic and paleoclimatic data led to a geomorphological system with two stages and subdivisions.

The pre-Carpathian stage (Proterozoic-Lower Mesozoic, belonging to Vorland) is characterized by: completing the platform units (E, S) and the Paleozoic rigid geotectonic system of Northen Dobruja; levelling stages resulting in pediplains which were subsequently fragmented and fossilized almost entirely (Central and Northen Dobruja sectors).

The Carpathian stage is defined by: completing the Carpathian orogenic system (between Jurassic and Quaternary) in labile edge sectors of the Eastern European plate in which the evolution of some regional rifts (in Jurassic – Cretaceous) and the moving of some rigid blocks (Moessic, Pannonian and Transylvanian) created sequentially tectonic basins where the accumulated materials were folded, faulted and overthrusted, or mountain systems resulted by lifting (the upper Cretaceous and Miocene); creating tectonic depressions filled with sedimentary formations; reactivating some deep fractures accompanied by volcanic eruption phases and creating a specific relief; the tectonic movements in the upper Pliocene – Quaternary raised differently all geographic units representing the current orostructural system by Carpathians's emersion and join to the adjacent regions; the climate change from savanna (Paleogene) to subtropical (Mio – Pliocene), then temperate and glacial (late Pleistocene) and so on, led to a succession of morphogenetic systems that have generated landforms among which the most representative were preserved mainly as steps, erosion surfaces areas and levels, or terraces from many morphogenetic phases.

Keywords: *leveled surfaces, erosion levels, pediplains, terraces, morphogenetic stages, geochronologic system.*

1. Researching Romania's Landforms – the Main Geographical Direction over 125 Years

The genesis and evolution of terrestrial landforms became a distinct issue of research and interpretation for geologists and geographers, even since the end of the 19th century. The genetic-evolutionary theories were based on landform

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analysis in different regions. In our country, W.M. Davis' theory (1899-1930) of normal erosion cycle was introduced by Emm. de Martonne's studies (1898-1924). During the last decade of the 19th century and the first decade of the 20th century, the French geographer conducted complex investigations in the Carpathians, wrote scientific papers and a geomorphological PhD thesis, considered for its in-depth analyzes, interpretations, graphs and cartographic materials, a model to study and to present a mountain system within the davisian theory. After that, many Romanian and foreign geographers studied the Carpathians, the hills or theplateaus (G. Vâlsan 1915-1942, V. Mihăilescu 1935-1980, V. Tufescu 1933-1970, C. Brătescu 1910-1943,N.Al. Rădulescu 1937, N. Popp 1939-1970, M. David1921-1949, R. Fischeux 1929-2000, A. Nordon 1930, T. Morariu 1940-1970, N. Orghidan 1929-1969 etc.), using mapping and interpreting the erosion surfaces according to geological data, as reliable methods in determining landform formation and evolution.

After 1955, the landforms were studied regionally or entirely, according to many directions required by the need to find the relations with other geographical components, to establish the mutual effects of the impact of anthropogenic pressure and morphodynamics on river beds and on slopes, to specify the morphostructural, morphodynamic, morphoclimatic etc. differences; the previous directions became traditional and important among geomorphologists.

Many geographers made outstanding contributions: Gr. Posea 1958-2013, C. Martiniuc 1956-1980, P. Coteț 1957-1970, Valeria Velcea 1960-2000, V. Gârbacea 1956-1980, Gh. Niculescu 1962-2005 , L. Badea 1968-2010, Al. Roşu 1968-1988, I. Rădulescu 1956, I. Sârcu 1958-1978, V. Băcăuanu 1962-1990, I. Donisă 1965-2000, I. Hârjoabă 195-1988, I. Mac 1966-2000, N. Popescu 1962-2000, N. Barbu 1970-1988, M. Ielenicz 1968-2013, F. Grecu 1992-2013, M. Bleahu 1964-1989, Gr. Mihai 1965-1995, I.D. Ion1960-1990, C. Brânduş 1973-1990, N. Josan 1969-1980, I. Ichim 1979-2010, C. Rusu 2002, E. Rusu 1999, P. Cocean 1988-2010, I. Irimuş 1998, as well as several geologists – V. Mutihac 2004, I. Săndulescu 1984, D. Paraschiv 1965-1966, E. Liteanu and C. Ghenea 1966-1975, I. Povară 2012 etc.

The achievements were the global morphogenetic syntheses, included in geomorphochronologic systems with stages, phases etc., all based on the correlation between the paleogeographic evolution and the resuted landforms (V. Tufescu 1933-1970, P. Coteț 1973, Gr. Posea 1958-2013, M. Săndulescu 1984, V. Mutihac 2004 etc.).

2. The Landforms of Romania – the Result of a Complex Morphostructural Evolution

The Alpine movements were essential in creating the Romanian landforms – the Carpathian system influenced directly or indirectly the neighboring units. According to their evolution and results, there were two morphogenetic stages:

2.1. The Pre-Carpathian (Pre-Alpine) STAGE of structural platforms and oldest lanforms (fundament level, uncovered in Dobruja):

- It had an *essential role* in the formation and evolution of the eastern and southern regions of the Carpathian system.
- It ran from the (especially late) Proterozoic and ended for each region differently (upper Paleozoic or early Mesozoic). At first, there was a series of processes (sedimentations, metamorphoses, folds and lifts) that created a structural system with landforms that were leveled (pediplain) and fragmented tectonically (especially on edges), becoming labile, subject to descents (sedimentation basins) or uplifting (reshaping).
- *Structurally,* some rigid platforms resulted finally, having cut fundaments of pediplain type, covered by sediments (except for Central and North Dobruja) of different thickness, achieved in several cycles. During its formation, in regression phases (dry), some leveled surfaces occured (up to the stage of erosion plains) and than they were fossilized to a new transgression (six in the sediments of the Moldavian Plateau during upper Proterozoic, between Ordovician and Silurian, middle Carboniferous, Triassic, middle Cretaceous, between Badenian and Oligocene, Pliocene; three of longer duration in the Romanian Plain - Carboniferous -Permian, Lias, upper Cretaceous-Badenian).
- According to V. Mutihac (2004), the pediplain at the base of the platform units had a wavy configuration (high parts on magmatic rocks and low parts on less resistant rocks); then it was fragmented tectonically into blocks. Their (labile) edges were included in the process of forming new morphostructural units (in Dobruja, the Carpathians) etc.
- the*present landforms* (plateaus, hills, plains) of these units were formed in different periods, but mainly in Pliocene-Quaternary.
- Depending on *how* the tectonic activities *joined regionally* the landform erosion ones, two morphostructural sub-stages may be separated:

  a) The sub-stage of Proterozoic structures and oldest landforms:

  - It includes *upper Proterozoic* when tectonics (in several orogenetic phases) created a large continental block (Eastern European) composed of rocks with varying degrees of metamorphosis, different magmatic structures and various altitudes. It was a cratonic block, subject to subaerial leveling. The result was a leveled surface of pediplain type (under hot climate and lack of vegetation).

- The *tectonic movements*, while creating cratons, fragmented the platform in late Proterozoic, resulting subunits of different sizes. In consequence, two deep fractures along which tectonic basins were gradually formed (they had different evolutions) separated the microplates – Moessic to the south and Pannonian-Transylvanian to the west (V. Mutihac, 2004). The morphotectonic evolution of this area extended over several periods.

b) The Paleozoic (Caledonian-Hercynic) sub-stage:
These three units had a platform structure and evolved subaerially or were covered by sea on large areas and in different times; their edges remained labile and were flexed or descended slowly in steps, especially toward south, west (the fundament of the Moldavian Plateau) or north (the Moessic fundament). In the sectors covered by sea (epicontinental character) some sedimentary facies occurred, reflecting different influences such as tectonics and morphoclimates for the dry sectors that represented the origin areas for the denudated and accumulated materials.

The morphotectonic evolution of the labile areas (between the plates) was made differently in two phases:

1. The Caledonian phase (lower Paleozoic). It was linked to the basin formed between the Eastern European plate and the west (Pannonian-Transylvanian) unit. Here the Caledonian movements in the lower Paleozoic created the orogenetic system that extended from Central Dobruja to the north-west (probably toward the Baltic shield). The geological maps indicate it certainly as a fallen fundament in north-eastern Romanian Plain (to Trotuş, between the Doruja faults Peceneaga-Camena and Capidava-Ovidiu); the interpretation of data (from geological studies) on the content of some Carpathian and Subcarpathian formations (eg – the elements of green schists in sandstones and conglomerates of Pleşu Peak) led to the idea that the Caledonian Mountains extended north-west, but near the East European plate (it was subsequently eroded, fragmented tectonically and included in other structures).

In middle Paleozoic, the southern mountain system was leveled, resulting a pediplain preserved in *Central Dobruja* (this is the oldest uncovered landform). The erosion under a warm and dry climate (eg Silurian) with little vegetation, favoured weathering and pluviodenudation.

2. The Hercynic phase (upper Paleozoic-Jurassic)depended on the lability existing at the contact between the eastern European Platform and the Caledonian land (the cadomian unit) where tectonics shaped the *Hercynian basin* (from Crimea, Northern Dobruja and the west of the eastern European Platform) that would function as a distinct orogenetic unit in Carboniferous-Permian. This would result in a *continuous mountain system extended to*

Western Europe. It would be *leveled* under a warm and wet climate, with lush forests (in the Carboniferous) and a hot and dry climate (in the Permian). The resulted leveled surface is known in several geographical works to be of *peneplain type*.

The peneplain evolution was different in the units where the Hercynian system fragmented tectonically.

- The *Măcin Unit* remained emerged and suffered permanently small lifts and a *polycyclic and poligenetic erosion*.
- In the *BabadagUnit*, the surface leveling continued until the *Cretaceous when the peneplain was fossilized* by a thick carbonate formation making a broad synclinorium (E-W); it the Neozoic, this land was subject to erosion, but the peneplain was not exhumed.
- In the *Niculițel Unit* from Triassic, a graben-rift appeared in the Paleozoic fundament (V. Mutihac, 2004) where flysch sediments and basalt accumulations occurred (they created a plateau); it was eroded (polygenetic and polycyclic) continuously since the Cretaceous.
- The *Tulcea Unit* was a large epicontinental sea in Jurassic; the landforms formed in Paleozoic (eroded metamorphic and sedimentary old rocks) were covered by limestone formations and emerged in upper Jurassic (the chimeric movements); the current landforms are the result of a long subsequent polygenetic leveling.
- *North of the Danube*, the northern Dobruja hercynian and chimeric formations extended as the fundament of Galați Plain and southern Moldavian Plateau (to the fault Fălciu-Plopeana, according to V. Mutihac); this fundament fell northward and north-westward, being covered by thick (Neozoic) sedimentary formations.

2.2. The Carpathian (Alpine) Stage

– *Its name* is related to the formation of the Carpathians and their role in creating our country's morphostructural system. These mountains have relief steps, as evidence of a complex development on phases and sub-stages. They generally belong to the Alpine geotectonic evolution and to all orogenetic cycles of Mesozoic and Neozoic.

– The *beginning* of this stage is related to lower Mesozoic, when the Tethys basin formed some *regional rifts* (Vardar, central Carpathian, western Transylvanian, etc.). Those were important especially in Jurassic-Cretaceous in breaking and developing distinct structural units. Initially, the *fractures* apperead in the labile areas of contact between blocks, generating a system of paleo-rifts between eastern and southern platforms and the Pannonian-

Transylvanian system. The Transylvanian rift basin was separated into two different entities with different evolutions.

– Within basins, there were sedimentations, foldings, and overthrusts in the crystalline-Mesozoic unit and its emersion (of relatively circular directions around the Transylvanian block).

– Successive development of tectonic depressions outside the crystalline land (Cretaceous-Neogene); different fragmentation and subsidence over time of the Transylvanian block, leading to several sedimentation cycles with various extensions and composition.

– All of these led to:

- developing successively the Carpathian structural units, in connection with the Cretaceous-Miocene orogeneses;
- completing the plateau and hill units due to the Pliocene movements;
- completing the Carpathian system and current altitudes through the Quaternary movements.

– The structural units completed successively by tectonic movements generated by block collision and had several long-term paleogeographical consequences – creating gradually land units that were lifted differently, volcanism and many subaerial leveling cycles. The latter resulted in morphogenetic steps with different extension, morphology, fragmentation and number, according to many factors, conditions and climate evolution (from savanna to subtropical, temperate of various types, cold, etc).

– The results were a *pediplain, quasi horizontal surfaces cutting the main interfluves, glacises, erosion levels and shoulders, piedmonts, terraces* etc. They led to different regional systems in number, age and fragmentation, from the Carpathian units (the most numerous and varied in age, extension, elevation, deformation, subunits) to the plains (with a few terraces).

Connecting the significant elements that define the simultaneous action, but different in time and space of tectonics and subaerial erosion, some different sub-stages and evolution phases of the resulted morphogenetic steps were separated:

a) The sub-stage of the Carpathian erosion surfaces and levels:

- It occured between Cretaceous and middle Pliocene.
- It relates mainly to the Carpathians, where the structural units were formed, emerged and fragmented gradually; the erosion created three complexes of morphogenetic steps (tectonically deformed later), corresponding to the evolution phases.
- The regions surrounding Carpathians lifted (becoming dry surfaces, subject to erosion) or descended (transgressions accompanied by sedimentation, especially in graben-type depressions).

1. The phase of completing the Carpathian pediplain[3].

- In the literature, the resulting step is considered peneplain or pediplain (according to the morphoclimatic conditions).
- Fragments of this pediplain may be found only in the Mesozoic crystalline units at the highest altitudes; it is the first final result of a long evolution (upper Cretaceous-Eocene, but extended in some places until the Oligocene, Gr. Posea et al., 1972).
- There were two intervals with distinct genetic consequences:

a)The rift-basinone(Jurassic- upper Cretaceous) developed in eastern and southern Transylvanian block, a labile contact area with the Vorland platforms; there were sedimentations, magmatism and metamorphoses during rift extension and folds, overthrust, emersions during the Austrian and Laramic orogeneses. The results were the crystalline-Mesozoic land unit (subject to leveling) and, on the other hand, the extent of the tectonic basin on Vorland labile area (with intense sedimentations).

b) Leveling the landforms created by tectonics

- The *erosion* acted on the Carpathian landforms of various heights and composition (sedimentary series accumulated in the adjacent seas, made up of carbonate, marl, clay and some conglomerates) under a warm and wet climate (the red clays resulting from lateritic accumulation on land).

The *result* was a leveled surface (*theCarpathian peneplain or pediplain*[4]) that has been identified and mapped on the highest peaks, as plateaus dominated by residual peaks and ridges. Its altitude varies from one massif to another due to the distortions imposed by the subsequent epirogenetic movements that had different intensity and frequency. As a result: the Apuseni Mountains down to +/– 1600m in the central sector (Bihor Mountains) from 1100 to 1000m in the north and northeast; in the Banat Mountains is at +/– 1400m in Semenic and 1100m outwards; in the Meridional Carpathians, it rises from +/– 1800m (west) to over 2000m (east); in the Rodna Mountains, it is at 1800-2000m; it has low altitudes (below 1000m) in Poiana Rusca (1350m), and peaks Meseş and Plopiş.

- In some Carpathian massifs with several sub-phases of epirogenetic lifting within a single tectonic period, the *leveling in two or three sequences* is indicated by as many morphogenetic equilibrium surfaces (eg they are relevant in the Apuseni Mountains at +/– 1750m, 1600m, 1450m; in the Meridional Carpathians at 2000-2200m and 1800-1900m).

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3 We used the names given by Gr.Posea *et al*. (1972), as they are entitled for generalization at a large scale.

4 These names are related to genesis' specifics; in most cases, we used the name of the place where the respective surface is representative (Borăscu, Farcaş-Cârligaţi, Semenic etc.), or the geological period in which it was created (Eocene).

- The *completion* of these *steps* is linked to a *long geological time* (from *upper Cretaceous* and until *late Paleocene*, but *frequently in Eocene* or *early Oligocene*); it ended when a new orogenetic cycle began (late Paleogene).
- The Laramic tectonic movements caused in the Carpathians and in Vorland some emersions of different extent and duration (Eocene, Oligocene and a large part of Miocene), resulting erosion surfaces considered by many to be peneplains (the Moessia peneplain, the Moldavian Paleogene fossil peneplain, the post-Cretaceous Dobruja peneplain). They also began to create the *Transylvanian tectonic depression* (through the subsidence of some sectors of the fragmented Transylvanian tectonic block) that would be subject to sedimentation in *several cycles*.

2. The phase of Carpathians' structural completing and forming (detaching) the morphogenetic complex „the medium Carpathian surface"

- The *name* is the first connected to the interval (upper) Oligocene - lower Pliocene, when the Carpathians' structure (flysch units, volcanic massifs and tectonic depressions) completed after several phases of orogenetic movements (Savic, Stiric-Moldavian).

Secondly, it refers to the erosion results of some new landforms generated tectonically and successively (the internal flysch in the Savic orogenesis and the external flysch in the Stiric-Moldavian orogeneses); they gradually joined the Mesozoic crystalline massifs (lifted entirely, but also fragmented into sedimentary basins in Badenian).

- *Linking* the two components (tectonics and subaerial erosion) with the results recorded in landforms and the formations of the adjacent sedimentary basins, there were several subphases (lower Miocene, upper Miocene) that created one or two pedimental steps.

As a result, within the peneplain and eroded massifs of the Mesozoic crystalline unit, another important erosion cycle occured, connected with an inclined outward step (+/– 1800m) and shoulders on the valleys penetrating them. The flysch mountains had two situations. There were two erosion sub-phases in the internal unit, and the result would be a system of quasi horizontal surfaces on the main interfluves (at +/– 1750m), continued outwards with slight slopes, but at the same hypsometric level. In the external flysch, the morphologic landscape would be represented by bridges dominated by peaks with many structural influences.

- The *erosion* was done under a subtropical climate (with obvious seasonal variations in thermic and pluvial regime) and therefore the resulted surfaces would be pediments.

The complex of the medium Carpathian surface consists of *one or two steps* located at *medium altitudes*. They were fragmented in Pliocene and Quaternary so that they currently have the appearance of smooth ridges that extend down from the center to the outlying mountains. In the Mesozoic crystalline unit, they are dominated by the relatively steep slopes the peneplain ends with, or lito-structural peaks in the flysch zone.

- *Altimetrically*, in the Apuseni Mountains (Măguri-Mărişel or Țara Moților surface) it extends at 1200-1000m in the central sector, but descends outward to +/-800m; in the Banat Mountains, it spreads at about 1000m in the Semenic Mountains, and 600-800m outward; in the Meridional Carpathians – the Râul Șes complex has two steps and ascends from the west (1400m) to the east (+/-1850m in the Bucegi Mountains); in the Oriental Carpathians, there are two obvious steps (1500 - 1700m in the north, in the mountains made up of Mesozoic crystalline rocks and 1200-1400m in flysch; in the Curvature Carpathians, only in the flysch mountains at 1650-1800m and +/-1400m).
  - The *existence of two steps* in some massifs was determined by the lifting movements in middle Miocene that stopped the evolution started in Oligocene and led to a new sub-phase completed in late Sarmatian.
  - The *regions bordering the Carpathians* subsided gradually with different intensity (a general subsidence in Badenian – lower Sarmatian). The volcanic eruptions created isolated volcanoes and finally an archipelago in the Transylvanian basin and south-eastern Apuseni Mountains.

Dobruja remained a low continental land, entirely subject to erosion until the Sarmatian, when another transgression occured (the limestone plaque).

After the Cretaceous, the Moessic platform emerged and was eroded (by karst processes) until the Badenian, when a new transgression occured and therefore the peneplain was fossilized.

The western regions of the Western Carpathians were covered by sea in Badenian-Sarmatian, having connections with the intra-mountainous depressions (a significant sedimentation).

2.3 The Phase of the Carpathian Border Surface

- The *name* is linked to its extent outside the mountain systems (plateaus or suite of rounded peaks). From here it penetrates the mountains through valley corridors (as upper level or erosion shoulders) or extends on depressions' mountainous edges (mainly tectonic), or on the hill peaks near the mountains (they were land sectors when that surface was made).
- *Duration and evolutive conditions*. It was completed during the Pliocene. It began when the Sarmatian movements weakened (the Moldavian phase), a fact that completed the structure of the Carpathian system and lifted it, breaking the cycle of the Miocene erosion phase. Meantime, the last volcanic eruptions (completing mountain chains or groups of this type) and the Pliocene

transgression in Pontian occured (it had a double role – the base level for all intra- and extra-Carpathian areas, and also regional erosion through "abrasion", especially outside the Carpathians).

- *The phase ended* with the tectonic movements in the latter part of the Pliocene which interrupted the cycle and started the large accumulations of sands and clays in the lakes or seas adjacent to the Carpathians.
- The Pliocene *climate* was *subtropical* and helped *pediment* formation.
- *Extent*. There are many proofs of this cycle; they have different configuration depending on the joint action of external agents, the intensity of tectonic uplift and subsequent fragmentation.

In the Meridional Carpathians, the Gornovița surface is usually at 850-1000m, but ascends on valleys (as erosion shoulders) to 1150m; in the Banat Mountains, it forms the level of peripheral ridges at 400-450m; in the Apuseni Mountains it rises in altitude from 450-600m (Feneş-Deva) outward to 700-900m (as shoulders), inward on the valleys; in the Oriental Carpathians it is located at 750-900m in the Paleogene flysch units, 950-1100m in the Cretaceous flysch units and 1000-1200m in the Mesozoic crystalline unit; in the Mehedinți Plateau it spreads from 400-450m in the region of Gornovița village and 400-600m on the neighboring mountain ridges.

a) The sub-stage of erosion levels and terraces

- The *name* can be correlated with the completion of the morphologic evolution of the last million years prevailing and having complex characteristics in the extra-Carpathian regions.
- *Duration and paleogeographic evolution*. It started in the second part of the Dacian along with the Carpathians' uplift and their adjacent regions that also emerged gradually (definitively in Transylvania, partially in central Moldavian Plateau and western side of the Occidental Carpathians) and their leveling (Dacian-Romanian). The tectonic movements of the Wallachian phase had important morphostructural consequences. The Carpathians uplifted again. There were at least two periods of intense activity (upper Romanian and upper Pleistocene) of uplifts and structure completion for the structural units neighboring mountains (the Depression of Transylvania changed its monoclinic structure in N, NW, SV to an almost circular diapir and then the domes in its center; a huge NW-SE monocline resulted in the Moldavian Plateau; in the Subcarpathians, the folded subunits formed two alignments, alternating with the monoclinic structures; in the Getic Plateau and the Banat-Someş Hills, the monoclinal arrangement turns into a tabular one outward; the last volcanic eruptions (resulted in isolated basalt structures) and the compensatory local or regional subsidences (in some depressions and some large areas of plains) kept lacustrine or marsh environments until the Holocene. The evolution of the external agents was performed under conditions that went from subtropical to

temperate or glacial cold climates with nuances of continentalism. There was a sequence of longer or shorter erosion intervals according to the climate variations, reflected in the genesis of some landforms as glacises, piedmonts and then terraces.

There were two separate phases according to the erosion characteristics.

1. The stage of carving the erosion levels

- *Name*. The erosion results are various, but the erosion levels are much more common in both the Carpathians and the adjacent hills.
- *Duration*. The correlation of the resulted landforms and the structural and tectonic data and sedimentary deposits indicates the period Dacian-lower Pleistocene.
- *Erosion characteristics*. On the one hand, the tectonic mobility (saccadic uplifts of different regional intensity) facilitated to achieve two (sometimes three) erosion levels reflected in the setting of secondary peaks in the Carpathian valleys and hills and, on the other hand, a generalized erosion in Transylvania (that was a plain slightly raised by emersions, forming its first hydrographic system) and on the contact strips with the mountains. The more pronounced uplifts in late Pliocene (especially for the Meridional Carpathians) correspond to the accumulation of the "Cândeşti formation" (a mass of gravels and sands that make up the Getic Plateau and the similar strata accumulated in the subsident plains).

The landforms evolved under a subtropical climate, favorable for pediments and piedmont plains.

- The *extent* of the resulted *morphogenetic steps* reflects both the conditions generated by tectonics and the regional influences of their manifestation.

In the Oriental and Meridional Carpathians, there are two erosion levels on the main valleys. They descend altimetrically from central to border in the mountains (+/– 1000m and +/– 750m, to 700-750m and +/– 550m) where form glacis surfaces (700m and 550 m). In the Occidental Carpathians, their altitude is 350-450m, dominating the terraces.

In the Subcarpathians, the levels coming from the mountain area continue along the main valleys; on the secondary valleys, there is only the lower level, connecting with the origin basinets. They have different altitudes because of the local rises (on anticlinal axes) in upper Pleistocene, the lithological differences and the fragmentation following the morphological processes. They generally descend from +/– 700m and 550 m (near the mountains) to 450-500m and 200-300m outward (the lower level extends to the Curvature Subcarpathians in the Cândeşti formation, where it is not deformed).

In the Moldavian Plateau it is located at 400-500m as patches on the main interfluves of a glacisplain (V. Băcăuanu, I. Donisă), then as shoulders on the main valleys and origin basinets, strongly eroded by landslides and torrents.

In the Hilly Depression of Transylvania, the researchers indicate either (Gr. Posea 1969) a higher level (that goes from +/– 500m in southwest and 650-700m in east and south) and a lower one (at 350-450m), or three steps (M. David, 1945, but also in various PhD theses) within the same hypsometric range, all named after the places where they are clearly noticed. They form glacises or erosion piedmonts near the mountains. The monoclinal structure units are influenced by them, while the Pontian formations are intensely eroded by landslides, torrents and rainwash.

There are two steps in the Banat and Someş Hills, the upper one (300-450m) at the level of interfluves, and the lower one as valley shoulders strongly eroded by torrents and landslides.

There is usually a single accumulation level on the interfluves of the Getic Plateau. It represents a fragmentation rest of the lifted Villafranchian piedmont plain.

In the Dobruja Plateau, the polycyclic and polygenetic erosion affects the entire area (including the southwest sector, affected by abrasion and lacustrine processes in Pontian-Romanian). A low plateau (below 300m) was eroded, having a complex lithologic structure. It was located between the silting Getic lake (W) and the Black Sea area (E).

2. The phase of Quaternary erosion (of terraces, flood plains and completion of the current landscape composition)

• Its *name* results from the correlation between the created landforms (spread over all relief units), and the local or regional ones generated by various factors, resulting in distinct morphological landscapes that complete the system acquired over the geological evolution.

• *Duration*. They were created during the last million year (middle Pleistocene - present) through an evolutionary joint of tectonics (epirogenetic movements and folds) with marine and lacustrine level fluctuations and a diversified exogenous agents and processes, according to the general climate changes or local petrographic, structural or anthropic (latest centuries) changes.

• *The paleogeographic evolution and the resulted landforms*

The *tectonic movements* of the Wallachian stage continued but with variable intensity over time (there are saccadic uplifts of maximum intensity in the second part of the Pleistocene, giving the current altitudes) and regionally (local morphostructural consequences as folding layers to vertical, subsidences, diapirism etc.). The piedmont plains lifted and the Getic lake disappeared, facilitating the creation of piedmont plateaus subject to subsequent fragmentation, and of some plains (glacis, terrace, subsidence, tabular plains) with different altitude and morphology according to their genesis.

The *climate changes* occurred gradually turning from a subtropical climate with continental shades in middle Pleistocene into a temperate one, with cool polar and temperate periglacial variations in upper Pleistocene, and finally a temperate climate with temperature and rainfall oscillations in Holocene.

The *Black Sea level fluctuations* had regional effects on a low plateau (or an erosion plain) multi-structurally continued eastward through an extensive shelf. There are obvious effects of these oscillations on the coastal morphology during the last millennia. They were the result of moving from one shore of regression accompanied by the coastal plain's expansion eastward (upper Pleistocene and lower Holocene) to one of ingression (oscillating) with bays, delta, lagoons, cliffs, narrow beaches and so on (the last two or three millennia). Dobruja's morphology was completed by the Danube Delta and a river-lagoon plain, which are its newest units. They were created by a combination of effects imposed by a significant contribution of fluvial and alluvial materials carried by permanent marine currents (N-S) with no tides and a extended shelf located at shallow depths.

The fluvial landscape

The terraces have the largest extent, being represented differently on valley generations. Along them, the terrace system is dominated by the Pliocene erosion levels and shoulders. Their number, physiognomy, extent, and age are frequently evaluated in the literature on valley generations and regional morphogenetic systems with several characteristics:

- there are 6-8 terraces at altitudes 5-160 m on the main valleys (in the Carpathians, Subcarpathian, hills and plateaus);
- their number drops to 2-5 in the Getic Plateau, Western Hills, southern Moldavian Plateau (below 160m), 1-3 in high plains (<20 m), Dobruja (1); there are no terraces in subsidence areas;
- along the Danube, there are 8 terraces in Buziaş-Vârcioroaia gorges, then 5 in Oltenia, 4 to Argeş, 3-1 to Brăila (according to the gradual withdrawal of the Getic lake eastward and setting the course of Danube). Similar situations are along the valleys crossing the Carpathian area. There is a decrease in the number of terraces (from 6 to 1) and gradually losing in the high plains, glacises or disappearance in the subsident plains.

In general, their dimensions and extent vary with the valley generations (extended for the old ones, narrow for the recent ones), age (extended for the upper Pleistocene and very fragmented for the previous ones), the role of tectonic movements (narrow and distorted in areas affected by uplifts, and missing in the subsident ones) etc.

The largest terraces are in the hills, plateaus, intra-mountainous depressions, high plains and at relative altitudes of maximum 60m.

The smallest terraces (strips or patches) are in the gorges, the relative altitudes above 80m and along the valley sectors made up of high resistant rocks.

– They are genetically related to the role of climate oscillations (they are parallel) or tectonic movements (deformed where they were raised or lowered) or their combination along large valleys (sectors with convergent, parallel, divergent extents).

– Structurally, the alluvial terraces have bridges covered by alluvial fans and colluvial deposits; locally, there are also rock terraces (in the Carpathians and Subcarpathians, in the areas made up of hard rocks or where the uplifts were frequent) and alluvial terraces (gravel layers).

– The age of the terraces was appreciated by various authors on the basis of several criteria, resulting three chronological marks (30-35m Wurm terrace; 60-65m middle Pleistocene, 90-115m lower Pleistocene terrace) that defined the general or regional morpho-chronologic systems (N. Popescu *et al.*, 1972).

- The *flood plains* belong to the Holocene and have a significant extents on the valleys in the plains (especially in subsident sectors), plateaus, hills or depressions (they have one or two steps at 1-3m or 5-6m). There are no flood plains along gorges or they are small in the mountains. The subsidence plains develop complex alluvial layers with flood plains of various functionality. During the recent decades, the flood plains were changed by hydroelectric or hydro-ameliorative constructions (Danube, Olt, Jiu, Argeş, Bistrița etc.).
- The *glacises and alluvial fans* have a significant frequency at the contact between mountains, hills and plains, or depression edges. They are stacked alluvial deposits (gravel, sand, clay lenses) covered by loess deposits. They get lost in the general level of plains or depressions and sometimes they are cut by the rivers that created them.
- *Other landforms*:
  - ◊ ***The glacial landforms*** were created under the cold, glacial climate (upper Pleistocene) on the Carpathian ridges (above 1750m), during 1-2 phases (or glacial stages).
  - ◊ The structural and lithological variety facilitated the creation of many specific landforms (sometimes even different landscapes).
  - ◊ The active morphodynamic slopes favored a variety of landslides (especially in the hills) that frequently changed the respective landscape physionomy.

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