

THE GREAT MORPHOSTRUCTURAL SYSTEMS IN ROMANIA

MIHAI IELENICZ¹, SMARANDA SIMONI²,
LUMINIȚA SĂFTOIU³¹

Abstract

On a global scale, the present relief is the result of a long tectonic evolution that started in the Precambrian by the dynamics of various lithospheric blocks. The tectonic events in the southwestern East-European Platform (generated by the Precambrian orogenies) influenced our country landforms. Blocks (partially emersed microplates) detached from its labile edge. Marine basins (with different sedimentation in time and space), deep faults, rifts, subduction alignments and finally orogenetic systems, post-tectonic depressions, volcanism and dry land units evolved between these blocks. They gradually merged by both tectonic influences and accumulation of eroded materials from the surrounding continental areas. In time, the selective denudation of the land units created characteristic landforms. Various types of leveling steps were preserved, being related to the long pre-Quaternary periods, and then to the various Quaternary landforms. They are all part of three major morphostructural systems resulted in different stages.

Keywords: tectonics, morphostructures, structural and tectonic plates, geomorphology, relief steps, paleogeography.

1. General Data

On a global scale, the present relief is the result of a long tectonic evolution that started in the Proterozoic by the dynamics of various lithospheric blocks (from macroplates to microplates). The tectonic events occurred in the southwestern East-European Platform or plate (generated by the Precambrian orogenes, and mainly composed of mesometamorphic and magmatic rocks) influenced our country landforms. Blocks (partially emersed microplates) detached from its labile edge. Marine basins (with different sedimentation in time and space), deep faults, rifts, subduction alignments and finally orogenetic systems, post-tectonic depressions, volcanism and dry land units evolved between these blocks. They gradually

¹ Prof. PhD, Faculty of Geography, University of Bucharest.

² Lect. PhD, Economic Sciences Faculty, University of Pitești.

³ PhD st, Faculty of Geography, University of Bucharest. Contact e-mail:
luminitacostina@yahoo.com

merged by both tectonic influences, different in type and intensity (side collisions and significant lifts) and accumulation of eroded materials from the surrounding continental areas (depending on the morphoclimatic systems).

The selective denudation of the land units depended on morphogenesis and created characteristic landforms in time. At first, some various types of leveling steps were preserved (from patches or plateaus, from alignments of ridges and peaks etc.); that may be related to the long pre-Quaternary periods, and then to the various Quaternary landforms (from the erosion shoulders, glacis, pediments, fluvial, glacial, periglacial, coastal, or karst landforms, etc.). They resulted in different stages, being all part of three structural systems; they may be labeled using the tectonic and structural terminology, or their morphological characteristics.

This synthesis is based on the research results of some renowned and experienced geologists (N. Oncescu, I. Băncilă, Emilia Saulea, M. Săndulescu, V. Mutihac, S. Airinei, B. Ionesi etc.) and on the ideas developed by the geomorphologists (Emm de Martonne, G. Vâlsan, V. Mihăilescu, M. David, A. Nordon, Gr. Posea, Gr. Pop, P. Coteț, Gh. Niculescu, V. Velcea, I. Băcăuanu, I. Donisă, N. Popescu, M. Grigore, M. Ielenicz, etc.) in their PhD theses, palaeologic papers or geographical studies.

2. The Major Morphostructural Systems

There are some global opinions (stated in recent decades) on the formation of the major structural systems of Central Europe, based on plate tectonics (also expressed through drawings and maps). These are the fundamental works of the geologists M. Săndulescu and V. Mutihac, and the geographer Gr. Posea. The first two authors reported the major tectonic events to the main structural units within an extremely wide area (between the East-European Proterozoic Platform and the Alpine and Hercynian structures to the south) and named it the Carpathian system or the Carpathian-Balkan system (the Carpathians, Pannonia, the Transylvanian Basin and the Balkans). The last author (refers only to the Romanian territory) separates the Carpathian mountain range as a system and its adjacent units (whose structure and evolution were influenced by the Carpathians in the Neozoic), given the association between the morphogenetic and tectonic effects.

There are some elements used to separate the major morphostructural systems (Figures 1, 2, 3):

- following the dynamics of the tectonic factors that determine, in time, the major structural units;
- the way in which their composition, structure and evolution combine in time and space;
- the morphological post-tectonic evolution resulting in landforms, many of them of phylogenetic and polycyclic nature, epirogenetic movements and different morphoclimatic denudation.

The analysis of geological and geomorphological materials allows us to understand (from general to particular) how the orostrucutural systems developed in Romania (and in Europe), from the point of view of global tectonics (*Figures 1, 2*).

The first mentioned criterion leads to three phases of major tectonic influence:

- Proterozoic – Upper Paleozoic when the platform system and oldest landforms developed;
- Mesozoic – Pliocene when the Carpathian system and old landforms developed;
- Pliocene – Quaternary when the morphostructural system developed between the previous ones, under active erosion, epirogenetic conditions and various climates (from subtropical to cold, glacial and periglacial, and finally tempered climates of various shades).

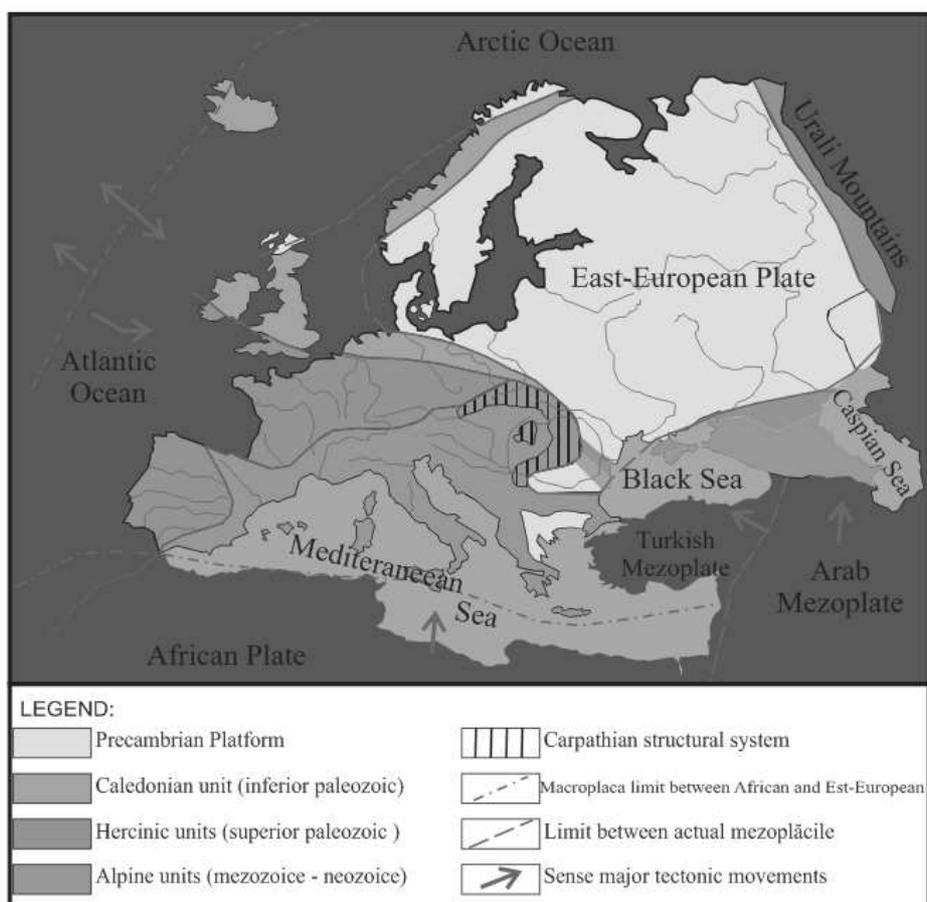


Fig. 1. Europe – The Structural Units

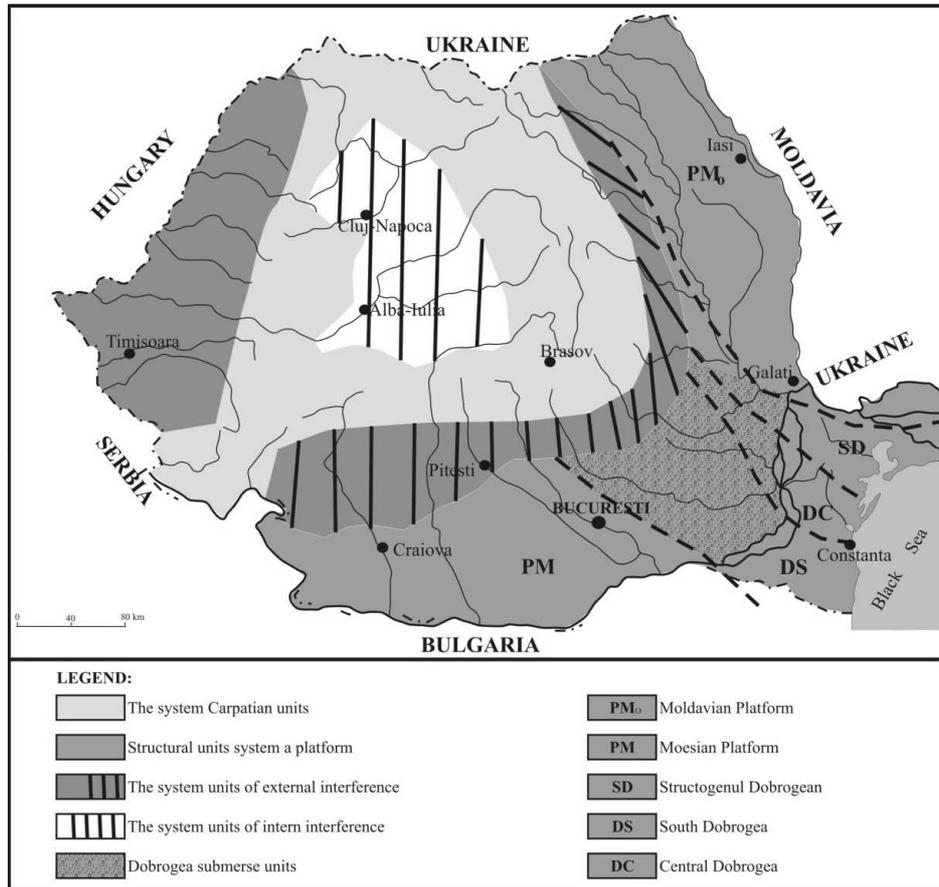


Fig. 2. Romania – Orostructural Constitution in the Carpathian System

2.1. The Platform System

The platforms lay in eastern and southern Romania. They resulted from the tectonic combination of the East-European Platform (Proterozoic) with the blocks (Southern Dobruja and Moesian) detached from its edge (Upper Proterozoic). The two units completed structurally in Lower Paleozoic (Caledonian in Central Dobruja) and Upper Paleozoic (Hercynian Northern Dobruja) in basins of rift and subduction evolution, extending westward and north-westward Europe (Figure 3). They gradually became rigid and evolved regionally by tectonic fragmenting, lifts (emersions and denudation) or falls (sedimentations); there was an overall advance of different rhythm and intensity

toward the subduction areas. The landforms resulted successively (plate tectonics of southern direction at that time), had different resistance on contact edges, and consisted of ridges with various altitudes from eastern to western and north-western Europe. The land was intensively eroded under warm and wet climates, lacking of vegetation (until the Carboniferous), resulting erosion plains (smooth on soft rocks, or with hillocks and rounded ridges on magmatic rocks). They were called in the literature "the pediplain of the Moldavian crystalline fundament" (Upper Proterozoic in the Moldavian Plateau, fossilized by thick sediments; it descends toward the Eastern Carpathians and southward), the Moesian pediplain (the foundation of the Romanian Plain and Southern Dobruja; Upper Proterozoic – Lower Paleozoic; fossilized, with northward steps), the Casimcea pediplain (Paleozoic, emerged, with Mesozoic limestone outliers), the post-Hercynian pediplain (Northern Dobrogea, Permian – Mesozoic; fossilized in some subunits, having a polycyclic character). All are faulted, descending in steps west of the Danube and covered by thick sediments.

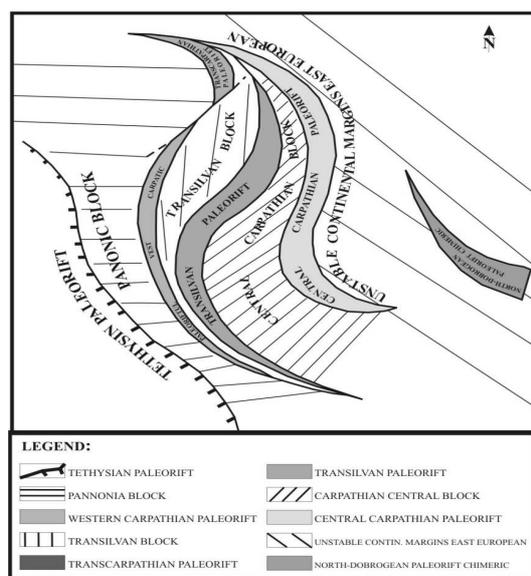


Fig. 3. Paleozonne of Rift (after M. Sandulescu, 2000)

At the end of the Paleozoic, the rigid units of Dobruja and the Moesian land joined the East-European Platform; they continued westwards with submerse sectors and low lands of unstable nature. So that was the moment when the relatively rigid platforms completed; their subsequent evolution would be dominated by two factors – a weak tectonic of dominant epirogenetic

character, flexures toward the adjacent marine basins, many sedimentary cycles alternating with emersions.

2.2. *The Carpathian System*

This stage began in the Triassic, correlated with the tectonic system Tethys – Paratethys between the African and European plates, and the beginnings of the North Atlantic rift. The general tectonic pulses sent from the south and west created the unstable Paratethys (fragmented sectors of the Proterozoic plate edge, but also Caledonian and Hercynian areas, emersed and submerged, faulted and levelled) and dynamic sectors with rifts or regional subduction, folds, thrust-sheets and successive emersions; the resulted landforms were hilly and mountain ridges and tectonic depressions filled with sediments. There were different genetic processes in time, leading to two sub-phases:

The sub-phase of extending tectonic basin and submerged relief included the unstable area between the rigid structural platforms of a tectonic depression with subsequent complex evolution (rift extensions, restrictions by subduction, underwater landforms, magmatism etc.).

After M. Săndulescu (1984) and V. Mutihac *et al.* (2003), the rifts occurred and gradually evolved in the Mesozoic, having various dynamics according to the regional structural and tectonic conditions in the basin (*Figure 2*).

In the Triassic, the following rifts developed: Transylvania and Vardar (in eastern and southwestern Transylvanian and Pannonian and northern Moesian block), and Niculițel in northern Dobruja (the plateau of ophiolites and some magmatic bodies are the proofs). They occupied an unstable area between the East-European (N) and the Moesian (S) plates, while their rigid edges faulted into steps (relatively parallel, affected by subsidence, probably related to subduction contacts).

Their evolution created a complex Carpathian basin where:

- metamorphic and old magmatic formations regenerated;
- sediments, eruptive materials and new magmatic materials accumulated;
- folds, submerse ridges and partial emersions.

In the Jurassic, the previous rifts closed partially and other rifts occurred (central-Carpathian, western Carpathian, Transcarpathian) and their evolution – including the Cretaceous – led to:

- the crystalline-Mesozoic units of the three main Carpathian groups (complex structure in sheets; fragmentation and emersion after the Austrian and Laramic orogenesis;
- the two morphostructural sectors of the Apuseni Mountains: crystalline with thrust-sheets, blocks separated by grabens with sedimentary and Cretaceous magmatic rocks, in the north; a combination of crystalline

- blocks with units of extended ophiolites, post-tectonic depressions filled with Mio-Pliocene sediments and Neozoic eruptive massifs, in the south;
- the Pannonian block separated from the Transylvanian one; the Apuseni Mountains formed between them, as a tectonic structural system determined by the evolution of the western Carpathian rift and the tectonic influences from Pannonia, Vardar and Transcarpathia;
- the Carpathian basin developed eastward by including subsident sectors from the unstable area and East-European Platform. The thick flysch formations would accumulate and fold (Upper Cretaceous, Paleocene, Miocene); they directed from west to east sheets and gradually emerged as massive parallel rows from north to south.

In the Neogene, 2-3 phases of volcanic eruptions along some deep fractures of the rift alignment (central Carpathian, Transcarpathian) generated the system in the Eastern Carpathians.

The sub-phase of the Carpathian orogeny and leveling steps started in the second part of the Cretaceous and continues today, having several morphogenetic characteristics:

- The transition between a tectonic basin (with significant role through rifts) to an orogenic system (highly active in Upper Cretaceous-Miocene), with emerged landforms subject to (in time and regionally) different denudation of the exogenous processes and a tectonic background dominated by regional folds and general epirogenesis.
- The Carpathian system developed especially during the Austrian and Laramic orogeneses (the crystalline-Mesozoic units), the Savic, Stiric and Moldavian orogeneses (the flysch units), as tectonic and structural assemblies. In time, some were divided into subunits of horst or graben type (Upper Cretaceous, Badenian, Pliocene).
- The landforms resulted from orogenesis and lifts were completed in Mio-Pliocene by volcanic massifs (2-3 phases of volcanic eruptions) in southern Apuseni Mountains and west side of the Eastern Carpathians.
- From the Upper Cretaceous when the first stable landforms formed in the Carpathian system until the Upper Pliocene when the subunit formation completed, there was a long denudation activity determined (in many morphogenetic phases) by groups of morphosculptural and tectonic factors. They define cycles of different duration and therefore various leveling steps.
- Their study (especially in PhD theses or geomorphological syntheses) revealed several morphogenetic types: a *level of peaks and crests (gipfelflur)*, *leveling surfaces of pediplain (peneplain) type* on the main ridges with altitudes above 1,600 m; *erosion levels and erosion shoulders* on the secondary ridges of the main river basins, *alignments*

of parallel ridges on the morphostructural contacts (morphogenetic borders), *piedmonts, glacis, terraces* etc.

- The resulted steps (*Table 1*) differ *genetically* and *physiognomically* (plateaus, crests, alignments of peaks, smooth ridges etc.) and have different *altimetric* position (due to some local or regional lifts or falls of various intensity, resulting in altimetric differences of hundred meters); *the lithostructural heterogeneity* generated differences of ten meters due to different erosion according to rock resistance; *the degree of fragmentation* facilitated by age differences and the ratio between the attack of external agents and the characteristics of rocks, structures, morphometry of each landform etc.); *the age* – those old pre-Quaternary steps were subject to denudation in cyclic morphogenetic systems, and hence their polygenetic and polycyclic character; the Quaternary steps are mainly monogenetic, with few significant changes).

2.3. The Contact Morphostructural System between the Platform and the Carpathian Orogeny

The position, composition and evolution of the Carpathian Orogen reflect the transition between the two distinct types of systems. It developed in the unstable areas of the East-European Platform and of some Paleozoic structural units, where the influences of plate tectonics were weaker and the epirogenetic movements were dominant.

They extend outside and inside the Carpathian system, having a few *common elements*:

- the foundation is a Proterozoic platform (mesometamorphic and magmatic crystalline schists), fragmented into blocks located at different depths;
- a sedimentary cover with formations from more old (discontinuous patches from the Paleozoic and the Mesozoic) and new cycles (the Mio-Pliocene are at surface);
- a network of fractures, gradually formed from Upper Proterozoic to Lower Neozoic. It was first generated by rifts and regional subductions (between the East-European Platform and the structural blocks detached from it) and then by subductions resulted from the regional collision of blocks (determined by the movements of the European and African macroplates and global rifts);
- a landscape of plains, plateaus and hills created mainly in Romanian-Quaternary.

The regional differences are:

- the transformation degree of the crystalline foundation through tectonic evolution (until the Lower Neogene);

- the variation of materials brought from the Carpathians and their type; these sediments accumulated in Neozoic basins;

The diversity of neotectonic impulses they received from the Carpathians in the Neozoic was reflected in:

- various effects on the areas adjacent to mountains (secondary morphostructural units as monoclinical plateaus, hills and depressions on diapir or folded structure, especially in Transylvania or the Subcarpathians);
- emersions in distinct phases in the Pliocene and Quaternary (Dacian in Transylvania and Western Hills; Dacian – Villafranchian in the Subcarpathians; Pleistocene in the Western Plain and much of the Getic Depression);
- local subsidence resulting in rich accumulations of Carpathian materials (the Getic Depression and the Western Plain).

There were separate evolutive stages, as the results of genetic factors (especially the tectonic ones) generated distinct structural units:

- the stage (with more phases) of the platform system (about 2 million years) had several components in Upper Paleozoic (the East-European Platform, blocks from the Caledonian and Hercynian systems, the Moesian Platform); they were rigid, but reunited and the denudation (in time) reduced them to the pediplain stage.
- the stage of platform tectonic fragmentation, of Paratethys formation and evolution as a separate unstable structure (Triassic – Paleocene, about 250 million years). Between the rigid Mesozoic units (Pannonian-Transylvanian, Moesian, Dobruja and East-European Platform) there was a submerged tectonic area that would be basin of the future Carpathian system. The tectonic factors developed rifts (resulting in oceanic foundation) and crystalline-Mesozoic Carpathian units with sheet structure and subduction (both oceanic and unchanged platform foundation), secondary structures (hosts and grabens, emersions) subject to denudation and material production to be carried in submerged areas. The general evolution of this stage had some results:
 - the Carpathian structural units had curved direction due to the old and rigid blocks (in the north-east, Vrancea-Buzău; Banat-Timoc; Deva-Turda);
 - the Transylvanian block (east) separated from the Pannonian block (west) by the Drocea-Trascău unit;
 - some subsident tectonic basins (flysch, molasse) extended at the expense of some unstable edges of the platform.
- the stage of the Carpathians' influence on the structural completion of the system belonged to the Neogene and Quaternary (about 23-25 million years) when the general structure of the Carpathian system ended. It would influence differently, regionally and temporally, the suite of processes

imposed by the morphogenetic factors in the adjacent units. There were two sub-phases, different in dynamics and results:

- Mio-Pliocene with a separate evolution of the Carpathians (in development and lifting) and border regions (mainly subsident). Faulting, folding, overthrust and lifting occurred in the Carpathians, different in intensity in the flysch and molasse units; fragmentation in the crystalline units, with horsts and graben depressions, 2-3 phases of volcanic eruptions that created single massifs or systems of massifs; morphosculptural cycles reflected in complexes of leveling surfaces, etc. Rich materials of Carpathian origin accumulated in the adjacent units; there were general transgressions in Badenian-Sarmatian and Pontian;
- Romanian-Quaternary with a common evolutive character. The Carpathians completed their structural units tectonically, reaching their current altitudes, landscapes, system of valleys and morphogenetic steps. Their influence on the adjacent areas was related to directions – the source of the materials carried by rivers, the epigenetic movements and evident structures on contact sectors. Their erosion would be influenced by the regional level of the neighboring regions. The tectonic movements in the Wallachian phase produced a total lifting of the extra-Carpathian regions, different regionally first in intensity (from several hundred meters to more than 1,000 meters) and then in rhythm (intermittent character), determining more cycles of leveling (reflected in erosion shoulders and levels, terraces); there were also local subsidences and lifts of the Miocene salt blocks (in Transylvania and the Subcarpathians) resulting in diapire folds; other folds occurred in contact areas of subsident nature (in systems ranging from simple to faulted folds and sheets in the Subcarpathians).

In brief, there are four large units forming the transition system, each having certain characteristics (*Table 1*):

Table 1

The Morphostructural Units

Structural characteristics	Morphostructural characteristics
<i>The Hilly Transylvanian Depression – Hinterland</i>	
<ul style="list-style-type: none"> - intermittent lifting of different intensity; - final emersion in Dacian; - Neogene sedimentary superstructure (several series of various thicknesses – sandstone, marl, clay, tuff, and sand layers of Carpathian origin) contained in structures determined by the tectonic lift of the surrounding Carpathian massifs and the Miocene salt blocks; - Proterozoic platform foundation, 	<ul style="list-style-type: none"> - structural landforms; - massive landslides; - piedmonts, glacis, terraces (2-8 steps); - two-three nival cycles (Dacian-Romanian); - landscape with plateaus, hills, depressions; - leveling to the stage of pediplain (fossilized at various depths); - partial leveling of the Mesozoic and Neozoic sedimentary.

<p>fragmented into blocks arranged in different alignments, at depths of 1,500-7,000 m. They belong to the Transylvanian block; deep fault contact with the Carpathian massifs (V. Mutihac);</p> <ul style="list-style-type: none"> - Mesozoic sedimentary patches; - tectonic evolution under the impulses generated by the Mesozoic rifts and subduction areas. 	
<i>Western Plain and Hills</i>	
<ul style="list-style-type: none"> - intermittent lifting of small intensity (east), subsidence (west); - emersions in the Romanian (east), and the the Pleistocene (west); - sedimentary superstructure whose thicknesses grows westward; Quaternary Panonian and Badenian sheets on top of Carpathian origin. 	<ul style="list-style-type: none"> - landscape with monoclinal hills and eruptive or crystalline hillocks; - low, swamp (subsident) plains westward and high plains (glacis) eastward; - 1-3 terraces on the main rivers in the hills and extensive meadows; - the materials transported by the Carpathian rivers created alluvial cones (glacis) at plain contact;
<ul style="list-style-type: none"> - mixed foundation (Carpathian eastward, Proterozoic platform westward) of blocks separated by the specific fractures of the two structural systems; - tectonically completed in the Proterozoic, fragmented and changed eastward in the Mesozoic. 	<ul style="list-style-type: none"> - the platform units were pediplains (subsequently deformed and fossilized); during the Neozoic emersions, they generated erosion plains; - the Romanian emersion generated an erosion level in the hills.
<i>The Subcarpathians and The Getic Piedmont</i>	
<i>The Moldavian and Curvature Subcarpathians</i>	
<ul style="list-style-type: none"> - sedimentary of molasse type, made up of Carpathian materials; the tectonic pressures on mountain contact and the salt tectonics led to monoclinic and faulted (simple faults, diapire) structures, significant lifting and seismic activity; - gradual emersions gradually from north to south and from the contact with the Carpathians outward; - formed in avant-fossa, on a platform foundation (Moldovian and Dobrujan), subducting the Carpathians; subsident Miocene basin, differently affected by the Wallachian movements. 	<ul style="list-style-type: none"> - landscape with hills (intense slope dynamics), depressions and valley lanes (deformed terraces, intensive river bed processes); - structural and petrographic landforms; - two-three erosion levels of erosion in Villafranchian – Lower Pleistocene.
<i>The Getic Subcarpathians and the Getic Piedmont</i>	
<ul style="list-style-type: none"> - the sedimentary is thick and has a Carpathian origin (heterogeneous and coarse at the base, dominant sandy-clay on top); piedmont gravel accumulations in Villafranchian; - emersions in Lower Quaternary as a reflection of mountain lift and salt dynamics; They were formed in the Getic Depression, created by tectonics in Upper Cretaceous, at the contact between the Meridional Carpathians (still forming) and the Moesian (Proterozoic) 	<p>The landscape of the Subcarpathians is dominated by hills (some with obvious structural characteristics) and structural and contact depressions (created by tectonics and erosion: folded and monoclonal units, diapires with very active slope and river bed morpho-dynamics). The Getic Piedmont has a monoclinal structure, with flat interfluves and hills; the slopes are intensively eroded by landslides, rills, torrents; the river beds have rich accumulations.</p>

<p>Platform, fragmented into blocks (with posttectonic sedimentary) falling northward. The Cretaceous Laramic movements transformed tectonically the edge of this platform into the Danubian Autochthonous, covered by the Getic Sheet. The depression formed outside of it (probably as a reflection of the tectonic push of the Carpathian system). It functioned as a sedimentary, subsident basin in the Neozoic. The basin extended southward in the Pliocene, while emersions and folds occurred in the north as an effect of the Meridional Carpathians lifting, separating the two units structurally and morphologically.</p>	
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