THE CARPATHIAN RIVER SYSTEM IN ROMANIA – GENESIS AND EVOLUTION

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The present Carpathian valley network is the result of a long and complex process synchronous to the evolution of the Carpathian orographic system during the Cretaceous – Quaternary period. Among other issues, this study focuses on the genesis of the great defiles shaped by the rivers that cut across (partially or totally) the mountains (the Danube, Olt, Jiu, Prahova, Crişul Repede, Bistriţa, Trotuş, Buzău, Mureş, Someş, etc.), also explaining lower-order valleys, of limited length (the Bistricioara, Ilva, Tazlău, Teleajen, Cuejd, Strei, etc.). The specialist literature contains a diversity of opinions on two evolutionary concepts – antecedence and stream piracy, but the conclusions have not always been accepted. In establishing the formation stages of different generations of Carpathian valley systems, some general conditions have been taken into consideration (formation of the mountain system by tectonic movements; the evolution of marginal base levels, significantly influencing the intensity of linear and headward erosion; the orographic structure – a relatively ring-like mountain system built of groups of massifs and tectonic basins; the evolution of morpho-climatic systems). At the same time, some regional conditions (partial or total transversal corridors, erosion levels and terraces along the valleys, piedmont glacis, etc.) have been taken into account. The analysis of these elements allowed us to highlight two main evolution stages: Miocene – Middle Pontian (preserving the traces of the oldest valleys) and Dacian – Holocene (when many different generations of valleys were formed, preserving the most numerous morphological evidence), revealing the formation by antecedence and superposition of defiles and gorges, of the four generations of the valley system, and their varied local structure determined by tectonics, volcanism, geological patterns and changing role of the base levels.

1. GENERAL FRAMEWORK

The formation of the drainage network in Romania, and especially in the Carpathians (where at least four generations of important valleys can be identified) has focussed the attention of Romanian and foreign geologists and geomorphologists for over 130 years now. On the basis of field mappings (terraces, erosion surfaces, etc.) and analyses of sedimentary deposits of the inner and outer Carpathian basins (paleogeographic interpretations) arguments were brought in support of the genesis of some Carpathian valley sectors. The most circulated ideas refer to the formation of the great defiles shaped by the rivers (partially or totally) deep cutting across the mountain system (the Dunăre, Olt, Jiu, Prahova, Crişul Repede, Bistriţa, Trotuş, Buzău, Mureş, Someş, Crişuri, etc.), and explain the formation of some limited sectors (the Tisa, Vişeu, Iza, Bistricioara, Ilva, Tazlău, Teleajen, Cuejd, Dâmboviţa, Strei, Timiş, Nera, etc.).

Two evolutionary concepts were constantly sustained, some upholding antecedence, others stream piracy (Table 1), but in almost every case no conclusion was unanimously accepted. Several syntheses of this issue are due to Romanian authors (Orghidan, 1969; Mihăilescu, 1963; Posea, 1967 – for the Carpathians; Donisă, 1981 – for the Eastern Carpathians, and Ielenicz, 1973 – for the Curvature Carpathians).

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Table 1

Valley sectors generated by stream capture, antecedence, superposition, etc.

River	Sector	Formation	Authors
Bistrița	1. Zugreni	- overflow - stream capture - antecedence	S. Athanasiu, A. Nordon, Emm. De Martonne, T. Naum, I. Sîrcu, V. Gîrbacea
	2. Toance	- antecedence	M. David, I. Donisă
Cuejd	3. Piatra Neamț	- antecedence - stream capture	I. Donisă, I. Bojoi
Trotuş–Tazlăul Sărat	4. Moineşti	- antecedence - stream capture	N. Lupu, C. Brînduş
Someşul Mare	5. Rodna – Ilva Mică	- superposition	I. Sîrcu
Mureş	6. Toplița – Deda	- overflow - antecedence	L. Someşan
	7. Deva – Zam	- antecedence - superposition - stream capture	Gh. Pop, E. Vespremeanu, R. Ficheux
Olt	8. Racu, 9. Jigodin 10. Tuşnad, 11. Bod	- antecedence - overflow - stream capture	I. Tovissi, I. Schreiber, M. Iancu
	12. Racu – Augustin	- stream capture - antecedence	N. Orghidan, N. Popescu, N. Mihăilă
	13. Turnu Roşu 14. Cozia	- stream capture - antecedence	Emm. de Martonne, I. Popescu-Voiteşti, L. Mrazec, H. Wachner, N. Popescu, Gr. Posea, I. Rodeanu etc.
Buzău	15. Întorsura Buzăului 16. Harțagu	- beheading - antecedence	G. Schilling, N. Orghidan, A. Nordon, Gr. Posea, V. Gârbacea, M. Ielenicz
Bâsca Mare	17. Comandău	- beheading	M. Ielenicz
Prahova	18. Predeal – Timiş	- beheading	G. Vâlsan, Gh. Neamu, Valeria Velcea
	19. Predeal – Sinaia	- antecedence	Valeria Velcea
	20. Posada	- stream capture - antecedence	G. Vâlsan, Gr. Posea, M. Ielenicz
	21. Jepi and Izvorul Dorului	- stream capture	Valeria Velcea
Dâmbovița	22. Podul Dâmboviței	- superposition	M. Ielenicz
	22. Rucăr	- antecedence	M. Ielenicz
	22. Dragoslavele – Stoeneşti	- stream capture - antecedence	C. Brătescu, N. Muică
	23. Cetățeni	- antecedence - superposition	C. Brătescu, N. Muică
Jiu	24. Bănița 25. Livezeni – Bumbeşti	- beheading - stream capture - antecedence	D. Burileanu, Emm. de Martonne, N. Orghidan, V. Mihăilescu, Gr. Posea, Silvia Lupu, Gr. Murgoci
Danube	26. Defileul Moldova Nouă – Porțile de Fier	- antecedence - stream capture - complex overflowsand stream capture	J. Cvijic, R. Sevastos, Emm. de Martonne, G. Vâlsan, R. Ficheux, G. Verges, P. Coteț, V. Mihăilescu, Gr. Posea *et al*., M. Iancu *et al*., N. Orghidan
CrişulAlb	27. defiles down stream Brad	- superposition	P. Coteț, P. Tudoran
CrişulNegru	28. Şoimi	- antecedence - superposition	I. Berindei
CrişulRepede	29. Huedin – Vadu Crişului	- stream capture - antecedence	R. Ficheux, Aurora Posea

Table 1 (continued)

Nera	30. defile	- superposition - antecedence	Gr. Posea, V. Gârbacea
Mehadia	31. gorges	- antecedence	N. Schmidt
Bistra	32. defile	- antecedence	F. Mateescu
Valleys crossing the Trascău Mts.	33. gorges	- antecedence - superposition	I. Popescu – Argeşel
Arieş	34. defile	- antecedence	R. Ficheux
SomeşulMic	35, 36. defiles, gorges	- antecedence	R. Ficheux
Moldova	37. upstream of Sadova, Vama, Gura Humorului	- defiles	S. Athanasiu, A. Nordon, I. Barbu
Suceava	38. upstream of Putna	- antecedence	I. Barbu, A. Nordon
Vişeu	39. downstream of Petrova	- antecedence	A. Nordon, N. Popescu
Iza	40. Strâmtura	- antecedent gorges	M. Ielenicz
Bicaz	41. Bicaz Gorges, Dămuc Gorges, Bicăjel Gorges	- antecedence	I. Bojoi
Vrancea rivers	42. defiles	- antecedence	M. Ielenicz

2. GENETIC AND EVOLUTIONARY ELEMENTS IN ESTABLISHING THE FORMATION OF THE CARPATHIAN MORPHO-HYDROGRAPHIC SYSTEM

In most situations, the evident and repeatable landforms (erosion levels, terraces) developed on interfluves and along the valleys, as well as some oro-hydrographic (saddles, defiles) or drainage features (direction of valley segments in the adjacent basins) are the elements that led to the development of genetic and evolutionary concepts at least for some partial or total Carpathian valley-crossing sectors). However, correlating them with a correct assessment of palaeogeographical relations between the area of the Carpathians' gradual uplift and completion, and the areas (acting as base levels for the erosion process) is imperative. These details have particular significance not only for explaining the formation of some defiles and gorges, but also for identifying the way in which generations of Carpathian valleys had gradually been built and relate to the valleys of marginal areas.

2.1. General features relevant for the formation of the Carpathian river system

The following events are significant:

The gradual uplift of the Carpathians and the position of the general base levels. The Carpathian Mountains were formed during the Cretaceous – Quaternary period (the Alpine Orogenesis) by the dynamic relations between the Foreland blocks (Moldavian Plate, Moesian Plate) and the blocks formed within the Tethys Basin (Pannonian and Transylvanian plates). First, sediments accumulated and folded; then they were turned into crystalline rocks, crossed by igneous and volcanic material. Gradually, a series of submersed mountains, which rose above sea level and made up the mountain range, acquired a specific structure shaped by their evolution in time and place.

Palaeogeographically speaking three stages can be distinguished:

- *Cretaceous – Palaeogene*, when an initial mountain system of medium altitude, made of crystalline schists caught into giant nappes was formed. Gradually, the weathered pediment-like ground (which finally the Carpathian pediplain resulted from) became rigid, leading (especially in the Neogene period) to intense tectonic movements which generated massifs (horsts) separated by basins (graben). Generally, all the massifs constituted a major circular orographic system, framed both outside and inside by marine basins connected by inner tectonic corridors. The expansion of fragmented land over small areas of medium altitude, surrounded by marine basins, proved favourable to the formation of a short radial valley network.

• *Neogene,* when most of the oro-hydrographic aggregate was gradually formed. Some important processes and events during this phase were:

– *tectonic movements* (in several phases), which folded the sediments accumulated within the marine basins located outside and in the north-west of the Eastern Carpathians and south-east of the Apuseni Mountains, generating the alignments of flysch massifs, which joined the existing (crystalline Mesozoic) land;

– *completion of intra-system tectonic depressions, gradually filling with sediments and their emersions* (differing during the Pliocene Age);

– *volcanic eruptions* in the eastern and south-western Transylvanian Basin led to the emergence of a chain of massifs in the Eastern Carpathians (consisting of dominant volcanic andesite and conglomerate) split from the eastern Mesozoic crystalline massifs by intramontane basins; they also determined the formation of several stratovolcanoes inside the flysch deposits of the south-eastern Apuseni Mountains;

– *abrupt elevation of mountain land* that facilitated the increase in altitude and succession of some new morphogenetic stages, completed by the sculpturing of erosion surfaces and levels (generated as a subtropical climate was being maintained), the individualization of trans-Carpathian valley corridors and significant accumulations of marine and lake deposits in the adjacent basins;

– *differentiation of the morphogenetic role of the base levels into three stages:*

– Badenian – Sarmatian and largely in the Pontian, when a general base level outside the Carpathians was under the control of direct connections between the Pannonian, Getic, Moldavian and Transylvanian lakes (while the Carpathian massifs formed an archipelago);

– Upper Sarmatian (Messinian) – and Upper Pliocene, when a common base level dictated by the plains formed around the Carpathian system, powered by its uplift; as a consequence, the connections between the remote lakes where provided by tributaries;

– Romanian (Levantine) – Pleistocene, with local base levels related to the intramontane tectonic basins.

Therefore, it was a long stage with important changes within the configuration and structure of the Carpathian system (formation of the flysch mountains separated by structural saddles or tectonic contact, which joined the previous land; the development of tectonic basins which gradually filled up with sediments and became land). They determined the special evolution of mountain watersheds during the Miocene and Lower Pliocene (for example, existing valleys were deepened into Palaeogene old massifs, new generations developed into new ones, and disappeared inside tectonic basins which turned into lakes). During the Upper Pliocene, the river system extended over the Carpathian land units as they tectonically emerged. Integration of all the valleys into a single unitary system was achieved in many cases through the trans-Carpathian tectonic corridors.

• *Quaternary,* the stage of Carpathian physiognomy and valley system completion. A significant role was played by: the general uplift of the Carpathians (regionally differentiated by magnitude); some local subsidence processes (in several small tectonic basins), which provided for a rich sedimentation; a 100–250 m abrupt incision of the river network, which created, during alternating climates (periglacial and temperate), a 6-to-8 general terrace system in the Pliocene valley corridors (some local terraces occurring in the actively uplifting sectors); the growing importance of regional and local base levels compared to the general one (the Black Sea through its tributary the Danube River), which remained far from the mountain area. The last important generation of valleys was formed.

The active uplifts on certain alignments have facilitated the formation of antecedent or superposed rivers (which are obvious in the hard rocks sectors– gorges, defiles).

2.2. Tectonic, structural and orographic features of secondary influence upon the formation of the Carpathian valleys system

These features have an important local contribution to controlling the direction and evolution of the Carpathian valleys system (Fig. 1). The most significant ones are:

- The contact between different litho-structural units in which either longitudinal, or transversal valley sectors are cutting into (in the flysch mountains or at the contact between crystalline massifs and sediment fill in some basins);
- Alignments of major faults along which vigorous stream have downcut (Cerna, Bistra, etc.);
- Discordant structures favourable to superposed defiles (in the west of the Western Carpathians);
- Tectonic corridors which functioned as marine (lake) straits especially during the Badenian and the Pontian, and after exhumation they became narrow strips of land in which the Carpathian rivers gathered and convered (Danube, Jiu, Olt, Strei, etc.);

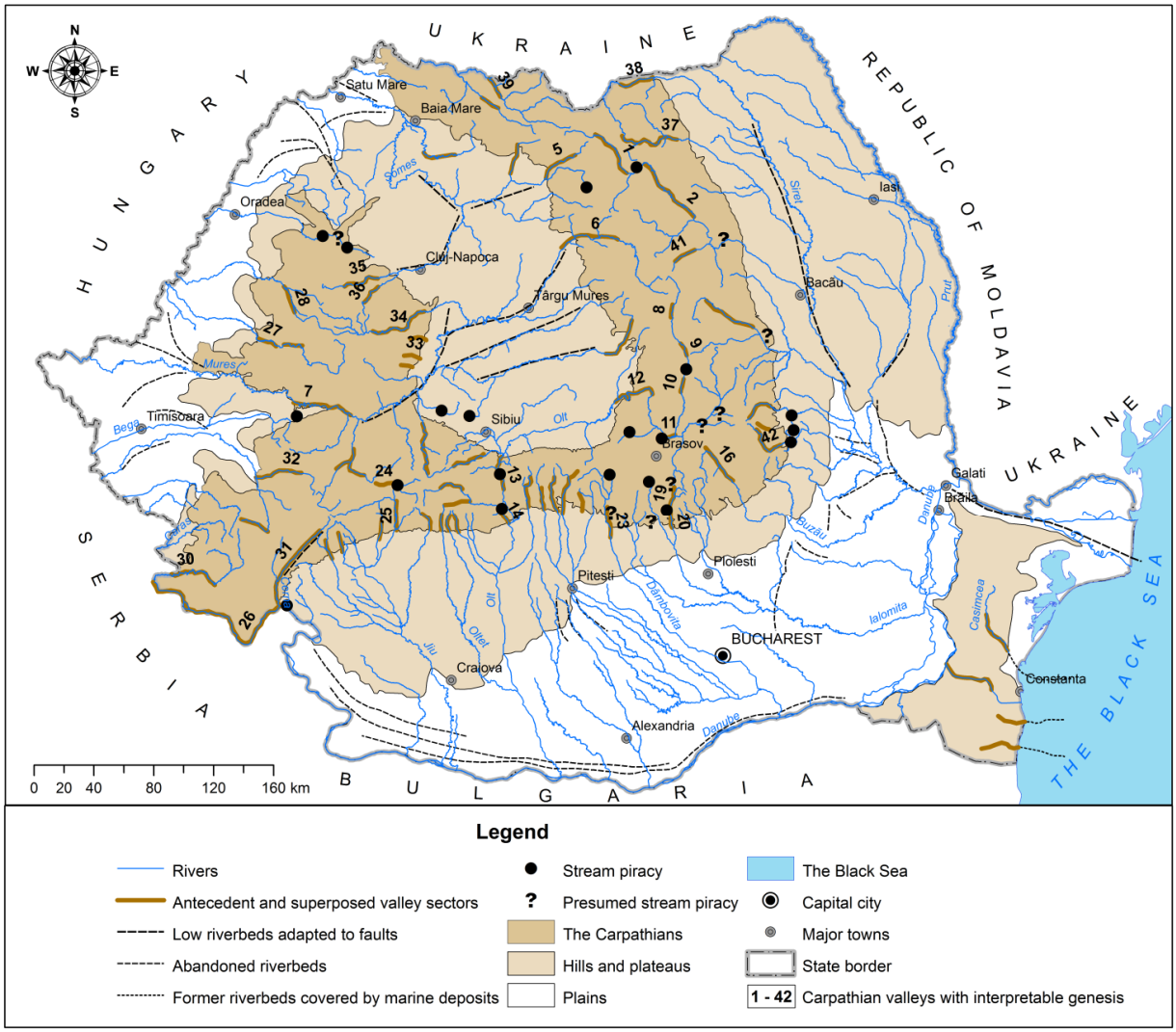

Fig. 1 – Defining features of the river system evolution and the Carpathian valley sectors of interpretable genesis in Romania.

- The contact between the foothills of Neogene volcanoes, which autochthonous rivers were flowing through towards the Transylvanian Basin (the west of the Eastern Carpathians);
- The formation of tectonic basins during the Tertiary, which became sedimentary basins and led to the destruction of some sectors belonging to the previous drainage network (Braşov);
- Active uplifts of some massifs, determining the formation of antecedent defiles and a sort of unconformity between the position of the major drainage divides and the highest ridgeline (Eastern Carpathians);
- Tectonic and volcanic barrier and differential erosion basins, which played a local base level role and determined the convergence of rivers flowing from the neighbouring massifs into a main stream (Ciuc, Gheorghieni, Haţeg) or subsidence areas (Braşov);
- Large folding of the thrust nappes, creating possible access ways for some rivers in the early stage of crystalline area evolution, exemplified by D. Burileanu for the Southern Carpathians (Burileanu, 1941);
- Subsidence areas in some basins or adjacent landforms, as river convergence points (Braşov, Gheorghieni, Someş Plain, Criş Rivers Plain, etc.);
- Formation of piedmonts, extended alluvial fans, and glacis on which the riverbeds of tributaries have repeatedly shifted (Haţeg, Braşov, Beiuş, etc.);
- Evolution of rivers in limestone massifs, often attended by subsurface stream captures and development of hanging dry valleys (Padiş – Cetăţile Ponorului, Pădurea Craiului Mts., Aninei Mts., etc.).

3. STAGES OF CARPATHIAN VALLEY NETWORK FORMATION AND DEVELOPMENT

The Carpathian valley network occupies a distinct place in the Romanian oro-hydrographic system, determined by the following features:

– The largest number of generations of valleys gradually completed in close dependency to stages of mountain units and adjacent base levels evolution;

– It contains the oldest Romanian valley sectors (dating back to the Miocene), and also the most representative ones (Pliocene - Quaternary);

– The most numerous areas in which, frequently based on their morphological features, antecedent, superposed or captured rivers were recognized;

– The mountain valley network has extended its shape and downcut into the adjacent landforms (hills, plateaus, plains), as they were formed after emerging from under the lakes or seas (driven by the Carpathian uplift).

Based on above the ideas, as well as on oro-hydrographic, tectonic and structural evidence stated in the literature, two major stages consisting in complex paleaogeographic events are outlined:

- Upper Miocene – Middle Pliocene;
- Upper Pliocene – Quaternary.

3.1. Upper Miocene – Middle Pliocene stage, with the oldest morphological remnants of the existence of a Carpathian valleys network

Until the Middle Miocene, the Carpathian Mountains formed in a discontinuous stretch of land made up of metamorphic rocks and Cretaceous flysch, some hundreds of meters in height, and drained by a radial valley network which reached the nearby marine basins. The idea that some folding of thrust nappes or the tectonic-structural contacts had probably constituted primary drainage sectors was also advanced (Munteanu-Murgoci and Burileanu for the Getic Nappe).

By emphasizing the tectonic fragmentation during the Badenian, the Carpathians became an archipelago drained by a radial river network, connected to a common base level. Some erosion levels were preserved especially in the crystalline massifs (Godeanu Mts., Făgăraş Mts., Bucegi Mts., Bistriței Mts., etc.), whose extent indicates valley sectors dating back to the stage when the Carpathian middle erosion surface was sculptured (Martonne, 1907; Niculescu, 1965; Micalevich-Velcea, 1961; Donisă, 1968; Posea, 1967; Popescu, 1990; Ielenicz, 1984, etc.).

In the Upper Sarmatian – Meotian, by the structural completion and uplift of the flysch Carpathians, the mountain river system extended over the newly emerged landforms, such as the low hills and plains, to the east of the Eastern Carpathians, Transylvania and the north-east of Moldavia, where it took over a generation of developing valleys.

The Pontian (Pannonian) transgression reduced the Meotian land surface (especially the peri-Carpathian one, but also a few intramontane basins) – most in the Western Carpathians and less so in the other ranges, removing a significant part of the previous river network. Important volcanic eruptions took place during the Pliocene, gradually completing the volcanic mountain system, with local consequences on the extent of developing valleys, divergent on the volcanic cones and convergent to the inner basins (Gheorghieni, Ciuc, etc.), occupied by lakes or marshes drained by tributaries reaching the Transylvanian Lake.

The Pliocene erosion levels in the upper slopes of the valleys are different in number, depending on the generations of valleys formed during this period. They already prove stable drainage directions reflecting a river network emerging from the high mountain area, which frequently converged towards some tectonic corridors and basins at the outer edge of the Carpathians. In the Eastern Carpathians, rivers were collected by main stems following either tectonic alignments inherited along the most important litho-structural contacts, or lower sectors remained between various uplifted land units. The major rivers were transversally (totally or partially) cutting the mountain chain, as the later uplift of the Carpathians determined their antecedence and superposition (Bistrița, Moldova, Moldovița, Trotuş, rivers in the Curvature Carpathians).

3.2. Upper Pliocene – Quaternary stage of completion of the present river system

This stage was defined by several significant events:

- Uplifting of the mountains in several stages, which caused the antecedence of all the valleys formed before the intense uplift took place. The cross profiles of the valleys show an obvious transition from an upper open sector of low energy to gradually smaller sectors dominated by limited erosion levels. The cross profiles also highlight by their V-shaped angle and hardly visible erosion shoulders, a rapid, but abrupt downcutting. In some cases antecedent rivers are also superposed (rivers in the Trascău Mountains, Metaliferi Mts., Codru – Moma Mts., etc.).
- Formation of a generation of Carpathian valleys during the Upper Pliocene which joined the previous system. There are narrow erosion levels along them, correlated with erosion surfaces in the neighbouring outer landforms (at the transition from the Carpathians to the Subcarpathians), then (beneath them) terraces (in varying number) of limited length, relatively hanging longitudinal profiles, comparing to the main stems and many litho-structural steps. The most recent generation of valleys (Quaternary) originates from the lower third of the slopes, but also inside the great tectonic basins, only preserving terraces and meadows.
- The emersion first of the Transylvanian basin and then progressively of the gulf-like basins in the Western Carpathians (during the Dacian Age), the Foreland and some of the intramontane basins (Gheorghieni, Ciuc, Braşov, Comăneşti) during the Romanian – Pleistocene led to different regional evolutions. The alluvial plains created after the Pannonian and Transylvanian lakes had been drained out, were gradually uplifted, then split apart by erosion and turned into plateaus or hills. Piedmonts

(much extended to the south of the Southern Carpathians), glacis and superposed alluvial fans, differently developed depending on the size of the rivers which created them (Haţeg, Petroşani, Făgăraş, etc.), were formed at the contact between these landforms and the mountain areas or in some intramontane basins.

- The tectonic corridors formed at the end of the Pontian when, becoming strips of land, provided a drainage from the low neighbouring mountain areas (Danube, Someş, Olt, Mureş). As a consequence, for the first time since the Romanian and the Lower Upper Pleistocene they became major drainage passages for the Carpathian valley systems which reached the Pannonian, Transylvanian, Getic and Moldavian basins.
- The rivers downcutting during the Quaternary was provided by an abrupt uplift, highlighted by a difference in altitude of 200–250 m between the Pliocene erosion levels and the present thalwegs. They generated in the Carpathians antecedent defiles with narrow sectors shaped into resistant hard rocks (erosion shoulders and terraces were not preserved or they are discontinuous and limited in size) and small basins (terraces were better preserved when younger, and less so when older, because of fragmentation). Through these corridors, the main stems flowing from the Carpathians extended on the Foreland units, gradually joining the hills and plain rivers into a complex system. The major drainage axes of the non-Carpathian rivers followed either lower alignments generated by tectonic impulses from the Carpathians, or resulted from the different movement of the deep underground blocks (in Transylvania or the Subcarpathians the tectonics of salt layers, determining local folding or subsidence, was also significant), or followed litho-structural contact lines, or where Romanian – Pleistocene alluvial sheets had been accumulated.
- During the Dacian – Romanian evolution (in some places also in the Lower Pleistocene), when landforms were low and poorly fragmented, stream piracy and divergent flowing could occur in organizing the river system. Some authors support these opinions and motivate them by bringing into discussion the existence of some wide saddles preserving supposed alluvial remnants, wide valleys comparing to narrow riverbeds of the present valleys, the extent of valley shoulders or the configuration of the valley sections, etc. The importance of this process was in some cases overestimated (especially when analysing the genesis of great defiles).
- The downcutting of rivers into the post-Pannonian lowlands of some basins and corridors made of sedimentary rocks covering magmatic bodies or crystalline blocks at low depths led in Pleistocene to the developing of superposed gorges and defiles by cutting the hard rocks through, more frequently in the Western Carpathians (Tău, Timiş, Crişul Alb, Crişul Negru, Crişul Repede, Barcău, etc.), Eastern Carpathians (Someşul Mare, Ilva, Olt at Racu and Jigodin), Southern Carpathians (Crivadia, Sebeş, Dâmboviţa, etc.), upstream of which alluvial basins developed.
- Formation of the volcano system determined first a rearrangement of divergent rivers (on their side slopes), associated with that of rivers convergent (within the craters), followed by the it led to formation of several stems on the marginal (contact) sectors between the main eruptive massifs (Mureş from Topliţa to Deda; Tur and Talna in Oaş; Săsar, Cavnic, Olt at Tuşnad, partially Târnava Mare, Târnava Mică, etc., and the sedimentary in Transylvania). The last case is also supposed to be determined by the draining of some lakes variable in size, occupying the dam basins either by overflowing, or stream piracy, but arguments are not conclusive.
- Formation within the mountain area of some tectonic basin during the Upper Pleistocene (Comăneşti, Braşov), which functioned as lakes or marshes until early Quaternary, had several consequences for the river network. At first, rivers in the areas which later became sedimentary basins, vanished; some interfluves located downstream of the fault slopes delimiting the basins preserve of the remnants of some wide valleys having low charge riverbeds (Lădăuţele and Popliţa at Întorsura Buzăului and Comandău), shaped by steep slopes and a relief energy exceeding hundreds of meters. During the Quaternary, as the local river system tributary to the Olt, Trotuş, etc. was being completed, the major tributaries caused limited stream piracy (Râşnov, Timiş, Gârcin against the Prahova drainage basin; Boroşneu, and Doboli against Lădăuţele basins; Covasna against Popliţa basin, etc.). The process

was also favoured by some active uplifts occurred in the central Curvarture Carpathian area, where the main stems (Buzău, Bâsca rivers, Teleajen, Prahova, etc. created antecedent defiles).

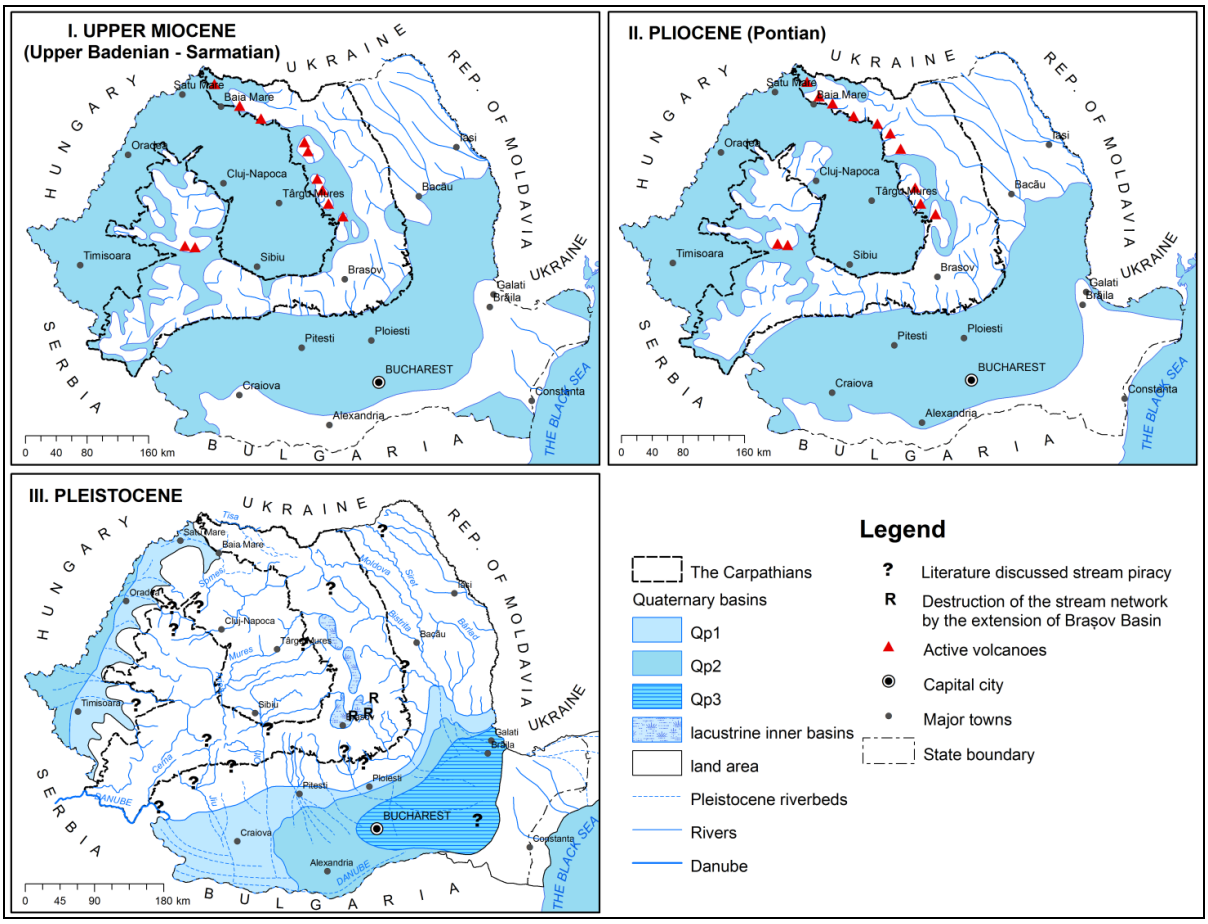

Fig. 2 – The valley system evolution stages and the Carpathian Mountains in Romania.

- Changes of riverbeds by divergence occurred both at the exit of some tectonic corridors (Mureş downstream of Dobra, on the accumulative outwash around the eruptive and crystalline hills), and within basins surrounded by prominent piedmont glacis (Haţeg, Făgăraş, Petroşani, Beiuş, etc.).
- Local lateral stream piracy occurred amidst adjacent basins drained by stems at different elevation (Izvorul Dorului, Jepii, Poarta in the Bucegi Mountains, etc.).

CONCLUSIONS

The Carpathians form a geographic landform unit preserving the most ancient and numerous generations of valleys, resulting from a long evolution as land as far back as the end of the Mesozoic era, and completed by joining the flysch oro-structural system, volcanic mountains and developing the inner basins.

As the oro-structural completion of the Carpathians was developing, on the one hand the river network was created within their area by different tectonic, structural, geomorphic factors, and on the other hand (post-Dacian) extended to areas in the Foreland or to Transylvania, which were differently driven by the uplifting Carpathians.

Many papers (published even since the late 19th century) have analyzed the mechanism of gradual completion of the river network, especially within defile sectors, most arguments pleading for antecedence or stream piracy.

Analyzing them has allowed to establish two major stages in the formation and evolution of the valley system: Miocene – Middle Pontian (it preserves disparately the remnants of the most ancient valley corridors), and Dacian – Holocene (when several generations of valleys preserving many morphological evidence – among which erosion levels and shoulders, terraces, different accumulated sediments, etc. – were formed). The processes conducive to the completion of the valley system configuration had a different regional importance. Among these are:

- The abrupt, but different in intensity, uplift of the mountains, causing antecedent rivers to form, as well as divergent or convergent drainage (especially within tectonic basins and corridors);
- Downcutting into discordant structures (located especially in the peripheral area or around the large basins), determining the formation of superposed defiles and hanging basins;
- Simple or successive stream piracy, either immediately during the phase following the emersion of tectonic corridors inherited by the main stems (Upper Pliocene), or amidst tributaries of differently elevated watersheds;
- Destruction of several sectors in ancient watersheds by the formation of some tectonic basins (especially during the Miocene), which became marine areas or lakes.

REFERENCES

Atanasiu, S. (1899), *Morphologische Skizze der nordmoldavischen Karpathen mit einem Ueberblick über die Tektonik*. Bul. Soc. Şt., Bucureşti.

Berindei, I. (1977), *Ţara Beiuşului*, Vol. Câmpia Crişurilor, Crişul Repede, Ţara Beiuşului, Bucureşti, Edit. Ştiinţifică.

Burileanu, D. (1941), *Câteva observări asupra structurii şi reliefului în Carpaţii Meridionali în lumina ultimelor studii geologice*, Studii şi Cercetări Geografice, Bucureşti.

Burileanu, D. (1942), *Recherches morphologiques dans le défilé du Jiu*, Lucr. Inst. Geogr. **VII**, Cluj-Napoca.

Coteţ, P. (1954), *Problema defileului Dunării la Porţile de Fier şi cercetările geomorfologice din Câmpia Olteniei*, Probleme de Geografie, **I**, Bucureşti.

Coteţ, P. (1967), *Problèmes de geomorphologie historique en Roumanie. La peneplenation des Carpates Occidentales et Meridionales*, Ann. de Geogr., Paris.

Cvijič, J. (1908), *Entirichlung a geschischte des Eiserener Tores,* Peterm. Mitt. Erganzungsheft, 160, Gotha.

Donisă, I. (1968), *Geomorfologia Văii Bistriţei*, Edit. Academiei Române, Bucureşti.

Ficheux, R. (1929), *Remarques sur le réseau hydrographique du Bihor septentrional*, Mel. Inst. Fr. En Roumanie.

Ficheux, R. (1996), *Les Monts Apuseni (Bihor), valées et aplanissement*. Edit. Academiei Române, Bucureşti.

Gheorghiu, C., Iancu, M. (1967), *L'evolution géologique et géomorphologique de la valée du Danube entre Baziaş et Tr. Severin*, Assoc. Géol. Carpato-Balcanique, VIII. Congr. Belgrad.

Iancu, M., Velcea, Valeria, Glăja, Maria (1964), *Valea Dunării între Baziaş şi Coronini*, An. Univ. Bucureşti, Sr. Geol.-Geogr., **XIII**, *1*.

Ielenicz, M. (1973), *Aspecte privind evoluţia Carpaţilor Orientali şi de Curbură*, Realizări în Geografia României, Edit. Ştiinţifică, Bucureşti.

Ielenicz, M. (1984), *Munţii Ciucaş – Buzău. Studiu geomorfologic,* Edit. Academiei Române, Bucureşti.

Ielenicz, M. (2002), *Problema suprafeţelor şi nivelelor de eroziune din Subcarpaţi*, Revista de Geomorfologie **3**, *11-15*, Edit. Universităţii din Bucureşti, Bucureşti.

Liteanu, E., C. Ghenea (1966), *Cuaternarul din România*, Studii Tehnice şi Economice, **H,** *1*, Bucureşti.

Marinescu, Fl., Marinescu, Josefina (1963), *Geologia bazinului Bahna – Orşova şi legătura sa cu regiunile neogene învecinate,* Asoc. Geol. Carpato-Balcanică, Com. Şt. **III**, *1*.

Martonne, Emm. de (1907), *Recherches sur l'evolution morphologique des Alpes de Transylvanie*, Paris.

Martonne, Emm. de (1924), *Excursion géographique de l'Institut de Géographie de l'Université de Cluj*, 1921, Lucr.Inst. Geogr.Univ. Cluj, 1922, Vol. **I**.

Micalevich-Velcea, V. (1961), *Munţii Bucegi – Studiu de geomorfologie,* Edit. Academiei R.P.R., Bucureşti.

Mihăilescu, V. (1963), *Carpaţii sud-estici,* Edit. Ştiinţifică, Bucureşti.

Munteanu-Murgoci, Gh. (1908), *Terţiarul Olteniei,* An. Inst. Rom., I.

Naum, Tr. (1965), *Valea transversală a Bistriţei,* Hidrologia*,* **6**.
Neamu, Gh. (1963), *Aspecte din dezvoltarea morfologică a văii Timişului*, Com. Geogr. **II**.
Niculescu, Gh. (1965), *Masivul Godeanu. Studiu geomorfologic,* Edit. Academiei Române, Bucureşti.
Nordon, A. (1933), *Resultats sommaires et provisoires d'une étude morphologique des Carpathes Orientales roumaines*, C.R. Congr. Intern. Geogr., **II**, *1*, Paris.
Orghidan, N. (1969), *Văile transversale din România,* Edit. Academiei R.S.R., Bucureşti.
Paucă, M. (1965), *Contribuţii la geneza zăcămintelor de săruri miocene din România*, D.S. ale Şed. Com. Geol., **LIII**, *2*.
Paucă, M. (1977), *Reţeaua hidrografică a blocului Someşului – geneză şi evoluţie*, St. Cerc. Geol., Geofiz., Geogr., Sr. Geogr., **XXIV**, *2*.
Pop, Gh. (1947), *Noi contribuţii geomorfologice privitoare la cursul inferior al Mureşului. Vechiul curs Mureş-Bega,* Lucr. Inst. Geogr. Univ. Cluj, **VIII**.
Popescu-Argeşel, I. (1977). *Munţii Trăscăului. Studiu geomorfologic,* Edit. Academiei Române, Bucureşti.
Popescu, N. (1966), *Observaţii geomorfologice asupra depresiunii Ogradena-Bahna*, An. Univ. Buc., Sr. Geol.-Geogr., **XV**, *1*.
Popescu, N. (1972), *Valea Oltului între Turnu Roşu şi Cozia. Observaţii geomorfologice,* Bul. Soc. Şt. Geogr. din R.S.R., **II (LXXII)**: *90-98*. Bucureşti.
Popescu, N. (1990), *Ţara Făgăraşului. Studiu geomorfologic,* Edit. Academiei Române, Bucureşti.
Popescu-Voiteşti, I. (1918), *Evoluţia geologică şi paleogeografică a pământului românesc*, Rev. Muz. Min.Univ. Cluj, **V**.
Posea, Aurora (1977), *Bazinul Crişului Repede*, Câmpia Crişurilor, Crişul Repede, Ţara Beiuşului*,* Edit. Ştiinţifică şi Enciclopedică, Bucureşti.
Posea, Gr. (1962). *Ţara Lăpuşului*, Edit. Ştiinţifică, Bucureşti.
Posea, Gr. (1967), *Antecedenţă şi captare la văile transversale carpatice*, Lucrările Ştiinţifice ale Institutului Pedagogic din Oradea, **1**.
Posea, Gr. (1969), *Asupra suprafeţelor şi nivelelor morfologice din sud-vestul Transilvaniei*, Lucrările Ştiinţifice ale Institutului Pedagogic din Oradea, A.
Posea, Gr. (2002), *Geomorfologia României*, Edit. Fundaţiei „România de Mâine", Bucureşti
Posea, Gr., Grigore, M., Popescu, N. (1963), *Observaţii geomorfologice asupra defileului Dunării*, Analele Universităţii din Bucureşti, Geologie – Geografie, **XII**, *37*. Bucureşti.
Posea, Gr., Popescu, N., Ielenicz, M. (1974), *Relieful României,* Edit. Ştiinţifică, Bucureşti.
Rădulescu, D., Peltz, S. (1970), *Observaţii asupra paleogeografiei teritoriului eruptiv Călimani-Gurghiu-Harghita în cursul pliocenului şi cuaternarului*, Studii şi Cercetării de Geologie, Geofizică şi Geografie, Seria Geologie*,* **15**, *1*, Bucureşti.

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