Caspian J. Env. Sci. 2009, Vol. 7 No.2 pp. 99~106

CJES
Caspian Journal of Environmental Sciences

[Research]

Some Considerations on Climatic Geomorphology of the Romanian Territory

A. Nedelea, L. Comănescu* and M. Ielenicz

Dept. of Geomorphology-Pedology, Faculty of Geography, University of Bucharest, N.Balcescu Avenue, n.1, Bucharest, Romania
** Corresponding author's E-mail: lauracomanescu@yahoo.com*

ABSTRACT
The main issues about relation between climate and relief in the Romanian geomorphological literature follow three directions of research: the description of Pleistocene glacial and Pleistocene-Holocene periglacial landforms in the Carpathians; the direct analysis of climate's role in landform development; the integration of separate works and findings in a synthetic morphodynamic system applicable to all of the country' territory. The analysis of the present-day geomorphic landscape reveals two important generations of morphoclimatic landforms (old climatic landforms and the recent climatic relief-forms). In Romania we can identify three distinct morphoclimatic regions: the central-western region, the eastern and south-eastern region and the south-western region.

Keywords: Glacial, Glacis, Pediment, Pediplain, Peneplaned surfaces, Romania

INTRODUCTION
The importance of the climate in gradating the earth's crust has directly or indirectly become worldwide since the end of the 19th century, when a special attention was given to the ideas referring to the genesis of peneplaned surfaces or to the specific landforms in the desert, glacial and periglacial regions. These ideas have further been developed into valuable theories concerning specific erosion cycles (Gee 1897, Davis 1898, De Martonne 1948, Penck 1894, Penck, 1924, King 1954, Marcov 1957) (Ielenicz 2004). Comprehensive studies and detailed morphoclimatic analyses have then become more and more numerous in the sixties (Tricart & Cailleux 1953, 1965; Budell, 1977) (Ielenicz 2004).

The main issues discussed in the Romanian geomorphological literature follow three directions of research: a) the description of Pleistocene glacial and Pleistocene-Holocene periglacial landforms in the Carpathians (either locally, on small relief sub-units, or regionally, on various mountain ranges); b) the direct analysis of climate's role in landform development and gradation (with special focus on planation surfaces); c) the integration of separate works and findings in a synthetic morphodynamic system applicable to the country's whole territory (emphasis being, however, laid on the climatic variations that largely diversified present-day morphodynamic structures). In this respect, important contributions have been brought by de Martonne (1907), Vâlsan (1915, 1917), Brătescu (1928), Posea (1962), Posea et al. (1974), Coteț (1957), Niculescu (1965) and others.

RESULTS AND DISCUSSION
The old climatic relief landforms
This morphoclimatic generation of landforms includes erosional and accumulation landforms developed during different climates of the past. Some of them are very old (of Paleozoic-Mesozoic age) but others have been recently built (in the Pleistocene epoch). Their differing of age makes it difficult to restore their initial geomorphological features since subsequent climatic conditions have always created newer morphoclimatic

systems, thus covering any evidence of former landscape characteristics. That's why, the older the morphoclimatic systems are, the more difficult to discover the key-features, and the better preserved landforms probably have been gradated by policyclic morphoclimatic processes. Paleomorphology includes both erosional and accumulation landforms.

The erosional paleorelief landforms are represented by various peneplanation surfaces (pediplains, pediments, glacis slopes and terraces), Carpathian glacial and periglacial landforms.

The pediplains fall into two different categories. The first type is observable in Central Dobrudja, where most of the tableland area is, in fact, a pediplain surface formed in the Paleozoic era, by the denudation of a former Proterozoic-Cambrian mountain range mainly consisting of green schists (*Casimcea pediplain*). It has evolved in a hot, tropical climate which, in the conditions of a scarce vegetal cover, has determined a continuous and active pedimentation. Transgressive Jurassic limestone formations have been deposited in the erosional area of a nearly level land that has resulted, but they have later been outwashed by the end of the Neozoic era. The low elevation of the respective erosional plain has ultimately prevented intense fragmentation, because the relief energy was constantly kept below 100 m. The second pediplain type is represented by the *Carpathian pediplain,* out of which only sparse fragments have been preserved as small-sized plateaus lying at different altitudes due to the uneven Neogene and Quaternary neo-tectonic uplifts. This pediplain cuts into crystalline bedrock of Proterozoic-Paleozoic age and has been gradated mostly in a warm Upper Cretaceous-Paleogene climate with alternating humid and dry seasons, which determined landscape shifts from savanna to subtropical conditions (Pop 1963). The height of the massifs being gradated has clearly determined not only the vertical zoning of climatic conditions and vegetation species, with mangroves sticking to foothills, savanna grasses growing on most highland areas and heat-loving beech and fir-trees covering the tops, but also the vertical differentiation of gradation levels.

The morphodynamics of these areas is different. For instance, the Carpathian pediplain evolved through the unification of sparse pediments, while the clay depositions resulting by outwashing the silt alteration crust, accumulated into the surrounding sea basins. Such flat plateau areas are still being preserved in the Apuseni Mts. and in more mountain ranges (Godeanu, Parâng) of the Southern Carpathians.

Although intensely-fossilized, genetically similar surfaces are also traceable at different depths in the Vorland platform areas of the Romanian Plain and of the Moldavian Plateau, as well as in certain massive crystalline bedrocks of Carpathian origin covered by the Transylvanian Basin deposits.

Other peneplaned surfaces refer to 1-3 level led areas located in the Carpathian Mts. or encircling hills and tablelands, either as first or second-order interfluves resulting from long gradation processes under mediterranean climate that favoured intense Neogene pedimentation. However, these surfaces, consequently evolved after neotectonic movements, had fragmented the underlying bedrock during successive phases, so that the resulting peneplaned surfaces are only partially, developed in marginal areas or along the valley-floors. The main consequence of such a climate-tectonics coupling is the concentric zoning of peneplaning the surfaces (either outwardly from the masiff cores or downwardly from the main interfluves to valley thalwegs) and their particular extention and degree of conservation, depending on lithology. The most important surfaces in this cathegory are the middle Carpathian planation surface (Miocene) (Ielenicz 1984), the upper level of complex morphogenesis, consisting either of more or less well -developed pediments and glacis slopes in the hilly and tableland areas, that have been preserved as structural or lithological plateaus of Dacian-Romanian age, or of local glacis slopes and pediments on structural and lithological border fringes gradated under alternating mediterranean (Villafranchian-St. Prestien) or periglacial (Pleistocene) climatic conditions (Posea et al. 1974).

The terraces, whose numbers vary according to numerous factors (relating especially to valley generations and neotectonic influences), clearly reflect, mainly for the upper Pleistocene-Holocene epoch, the importance of climatic variations (due to alternating periglacial and humid or arid mid-latitude climates) in the development of some large terraces and in the accumulation of large alluvial deposits that may sometimes appear as 15-30 m-thick coarse gravel and pebble layers (in the Trotuş, Buzău and Bistrița valleys). Most studies referring to terraces (Posea et al. 1974) focus on the role of climatic variations in terrace formation at mean (55-60 m) or lower (below 30 m) altitudes, the leading author applying the Trevisan morphoclimatic cyclic theory to the Western and Romanian Plains terraces.

Glacial and periglacial landforms. The upper-Pleistocene general cooling of climate in successive stages, out of which two had a major impact on Romania's landforms, favouring the rapid development of numerous valley and cirque glaciers on top of highest mountains, on one side, and the intense periglacial gradation of high ridges and lower mountainsides. The present-day landscape still preserves glacial forms that have been only partially gradated afterwards, namely the glacial cirques, valleys and troughs (in the Bucegi, Făgăraş, Parâng, Retezat, Godeanu, Țarcu and Rodna Mts.), or residual periglacial morphologies (arête, columnar joinings, steep slopes).

Accumulation paleorelief forms are connected with piedmonts and piedmont plains reflecting the relationships between various contact units and specific climatic conditions. A large piedmont alluvial plain developed south of the Carpathians, which was later uplifted a few hundred meters, intensely fragmented and turned into plateau and hilly areas (the Getic Plateau, the piedmont hills fringing on the outer border of the Curvature Subcarpathians). Hills, which have genetically and structurally evolved from former piedmont areas may also be found also in other geographical units having similar subtropical climates (in the inner border at the contact between the Carpathian Mts. and the Transylvanian Depression, in the Lăpuş Land, on the Călimani and Gurghiu piedmonts bordering the volcanic mountains of the Eastern Carpathians, on the outer border of the Western and Eastern Carpathians, northwards from the Moldavia valley).

Under specific periglacial climatic conditions, further piedmont alluvial fans and plains have been built towards the end of the Pleistocene and partly in the Holocene epochs (e.g. the Ploieşti and Buzău Plains or the marginal areas of the Braşov Depression).

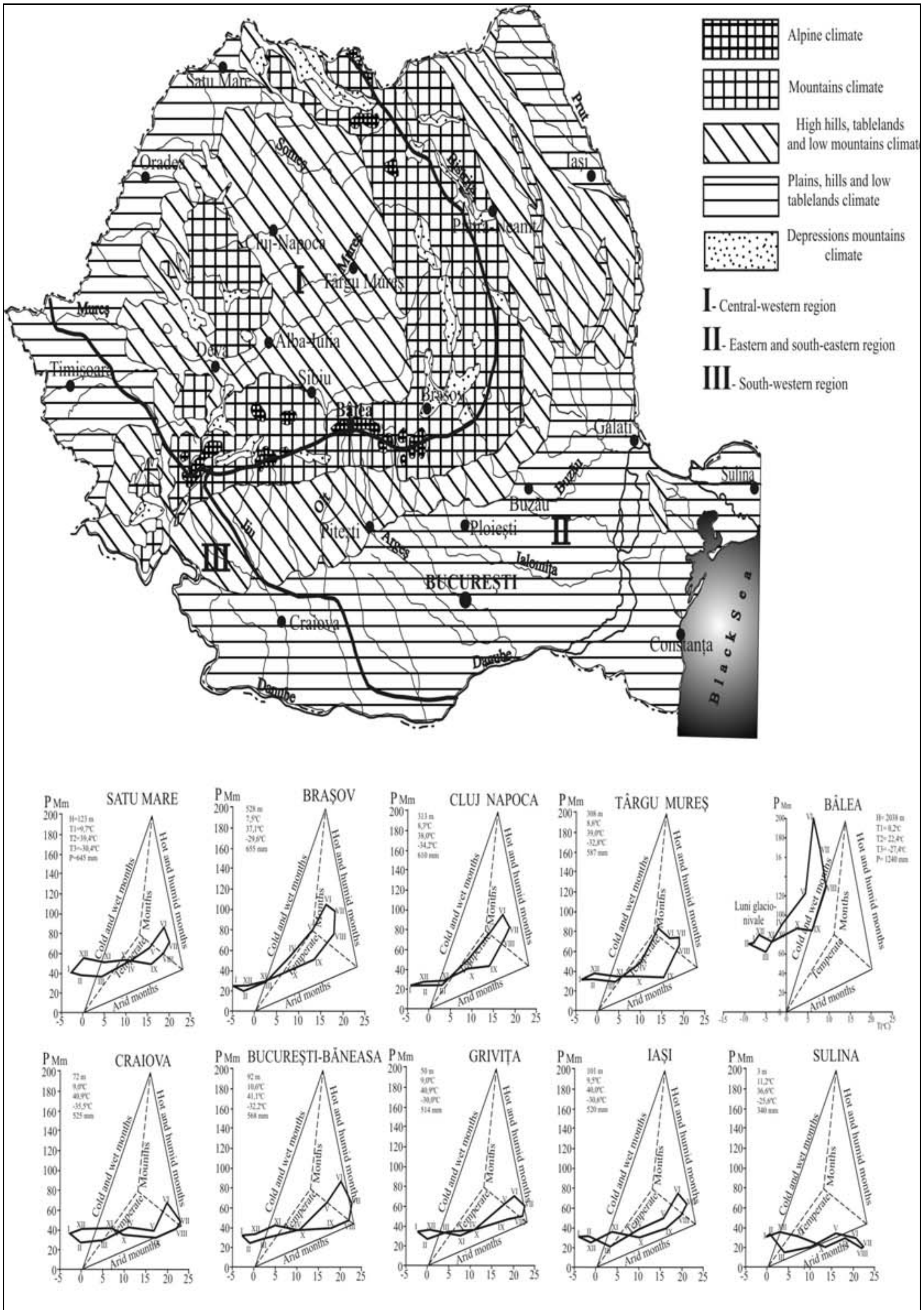
The intense periglacial gradation in the Carpathian Mts. has created large talus slopes on steeper foothills. Actually, these are large debris cones and glacis slopes being heavily forested with coniferous species.

Recent climatic landforms

This morphoclimatic generation of landforms has recently evolved through weather and climate gradation; their formation, frequency and spatial distribution is more or less influenced by various combining factors. The extremely varied landforms as regards lithological composition, structural configuration, fragmentation and declivity degree, soil and vegetation cover, have unevenly been gradated by district climatic conditions which played a major role in selecting the morphodynamic agents and influencing their frequency of action in time, by ultimately determining the intensity of gradation processes and the spatial distribution of the resulting landforms (Fig.1). Although all climatic components have directly or indirectly contributed, to a greater or lesser degree, to the gradation of various landforms, the most important morphodynamic factors are:

- The daily air-temperature ranges in spring and autumn;
- The duration and frequency of dry and droughty periods;
- The early fall or late spring frosts;
- The seasonal rainfall amounts, rainfall showers and drizzles;
- The snow-layer duration;
- The wind speed and frequency.

The spatial extention of the Carpathian Mts. on the country's territory lying on most than 5^0 of latitude, between the main European air-pressure centres, has determined the spatial compartmentalization of the climatic elements influencing the geomorphological agents and processes, as well as the resulting landforms.



Peguy climograme. H-Height absolute; T1- The average annual temperature; T2- The maxim absolute temperature; T3- The minim absolute temperature; P- Yearly quantity of precipitation.

Fig. 1-*Morphoclimatic regions of the Romanian Territory*

Therefore, three distinct morphoclimatic regions can be identified (Fig.1):

- *The central-western region* (with oceanic mid-latitude climate) in which all climatic elements being moderate values have determined moderate morphodynamic processes;
- *The eastern and south-eastern region* (mid-latitude continental climate) in which the main climatic elements (air-temperature, rainfalls) go to extremes and the resulting morphoclimatic landforms have been unevenly and discontinuously gradated;
- *The south-western region* (with mid-latitude climate under frequent mediterranean air-mass influences) in which the seasonal variations of climatic elements, that may sometimes go to extremes, have determined moderate morphogenetic processes.

Regional morphoclimatic differences depend mainly on altitude. Although Romania's landforms have heights ranging from 0 m to 2,544 m, yet the role of the vertical morphodynamic zoning becomes evident only in the Carpathian Mts., at altitudes higher than 1,800 m, where the alpine region that has developed above the tree-line, due to a colder climatic conditions, heavier rainfalls and stronger winds, intensified the seasonal cryonnivation and river-erosion processes. However, an intervening zone has subsequently been gradated between the alpine region and the rest of the areas below 1,800-800 m.

The role of these important factors in the regional differentiation of recent morphodynamic processes and morphoclimatic characteristics is largely supplemented by other factors relating to landform exposition, extent of depressions and valley-corridors extent or anthropic intervention which disrupt the natural balances, accelerating the land degradation processes. Therefore, it finally comes out that the moderate climatic conditions have determined numerous and various geomorphological processes that gradated specific morphoclimatic landforms, on one side, and that the climatic compartmentalization of the Romanian territory has eventually determined the corresponding regionalisation of morphodynamic processes. Despite the fact that the morphodynamic agents and processes act equally over the country's territory, there appear regional or local differentiations due to their specific intensity, duration and mode of association, so that the resulting deposits and landforms are very different from one place to another (Tables 1, 2 ,3).

Table 1- Eastern Morphoclimatic Region.

Eastern Morphoclimatic Region		
Hills and Plains Region		
Processes	**Landforms**	**Average denudation rate (mm/year)**
Weathering Solution in limestone rocks (Dobrudja)	Carbonatic-syallitic and clay-syallitic weathering deposits (in regions with more 450 mm rainfalls/year)	0.05-0.07 in Stanisoara and Gosmanu Mts. (Radoane 2002)
Raindrop impact Active on hillslopes (with no vegetal cover) because of heavy rainfalls and rock's weak resistance.	Large soil-eroded areas (especially on the upper slopes), long colluvial glacis slopes	0.05-0.32 in Covurlui basin, Moldavian Plateau (Băcăuanu et al. 1980) 0.5-0.8 in Dobrudja Plateau (Popovici et al 1984)
Gully and stream erosion Very intense on hillslopes, because of heavy rainfalls; local occurrence on high river banks.	Ravines, gullies, torrential streams disrupting slope balance processes; alluvial fans	900 for ravine upstream development in Barladului Plateau
Fluvial erosion Important seasonally flowing variations; Suspension transport; important accumulation and lateral erosion during high-flows.	Large floodplains, intense alluvial processes.	
Nival processes Weak subsides in erosion hollows ("crovuri") or between the levees of the landslide bodies.	Microdepressions (lakes, swamps; bogs).	
Wind-erosional processes Deflation-accumulation in sandy areas	Active and semiactive dune landscapes (partially stabilized in the southern and eastern parts of the Romanian Plain)	

Table 2- Central Western Morphoclimatic Region.

Central Western Morphoclimatic Region				
Carpathian Region			Hills and Plains Region	
Processes	**Landforms**	**Average denudation rate (mm/year)**	**Processes**	**Landforms**
Weathering: Moderate gelifraction on baren steep slopes; relatively intense chemical weathering; intense solution on limestones.	Tallus cones and glacis; syallitic weathering deposits; karst landforms.	Frost heaving 135 (Urdea 2000) 47.44 in the Retezat. Mts. (Urdea 2000). 0.05-0.07 in the Rarau Mts. (Rusu 2002).	**Weathering:** Local gelifraction on bare slopes; Intense weathering with Moderate argillization in hills area; Clay/depositions in plain area; solution on salt, gypsum and limestone formations.	Tallus glacis; argillo-syallitic and carbonatic-syallitic weathering crusts; karst landforms.
Raindrop impact Moderate on deforested lands, related to rainfall frequency and slope-declivity.	Upper soil outwash.	1-2 in Baraolt Mts. (Bacaintan 1999)	**Raindrop impact** Moderate (locally) to excessive (hills area); weak in plain areas.	Severe rill flow or sheet wash.
Gravitational processes Active mass movements on sedimentary rocks.	Landslides and mudflows of varying volumes.	Talus creep 90-170 (Urdea 2000) Creep 30-50 in, forests, Rarau Mts. (Rusu 2002).	**Gravitational Processes** Active landslides on hill slopes; rockfalls in salt dome areas (mines).	Frequent land slides and erosion hollows.
Gully and stream erosion Intense processes on deforested slopes due to heavy rainfalls.	Middium-sized ravines and streams.	22-55 in Retezat Mts. (Urdea 2000).	**Gully and stream erosion**: Intense on steep, deforested hill-slopes.	Deep ravines and streams; outspread alluvial fans; badlands.
Fluvial erosion: Permanent, but occasionally intensifying in March-December.	Linear erosion; bulk transport, lateral dispersal of flood deposits.		**Fluvial erosion:** Permanent, but with seasonal variations; lateral erosion; suspension transport; rich alluvial depositions in lowland valley-floors.	Wide valley-floors; natural levees; meander scrolls; river-channel divide.
Nival and wind erosion: Rare avalanches; weak surface slides.	Nival depressions (locally: Reci)		**Nival and wind erosion:** Second-order agents in depression's gradation.	Sand-dunes (Carei).

Table 3- Southwestern Morphoclimatic Region.

Southwestern Morphoclimatic Region				
Carpathian Region		Hills and Plains Region		
Processes	Landforms	Processes	Landforms	Average denudation rate (mm/year)
Weathering: low intensity gelifraction; relatively intense chemical weathering; solution on limestones	Debris cones, Weathering syallitic and clay-syallitic Deposits, karst forms.	**Weathering:** Low to moderate chemical weathering; solution on limestones (Mehedinti Plateau).	Clay-syallitic deposits, karst forms.	
Raindrop impact: Low to moderate on deforested slopes.	Shallow soil-cover.	**Raindrop impact:** Moderate in hill areas, especially in March, April, October, and December.	Partial soil erosion.	0.33 in Jiu basin (Ujvari 1972).
Gully and stream erosion: moderate on deforested slopes.	Gullies and ravines.	**Gully and stream erosion:** Moderate to excessive on deforested slopes in the Getic Piedmont.	Ravines and deep stream-valleys, large alluvial fans.	500-700 for ravine upstream devel-opment in Buzau Subcarpathians Hills. (Balteanu 1983).
Gravitational Processes: Shallow landslides, in weathering deposits.	Shallow landslides and rockslides.	**Gravitational Processes:** Deep landslides on steeper slopes.	Landslides and mudflows.	0.5-10 for landsl-ides in Buzau Subcarpathian Hills. (Balteanu, 1983). 20-70 for Mudflows in Buzau Sub-carpathian Hills. (Balteanu 1983).
Fluvial erosion: Important river-flows (March-May, Nov.-Dec.)	Linear erosion, intense transport, low accumulation.	**Fluvial erosion:** Important river-flows during intervals with heavy rainfalls.	Moderate intensity erosion; intense transport, alluvial accumulation.	
Low intensity **nivation processes**.				

Conclusion

Various authors have tried to assess the mean denudation rates in the country's different geomorphological regions and the following guiding lines have resulted:

- strong denudation rates are characteristic of the alpine regions, in which Pleistocene glaciation has produced important perig-lacial depositions;
- intense soil creep is active in the high mountain regions, while chemical weath-ering is obvious in deforested areas;
- moderate denudation rates are main-tained in forested areas overlying flysch formations, mainly due to intense stream-erosional processes;

intense stream-erosional processes grad-ate the eastern plateaus with steppe and

- sylvo-steppe vegetation;
- landslides, earthflows and mudflows are extremely active on the deforested slopes of the Curvature Subcarpathian hills, affected by strong neotectonic and seismic movements, which are extremely active;

The delimitation of the morphoclimatic provinces on Romania's territory was achieved by the systemic knowledge of the analysed area's relief (first of all, the knowledge of the present day geomorphological processes) but also by analysing the spatial-temporal distribution of the main climatic parameters and of the existent climatic influences within the Romanian territory. Consequently, bringing together data of the morpho-dynamic potential and data which define the specific of the present modelling of the relief leads to several main units within the above mentioned provinces (tables 1-3), which are based on the main relief levels. Within these, there are subunits where processes are grouped depending on the characteristics of the preparing and starting factors.

- In the Carpathians there are: the alpine and subalpine morphodynamic levels (the gelifraction are dominant and they alternate with gully and stream erosion), the mountainous morphodynamic level with average altitudes, (fluvial and torrential erosion associating with gravitational processes, especially landslides,sheet-wash, solution on limestones), the morphodynamic level of the valleys' corridors, depressions and low mountains (fluvial erosion, floods plains, solution on limestones and gully and stream erosion, karstic processes, anthropic processes locally).

- In the hilly and plateau regions (altitudes over 300 m), there are fluvial and torrential erosion processes, as well as gravitational and anthropic processes.

- Low regions under 300 m with a different modelling between the plain units (compaction, suffosion, intense alluvial processes) and the plateau units (raindrop, landslides and gully erosion)

REFERENCES

Băcăintan, N. (1999) *Munţii Baraolt: Studiu geomorfologic*. Edit. Academiei, Bucureşti. 160 p.

Băcăuanu, V. (1980) *Podişul Moldovei, natură, om, economie.* Edit. Ştiintifica şi Enciclopedică, Bucureşti. 347 p

Bălteanu, D. (1983) *Experimentul de teren în geomorfologie.* Edit. Academiei, Bucureşti. 159 p.

Brătescu, C. (1928) Pământul Dobrogei. Dobrogea. I: 1-30.

Coteţ, P. (1957) *Câmpia Olteniei. Edit. Ştiinţifică, Bucureşti*, 272 p.

Ielenicz, M. (1984) *Munţii Ciucaş-Buzău - studiu geomorfologic.* Edit. Academiei, Bucureşti. 138 p.

Ielenicz, M. (2004) *Geomorfologie.* Edit. Universitară, Bucureşti. 344 p.

Martonne, Emm. (1907) *Recherches sur l`évolution morphologique des Alpes de Transylvanie,* Paris. 279 p.

Niculescu, Gh. (1965) *Munţii Godeanu. Studiu geomorfologic.* Edit Academiei, Bucureşti. 340 p.

Pop, Gh. (1963) The importance of the genesis of some levelled surfaces in the Apuseni Mountanies. *Rev. Roum. de G.L.C.* 8: 3-9.

Popovici, I et al. (1984) *Podişul Dobrogei şi Delta Dunării: natură, om, economie*. Edit. Ştiinţifică şi Enciclopedică, Bucureşti. 301p.

Posea, Gr. (1962) *Ţara Lăpuşului. Studiu geomorfologic.* Edit. Ştiinţifică, Bucureşti. 238p.

Posea, Gr. Popescu, N. and Ielenicz, M. (1974) *Relieful României*. Edit. Ştiinţifică, Bucureşti. 484p.

Rădoane, N. (2002) *Geomorfologia bazinelor hidrografice mici.* Edit. Universitară, Suceava. 255p.

Rusu, C. (2002) *Munţii Rarău. Studiu de geografie fizică.* Edit. Academiei, Bucureşti. 420p.

Urdea, P. (2000) *Munţii Retezat. Studiu geomorfologic.* Edit. Academiei, Bucureşti. 272p.

Ujvari, I. (1972) Geografia apelor României. Edit. Ştiinţifică, Bucureşti. 592 p.

Vâlsan, G. (1915) *Câmpia Română*. BSRG. 36: 3-105.

Vâlsan, G**.** (1917) Influenţe climatice în morfologia Câmpiei Române. Institutul Geologic. VII: 419-432.

(Received: Aug. 7-2009, Accepted: Nov. 7-2009)