LINKING GEOLOGICAL AND GEOMORPHOLOGICAL FEATURES. CASE STUDY: SLĂNICUL DE BUZĂU VALLEY

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Abstract. This paper presents the correlation between the geomorphological features of the Slănicul de Buzău Valley and the geological ones, such as the tectonic regime and the type of rocks. We are pointing out that the geomorphology of the valley and the change of the flow direction are linked to the type of rocks and tectonic elements of traversed geological structures. The change of the upper course of the river from NS to WE upstream the Lopătari locality coincides with a major tectonic element, a digitation occurring in the deposits formed by hard compact Paleogene rocks. The upper course deep valley is replaced by a larger one in the sector that exposed Miocene and Pliocene deposits, showing a W-E direction. The lower course of the river shows again a change in the course direction from N towards S, up to its confluence with the Buzău River. This modification corresponds to the occurrence of the friable Pliocene, Pleistocene and Holocene deposits, such as sandstones, clays, marls and weakly consolidated ones, *i.e.*, sands and loess.

Key words: Slănicul de Buzău River; geology; geomorphology; relationship between tectonics and relief

1. INTRODUCTION

The geologic structures can change the geomorphology, but also the various geomorphological processes, such as weathering and erosion that occur in the atmosphere and hydrosphere and have an important impact on the major and minor landform configurations of our planet. The geomorphological features might be mainly modified due to the tectonic regime (including neotectonics) and the type of rocks that differentially reacted to erosion and weathering. There is also a close relationship between the shape of the valleys and related landscapes, the type of traversed rocks and the tectonic regime.

This paper is focused on the aforementioned topic; the case study is the Slănicul de Buzău Valley. Geographically, this valley is located at the contact of Buzău and Vrancea Subcarpathians (Fig. 1), in the north-central part of the Buzău County.

2. REGIONAL SETTING

2.1. Geography

Slănicul de Buzău Valley crosses two distinct geomorphological units (Chendeș, 2011), which are: (i) the outer area of the Eastern Carpathians, including the upper course of the Slănicul de Buzău and (ii) the hilly area of the Subcarpathians, in which the middle and lower course are comprised.

This valley is an epigenetic one (Pătroescu, 1996). The area between Râmnicul Sărat and Slănicul de Buzău rivers belongs to the Vrancea Subcarpathians, while the region between Slănicul de Buzău and the Buzău rivers is part of the Buzău Subcarpathians (Posea & Badea, 1984). Geographically, the northern boundary between the Subcarpathians and the Carpathians follows the southern edge of Ivănețu Mountains, along the Sibiciu-Brăești-Lopătari alignment. It is dominated, in the western part, by the withdrawal witnesses of the mountains, *i.e.*, the peaks Goși, Vătraiului, Hoților, Pinului, Malul Alb and Pietriș (Tufescu, 1966).

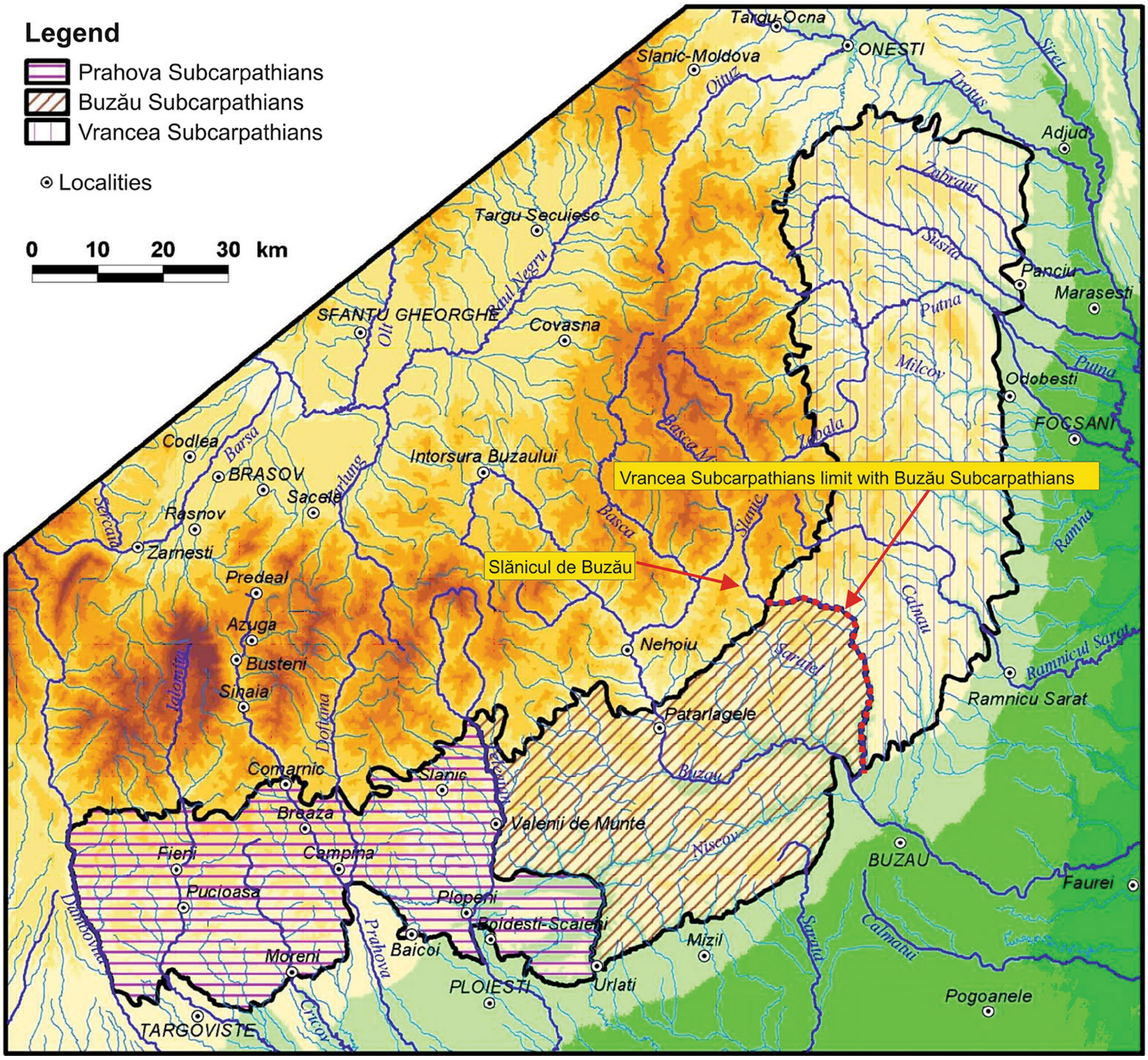


Fig. 1. Location of Slănicul de Buzău Valley in-between the Buzău and Vrancea Subcarpathians (after Chendeş, 2011).

Slănicul de Buzău River is the largest tributary of the Buzău River, with a total length of 73 km, of which 19 km in a mountainous region and 54 km in a hilly area. The surface area of the river basin is 450 km^2. Its spring is placed at the foothills of the Furu Peak, at 1,240 m altitude (Grecu & Comănescu, 2006). At the spring, the water is sweet, but passing through the Săreni area, downstream of Lopătari, it accumulates a large amount of salt and, additionally, more salt is brought by the Pecineaga stream (its confluence is situated near the Sări village, Săruleşti commune). The mountain course of the Slănic Valley delimits to the west the boundary of the Buzău Mountains, separating Ivăneţul Peak from Furu Peak. The relief combines different units with altitudes gradually decreasing from 1,400 m to 120 m. The river is characterized by permanent flow. Slănicul de Buzău flows into the Buzău River, at 120 m altitude, in Săpoca locality (Fig. 2).

2.2. Geology

Geologically, the studied area includes the eastern (outermost) extremity of the Tarcău Nappe (Fig. 3) that has a significant stratigraphic extension, starting within the Late Cretaceous interval (Cenomanian, Turonian and Coniacian age, Melinte-Dobrinescu *et al.*, 2017). Besides, Paleogene deposits (Eocene sandstone flysch facies and Oligocene bituminous facies – Fig. 4) occur on large areas (Ştefănescu *et al.*, 1993).

Upstream of the Lopătari locality, Slănicul de Buzău Valley crosses also units extending within the Oligocene-Miocene boundary interval (Fig. 4), made by turbidites, *i.e.*, rhythmically alternating sandstones, claystones and marlstones. Evaporite rocks, e.g., gypsum and salt, along with clays, marls and sandstones belonging to the Early Miocene interval are cropping out.

Fig. 2. Slănicul de Buzău confluence with the Buzău River near Săpoca locality, August 2018 (Latitude N 45°14’8.46”; Longitude E 26°43’55.4”).

Downstream the Lopătari locality, Slănicul de Buzău Valley traverses the Subcarpathian Nappe structures, on an approximately W-E direction, perpendicular to the geological structures. In the front of the nappe, an Early Miocene (Aquitanian) salt diapir occurs. The deposits crossed by Slănicul de Buzău Valley are Lower and Middle Miocene (Fig. 4): Burdigalian (conglomerates, clayey marls with gypsum and volcanic tuffs) and Badenian (sandstones, marls, sandstones and resedimented volcanic material, including the Mânzălești Tuff).

From upstream Mânzălești, Slănicul de Buzău Valley crosses, up to its confluence with the Buzău River, the Inner Foredeep deposits (Fig. 3). These are Late Miocene, Pliocene, Pleistocene and Quaternary in age (Fig. 4). The oldest deposits of the Inner Foredeep belongs to the Late Miocene interval, *i.e.*, Sarmatian stage, and are composed of sandstones, clays and gray marls, with locally red clay intercalations. The Pliocene is represented by sandstones, marls, sands and clays. These are in general poorly consolidated, containing sandstones, marls and sandy marls or unconsolidated such as sands. In the lower basin, an important place is occupied by the Pleistocene and Holocene sediments made by gravels, sands, clays and loess deposits (Motaş *et al.*, 1967 and Murgeanu *et al.*, 1968; Jipa & Olariu, 2009; Stoica *et al.*, 2012).

The spatial arrangement of the geological formations is quite complex. The folds from flysch area are tight, the so-called scale folds, and wider on the molasses (Ştefănescu *et al.*, 1993). Anticlines, synclines and digitations are also found on the studied area, suggesting a complicated tectonic regime (Melinte-Dobrinescu *et al.*, 2017). Although consolidated, sometimes, the lithological units are strongly cracked and fragmented during tectonic and uplifting processes through neotectonic movements, which may determine uplift or subsidence with 2-4 mm/year in this area (Zăvoianu *et al.*, 2005). The Slănicul de Buzău valley is subject to significant tectonic mobility that is specific to the entire contact area of the Eastern and Southern Carpathians (Visarion *et al.*, 1977; Săndulescu, 1994).

All along its course, Slănicul de Buzău Valley shows complete Upper Cretaceous, Paleogene, Miocene, Pliocene, Pleistocene and Quaternary successions (Ştefănescu *et al.*, 1989; 1993; Jipa & Olariu, 2009; Stoica *et al.*, 2012; van Baak *et al.*, 2015; Melinte-Dobrinescu *et al.*, 2017). Within the Mesozoic (including the Cretaceous period, which the rocks are cropping out in the study area), up to the end of the Eocene, this region, as the entire area of the Carpathians, was part of the Tethyan Domain (Săndulescu, 1984). Hence, the global stages are used (Fig. 4).

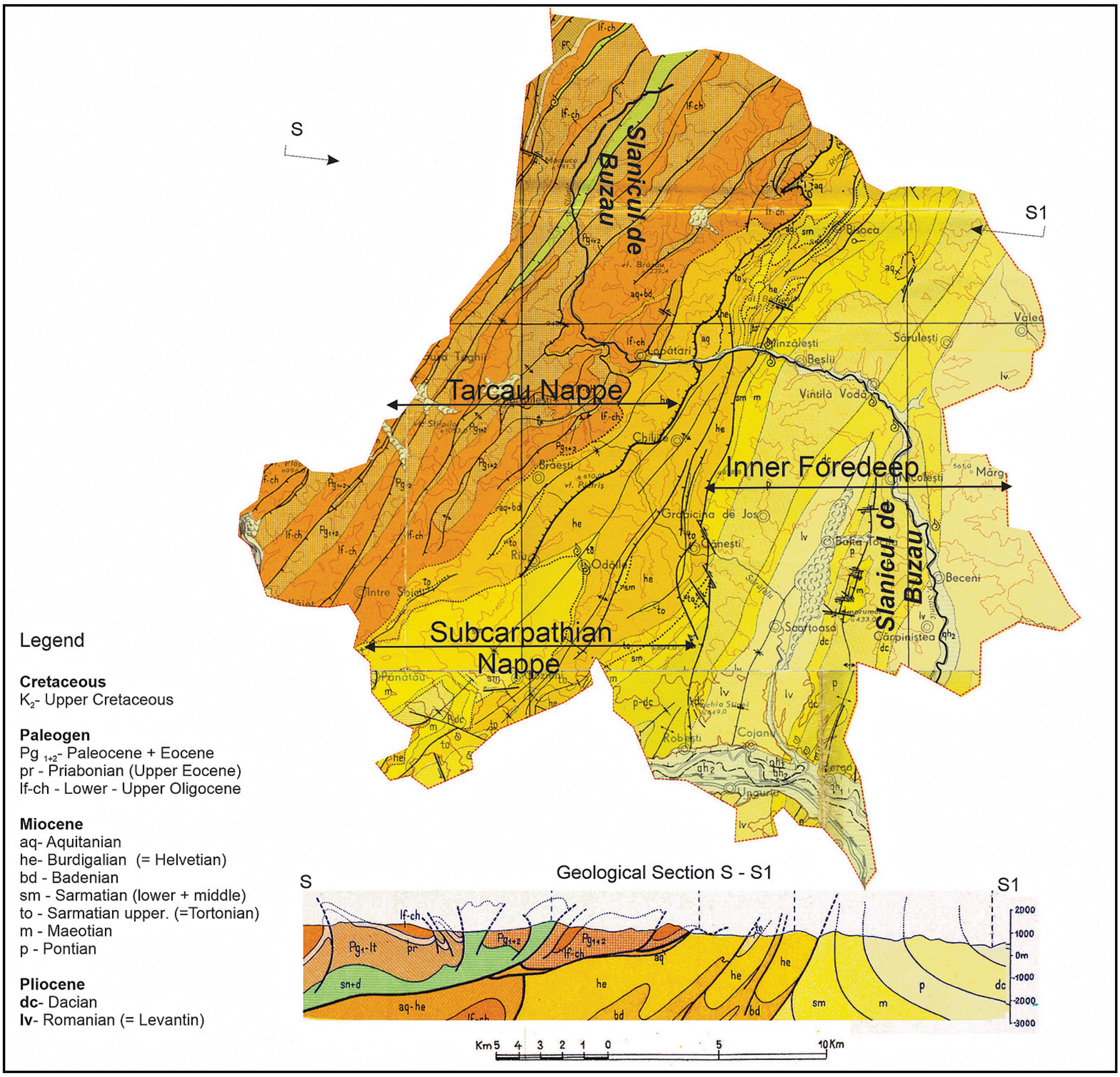


Fig. 3. Geological map of the Buzău Land Geopark that includes the region crossed by Slănicul de Buzău river (after map Motaş *et al.*, 1967 and Murgeanu *et al.*, 1968, Maps scale 1:200,000 Sheets Covasna and Ploieşti, published by the Geological Institute of Romania).

Starting from the base of the Oligocene, when firstly the Paratethys isolated from the Tethys Ocean, this area belongs to the Central Paratethys (Săndulescu, 1994; Popov *et al.*, 2004), so the stages used in the Carpathian area are those of the Central Paratethys Domain (covering mostly the whole Central and Eastern Europe – Piller *et al.*, 2007). Notably, in the Romanian geological literature, especially in the extra-Carpathians areas, for the interval Oligocene-Early Miocene, the geologists are in general using the global stages, *i.e.*, Rupelian, Chattian, Aquitanian and Burdigalian, and not the Paratethyan ones. From the Middle Miocene, the area crossed by the Slănicul de Buzău Valley belongs, paleogeographically, to the Dacian Basin (Eastern Paratethys), evolving as a closed or semi-closed basin, a bay of the Euxinic Basin (Jipa & Olariu, 2009; van Baak *et al.*, 2015). Therefore, the stages of the Eastern Paratethys are used.

3. MATERIAL AND METHODS

For this study several field campaigns were achieved during two successive years (2018 and 2019). During these field campaigns the outcrops along the Slănicului de Buzău Valley were analyzed from the lithological/sedimentological points of view, taking into account the tectonic features.

The study was focused on the valley geomorphologic features occurring on the entire valley, from the spring to its confluence. Besides *in situ* observations, a DJI Phantom 3 and a DJI Inspire 2 drones were used, for acquiring aerial observations and photographs.

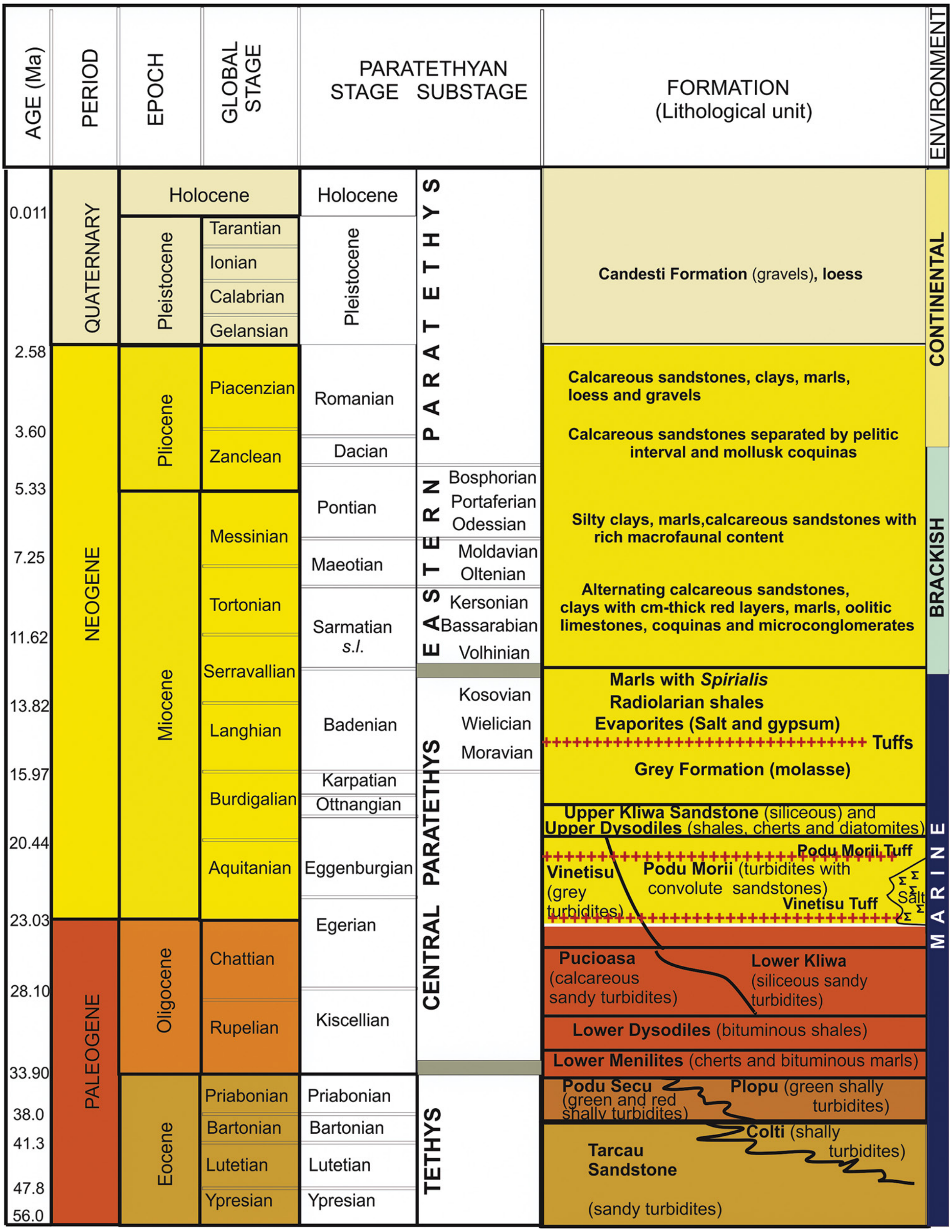


Fig. 4. Lithostratigraphy of Paleogene to Quaternary sediments cropping out in the Slănicul de Buzau River (compiled from various sources: Motaş *et al.*, 1967; Dumitrescu *et al.*, 1968; Murgeanu *et al.*, 1968; Ştefănescu *et al.*, 1989; 1993; Ştefănescu & Melinte, 1992; Jipa & Olariu, 2009; Stoica *et al.*, 2012; Melinte-Dobrinescu *et al.*, 2017). Correlation of the Global stages with Paratethyan ones after Piller *et al.* (2007).

To point out some Slănicul de Buzău features, different parameters were vectorized in ArcGis. It is important to locate the vectorized areas on the trough for obtaining an accurate analysis. Hence, Slănic de Buzău River was divided into 3 sections. Further, we divided the river in 100 m segments and calculated the geometry of the segments. Finally, we established the erosion classes as follows: negative values up to -1.5 for the depth erosion, positive values of 1.5 for equilibrium and values that exceed 1.5 for lateral erosion.

4. RESULTS

Considering the morphology of the Slănicului de Buzău Valley, we have divided it into several sectors (Fig. 5). The relationship between the type of rocks and the shape of the valley is presents below (from upstream to downstream).

SEGMENT 1 extends from the springs of Slănicul de Buzău (Furu Peak) up to the Lopătari locality (Fig. 4). This sector is part of the Tarcău Nappe, crossing Cretaceous and Tertiary (Eocene and Oligocene) deposits. From a lithological point of view, the mountainous sector of the Slănicul de Buzău valley is made by Upper Cretaceous turbidites (*i.e.*, rhythmic alternation of gray calcareous sandstones and gray clays) and Paleogene turbidites, such as Eocene calcareous sandstones, clays and gray-green marls, followed by Oligocene siliceous sandstones interbedded with bituminous clays and silicolites (Figs. 4 and 5).

The orientation of the valley is north-south, being generally perpendicular to the direction of crossed structures, which the vergence is mainly NE to SW. From the geographical point of view, Sector 1 falls into the mountainous sector. The mountain course of the valley delimits at the west the boundary of the Buzău Mountains, separating on this sector the Ivănețului Peak from the Furu Peak. The mountains occupy the northern part of Slănicul de Buzău Valley: Furu Mare Peak (1414 m), Măceșului Peak (1364 m), Breazvu Massif (1239 m), and on the right side of Slănicul de Buzău there is another mountainous ridge, which run parallel to the river: Chilmiziul mountain (1266 m), Plaiul Răbojului (1241 m), Plaiul Războiului (1096 m) and Ivănețu peak (1191 m) – Topographic Map scale 1:100,000 L-35-90.

Downstream, the valley crosses a hilly area at the foot of the Mts. Ivănețu and Breazau. The lowest relief element of this sector is represented by the Lopătari Depression, located on both sides of the Slănicul de Buzău Valley.

Slănicul de Buzău River crosses, from its spring up to the N Terca locality, Upper Cretaceous sediments, as well as Paleogene (Eocene and Oligocene) ones. It is noteworthy that in Segment 1, the valley is narrow, with steep slopes and without terraces (Fig. 6). In the steep slopes, vertical layer formed of hard siliceous sandstone intercalated with bituminous rocks (dysodiles and menilites) of Oligocene age (Melinte, 2005) occur.

Within Segment 1, south of the Terca locality, the Slănicul de Buzău Valley changes its direction. Thus, from a N-S direction the valley flows towards NW-SE up to the Lopătari locality (Fig. 5). The change of the river direction seems not to be related to any lithological changes, as the same type of rocks (mainly siliceous hard sandstones, *i.e.*, Oligocene Kliwa Formation) is crossed by the valley. Most probably, the modification of the valley direction is related to the tectonic features of the region. The change in direction of the valley coincides with the overpass of an important tectonic element that is a digitation of the Tarcău Nappe; additionally, in the area the sedimentary beds are almost vertical.

In Segment 1 (*i.e.*, at the confluence with Nucului Valley), Slănicul de Buzău formed a deep and narrow valley, but at the exit from the mountainous sector, due to the lithology (Miocene softer deposits than the Oligocene hard rocks cropping out), the valley is wider and river terraces appear. Still, the meanders are missing (Figs. 7 and 8).

SEGMENT 2 extends south of the Lopătari locality up to south of the Vintilă Vodă locality (Fig. 5). The crossed deposits are Miocene sediments of the Tarcău Nappe (marls, clays and calcareous sandstones), as well as those belonging to the Subcarpathian Nappe, including the Lower Miocene salt breccia exposed in the Nature Reserve of the Meledic Plateau (protected site IUCN category IV mixed geological, speological, botanical and zoological reserve – Fig. 9).

The plateau is located at an altitude between 400 and 600 meters, in the Lower Miocene deposits. The Meledic Plateau has steep slopes along the valleys of Sării, Izvorul Sărat and Grădinii, the last two drain the Slănicul de Buzău Valley. On the slopes, clays and marls towards top, 10-30 m thick, which overlays the salt breccia, are exposed. Exploration drilling showed an average NaCl content of 81.7%, the salt being deposited about 23 million years ago (in the Lower Miocene, respectively the Aquitanian stage). On the slopes micro-valleys were formed, with short lengths and high slope thalweg, sometimes lowered into deep canyons of several meters. Downstream Lopătari, the Slănicul de Buzău water becomes salty. On the Meledic Plateau there is a freshwater lake. This one, the Lake Meledic, is unique because it is made of fresh water, although it is located on a salt massif. The formation of the lake went through several phases: the infiltration of water through the salt breccia, the sinking of the plateau with the bottom of the lake and the connection with the hydrographic network. The low grain size alluvial material transported by the meteoric waters, waterproofed the bottom of the lake and interrupted the connection with the salt deposits. The pluvial contribution and the lack of contact with the salt deposits (on which this lake formed) produced the fresh character of the lake and implicitly the change in vegetation.

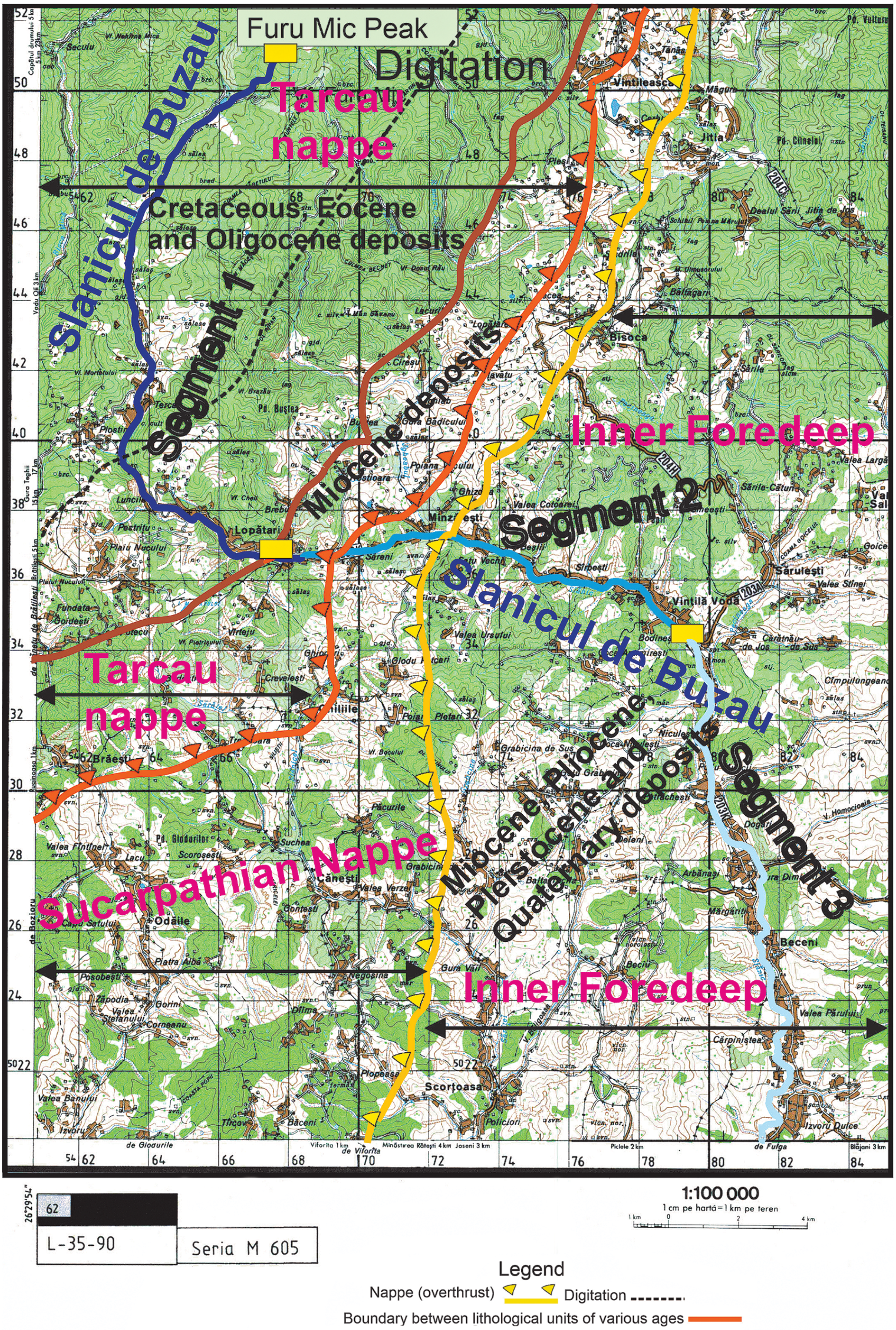


Fig. 5. The segments of Slănicul de Buzău Valley identified according to the geomorphology of the valley and type of the rocks.

Fig. 6. Abrupt relief on Oligocene Kliwa sandstones interbedded with bituminous marlstones, claystones and siliceous rocks on the right bank of Slănicul de Buzău, south of its confluence with Nucului Creek, Luncile locality (Photo March, 2019).

Fig. 7. Slănicul de Buzău Valley at the confluence with the Nucu Valley (Photo March 2019).

Fig. 8. Slănicul de Buzău Valley to N of the Lopătari locality (Photo March 2019).

Fig. 9. The Salt Mountain, included in the Nature Reserve Meledic Plateau (Photo March 2019).

In the Segment 2 of the valley, downstream Lopătari, at Mânzălești, another Nature Reserve "The White Stone *La Grunj*", protected site IUCN category III - Geological reserve, is located (Fig. 10). There, it is an impressive outcrop of Middle Miocene (Badenian) resedimented volcanic material described as the Mânzălești Tuff (Stoica *et al.*, 2012) that contain microfaunas, *i.e.*, globigerinids and calcareous nannofossils (Melinte-Dobrinescu & Stoica, 2013), similar to the Slănic Tuff (Piatra Verde Hill), situated at Slănic-Prahova. South of the Mânzălești locality, the river crosses the Upper Miocene-Pliocene deposits of the Inner Foredeep (Fig. 11), such as Sarmatian, Pontian, Meotian, Dacian and Romanian (formerly described in the Romanian literature as the Levantin Stage).

From Mânzălești up to Vintilă-Vodă, the direction of the river flow is perpendicular on the traversed lithological units, while south of Vintilă-Vodă the river is parallel with the bed direction. The outcrops exposed sidelong the valley are mainly made by friable sandstones, clays and sands, commonly with coal lenses. Rich and diverse macrofaunas (mainly bivalves) may be found in the aforementioned sediments.

Fig. 10. "The White Stone *La Grunj*" protected site IUCN category III (Photo March 2019).

Fig. 11. Lower Pliocene deposits N of Vintilă-Vodă capped by a river terrace (Photo March 2019).

Terraces appear along the river, especially in the eastern part of Segment 2, at Beşlii, Sârbeşti and Vintilă Vodă (Figs. 11 and 12). The valley widens and becomes meandered.

SEGMENT 3 extends east the locality Vintilă Vodă (Fig. 13), from the confluence of the Slănicul de Buzău Valley with the Pecineaga stream (left tributary) to the discharge of Slănic de Buzău into the Buzău River (at Săpoca locality). On Section 3, the Slănicului de Buzău Valley flows in the N-S direction until the spill. The valley is very wide and strongly meandered (Fig. 14) and has 3 terraces (a high terrace of 100-150 m, a medium terrace of 40-50 m and a low terrace, of 3-4 m, with meadow character). These terraces can be found at Niculești, Gura Dimieni, Beceni and Săpoca localities (Figs. 15 and 16).

In Section 3, Slănicul de Buzău Valley crosses exclusively the Pliocene and Holocene deposits of the Inner Foreland basin, consisting of sands, sandy clays, marls, sandy sandstone and loess deposits; these mainly outcrop N Săpoca and up to the discharge of the Slănicul de Buzău in the Buzău River. From Vintilă-Vodă towards south, the valley is parallel to the direction of the geological strata (the river has a directional flow). Probably the presence of these deposits was decisive in changing the course of the Slănic de Buzău Valley, from the E-W to N-S direction. Besides the nature of the crossed deposits, very soft comparing with upstream crossed Paleogene and Lower Miocene ones, a determining factor might be the tectonics; the valley is crossing the rocks directionally, in the area of a minimum resistance.

Slightly upstream the confluence of Slănicul de Buzău near the confluence with the Buzău River, wide valley, slightly deep, with thickened walls may be observed (Fig.17).

Establishing the river sectors in which one of the processes predominates is very important for the river dynamics, not only to make this analysis diachronic, but also for the fact that the impact on anthropogenic elements is related to these riverbed processes. If there is lateral erosion, it will tend to meander and erode the river banks and everything on that bank will be affected. In case of a deep erosion, the bridges may be affected, because the river deepens and the pillars or bridges extremities remain suspended. Hence, it is very important to know which sectors are prone to erosion and what type of process predominates, for estimating which element is affected (Fig. 18).

In Section 1 (Fig. 19), the riverbed processes are active, and the lateral erosion process dominates with 55%, followed by the depth erosion with 34.65% and equilibrium process with 9%. Although this sector is a mountainous sector, the predominant process is represented by a lateral erosion. In Section 2 (Fig. 19), the values of the riverbed processes are similar with those aforementioned. Thus, the lateral erosion is the highest with 36%, followed by the river equilibrium with 35% and depth erosion with 29%. Section 3 is characterized by more stable processes, with 41% river equilibrium, followed by the process of lateral erosion with 30% and depth erosion with 29%. The trend of the river in this sector is to reach a dynamic balance.

Fig. 12. Slănicul de Buzău Valley south of the Sârbeşti locality (Drone photo, March 2019).

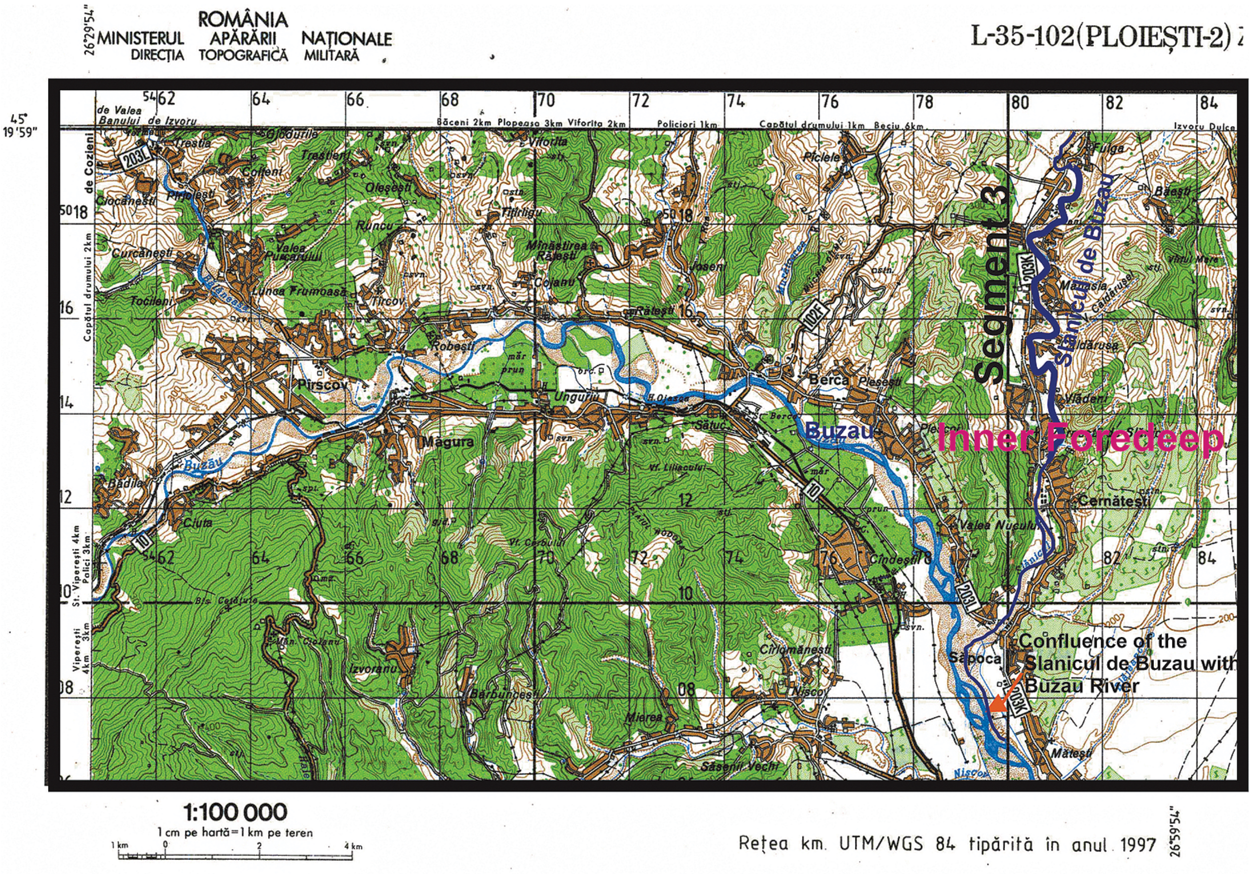


Fig. 13. Segment 3 of the Slănicul de Buzău, showing a flow direction N-S, and including the confluence with the Buzău River at Săpoca.

Fig. 14. Slănicul de Buzău valley near the Aldeni locality. The valley widens, the meanders occur, and a low terrace with meadow character is present (Drone Photo March 2019).

Fig. 15. Slănicul de Buzău Valley showing a wide development and strongly meandered character in the Section 3, near the confluence with the Buzau River at Săpoca.

Fig. 16. The confluence of Slănicul de Buzău with the Buzău River at Săpoca, included in the Section 3.

Fig. 17. Slănicul de Buzău near the confluence with the Buzău River, wide valley, slightly deep, with thickened walls (photo March 2019).

The course of the Slănicul de Buzău River in Section 1 is generally influenced by the high relief of the valley, which naturally limits its width. Therefore, there are rarely natural changes in the riverbed; these changes may be due to landslides, which may partly block the major riverbed. In Section 2, the values of the riverbed processes are in a certain equilibrium, while the tendency of lateral erosion is slightly prevailing. In Section 3 the tendency of the Slănicul de Buzău river is to reach a dynamic balance, due to various factors such as decreased flow speed, along with slope small angles and lithological features, *i.e.*, mainly sands and gravels. We conclude that the riverbed processes map analysis in the Slănicul de Buzău is a meandering river.

The slope exposure represents the compass direction that a slope faces, being used to determine the action of direct solar radiation on the active surfaces. This process is useful establish the intensity and frequency of different geographical phenomena such as: modeling processes, soil types, vegetation types, topo climates, etc. Regarding the exposure, there are different types of slopes: shaded slopes, with N and NE exposures (60 kcal/cm^2/year), semi-shaded slopes, with E and NW exposures (120 kcal/cm^2/year), sunny slopes, with S and SW exposure (170 kcal/cm^2/year) and the semi-sunny slopes, with W and SE exposure.

The exposure is a parameter related to geomorphological processes, controlled by solar radiation, temperature and precipitation. By combining the slopes exposure map with the slope ones, the flat surfaces are highlighted (Fig. 20). These correspond to the meadows and interfluves in the river basin, representing the lower and upper limits of the slopes. For the analysis of slope dynamics or functional slope units, the identification of these areas is essential. In digital models, it is possible to work with slopes of 0°, but the existence of a perfectly horizontal slope in nature is considered unlikely, determining the grouping of slopes with values between 0° and 2° or even 0°up to 4° in a single class that is considered to be flat.

Slopes with southern exposure are exposed to the sun for a longer period of time, so that solar energy heats the earth and dries it more than the land with other direction exposures. Slopes with S and W exposure in the northern hemisphere are more prone to erosion than those with N and E exposure; the aggregates are dry, have a weaker cohesion and dissolve more easily. In winter, the soils on the southern slopes are more frequently exposed to the action of frost-thaw. Besides, on the southern slopes, evaporation is stronger than on those with exposed on other directions. Therefore, on these lands, although there are smaller leaks, the erosion process is more active. At slopes with a N exposure the erosion is lower, being generally more protected by vegetation.

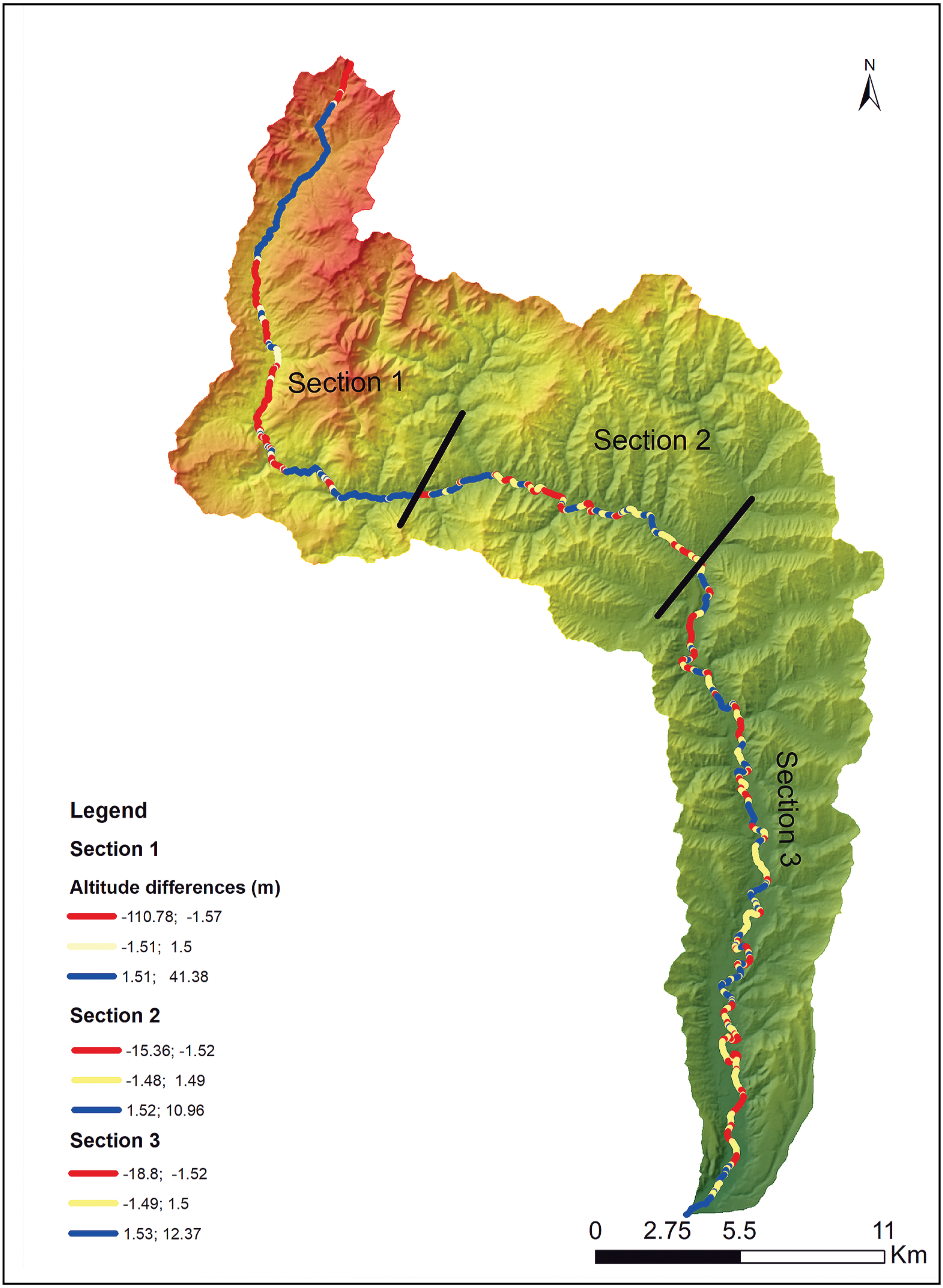
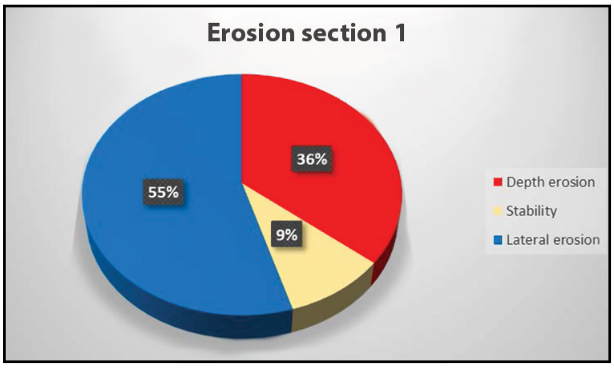
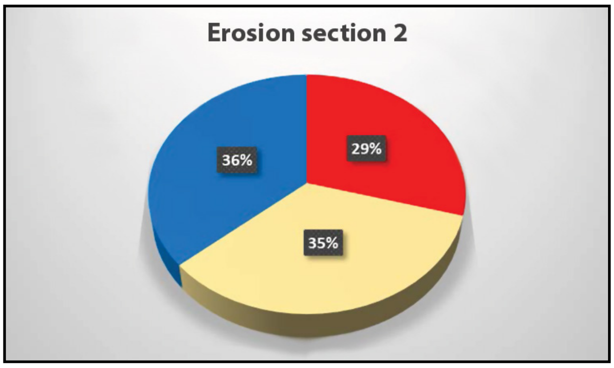


Fig. 18. Map of Slănicul de Buzău River processes divided in three sections. Red color represents depth erosion, yellow equilibrium and blue lateral erosion.





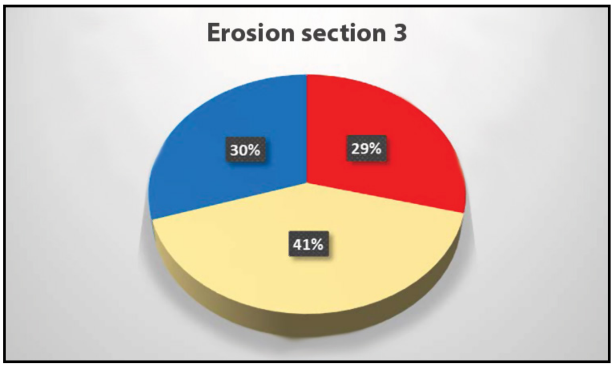


Fig. 19. Erosion processes in Slănicul de Buzău as identified in the three sectors.

The hypsometric map (Fig. 21) is a representation that generalizes the relief forms in hypsometric ensembles, by using colors. The hypsometric map represents the altitude of the earth surface grouped into altitudinal classes or ranges. In Slănicul de Buzău Basin, the largest area is characterized by altitudes comprised between 250 – 500 m, covering over 39% of the area and a surface of 170.37 km^2, located in Section 2. The least common altitudes are the ones below 120 m, with 0.03% and an occupied area of about 0.14 km^2. To note that 120 m altitude is found only at the confluence of Slănic de Buzău with the Buzău River. The altitudes comprised between 120 and 250 m are covering 7.76% and a surface of 33.26 km^2 and can be found in Section 3, especially in the meadow. The altitudes higher than 900 m are found especially in Section 1 covering over 28% and the surface of 120 km^2.

The plan curvature highlights the concave, flat and convex sectors of the terrain (Fig. 22). Concave sectors are convergent areas, which "hold" water and are consequently more susceptible to landslides; over 50% of the areas known to be affected by landslides correspond to concave surfaces.

The landslide susceptibility represents the possibility of a landslide in an area, taking into account the ground conditions in that area. The landslide susceptibility map (Fig. 23), in the Slănicul de Buzău Basin represents the probability of landslides in a certain area, which does not depend on time. The calculation formula of susceptibility to landslides includes, in equal measure, the characteristics of the topographic surface (slope, curvature in the plane), the rock substrate and the land use.

5. CONCLUSIONS

The relationship between the geological features and the geomorphology of the river valley is well expressed in the Slănicul de Buzău Valley that extends both in the Carpathian and Subcarpathian units. These mountainous and hilly chains show, from a geological point of view, a complex structure, as a result of a complex tectonics throughout the Neogene times.

Downstream the valley, there is a gradual transition from the folded, tight structure, belonging to the mountainous Paleogene deposits of the Tarcău Nappe to an ensemble of Miocene to Pliocene rocks of the Subcarpathian Nappe with wide folds. The easternmost part of the area is a monocline of the Inner Foredeep. In the mountainous sector, there is a relief developed in folded structures, including several anticlines, synclines and digitations. The shape of the valley is very narrow, without terraces, meanders and, therefore, influenced by tectonics and petrographic composition of the crossed rocks, that produced differential erosion. The peaks are represented by folded Paleogene deposits, with layers raised up to near vertical position. In the Subcarpathian sector, the structure does not change and the peaks are also made up by anticlines, with the larger folds prevailing. There is a concordance between the forms of relief and structure, peaks on anticlines and depressions on synclines (for instance, the Lopătari-Mânzălești Depression).

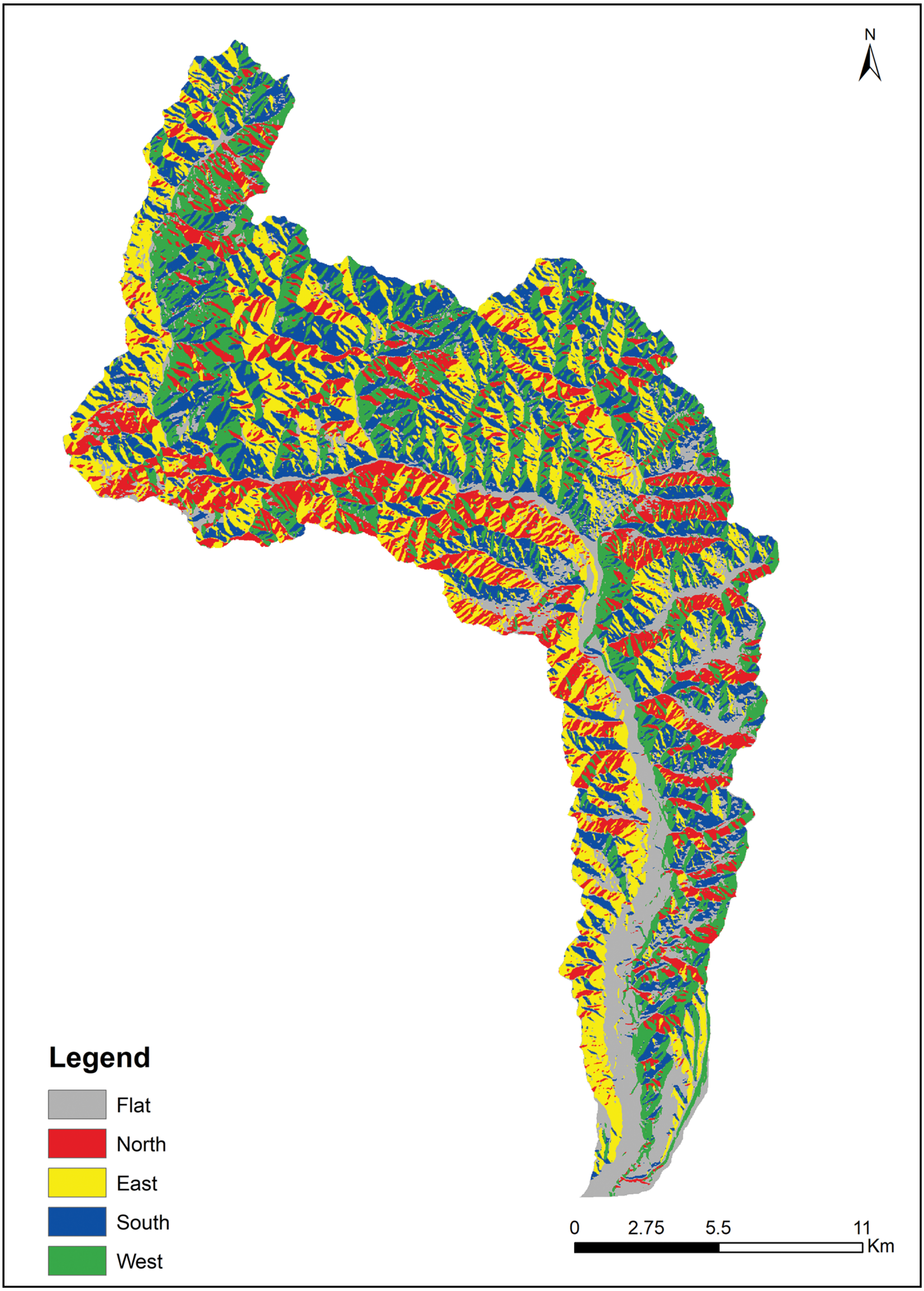


Fig. 20. The slope exposure map of Slănic de Buzău Basin.

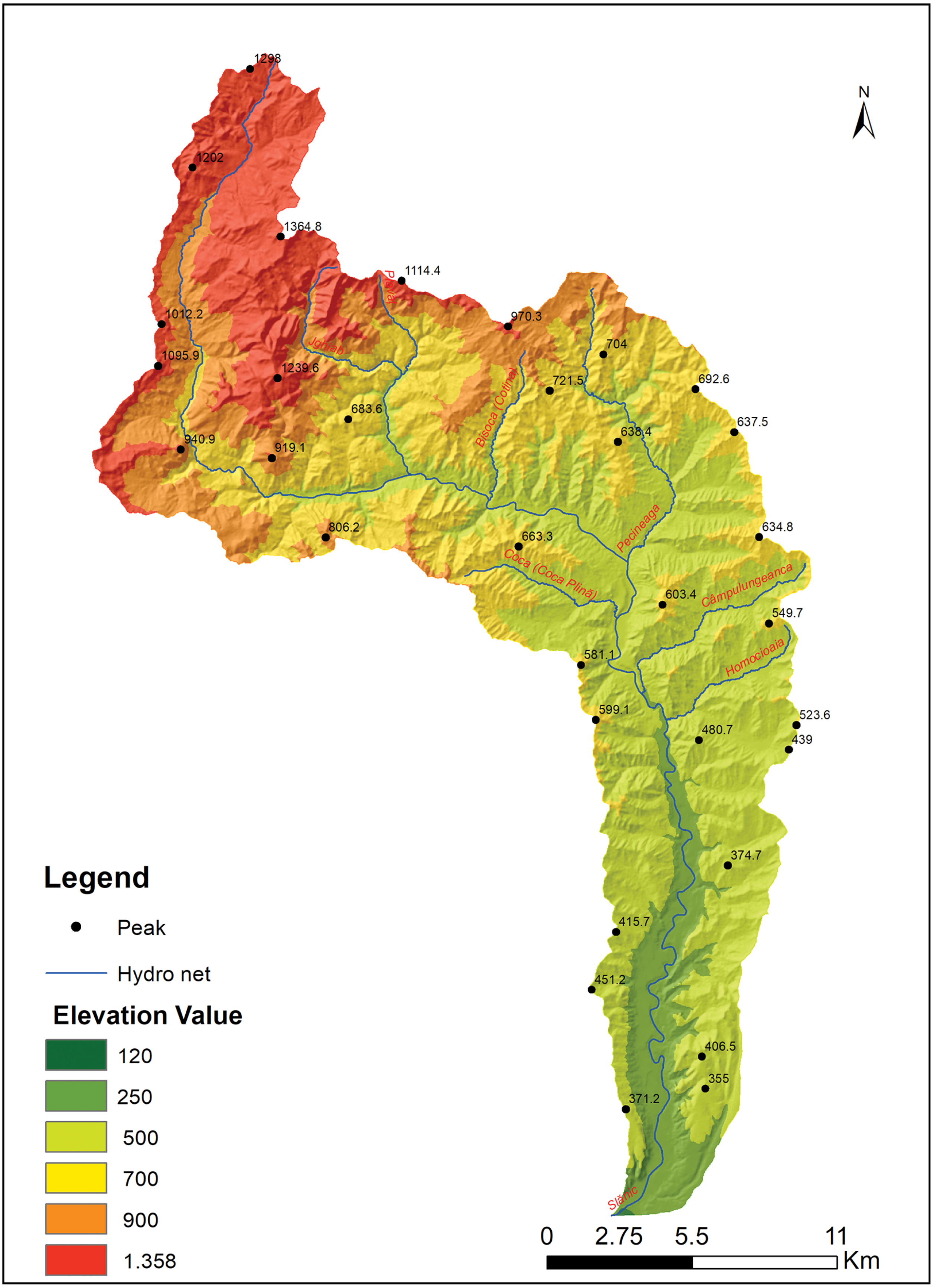


Fig. 21. Hypsometric map of the Slănicul de Buzău Basin.

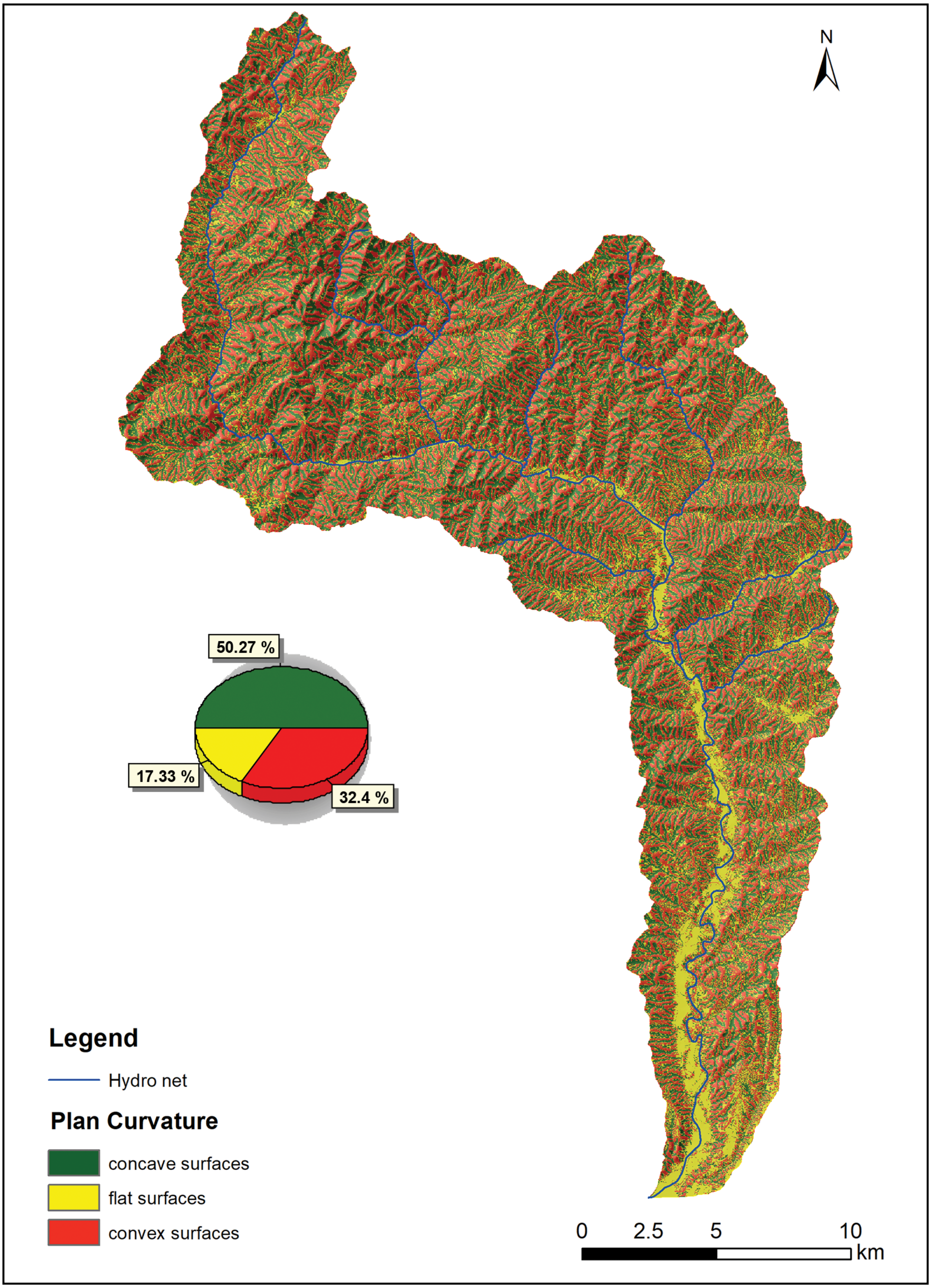


Fig. 22. Plan curvature map of the Slănicul de Buzău Basin.

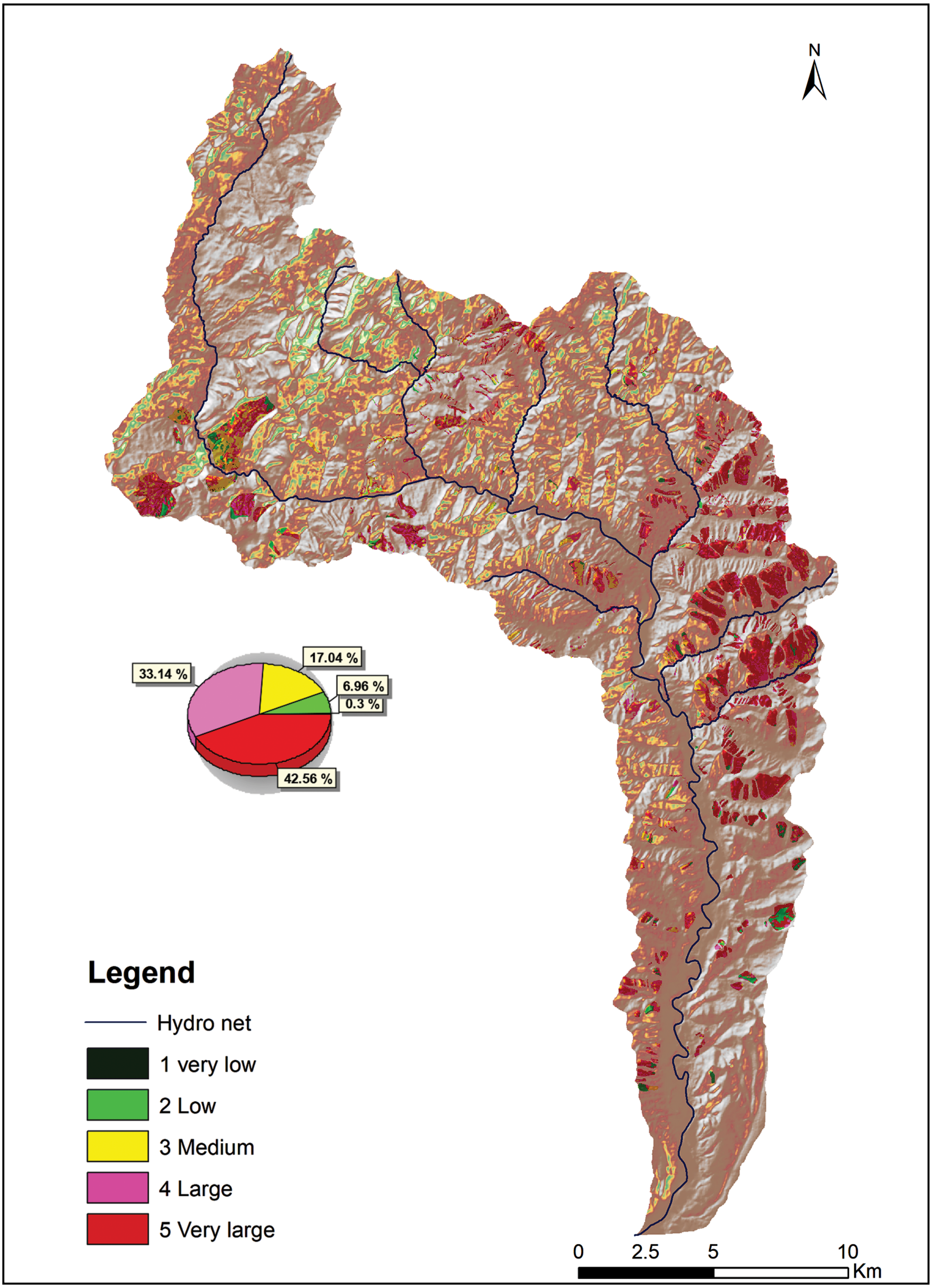


Fig. 23. Landslide susceptibility map of Slănicul de Buzău Basin.

At the entrance in the Subcarpathian geomorphological unit, Slănicul de Buzău Valley is characterized by a change in direction (from NS to WE) related to the position of strata and the existence of a major tectonic element, a digitation formed by hard sedimentary rocks (Late Cretaceous, Eocene and Oligocene in age). Downstream the confluence of Slănicul de Buzău Valley with Jghiabu stream, near Mânzălești locality, the structure changes, from a folded one, with several synclines and anticlines, to the monoclinal one. The structural contact is well highlighted by the erosion from the Mânzălești Slănic riverbed, where a dacitic tuff (resedimented material) with carved structure is exposed.

A new change of the valley direction (from, approximately, WE to NS) is remarked in its lower course, south of the Vintilă Vodă locality, where very soft, almost unconsolidated rocks, are traversed. The valley is large, with several terraces and highly meandered, with numerous thresholds in the thalweg. To note that up to Vintilă Vodă locality, the valley is perpendicular on the traversed geologically structures, while in the eastern and southern downstream the aforementioned locality, the development of the valley coincides with the direction of the crossed rocks.

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