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THE INFLUENCE OF PETROGRAPHY ON THE RELIEF OF THE BISTRIŢEI MOUNTAINS (THE EASTERN CARPATHIANS)

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ABSTRACT. – The Influence of Petrography on the Relief of the Bistriţei Mountains (The Eastern Carpathians). The petrographic characteristics impose certain general aspects in the morphology of any region. The geological composition of the Bistriţa Mountains is varied, being dominated by epimetamorphic rocks (sericitic, chlorite, graphite and quartzite schists) and mesometamorphic rocks (paragneisses, mica-schists, crystalline limestones and dolomites, amphibolites). To these, some isolated island-like areas of Mesozoic sedimentary rocks are added in the southern part, while in the eastern and southeastern parts, Cretaceous flysch, belonging to the Ceahlău Nappe is common. In the central axis there is a porphyroid dyke.

From a geomorphological point of view, metamorphic rocks have encouraged the formation of dull, widely vaulted ridges, domes and deep valleys, with slopes having a convex profile. The porphyroid gneisses generated a relief of sharp, lofty ridges and peaks, with steep slopes. Long, narrow crests (called "obcine" in this area, too) and wide valleys develop on the sandy-shale flysch in the southeastern part. In the south, slender hills appear, due to the presence of dolomites and limestones, whose hardness exceeds that of the metamorphic rocks surrounding them. Levelled surfaces are very well preserved on the crystalline rocks. Where the valleys cut the Pietrosu gneiss bar or the epimetamorphic schists, gorges and defiles come into existence.

Keywords: *Bistriţei Mountains, petrography, vaulted backslopes, ridges, levelled surfaces, low mountains.*

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1. Introduction

Geological structure and tectonics are two factors that decisively influence the geomorphological characteristics of a region. They have an impact on slope stability, bring about differences in the sequence of the layers with various degrees of resistance, account for the relation between dip and slope angle, and are responsible for the occurrence of fissures, diaclases, faults, etc. And the influence goes beyond the genetic types of relief imposed by rock and geological structure in a certain evolutionary stage, taking also into account the aspects induced by petrography in the overall morphology of a region (Ielenicz, 1984).

Bedrock is a control factor of the current geomorphological processes (collapses, topples, landslides, etc.), but it can also impact other aspects of the terrain, which cannot be included in the petrographic relief, but are determined by rock properties (Săndulache, 1997).

The Bistriţei Mountains are located in the northern part of the Central Group of the Eastern Carpathians ("The Moldavo – Transylvanian Carpathians", Geography of Romania, vol. III, The Academy Publishing House), between the valleys of Bistriţa to the North and East, Bistricioara to the South, and the Neagra Şarului – Drăgoiasa – Bilbor corridor to the West. If to the North, East and South the borders are clearly outlined, to the West they are separated from the Călimani Mountains by Neagra Şarului (a compartment of the Dornelor Depression), Drăgoiasa – Glodu and Bilbor depressions, and the high saddles between them. They cover an area of 1086 km^2. Adjacent to them are the Giumalău (to the North), Rarău (to the North-East), Stânişoara (to the East), Ceahlău, Hăghimaş, Giurgeu (to the South), and Călimani Mountains (to the West) (Fig. 1 a and b).

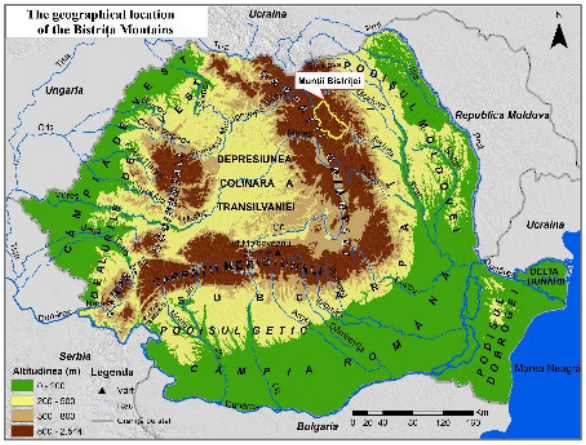

Fig. 1a. Geographical location of the Bistriţei Mountains in Romania.

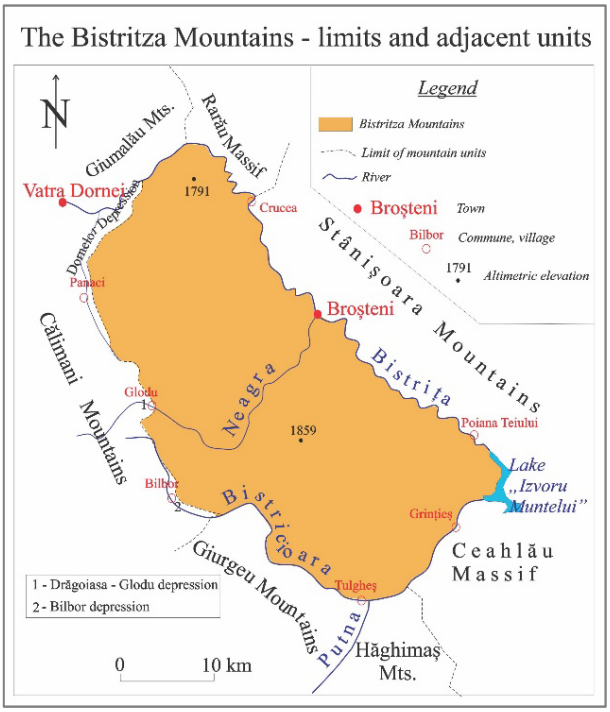

Fig. 1b. The Bistriţei Mountains – limits and adjacent units.
Source: the authors

2. Methods and Materials

In carrying out this study, the following stages were completed: consulting the specialized literature (geomorphological and geological maps, articles and treatises), georeferencing the contour lines on the topographic map of scale 1:25000, in the ArcMap program GIS 10.5, and creating morphometric maps. The documentation stage was supported by field investigations, mappings on topographic maps of scale 1:25000, various observations and thematic photographs. The geological map was accomplished based on the Geological Map of Romania, scale 1:200000, Topliţa sheet, and subsequently, by corroborating it with field observations, the map of levelled surfaces was drawn, in accordance with those identified in the field.

3. Results and Discussions

Fig. 2. Red granitic gneiss belonging to the upper complex of the Hăghimaș – Rarău – Bretila mesometamorphic crystalline, on Mount Măgura (photo: Feb. 2016).
Source: the authors

3.1. Geological features. Petrographic structure, although diverse, is dominated by the epi- and mesometamorphic rocks, which to the South are accompanied by several Mesozoic sedimentary "islands", and to the East and South-East by the internal flysch, of Cretaceous age, of the Eastern Carpathians, represented by the Ceahlău Nappe (Mutihac, 1990) (Fig. 3). The mesometamorphic crystalline formations of Hăghimaș – Rarău (Fig. 2) and Rebra – Barnar (Mutihac, 1990), and the epimetamorphic ones of Tulgheș and Repedea, have relatively equal weights. The first category includes paragneisses, micaschists, limestones, crystalline dolomites, and amphibolites, while the latter, sericitous schists (Fig. 4), chlorite schists, graphite schists and quartzite schits. At the southern end, on confined areas, sedimentary rocks, prevailingly carbonate, are found, belonging to the "Bucovinic sedimentary formation" of the crystalline – Mesozoic domain[4] (Mutihac, 1990): Triassic dolomites and limestones, Jurassic sandstones and limestones, and Lower Cretaceous wildflysch – in the Bâtca Arsurilor, Comarnic, Piatra Runcului, and Măgura massifs. Triassic dolomites also occur in the North-West (Mount Rusului, Șarului Peak, Ulmului Peak) (Fig. 7).

[4] The cited author calls the northern section of the crystalline – Mesozoic area, "the central-eastern Carpathian unit", which includes most of the Bistriței Mountains, while the southern section belongs (from a geographical standpoint) to the Southern Carpathians, specifically to the Bucegi – Leaota group, as well as to the Postăvaru and Piatra Mare massifs, and it is called "the Leaota – Bucegi – Piatra Mare unit".

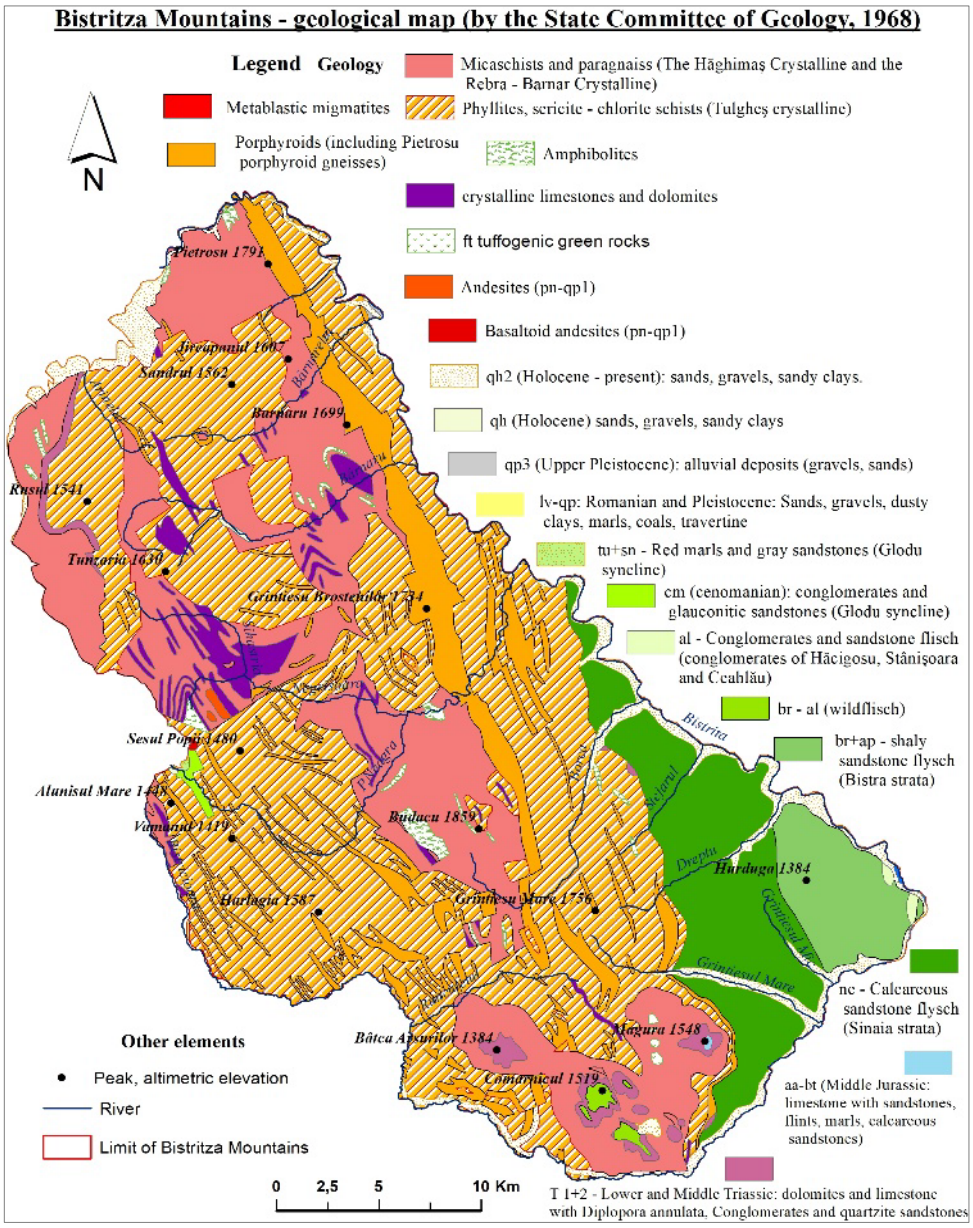

Fig. 3. Geological map of the Bistriţei Mountains.
Source: The Romanian Geological Society, 1968, Topliţa and Rădăuţi sheets

Fig. 4. Sericito – chlorite – quartzite schist belonging to the Tulgheş epimetamorphic crystalline formation, on Mount Harlagia (photo: May 2001).
Source: the authors

Fig. 5 – Porphyroid gneiss of Pietrosul Bistriţei, found on the Neagra Broştenilor valley (July 2009).
Source: the authors.

Within the Tulgheş crystalline formation, along the central – eastern axis of the Bistriţei Mountains, there is a large dyke of porphyroid rocks, trending North – South (between Giumalău and Grinţieşu Mare peaks) (Fig. 3 and 5). According to some geologists (Balintoni, Gheuca, 1977), these rocks do not represent a magmatic body, but a subaerial tuff formation (subsequently metamorphosed), which settled on a premetamorphic planation surface carved in quartzite paragneisses with biotite.

In the Glodu section, in the extreme West, there is an area with Upper Cretaceous and Paleogene sedimentary rocks (Fig. 6), making a syncline which rests upon the Tulgheș crystalline formation. Here, one can find quartzite conglomerates, micaceous sandstones, grey marly limestones, red marls, gray sandstones, variegated marls and clays, which are strongly folded (Alexandrescu et al., 1968).

The entire crystalline – Mesozoic complex in the area is affected by transversal faults (trending WSW – ENE or W – E), generally vertical; the most affected section is the one running from Valea Seacă to the northern edge of the Bistriței Mountains.

Fig. 6. The Upper Cretaceous – Paleogene sedimentary layer at Glodu (photo: July 2021).

Fig. 7. Triassic dolomites on Mount Măgura (photo: Jan. 1999)

To the East, the Sinaia Strata (Tithonian – Neocomian) and the Bistra Strata (Barremian – Aptian) (Fig. 8), belonging to the Ceahlău Nappe (Mutihac, 1990), come to surface. Both lithofacies, relatively similar, are composed of calcareous sandstones, flysch with sandstones and clays or with sandstones and marls, marly limestones and microconglomerates; however, the Bistra Strata are somewhat harder than the Sinaia Strata, as they are richer in calcareous sandstones, which generate a higher relief (Hurduga Peak, 1384 m). Likewise, on the Grințieșu Mic – Bistricioara section, the Bistricioara Valley gets narrower when crosses this area.

Fig. 8. The Bistra Strata (Barremian – Aptian), near the "Petrom" gas station at Poiana Teiului (photo: Jan. 2019). *Source: the authors*

3.2. Geomorphological features imposed by petrography

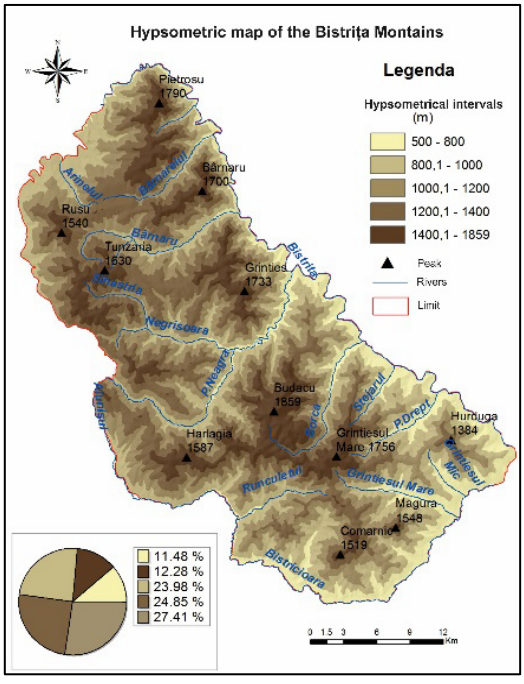

Fig. 9. Hypsometric map of the Bistriţei Mountains. *Source: the authors*

From the hypsometric standpoint, the Bistriţei Mountains start from the elevation of 502 m (at the confluence of Bistriţa and Bistricioara[5]) and reach 1859 m in the Budacu Peak (Fig. 9 and 10). In general, the area displays large vaulted backslopes and domes (Budacul, 1859 m, Grinţieşu Mare, 1756 m, Harlagia, 1587 m, Tunzăria, 1630 m etc.) (Fig. 10), developing on metamorphic rocks, while most of the valleys are deep and dark, with convex slopes (Borca, Borcuţa, Neagra, Negrişoara, Barnarul, Bârnărelul, Izvorul Rău, Muncelul, Bradul, Primătarul etc.).

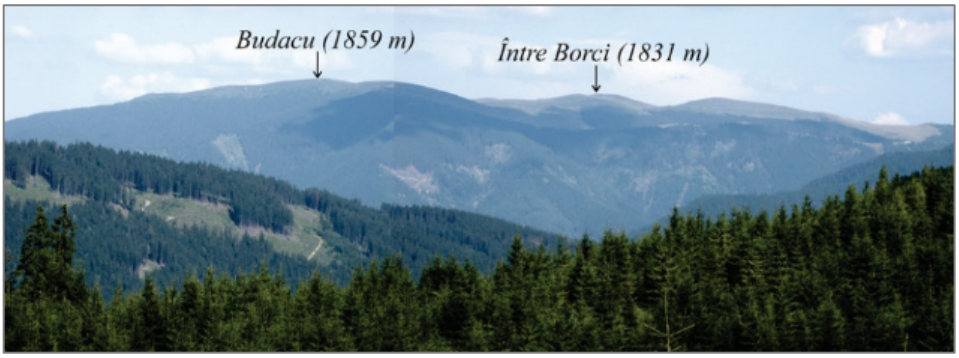

Fig. 10. General appearance of the Bistriţei Mountains, with vaulted backslopes and domes – the Budacu Massif seen from the Aluniş peak, lying in the west (photo July, 2012). *Source: the authors*

In the central-eastern strip, the porphyroid gneisses of Pietrosul Bistriţei have generated the highest and most spectacular relief: ridges and pointed peaks with steep sides (Fig. 11 and 12) and elevations between 1600 and 1800 m, which tower both the levelled summits in the West (by about 200 – 300 m) and the Bistriţa Valley in the east (by 800 – 1800 m): the Bogolin – Pietrosu summit, 1791 m; the Scăricica – Barnar summit, 1711 m; Mount Grinţieşu Broştenilor, 1734 m; and the Slopăţului summit, 1684 m. These peaks and summits make up the ridge line, which does not overlap the main watershed, because the latter has been pushed far to the west, near the edge of the Călimani Mountains (fig. 12 and 16).

[5] Starting with 1960, this confluence is flooded most of the time by Lake Izvoru Muntelui, which allows us to consider its free surface as the lowest elevation of the Bistriţei Mountains, namely 509,32 m at normal pool elevation (Ichim et al., 1980).

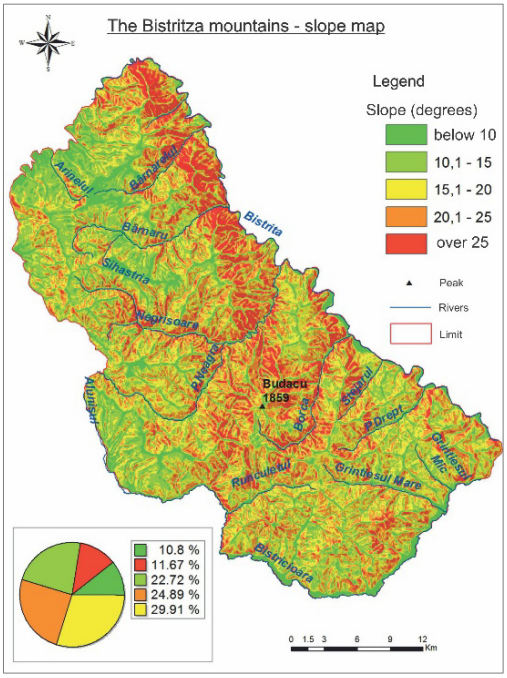

Fig. 11. The Bistriţei Mountains – slope map

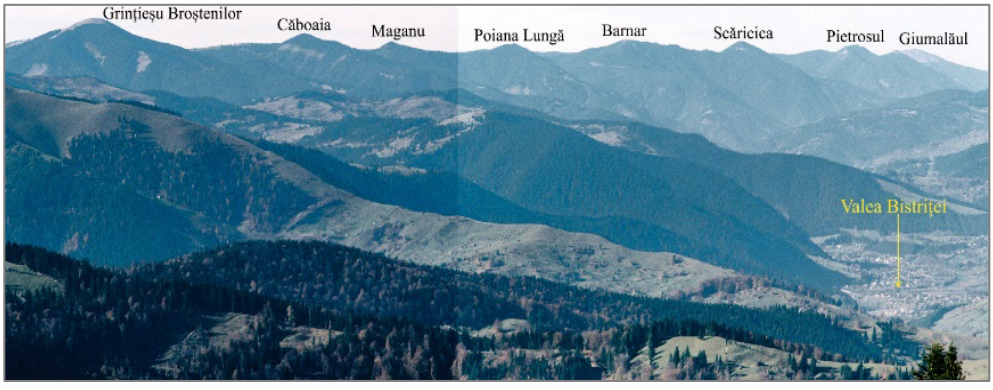

Fig. 12. The pointed peaks alignment developed on the gneiss of Pietrosu Bistriţei, between Grinţieşul Broştenilor and Giumalău, forms a ridge similar to those occurring in the Southern Carpathians (Făgăraş, Parâng, Retezat) or in the Rodnei Mountains, the main differences being the high degree of afforestation and the absolute elevations, which are by 500 – 800 m lower and which makes the glacial relief missing (photo: Oct. 2001). *Source: the authors*

Fig. 13. The main ridge of The Făgăraș mountains; wiew from Roșu peak (2462 m), Iezer Mountains; photo July 2022. *Source: the authors*

On the sandstone schists in the southeastern section, the topography consists of long and narrow ridges ("obcine"[6]), with low and medium altitudes (1384 m in the Hurduga Peak), low and medium inclined slopes (mostly 10 – 20 degrees), and large V-shaped valleys, like the ones of the Bistricioara, between Pintec and Grințișel, the Grinţieşul Mic, the Dreptului, etc. This subdivision of the Bistriţei Mountains (which also includes Obcinele Boiștei and Târşoasei from the Ceahlău Massif) was named "the Grinţieşului Low Mountains" (Săndulache, 2007). Likewise, the lower unit (1000 – 1300 m) of the neighboring Ceahlău Mountains was named "the Lower Peripheral Ridges" (Stănescu, 1980); here, most of these low ridges are called "obcine" (Fig. 14).

Fig. 14. The Bistricioara valley at Grinţieş and the Grinţieşului Low Mountains, looking like "obcine" (photo: May 2016). *Source: the authors*

[6] The toponym "obcină" (plural "obcine") refers to a long and narrow ridge, usually afforested, and it is frequent in the Eastern Carpathians, from the northern state border to the Ciucului Mountains (Bacău County).

In the South, against the general background of the dull summits shaped on crystalline rocks, some slender hillocks appear, developed on Triassic dolomites and Cretaceous limestones (Măgura, 1548 m, Piatra Mocilor, 1109 m, Piatra Runcului, 1215 m, Comarnic, 1519 m, Bâtca Arsurilor, 1384 m) (Fig. 15).

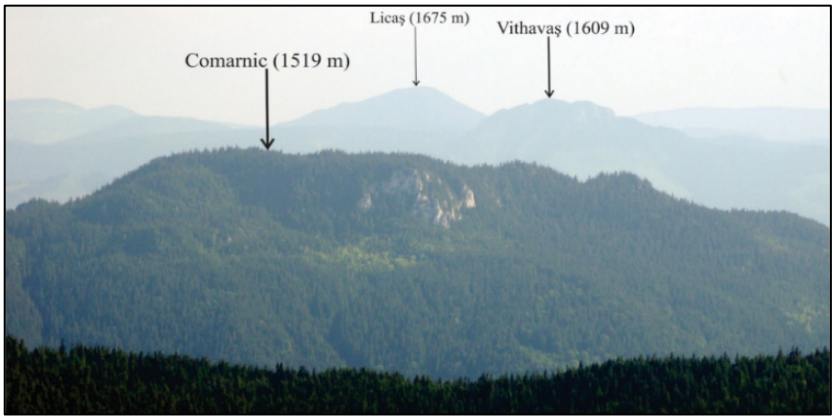

Fig. 15. Hillocks developed on Triassic dolomites and Cretaceous limestones: Comarnic, 1519 m (the Bistriței Mountains), Vithavaș, 1609 m and Licaș, 1675 m (the Hăghimaș Mountains) (photo: Aug. 2013). *Source: the authors*

On the crystalline rocks, levelled surfaces are preserved (Fig. 16), which here and there are very wide; their "classical" sequence was established by David (1949): "Poiana Ciungilor", at 1500 – 1550 m, deemed of Helvetic age, "Bâda", at 1200 – 1440 m, of Sarmatian age, and "Dornelor", of Pontian age. The planation steps are best preserved within the first order catchments of River Bistrița, which have succeeded in piercing the porphyroid gneiss bar of Pietrosu (Neagra, Negrișoara, Bârnărel, and Barnar), acting as a shield against erosion and thus preventing their rapid destruction. Here, the best preserved are the "Poiana Ciungilor" and "Bâda" surfaces (Fig. 16, 17 and 18).

For the section adjacent to the Bistricioara River, Săndulache (2007) identified five planation steps: "Grințieșu Mare", at 1650 – 1750 m (in the homonymous mountains), "Harlagia", at 1500 – 1600 m (Mount Harlagia, Țibleșu Mare – Grințieșu Mare ridge), "Făget – Mezovești", at 1200 – 1400 m (on the Harlagia – Vamanu ridge, East of Bilbor, and Pietrele Roșii – Grințieșu Mare ridge), "Malnaș – Dosu Cheosrezului", at 1000 – 1200 m (most of the secondary summits detaching from the ridge junctions Măgura, Bâtca Arsurilor etc.), and "Frasinul", at 850 – 1050 m, which appears as a sequence of valley shoulders belonging to the Bistricioara Valley (Fig. 19).

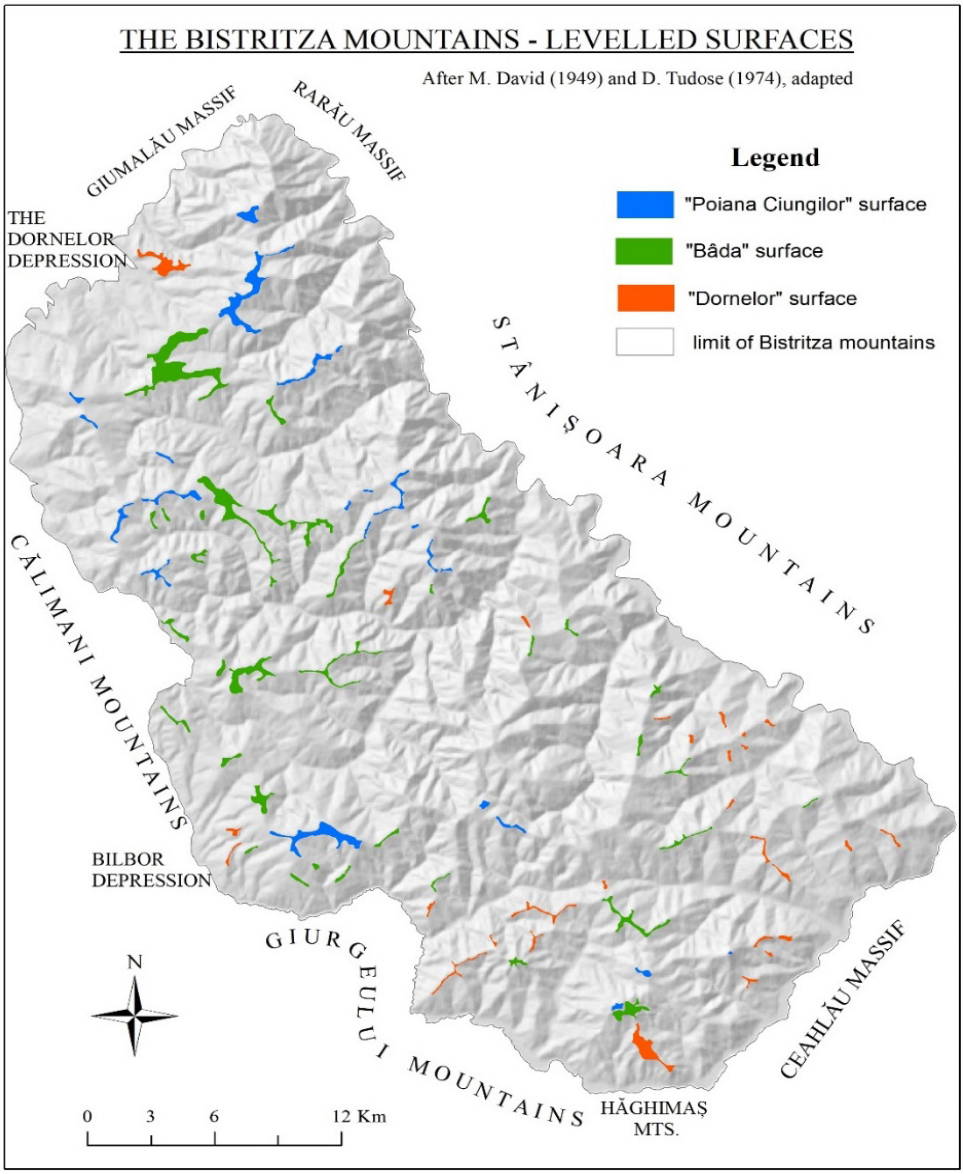

Fig. 16. The Bistriței Mountains – map of the levelled surfaces, based on the topographic map of scale 1:25000, the 1981 edition.
Source: the authors

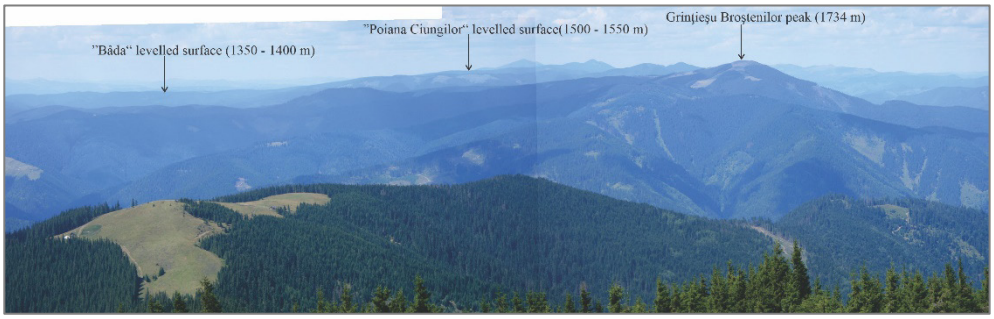

Fig. 17. "Poiana Ciungilor" and "Bâda" planation surfaces, developed West of the porphyroid gneiss bar of Pietrosu, which has shielded them against the erosion exerted by the Bistriţa's tributaries; view from the Budacu to the North-West (photo July 2009).
Source: the authors

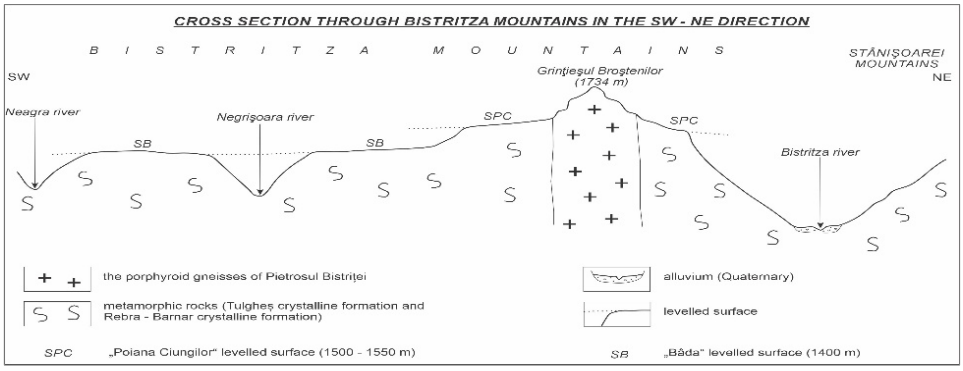

Fig. 18. Cross section through Bistriţa Mountains.
Source: Săndulache (2018)

Fig. 19. Valley shoulders ("u"-shaped), with relative altitudes of 200 – 250 m, on the Borca valley; view from the Grinţieşu Mare peak (1756 m) to the North (Photo Aug. 2008).
Source: the authors

Petrography is also responsible for the appearance of gorges and defiles. These are narrow valley sections, which generate high and very high values of local relief (Fig. 20). Such are, for the Bistriţei Mountains, the gorges formed by the antecedent deepening of the rivers in the gneiss bar of Pietrosu (the Bistriţei gorges at Sunători – Zugreni (Fig. 21), the Barnar gorges, the Bârnărelului gorges and the Neagra Broştenilor defile) or in the epimetamorphic schists of Tulgheş (the Bistricioara defile between Bilbor and Valea Seacă, and the Bistriţei gorges at Toance).

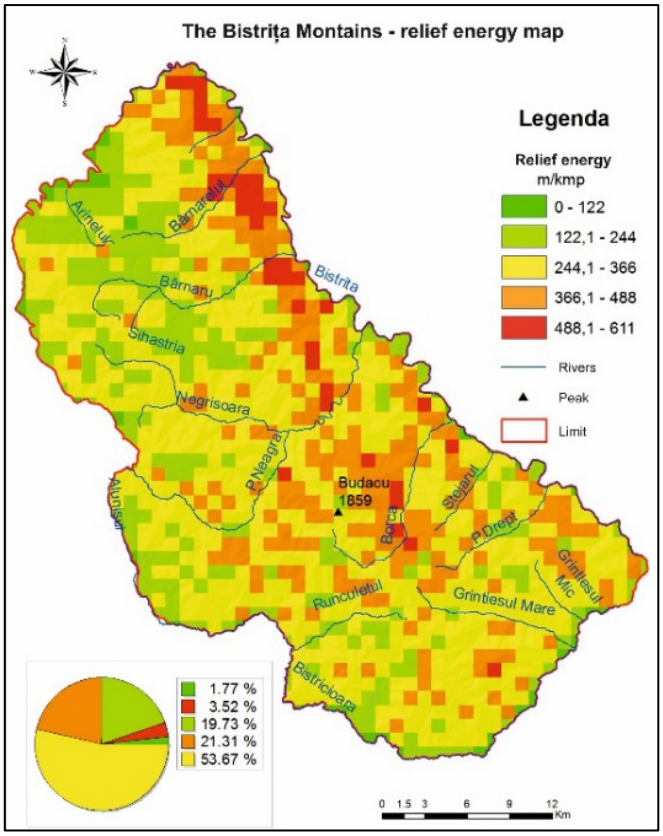

Fig. 20. The Bistriţei Mountains – local relief map.
Source: the authors

The lowest local relief values are specific for the northwestern section (as a result of the large extension of the Bâda and Poiana Ciungilor planation steps) and for the Bistricioarei Valley (due to the brittleness of the Cretaceous flysch of Sinaia and Bistra – Fig. 22).

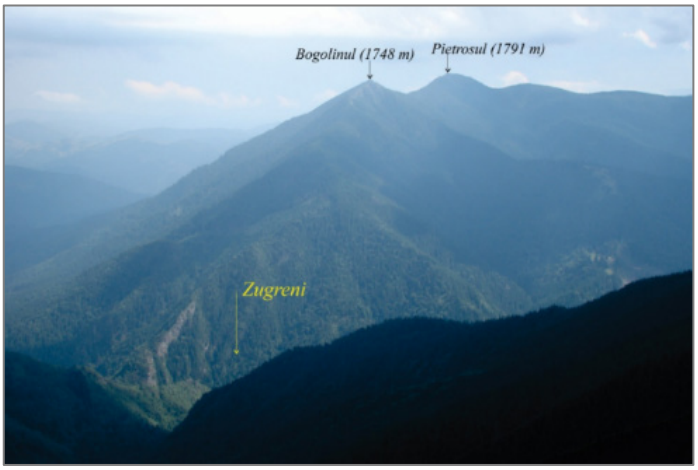

Fig. 21. High local relief and slope gradients, due to the porphyroid gneiss bar of Pietrosu and the Bistriţa's proximity (view from the Giumalău massif, Aug. 2012). *Source: the authors*

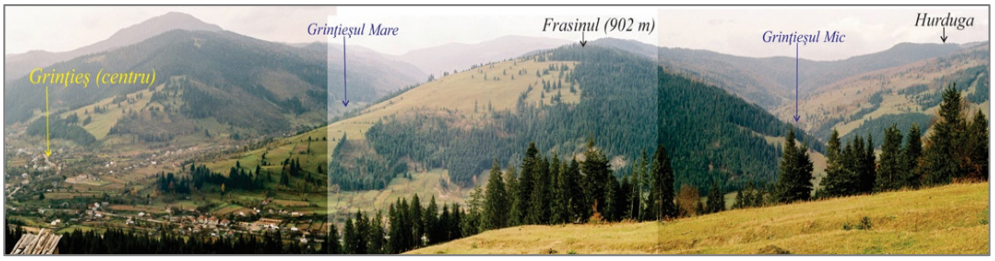

Fig. 22. Moderate and low local relief and slope gradients, due to the brittleness of the Cretaceous Carpathian flysch: Sinaia Strata and Bistra Strata (the Bistricioarei Valley at Grinţieş) (photo: Oct. 2001). *Source: the authors*

4. Conclusions

Although the crystalline facies predominates, the Bistriţei Mountains (one of the best defined mountain units in the Eastern Carpathians) exhibit a variety of landforms, from widely vaulted domes, to ridges and pointed peaks, levelled platforms, gorges, defiles, landslides etc., all originating from the different properties of the petrographic substrate.

In the morphogenesis and morphography of the Bistriţei Mountains, a very important role is played by:

- the lithological monotony of the crystalline formations of Tulgheş (epimetamorphic), and of Rebra – Barnar and Hăghimaş – Rarău – Bretila (mesometamorphic), which are responsible for the occurrence of domes and rounded backslopes;
- the high hardness of the porphyroid gneiss of Pietrosul Bistriţei, developed as a bar in the South-North direction, in the central-eastern area of the mountains, which is responsible, firstly, for the spectacular, steep and uneven terrain in this section and, secondly, for the good preservation of the "Bâda" and "Poiana Ciungilor" levelled platforms, sheltered (by this bar) against the regressive erosion of the Bistriţa tributaries;
- the higher hardness in comparison with the metamorphic rocks of the Mesozoic dolomites and limestones occurring in the southern part of these mountains, which has led to the individualization of some hillocks, usually slender, with steep slopes, rocky features and scree at their foot: Măgura, Comarnic, Bâtca Arsurilor, Piatra Mocilor;
- the brittleness and plasticity of the Cretaceous flysch in the South-East and East, resulting in the development of a less impessive terrain: wide valleys, medium and slightly inclined slopes, and medium and low local relief values ("the Grinţieşului Low Mountains" – Săndulache, 2007).

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