sciendo

ASN, Vol. 12, No 1, Pages 59–72, 2025

Acta Scientifica Naturalis

Former Annual of Konstantin Preslavsky University of Shumen: Chemistry, Physics, Biology, Geography

Journal homepage: https://content.sciendo.com/view/journals/asn/asn-overview.xml

Morphostructural features of the Kamchia Mountain

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Abstract: *The morphostructure of the Kamchia Mountain forms the northern border of the Primorska part of the Eastern Stara Planina Mountain. The topicality of the topic stems from the insufficient geomorphological and morphotectonic studies of the Kamchia Mountain from the point of view of plate tectonics. New views on the morphostructure and evolution of the Eastern Stara Planina are presented. An attempt was made to build a modern model for the Neogene-Quaternary paleogeographic and geodynamic features of the Eastern Stara Planina Mountain.*

The Kamchia Mountain has the character of a complex structure, highly complicated by listric faults, a positive morphostructure, formed in a Paleogene flysch alternation of marls, siltstones, sandstones and limestones. The Kamchia morphostructural unit, like the Emine one, is relatively monolithic in its western part. To the east, the ridge of the mountain is veritril-shaped branched and its altitude decreases in the direction of the Black Sea.

From a morphostructural point of view, the Kamchia Mountain falls on the eastern edge of the Bulgarian continental microplate. The proposed study will contribute to the clarification of the role of the interaction between the Bulgarian continental microplate and the Black Sea oceanic microplate located east of it, representing a remnant of the Tethys Ocean that is not absorbed by the subduction zone.

Keywords: Kamchia Mountain, Bulgarian continental microplate, plate tectonics, listric faults

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DOI: 10.2478/asn-2025-0007

Introduction

The article proposes a morphostructural study of the Kamchia part of the Primorski region of the Stara Planina (Hemus) morphostructural zone. The study is consistent with the modern mobilist concepts of plate tectonics. It aims to contribute to the clarification of the morphotectonic basis for the modern morphological appearance in this part of Bulgaria [1]. The relevance of the study is determined by the border nature of this morphostructural zone between the Bulgarian continental microplate and the western margin of the Black Sea basin.

A specific object of the study is the relief of the Kamchia Mountain. A more complete disclosure of the main features of the geomorphological and morphotectonic nature of this orographic unit has been carried out.

Methods

The applied research methodology is based on modern mobilist concepts of the formation of the land relief in mountainous areas. This new approach to relief analysis is yet to be developed in detail. In this respect, the proposed article is largely pioneering.

The main method used in the study is morphostructural analysis [2]. It is mainly based on the Neogene-modern morphogenesis of the eastern Bulgarian lands, caused by listric tectonics. The application of this method aims to establish the relationships between the forms of the relief, the geological structures and the material composition that builds them. The role of endogenous and exogenous deformation processes for the specific morphographic and morphometric features, the morphological style and development of the mountain is clarified.

Morphography and morphometry

The Kamchia Mountain is part of the eastern end of the northern orographic branch of the Eastern Stara Planina Mountain (Mator Planina) (Fig. 1).

In morphometric terms, the relief of the Kamchia Mountain almost entirely belongs to the hilly and low-mountain hypsometric belt. It contrasts sharply with the other parts of the Eastern Stara Planina. This contrast is especially well expressed with the massive, relatively monolithic, highly elevated body of the Kotel Mountain and the Varbitsa Mountain (Fig. 1).

An important role for the low-mountain and hilly relief in the Kamchia Mountain is the predominantly weakly resistant lithological substrate, mainly flysch sediments, on which it is modeled. The distribution of relatively denudation-resistant limestones, sandstones, etc. in the western parts of the region determine the dominant position of positive forms of the relief.

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The Kamchia Mountain is characterized by a wide and flat ridge, formed mainly in the hypsometric interval 400 – 500 m (Photo 1). In its western part is the highest point, peak Kamenyak or Karakyzyljik (627.1 m). To the east, the ridge of the mountain decreases. Here it is formed in the interval 150 – 200 m. In the immediate vicinity of the Black Sea coast, the ridge is even more uneven, and at the cape of Beli Nos and the cape of St. Atanas it reaches about 100 m.

The general orographic and structural-geomorphological plan of the Eastern Stara Planina Mountain is a classic example of the manifestation of the virgation phenomenon. It is the main reason for the formation of the specific morphographic features and the peculiar morphological and morphotectonic style and development of the Eastern Stara Planina Mountain, in particular its eastern periphery – the Kamchia Mountain.

Within the boundaries of the Kamchia Mountains, about 2.5 km east of the village of Solnik at Gradenata Mogila (275.1 m) and Tashltepe (277.8 m), the ridge is divided, forming two orographic fragments, between which the valley of the Fundakliyska River is developed.

The northern slopes of the Kamchia Mountain are sloping, dissected by the deeply incised valleys of the Balabandere, Eleshnitsa, Chairdere rivers and reach the valley of the Kamchia River. The northeastern slopes are dissected by the Fundakliyska River and its tributaries.

The southern slopes are steep, fault-induced, as evidenced by the numerous facets, and reach the valley of the Dvoynitsa River (Photo 2). The Kamchia Mountain is crossed by the Djulinski Pass (428 m).

In general, the Eastern Stara Planina Mountain are characterized by significantly lower values of morphometric indicators compared to the Western and Central Stara Planina Mountain, especially in terms of vertical dissection and slopes. Their prevailing values are 150 – 250 m/km² and 10 – 15°, respectively [3]. On the other hand, high values of horizontal and vertical dissection of the relief are observed here, which is due to the easily denuded flysch sediments.

The highest values of horizontal dissection of the order of 2.5 – 3 km/km² are found in river valleys and in particular their alluvial bottoms occupied by relatively wide floodplain terraces. High values of horizontal dissection of the order of 2 – 2.5 km/km² are also found on mountain slopes. This is due to the presence of structural depressions, grabens, etc. in the immediate vicinity. Low values of horizontal dissection (0.5 – 1 km/km²) are characteristic of the wide ridge-leveled parts of the mountain [3].

The lowest values of vertical dissection in the studied area (30 – 50 m/km²) are observed in the axial parts of the river valleys of the rivers Dvoynitsa, Eleshnitsa, Balabandere, Fundakliyska, etc. In the direction of the watershed ridges, these values increase to 90 – 100 m/km², and along the main ridge they reach 150 – 200 m/km² [3]. There is a tendency of a gradual decrease in the values of vertical dissection from 120 m/km² in the west to 90 m/km² in the east, in the direction of the Black Sea coast.

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Morphotectonics

In morphostructural terms, the Eastern Balkan Mountains fall within the boundaries of the Eastern Balkans. The question of their volume as a whole is very complex and debatable. According to [4], the scope of this morphostructural zone is given by the position of the Pre-Balkan and Trans-Balkan faults, which limit it from the north and south. In essence, these faults give the contours of the late Alpine Balkans. These include the block-fold structures of the Eastern Balkan Mountains and the Fore-Balkans. Bonchev [4] includes the Eastern Balkan Mountains in the Balkanide system because, according to him, it "represents a spatial continuation of the Middle Balkan, has the same orientation of the fold axes and the main fault lines. Moreover, during the last tectonic stage of construction, the so-called "Illyrian upheaval", it developed according to the same laws".

From a geological-tectonic point of view, the geographical concept of the Eastern Balkan Mountains largely overlaps with the Ludokamchiy zone. It represents the southernmost longitudinal structural zone in the Eastern Balkanides [4]. In tectonic terms, the Ludokamchiy zone is understood as a wide and flat synclinorium. Its hinge dips to the east. The greater part of the Ludokamchiy zone is occupied by the valley of the Luda Kamchia River.

The ideas about the geology and tectonics of the Ludokamchiy zone are summarized in the work of [5], and about the geotectonic position and development of the studied lands – in the monographs of [4, 6] and others.

In the late 1970s, the maritime extension of the Stara Planina Mountains was intersected by seismic profiles [7]. Based on their data, the idea of a structural connection between the Stara Planina Mountains and the Western Pontides of the Asia Minor Peninsula [8].

The views of [9] on the primary role of the Black Sea Basin in the formation of the structural-geomorphological style of the adjacent land are determined by a large number of researchers.

According to [10], the beginning of the virgation of the Stara Planina structures east of the meridian of the city of Sliven should be sought in the Paleocene-Eocene time. In the modern morphostructural plan, it is emphasized by two large mountain branches. The valley system of the Luda Kamchia River is "embedded" in the formed structural depression.

Later, the same author [11] emphasized the influence of the Black Sea Basin on the structural-geomorphological development of the eastern Bulgarian lands and in particular the Eastern Balkan Mountains.

The concepts and models for the Alpine paleogeodynamics and tectonics of Bulgaria are diverse. They are related to the geosynclinal hypothesis or to plate tectonics.

Based on the concept of neomobilism and paleogeodynamics, [12] interpret the Alpine evolution of the Bulgarian lands. They consider the Balkan Fold System as formed within the scope of the Alpine Balkan

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Microplate ("Balkan Microcontinent"). These authors describe in detail the Stara Planina tectonic zone, of which the studied area is a part, as well as structural units, fold structures (anticlines and synclines), thrusts, thrusts, thrusts and faults. They define the Stara Planina tectonic zone as late Laramian or Illyrian and young (42 Ma).

Tzankov and Stankova [13, 14] propose a mobilist model for the structure, morphotectonic origin and evolution of the eastern part of the Balkan Peninsula. They present new views on the morphostructure and evolution of the Eastern Balkan Mountains, between the Vratnik Pass and Cape Emine. They attempt to build a modern model for the Neogene-Quaternary paleogeographic and geodynamic features of the Eastern Balkan Mountains. The same authors proceed from the idea that the Middle Pleistocene-Holocene morphogenesis in Bulgaria took place in a continental setting under conditions of brittle deformations and with the decisive role of listric tectonics in the formation of regional block, mountain, basin and other morphostructures.

According to [15], east of the Vratnik Pass, the modern hilly-mountainous relief in the Stara Planina Mountain range system arose during post-Alpine (post-Early Oligocene) morphogenic processes.

The active manifestation of young tectonic movements during the Neogene led to the upward development of the relief in the studied area. It was interrupted by stages of planation associated with relative tectonic rest. Extensive planation of the regional relief led to the formation of several denudation plains (orthoplains), which have different ages. Their dating is very difficult due to the lack of direct data for determining the age. The youngest of them arose at the end of the Early Pleistocene. It has the character of an extensive plain [13].

The monotony of the flat relief was broken by single or group-located residual elevations – residual hills. The formation and very long existence of this type of landscape is undoubtedly due to the undisturbed dominance of exogenous processes that lasted for several tens of millions of years (in the Upper Oligocene – Early Pleistocene interval). According to [13, 14], in recent years a lot of data and evidence have been accumulating that a similar paleogeographic situation was characteristic of almost the entire territory of the eastern part of the Balkan Peninsula.

The regional morphotectonic regime changed at the end or after the Early Pleistocene. These changes are due to endogenous processes of mosaic faulting and block displacement in the deeper parts of the earth's crust.

The effects of this deep destruction of the Earth's crust gradually led to the formation of the first dome and mountain morphostructures under the influence of near-surface listric tectonics (Fig. 2). The newly formed hilly and low-mountainous relief quickly began to reduce the area of the orthoplain surface [16, 17].

The emerging post-Early Pleistocene positive morphostructures were subjected to the action of intensive exogenous processes. As a result, they were partially destroyed (eroded) and gradually transformed from dome

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to concentric morphostructures. Today, their traces mark the early stage of the rapidly expanding endogenous morphogenesis.

The subsequent morphogenic development in the region is associated with a more intensive and more massive emergence of positive (dome and mountain) morphostructures. The areal expansion of this new morphostructural generation occurred at the expense of the reduction of the area of the remains of the post-Early Pleistocene orthoplain. Its relics were localized within the bottoms of the valley morphostructures, morphostructural corridors, the morphostructural sills associated with them, as well as the river-valley morphostructures. All these negative morphoelements with an older origin currently distinguish the individual regions of the later emerged positive morphostructures (Fig. 3). The growth rate of the positive morphostructures was greater than that of the exogenous destructive processes [13].

According to [1], the determination of the age of the fragments of denudation (flattened) surfaces, both in the Stara Planina Mountain and in all other morphostructural zones in Bulgaria, is very conditional. According to the same authors, studies in recent years have shown that a significant part of the fault-displaced fragments of denudation surfaces are actually of the same age and reflect the traces of the last (early Quaternary) peneplainisation of the Bulgarian lands.

According to [13, 14], the occurrence, nature and age of these local denudation flatnesses is undoubtedly related to the processes of listric tectonics in the formation of the positive morphostructures (Fig. 4 and Fig. 5).

Along the ridge of the Kamchia Mountain, the initial denudation surface is developed in the hypsometric range of 400 - 500 m. It is best visible towards the Bahova Chuka hill (482.4 m) to the east. This gives the ridge a plateau-like character. The leveling is relatively well traced between the villages of Rechitsa, Kamenyak, south of the villages of Snezha, Zaimchevo, north of the villages of Bulair, Golitsa, Bardarevo, Solnik, west of the villages of Rudnik and Yunets.

On the slopes of the mountain ranges in the Eastern Stara Planina Mountain (and in particular on the Kamchia Mountain), in many places, variously well-pronounced slope steps are found. In a number of cases, they give the slopes and secondary ridges a stepped structure. According to [13], these undoubted effects of listric tectonics in the formation of dome morphostructures have been referred to so far, completely unfoundedly, by researchers as Pliocene denudation surfaces.

In the Kamchia Mountain, slope steps are established in the form of flat watersheds, at a height of 300 – 350 m in the west, and in the east they gradually decrease to 200 – 250 m. They are observed between the villages of Golitsa Bardarevo and Solnik, northeast of the peak of Bahova Chuka in the direction of the village of Gradishte [13].

From a morphostructural point of view, the Kamchia Mountain is part of the easternmost Primorsky region of the Stara Planina morphostructural zone.

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In the Primorsky morphostructural region, a wide spectrum of diverse negative and positive morphostructures is observed [18]. They are united in several morphostructural generations. Their traces form the complex mosaic of landforms that model the modern relief (Fig. 6).

Within the boundaries of the Kamchia Mountain, two types of main morphostructural elements stand out:

1/ relics of the initial post-Early Pleistocene orthoplain – Eleshnitsa River Valley Morphostructure (els), Krivitsa River Valley Morphostructure (krv), Fundakli River Valley Morphostructure (fnd), Perperidere River Valley Morphostructure (prp) and Dvoinitsa River Valley Morphostructure (dvn). Unlike the western and middle parts of the Stara Planina morphostructural zone, within the boundaries of the Udvoimatorieva and Primorska morphostructural areas, a large number of relics of the post-Early Pleistocene orthoplain have been preserved (Fig. 6).

2/ positive morphostructures. We include Late Pleistocene-Holocene dome morphostructures to these.

The modern relief of the mountainous terrains in the Stara Planina Mountain, east of the Vratnik Pass, is dictated almost entirely by the features of the numerous Late Pleistocene-Holocene dome morphostructures (Fig. 6). These landforms are grouped into morphostructural regions – the smallest and most elementary regional morphostructural units (Fig. 6). They are a product of active morphogenesis – i.e. the destructuring and restructuring of the initial orthoplain.

The borders of the Kamchia Mountain include the Asparuhovo morphostructural region (Mas), Kamchia morphostructural region (Mkm), Rudnik morphostructural region (Mrd), Golitsa morphostructural region (Mgl), Solnik morphostructural region (Msl), Byala morphostructural region (Mbl) [13].

Conclusion

The studied literature, the analysis of geological-geomorphological data and field research provide grounds for drawing some important conclusions regarding the formation and evolution of the relief in the Kamchia Mountain:

- The relief within the Kamchia Mountain is a product of the mountain morphostructures that emerged during the destruction of the post-Early Pleistocene orthoplain.
- Relics of the increasingly destroyed orthoplain are preserved in the peripheral areas – at the bottom of the Ludokamchiyska basin morphostructure, in the river-valley morphostructures – Fundakli, Perperidere, Dvoinitsa, Eleshnitsa, etc.
- The main elements of the modern relief are mountain and hilly-mountainous forms. They are the result of the growth of the Late Pleistocene-Holocene generation of dome and mountain morphostructures. Their rate of uplift, under the action of the ongoing regional endogenous processes, exceeds the rate of destructive

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action of exogenous processes. This is due to the ongoing construction of a positive low-mountain (hilly) relief within the studied area.

- The shape, size and orientation of the individual morphostructures depend on the preliminary faulting of the post-Early Pleistocene orthoplain and the different rate of displacement between the individual fragments.
- The conducted morphostructural analysis shows the advantages of the systemic regional complex interpretation of the effects of listric tectonics and of the dome and mountain forms emerging against the background of the regional fault network (from steeply and gently dipping faults). They build the real picture of the modern small-block mosaic of the Kamchia Mountain.
- The dense and deep dissection of the Kamchia Mountain is the result of the historically developing contradictory interaction of endogenous and exogenous forces with the leading active role of the endogenous factor – neotectonic movements, in shaping the modern morphostructure.

Acknowledgements

The article was published under project RD-08-117/31.01.2024 Regional studies on the territory of Northeastern Bulgaria – Phase 1.

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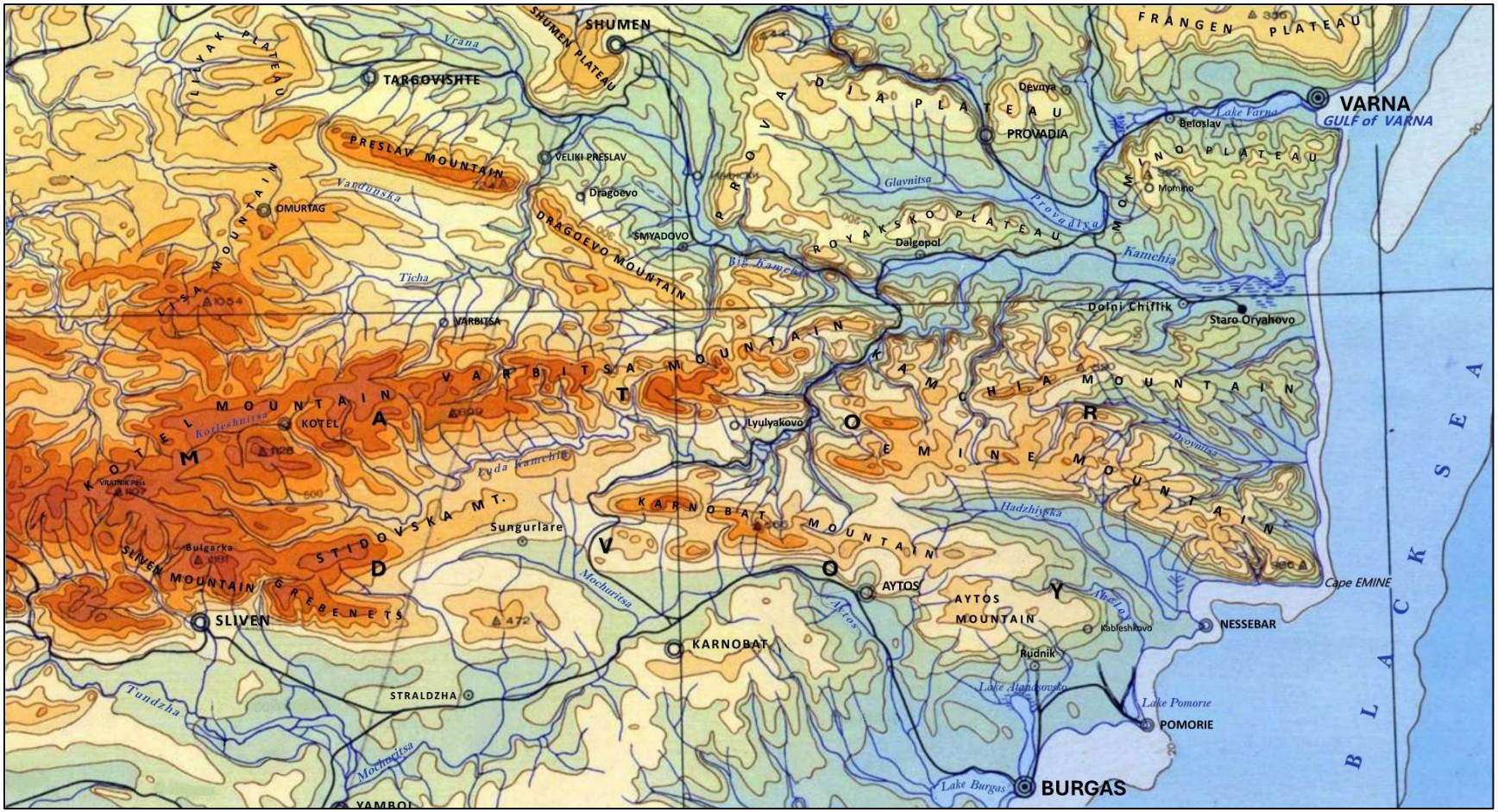

Fig. 1. Overview map of the Eastern Stara Planina Mountain at a scale of 1:600,000

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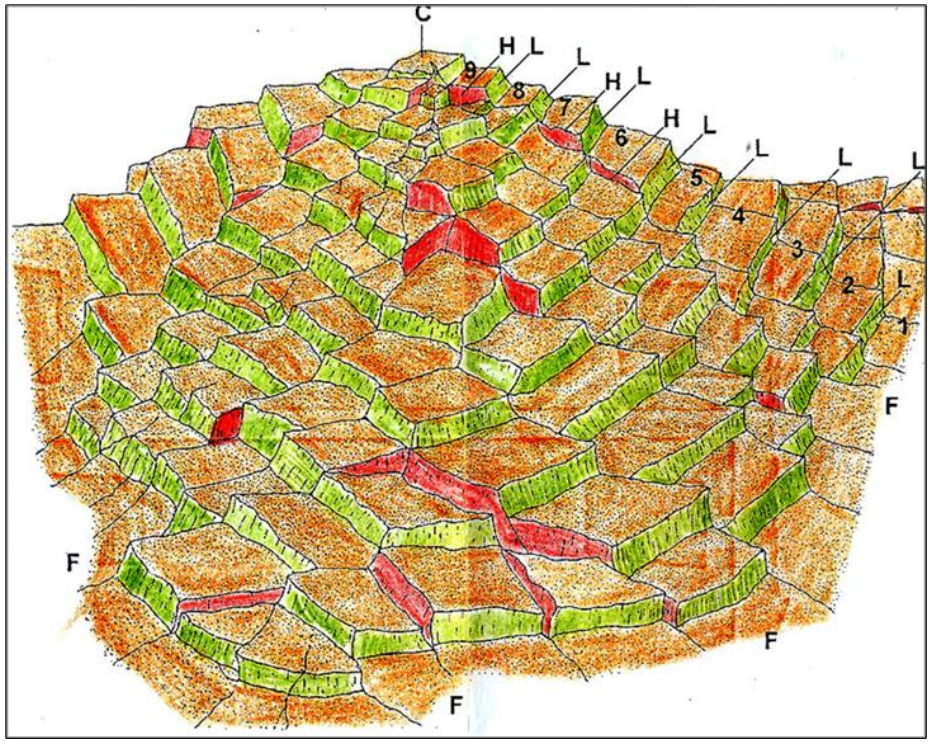

Fig. 2. Model (block diagram) of a dome morphostructure [2]
C – center of maximum synmorphogenic uplift, H – steeply dipping fault, L – listric fault (fault), F – foot of the morphostructure, 1-9 – series of listric prisms

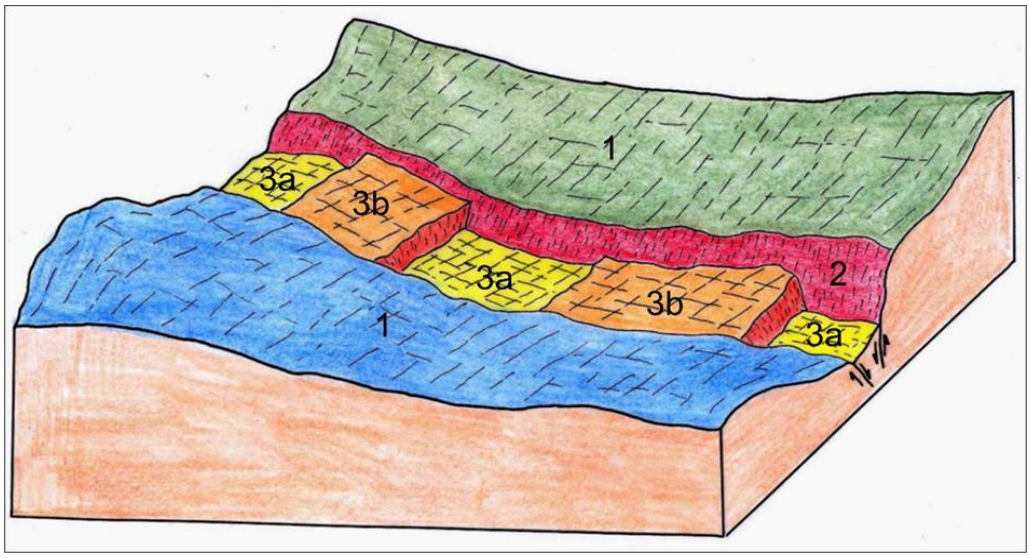

Fig. 3. Conceptual model of a complex morphostructural corridor [2]
1 – positive (dome, mountain) morphostructures; 2 – wall faults; 3a – valley morphostructures; 3b – morphostructural thresholds

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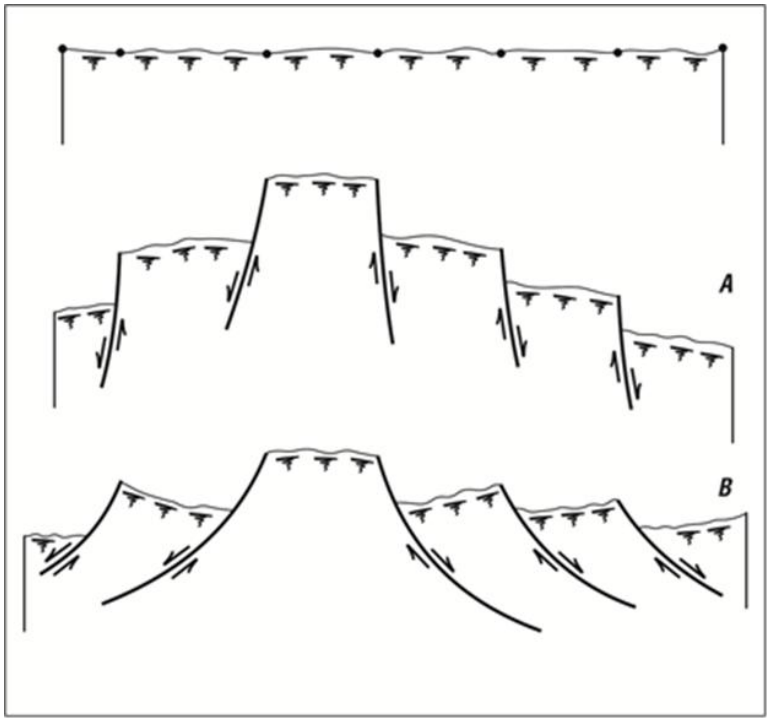

Fig. 4. Conceptual profiles for block subdivision of the relief by: A – steeply dipping normal faults, B – listric faults [2]

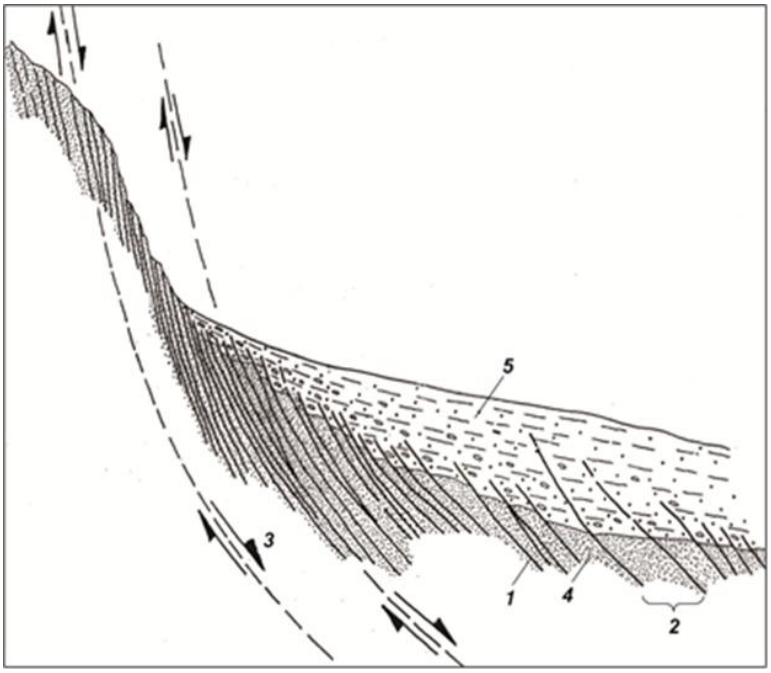

Fig. 5. Listric faulting [2]: 1. Listric fault; 2. Microlithon; 3. Boundary of the zone with the most intense listric faulting; 4. Basement rocks; 5. Synmorphogenic deposits

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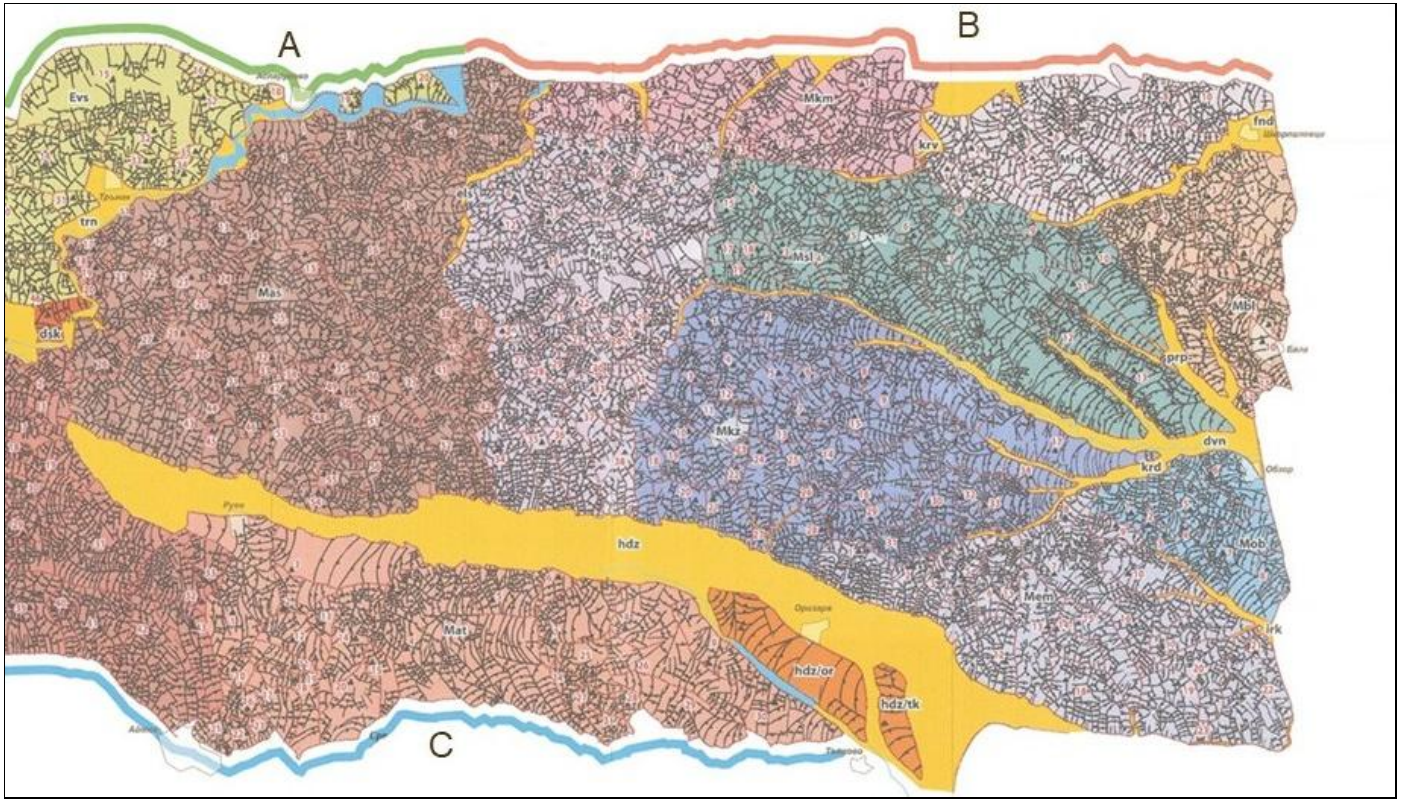

Fig. 6. Morphostructural map of the Primorska morphostructural area [13]

Bordering regional morphostructures: A - Eastern Pre-Balkan morphostructural area; **B -** Razgrad morphostructural area; **C -** Burgas morphostructural area; **Relics of the post-Early Pleistocene orthoplain**: Duskotna morphostructural threshold (dsk), Tarnak morphostructural passage (trn), river valley morphostructures – Eleshnitsa (els), Krivini (krv), Fundakliyska (fnd), Perperideren (prp), Dvoinitsa (dvn), Kurudere (krd), Irakli (irk), Hadzhiyska valley morphostructure (hdz); **Middle Pleistocene-Holocene morphostructures:** areas – Asparuhovo (Mas), Kamchia (Mkm), Rudnik (Mrd), Golitsa (Mgl), Solnik (Msl), Byala (Mbl), Kozichino (Mkz), Emine (Mem), Obzor (Mob), Karnobat (Mkb), Aytos (Mat); **Holocene-modern synmorphogenic uplands:** Orizare (hdz/or), Tankovo (hdz/tk)

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Photo 1. Panoramic view from the main ridge of the Kamchia Mountain between the villages of Solnik and Bardarevo

Photo 2. General view of the faceted southern slope of the Kamchia Mountain at the Dyulinski Pass

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