TECTONOMORPHOLOGIC CHARACTERISTICS OF ZAVALSKA MOUNTAIN, SW BULGARIA

Radostina Rizova[1], Georgi Nachev[1], Ivan Dimitrov[1]

1University of Mining and Geology "St. Ivan Rilski", 1700 Sofia, r.rizova@mgu.bg

ABSTRACT. Zavalska Mountain (Kitka peak, 1180 m) is the westernmost morphografic edifice from the Zavalsko-Planska mountain chain of the Western Srednogorie. In geologic sense it was studied extensively in the course of mapping initiatives in different scale but in geomorphologic sense it is insufficiently studied. The purpose of the paper is to analyze the lineament pattern of the Zavalska Mountain using modern technical tools. For the purpose of the investigation detailed digital topographic model of the terrain was made. Analysis of the lineament network was performed in GIS media. The lineament data were processed using stereographic software. The results received were analyzed in the context of the known geological fabric with emphasis on the tectonomorphologic significance of the lineament directions. The results shed light on the mechanism of formation of the Zavalska Mountain.

Keywords: tectonomorfologic characteristics, linear structure, lineament network, neotectonic

ТЕКТОНОМОРФОЛОЖКА ХАРАКТЕРИСТИКА НА ЗАВАЛСКА ПЛАНИНА, ЮЗ БЪЛГАРИЯ

Радостина Ризова[1], Георги Начев[1], Иван Димитров[1]

[1]Минно-геоложки университет „Св. Иван Рилски", София 1700, r.rizova@mgu.bg

РЕЗЮМЕ. Завалска планина (в. Китка, 1180 м) е най-западната морфографска постройка от Завалско-Планската планинска редица на Западното Средногорие. В геоложко отношение е изучена в хода на кондиционните геоложки картировки в различни мащаби, но в геоморфоложко отношение е сравнително слабо изучена. Целта на статията е да се анализира линеаментния рисунък на Завалска планина чрез използване на модерни технически средства. В хода на изследването е направен детайлен дигитален топографски модел на терена. В ГИС среда е изпълнен анализ на линеаментната мрежа. Линеаментният рисунък е обработен статистически чрез стереографски софтуер. Изведените резултати за линеаментите са анализирани в контекста на известния геоложки строеж с акцент върху тектономорфоложкото значение на отделните линеаментни посоки. Получените резултати хвърлят светлина върху механизма на образуване на Завалска планина.

Ключови думи: тектономорфоложки анализ, линеаментна мрежа, линейни структури, неотектоника

Introduction

The purpose of this article is to make a detailed analysis of the lineament network of Zavalska Mountain, using modern GIS tools, with the aim to clarify the neotectonic evolution of the area.

Zalavska Mountain (Kitka, 1180.7 m) is the westernmost mountain of the Zavalsko-Planska mountain range of the Western Srednogorie (Fig. 1). The main ridge of Zavalska Mountain stretches from northwest to southeast. The length of the ridge reaches 20 km and the width is 4-5 km. The higher part of the mountain reaches the village of Zavala, and to the southeast it continues with the ridges of Tsrancha and Breznishki Greben.

On the northwest, a saddle near the village of Prodancha (971 m) separates it from the Ridge Greben, then passing on to Serbian territory. The northwestern and western slopes of the mountain are limited by the Vrabcha and Butrointsi depressions. To the northeast, the hills reach the small Burelska valley - the westernmost of the Sub-Balkan valleys.

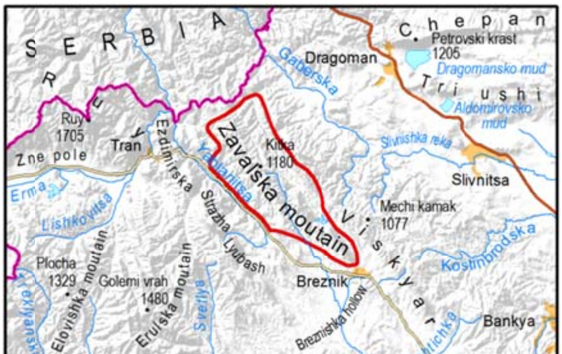

Fig. 1. Geographic position of Zavalska Mountain in SW Bulgaria.

To the east, the connection between Zavalska and Viskyar Mountains is made by a water dividing ridge over the Zavala Village, along which passes the main water divider of the Balkan Peninsula. To the southwest, the valley of the Yablanitza River separates the Zavalsa Mountain from the Ezdemirska Mountain and the Straja, and a saddle at 878 m connects it to Lubash Mountain.

Stratigraphy

Zavalska Mountain is built-up of Upper Cretaceous volcanic and sedimentary rocks and Quaternary deposits (Fig. 2). The Upper Cretaceous rocks in the area are well studied (Синьовски и др., 2012). Most of the sedimentary and volcanic rocks are considered to be of Campanian age (Маринова и др., 2010).

The marl–limestone unit, introduced by Загорчев и др. (1995), reveals from the village of Vishan to the southeast. It overlies with sharp lithological transition the limestone-marl unit, limestone unit or conglomerate-sandstone unit. It is covered with a sharp lithological contact by the marl-tuffite unit.

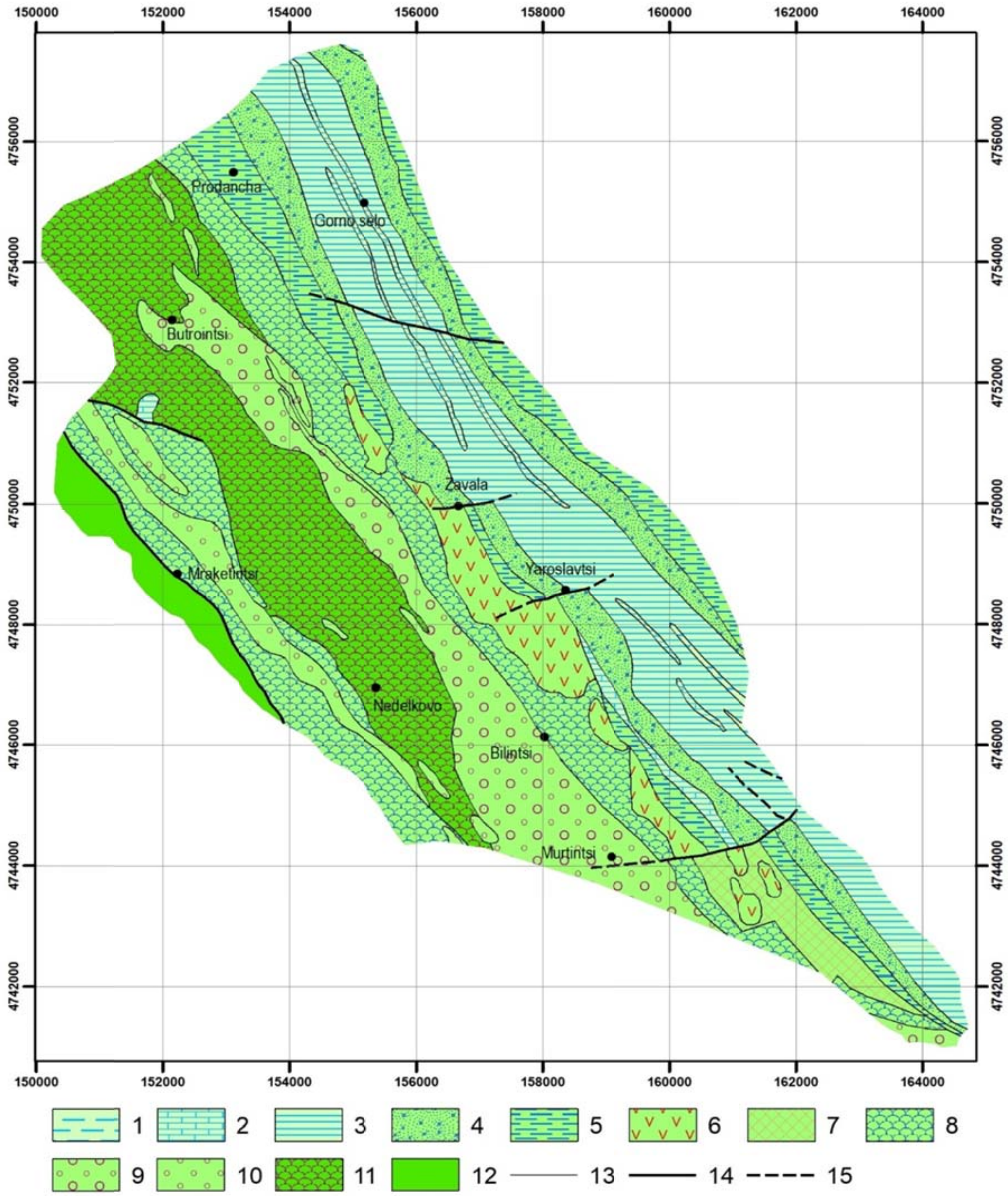

Fig. 2. Geological map of Zavalska Mountain, SW Bulgaria (by Маринова и др., 2010).

Legend: 1 – Sandstone-marl unit: bituminous argillites; 2 - Sandstone-marl unit: reef limestones; 3 - Sandstone-marl unit: marls, sandstones, clayey limestones, limestones; 4 – Sandstone unit: quartz sands, fine-grained conglomerates, marls; 5 – Flish unit: alternation of argillites, marls, calcareous sandstones, fine-grained conglomerates, limestones; 6 – Vidrishki volcanic complex - amphibole, pyroxene-amphibole andesites; 7 - Vidrishki volcanic complex – pyroclastic – tuffite unit; 8 - Marl-tuffite unite: marls, siltstones, tuffites, tuffs, limestones; 9 – Babski volcanic complex – large latites and trachytes porphyry; 10 – Babski volcanic complex: pyroclastic unit: 11 – Babski volcanic complex: Bunch of psammite-aleurite tuffs; psammite ashy tuffs, tuffites, epiclastites; 12 – Marl – limestone unit: alternation of clayish limestones and marls 13 – Geological boundary; 14 – Proven fault; 15 – Unproven fault.

The Babski volcanic complex, introduced by Grozdev (Ангелов и др., 2010), is exposed as a wide strip (2-4 km) from the state border near the village of Vrabcha to Breznik. It contains volcanic products with a distinct basic composition, as well as highly alkaline latites and trachytes.

The Vidrishki volcanic complex was introduced by Grozdev (Ангелов и др., 2010). The complex includes pyroclastics and various sediments, named as pyroclastic-tuff unit as well as crosscutting bodies of andesites. The area reveals also the effusive and sub-volcanic bodies of the complex.

The tuffite–marl unit, introduced by Grozdev (Ангелов и др., 2010), is exposed as a relatively wide NW-SE oriented strip south of the village of Prodancha.

The Flish unit (Загорчев и др., 1995) is exposed as two broad (500-800 m) stripes with NW-SE direction passing through the outskirts of the villages of Prodancha and Krusha. This is a folded package underlying the Krasava syncline.

Sandstone unite, introduced by Grozdev (Ангелов и др., 2010), is exposed as two broad (400-800 m) stripes with NW-SE direction, passing in the vicinity of the villages of Prodancha and Krusha. They build-up the linearly extended ridges of Tsrancha, Greben and others, which represent the main folded limb that shapes the Krasava Syncline.

The sandstone–marl unit was introduced by Загорчев и др., (1995). The unit has a large areal spread to southeast of the village of Garlo. It is the main rock assemblage of the Krasava Syncline.

Quaternary.(Holocene). Alluvial deposits from flood-plains and flooded terraces. The alluvial deposits form the floodplains of the Yablanitsa, Konska, Kalia Barra and other rivers. They are made of quartz sands and clayey sands with thin layers of impure, sandy clays. Among them gravel lenses are found.

Tectonics

In tectonic terms, the study area falls within the Sofia Unit of the Western Srednogorie (Иванов, 1998). The northern boundary of the unit is placed on the Sub-Balkan fault zone (outside the survey area) and the southwestern border is placed along the Pernik fault zone with a general direction of 120-140º, located southern of the area of study. The larger structures recognized in the studied area from south to north are the south vergent Dragovska Anticline, the south vergent Krasavska Syncline and the Galabovska Anticline. In the past, Late Subhercinian (Pre-Maastrihtian) onset of the earliest folding was inferred, because Maastrihtian shallow sea sandstones and clays were believed to cover discordantly the sedimentary and volcanic rocks of Koniacian-Santomian age (f.e. Nachev and Nachev, 2003). Later studies (Синьовски и др., 2012, 2013) have proven that Maastrihtian rocks are not present in the region, so the earliest onset of folding deformation must be ascribed to the Late Campanian. Since that time the total deformation progressed significantly, for example the limbs of the Krasava Syncline are isoclinally folded and locally overturned (Димитров, Белев, 1970). The stages of this deformation are difficult to recognize, however the opening of small, fault controlled sedimentary basins filled with Oligocene sediments mark the Post-Lutetian, Illyrian deformation stage as particularly important for the region. In general the geological maps for the area show a uniform strike of the fault formation in the range 120 -140º although this appears an oversimplification of a more complex structural setting, in which more westerly striking beds overprint the NW striking once (Fig. 3).

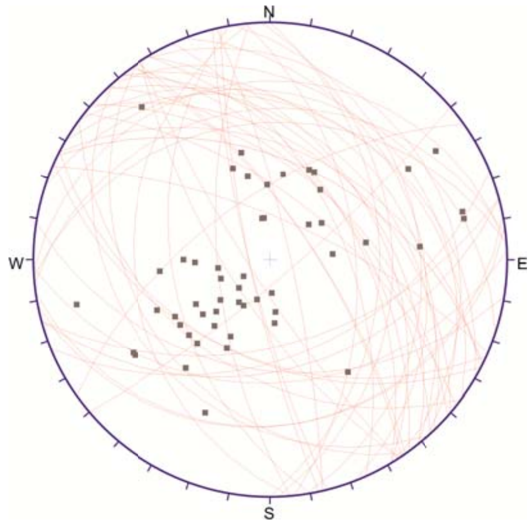

Fig. 3. Structural diagram of 52 bedding planes uniformly distributed over the study area after Загорчев и др. (1990)

Methods and analysis of the lineaments

To make precise relief pattern for the selected area, topographic maps in 1:25 000 scale are used. All are georeferenced in the WGS84, UTM35N. Horizontals are vectorized in the ArcGIS environment and the ArcScan tool after color division in PhotoShop. For better accuracy and reliability in inscribing and verifying the geometry of plotting, topology and error checking of this type were built in ArcGIS Workstation.

Linear structures are generated using Global Mapper and its Generate Watershet feature. ArcGIS tables are then generated, containing information about the direction of each line. The received data is processed in a text file, maintained by Stereonet. A rose-diagram with 24 classes and 1252 linear structures was generated.

Introduction in the terminology

In the beginning of the last century the term lineament was introduced in the works of some tectonicians such as Hobbs (1904). In their view, the lineaments are "characteristic lines in the face of the earth" (Challinor, 1964). The most significant lineaments are the ridges of hills, the boundaries of the elevated mountain areas, the river valleys, the coastal lines, as well as the boundary lines of the geological formations of different petrographic types. They are believed to be associated with deep faults or zones of intense fracturing, along which vertical or horizontal movements of the crust happened.

Tectonicians, such as Moody and Hill (1956), Moody (1966) etc. as well as geomorphologists (e.g. Герасимов, Рантсман, 1964) consider the linear structural elements on the surface of our planet for morphostructural elements. These are all areas of linear tectonic discontinuities.

Lineaments are studied using structural-geological, structural-geomorphologic and morphotectonic analyses. The study of the lineaments clarifies the relation of the orographic directions with the fault structures.

In Bulgaria, the terminology of lineaments was introduced by the tectonician E. Bonchev in a number of works (e.g. Бончев, 1963, 1971). Later this topic was also adopted by some geomorphologists. From morphostructural point of view, the problem of the lineaments and lineament zones in Bulgaria was examined by Мишев и др. (1986). According to these authors, 5 series of lineaments can be discerned on the territory of Bulgaria – two diagonal (NW and NE), two orthogonal (E-W and N-S) and one local (NNW). According to their study, the territory of Zavalska Mountain is in the so called Kraishtid lineament series, which encompasses lineaments striking 160 – 170º. They can be classified as local according to Hobbs (1904).

According to Бончев (1971), Zavalska Mountain is localized in the Kraishtid structural zone, located in Western Bulgaria, south of the Western Stara Planina Mountain. The specific feature of this area is that it is split in blocks, separated by faults. There are a number of faults striking at 160º, to which almost the entire river-valley network is attached.

Analysis of the lineaments and discussion

The rose diagram of the linear structures is shown on Figure 4. It has a very strong maximum of 136º, another at about 105º and two weaker at N-S and at 44º.

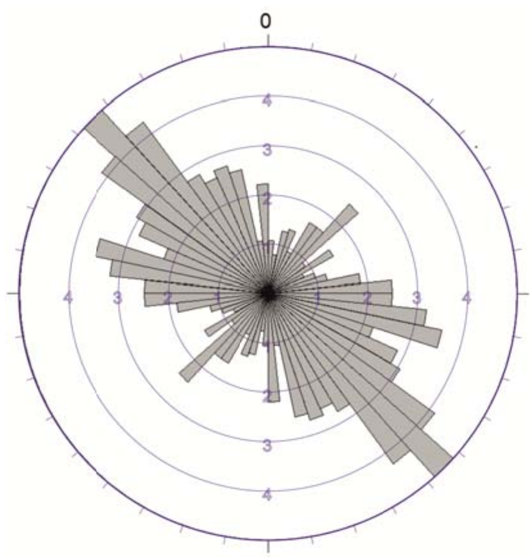

Fig. 4. Rose diagram of the 1252 linear structures

The map of the linear structures in Zavalska Mountain is shown on Figure 5. In the Bulgarian tectonic literature, no model has been presented so far to explain the overall picture of the occurrence of these lineaments. However, it is quite clear that the area is dominated by folds with northwest and southeast striking axes and there is a significant number of proven faults with similar strike.

These data fit into a well-known and well-studied tectonic model, which seems to be valid for this region as well. This is the wrench faulting model, which gained popularity with the classic publication of Moody and Hill (1956) and was further developed by authors such as Wilcox et al. (1973), Sylvester (1988), and others. What is important is that in this model the formation of folds and fractures is considered as a single process.

In short, the geotectonic development of the area can be reduced to the following events and processes:

There was strike slip shear motion statistically averaged by the direction of 136º. Probably this shear has been active from late Cretaceous to present day with periods of higher intensity, for example during the Illyrian phase.

The strike slip motion does not exclude reverse and normal fault translations but they are subordinated to it. Parallel to the fault shearing is the folding of the volcanics, the folding being the geometric effect of the shear movement.

The folding can be also a result of transpression (Sanderson and Marchini, 1984), which includes a portion of pure shear in addition to the simple shearing. In any case, the axes of the folds, being formed in this way, are oblique to the direction of shear.

In case of a left shear, they rotate counterclockwise, and in case of a right shear they rotate clockwise to the direction of shear.

At the onset of deformation they are initiated at a higher angle to the direction of shear but with its advance this angle diminishes never reaching full parallelism between the fold axes and the direction of shear.

From the geological maps (Загорчев и др., 1990; Ангелов и др., 2010), it is established that the strike of bedding does not coincide completely with the direction of the faults (Fig. 3), as it tends towards more westerly strikes, correspondingly to counterclockwise motion of the fold axes, compared to the strikes of the faults. This results from the fact that there are parasitic folds of a lower order on the terrain whose axes are oriented obliquely to the general direction of the strike-slip shear. In this sense, the maximum of lineaments of 105° reflects these folds. This maximum reflects both erosion of susceptible beds in fold limbs and extensional faults parallel to the fold axes. In theory these faults would be mainly reverse faults but limited strike and reverse motion is possible. On the other hand, the maximum of 136º corresponds mainly to strike slip faults. The kinematic sketch of these relationships is shown of Figure 6.

The results of the study comply with paleostress reconstructions in Northwest Bulgaria made by Kounov et al. (2011). Paleostress reconstruction from fault plains inferred that ”From the late Oligocene to the earliest Miocene, SSE-NNW transtension generated coal-bearing sedimentary basins and anticlockwise rotation of the main tensile axis happened by almost 50° with respect to the previous tectonic stage”.

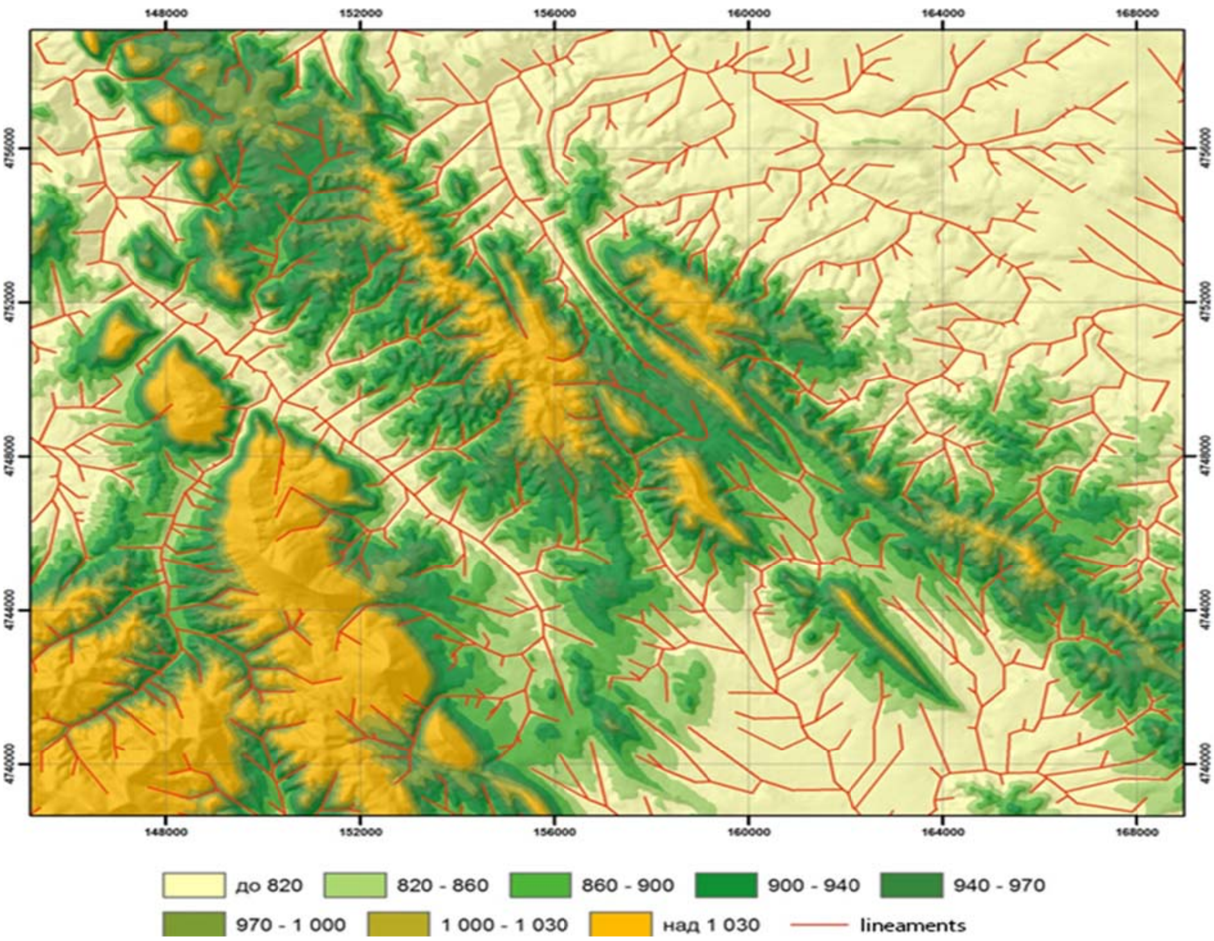

Fig. 5. Digital elevation model and linear structure derived from the hydrographic networkof the region

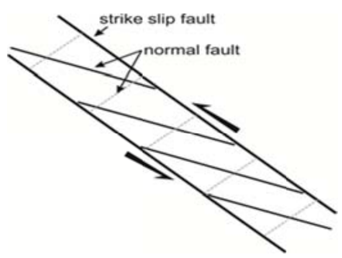

Fig.6. Kinematic sketch of the tectonic elements inferred from the lineament analysis and the geological descriptions of the study region.

Our study confirms the anticlockwise rotation of the structural elements, which can be result only from regional sinistral strike slip shear. On the other hand it is not obvious that this rotation happened only from late Oligocene to the earliest Miocene as it may have been initiated by even earlier sinistral shear contemporaneous with the opening of the basin that contains this volcano sedimentary assemblage.

To answer this question further studies and dating of the faults and folds have to be made in this seeming simply folded assemblage. It is noteworthy that a rose (Fig. 7) generated by the beds shown of Figure 3 produces very similar pattern as the lineament picture on Figure 5. This is a clear indication that the lineaments are produced predominantly by selective erosion of beds and thus are controlled by the folds.

Based on paleostress reconstruction from fault plains the authors inferred that ”From the late Oligocene to the earliest Miocene, SSE-NNW transtension generated coal-bearing sedimentary basins and anticlockwise rotation of the main tensile axis happened by almost 50° with respect to the previous tectonic stage”. Our study confirms the anticlockwise rotation of the structural elements which can be results only from regional sinistral strike slip shear.

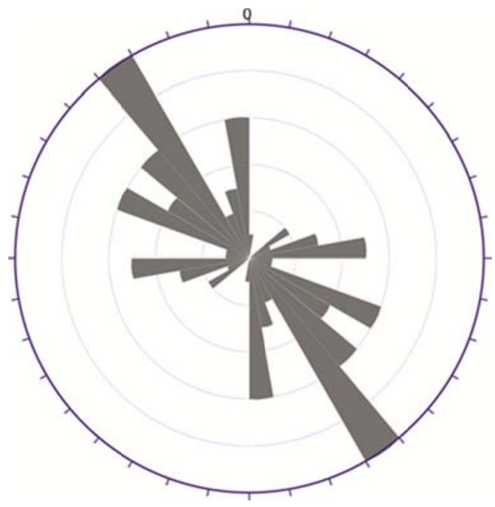

Fig. 7. Rose of 52 bedding planes from the studied area after Загорчев и др. (1990).

Conclusions

The studied region has a pronounced linear structure. The lineaments network is due to tectonic predisposition in which tight folds and numerous faults dominate. The data from the geological literature and these of the lineament analysis are in accordance and allow for a tectonomorphological model that includes simultaneous sinistral strike slip motion and folding in which erosional forms are formed in directions visible on the rose diagram.

The data shed light on the mechanism of formation of Zavalska Mountain. Moody (1966) classified the orogenic edifices into the following types: (1) linear uplifts with longitudinal fault zones; (2) autochthonous fold belts; (3) uplifted fault blocks; (4) domal uplifts; and (5) volcanic chains. The data accumulated so far suggest that Zavalska is a mountain from the first class. It is one of the pop ups related to the strike-slip tectonics of the region.

References

Ангелов, В., Р. Маринова, В. Гроздев, М. Антонов, Д. Синьовски, Д. Иванова, И. Петров, Л. Методиев, Г. Айданлийски, П. Милованов, А. Попов, В. Вълев. Обяснителна записка към Геоложката карта на Р. България, М 1:50 000, картен лист К-34-46-Б (Драгоман)., и К-34-46-Г (Брезник) - НИИ „Геология и геофизика" АД, МГУ „Св. Иван Рилски, Геологически институт, БАН, С., 2010. (Angelov, V., R. Marinova, V. Grozdev, M. Antonov, D. Sinnyovski, D. Ivanova, I. Petrov, L. Metodiev, G. Aidanliiski, P. Milanov, A. Popov, V. Valev. Obyasnitelna zapiska kam Geol. karta na R. Bulgaria, M 1:50 000, k.l. K-34-46-B (Dragoman) i k.l. K-34-46-G (Breznik) – NII "Geologia i geofizika"AD, MGU "Sv. Iv. Rilski", Geol. institute na BAN, S, 2010).

Бончев, Е. Нови идеи за тектониката на българските земи.- Сп. БАН, 8, 2, 1963. – 20-30. (Bonchev, E. Novi idei za tektonikata na balgarskite zemi. - Sp. BAN, 8, 2, 1963. – 20-30)

Бончев, Е., Проблеми на българската тектоника. – София, Техника, 1971. – 204с. (Bonchev, E. Problemi na balgarskata tektonika. – Sofia, Tehnika, 1971. – 204pp.)

Герасимов, И., Е. Ранцман. Неотектоника сеисмическийх районов Тян-Шаня и Памир Алтая по данным геоморфологического анализа. Активизированные зоны земни коры. М, Наука, 1964. (Gerasimov, I., E. Raintsman. Neotektonika seismicheskih rayonov Tyan-Shanya I Pamir Altaya po dannim geomorfologiskogo analiza. Aktivisirovannie zoni zemni kori., M., Nauka, 1664.)

Димитров, Р., С. Белев. Развитие на вулканизма в еруптивната зона на Люлин-Завалска планина. Сп. Бълг. геол. д-во, 31, 3, 1970. - 315–322. (Dimitrov, R., S. Belev. Razvitie na vulkanizma v eruptivnata zona na Lyulin–Zavalska planina. Sp. Balg. geol. d-vo, 31, 3, 1970. - 315–322.)

Загорчев, И., В. Костадинов, Х. Чунев, Р. Димитрова, И. Сапунов, Пл. Чумаченко, Сл. Янев. Геоложка карта и Обяснителна записка към геоложка карта на България, М 1:100 000, картни листове Власотнице и Брезник, Геология и геофизика АД, С, 1995. - 72с. (Zagorchev, Iv., V. Kostadinov, H. Chunev, R. Dimitrova, I. Sapunov, Pl. Chumachenko, Sl. Yanev. Geolozhka karta i Obyasnitelna zapiska kam geolozhka karta na Bulgaria, M 1:100 000, k.l. Vlasotnitse i Breznik, Geologia i geofizika AD, S, 1995. - 72p).

Иванов, Ж. Тектоника на България. СУ "Св. Кл. Охридски", 1998. - 675с. (Ivanov, J. Tektonika na Bulgaria, SU "Sv. Kl. Ohridski", 1998. - 675p.).

Маринова, Р., В. Гроздев, Д. Иванова, Д. Синьовски, П. Милованов, И. Петров, А. Попов. 2010. Обяснителна записка към Геоложката карта на Р. България, М 1:50 000, картен лист К-34-45-Б (Цървена ябълка)., К-34-45-Г (Власотинце) и К-34-45-А (Трън) - НИИ „Геология и геофизика" АД, МГУ „Св. Иван Рилски, Геологически институт, БАН, С., 2010. (Marinova, R., V. Grozdev, D. Ivanova, D. Sinnyovsky, P. Milanov, I. Petrov, A. Popov. Obyasnitelna zapiska kam Geol. karta na R. Bulgaria, M 1:50 000, k.l. K-34-45-B (Tsarvena yabalka), k.l. K-34-45-G (Vlasotintse) I k.l. K-34-45-A (Tran) – NII "Geologia I geofizika"AD, MGU "Sv. Iv. Rilski", Geol. institute na BAN, S, 2010).

Мишев, К., И. Вапцаров, Г. Алексиев. Линеаменти и линеаментиран релеф в България. Проблеми на географията, 4, БАН, С, 1986 - 12-22 с. (Mishev, K., Vaptsarov, I., G. Aleksiev. Lineamenti i lineamentiran relef v Bulgaria. Problemi na geografiyata, 4, BAN, S, 1986 – 12 -22 p.).

Начев, И., Ч. Начев. Алпийска плейт – тектоника на България. С., „Артик – 2001", 2003. - 200с. (Nachev, I., Ch. Nachev. Alpiiska pleit – tektonika na Bulgaria. S., "Artik – 2001", 2003. - 200 p).

Синьовски, Д., Р. Маринова, В. Желев. Литостратиграфия на Горната Креда в Западното Средногорие. Част 1. Сп. Бълг. геол. д-во, 73, 1-3, 2012. - 105–122. (Sinnyovsky, D., R. Marinova, V. Jelev. 2012. Litostratigrafia na Gornata Kreda. v Zapadnoto Srednogorie. Chast 1. Sp. Balg. geol. d-vo., 73, 1-3, 2012, 105 – 122 p.

Синьовски, Д., Р. Маринова, В. Желев. Литостратиграфия на Горната Креда в Западното Средногорие. Част 2. Сп. Бълг. геол. д-во, 74, 1-3, 2013. - 65–79. (Sinnyovsky, D., R. Marinova, V. Jelev. Litostratigrafia na Gornata Kreda. v Zapadnoto Srednogorie. Chast 2. Sp. Balg. geol. d-vo., 74, 1-3, 2013. - 65–79).

Challinor, J. Dictionary of Geology. Univ. of Walespress, 1964.

Hobbs, W.H. Lineaments of Atlantic border region. Bull. Geol. Soc. Amer., 4, 1904. - 15p.

Moody, J.D., M.J. Hill. Wrench-fault tectonics. - Geol. Sot. Am. Bull., 67, 1956. - 1207-1246.

Moody, J.D. Crustal shear patterns and orogenesis. - Tectonophysics, 3, 1966. - 479-522.

Sanderson, D. J., Marchini, W. R. D. Transpression. Journal of Structural Geology, 6, 1984. - 449–458.

Kounov, A., Burg J.P., Bernoulli D. Seward, D., Ivanov Z., Dimov, D., Gerdjikov, I., Paleostress analysis of Cenozoic faulting in the Kraishte area, SW Bulgaria. Journal of Structural Geology, 33, 2011. - 859-874.

Sylvester, A.G., Strike-slip faults. – Geol. Soc. Am. Bull., 100, 1988. - 1666-1703.

Wilcox, R. E., T. P. Harding, D. R. Seely. Basic wrench tectonics. Bull. Am. Ass. Petrol. Geol. 57, 1973. - 74-96.