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LINEAMENTS AND LINEAMENTED RELIEF IN BULGARIA

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The analysis of the linear elements in the relief such as faulted escarpments, monoclines, rectilinear sections of river valleys, etc., shows that there are five series of lineaments and lineament zones in Bulgaria. Four of them correspond to the cosmic series which belong to the orthogonal North-Southern, East-Western) and diagonal (North-Western, North-Eastern) systems. The fifth (North-Northwestern) is viewed as local. The morphostructural lineaments fully coincide with the basic regmatic network's directions, fixed by Bončev (1963, 1971, 1971a, 1983). Strong correlation exists between the regmatic network and morphostructural features, tracing the origin and evolution of the old morphotectonic units. They have been either entirely or partially activated or passively expressed in the contemporary relief. The lineament comprehensive characteristics, obtained by means of structural-geomorphological analysis, will enable the seismic and metallogenic zoning of Bulgaria.

Recently, the investigation of lineaments as geological and geomorphological objects have been acquiring growing importance. To this end heated debates concerning the Earth sciences take place. Their focus are the theories of mobilism and fixism in terms of which they try to explain the appearance and development of major forms in the relief, either global or local: continents, oceanic depressions, platforms, mountain systems, rift depressions, valleys, etc. The hypotheses launched by Hopkins, Philips, Dabrée, Kjerulf, Passarge and Hobbs a century ago (Katterfeld, 1984) and since the 40s further developed by Kloos, Sonder, Umgrove and others, give impetus to new regional surveys, to data analysis and data generalization carried out by a number of contemporary scientists (Katterfeld, Charishin, 1973; Schultz-junior, 1974; Schultz senior, 1979, atc.). A large bodies of publications from all over the world is a good evidence for the growing prestige of this kind of research. The aerocosmic images and their decoding enable considerably the study of the lineaments and lineament network on a global scale and throw light on certain regularities in their formation.

Simultaneously with the examination of lineaments, lineament zones and the mechanism of their evolution, the specialists aim at accurately defining

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the notion „lineament" and consequently, at improving the methodological strategy of research. The first half of the 20th c. was dominated by structural-formative and structural-geological principles of investigation while during the last two or three decades the methods of structural geomorphology and morphotectonic analysis gained popularity. Their implementation in lineament studying became possible because of the considerable achievements of structural geomorphology and improvements of its theoretical and methodological basis. Many Soviet geomorphologists like I. P. Gerassimov, Y. A. Meshcheryakov, S. K. Gorelov, D. A. Lilienberg were believed to be the first who applied the methods of structural geomorphology to their work. The progress of geomorphology turned it into a leading scientific discipline within the Earth sciences, dealing with the study and interpretation of the geodynamic processes on our planet. Structural geomorphology received a wide recognition and refined the definition of the term „lineament". The latter was again viewed in the way some geologists-tectonists had defined it in the early 20th c.: „. . . a line of landscape which reveals the hidden architecture of the rock basement". „The most significant lineaments on the Earth are considered to be the mountain ridges, the mountain marginal parts, the thalwegs, the coastal lines, the boundaries between different geological formations, the petrographic types of rocks and their contours" (Hobbs, 1904). Schultz (1979) noted in addition that „lineaments are associated not only with deep-seated faults but also with highly fissured zones where no vertical deformations occurred". Thus, the lineaments were interpreted mainly in terms of geomorphology. It was exactly this meaning of the term which gave serious reasons to Gerasimov and Ranzman (1964) to call the structural elements in concern „morphostructural lineaments". They include all zones of linear tectonic dislocations, either plicative or disjunct, clearly expressed in the relief. The latest studies of lineaments and lineamen zones, based on geophysical methods, made an attept to classify them by taking into account the depth of their setting into the Earth's crust and the upper mantle, their length, width and other indicators. Strong spatial correlations were established between the depth of lineaments and their surface characteristics (width, contrast landforms, morphological representativeness, etc.). The cosmic lineaments were found to regularly repeat their directions, partially or completely following the so called Sonder's „global regmatic network".

The involvement of geomorphologists in investigating the lineaments and lineament zones was due on the one hand to the full acceptance of the initial content of the terms and on the other — to the necessity of obtaining comprehensive historical and dynamic characteristics by means of structural geomorphological analysis. Geomorphological methods successfully assist the geophysical and structural geological ones in fixing the stages of lineament formation and development during the entire tectonic evolution of the Earth's surface. The lineament examination goes side by side with in-depth observations on the endogenic factors for they have significantly affected the nature of landforms, the ancient tectonic processes and stress fields and the extent to which the latest ones are inherited.

It was not earlier than the recent few years when geomophologists were charged with the task to investigate and analyse the lineaments and lineament zones on the territory of Bulgaria. Beforehand, the eminent Bulgarian

tectonist E. Bonchev was the first to have started working on this problem. In many of his publications (Bonchev 1963, 1971, 1971a, 1977, 1983) he outlined the regmatic network and marked its incision in the Earth's crust in Bulgaria, demonstrated the block structure of the Bulgarian territories, clarified the role of deep-seated faults belonging to the same regmatic network in shaping and controlling the geosynclinal troughs (according to Bonchev they are known as lineament-geosynclinal ones), the nature of magmatism and other geological processes. By focusing his attention primarily on various fault structures he distinguished and described six systems of faults, six systems of regmatic network: Krayshtidna (160°), Tvardishka (30°—45°), Berkovska (130°—145°), Yablanishka (70°), Balkanidna (170°—180°) and meridional system (5°—15°). He discovered that the major contemporary lines in the relief were closely bound to the lineament network and named this relief as deeply lineamented. He expected that „the future geomorphological surveys will take into consideration all conclusions made above because it is geomorphology which is to undertake more detailed investigations and recent activity of different fault structures — a goal hardly accessible by means of a purely 'classical' geology" (Bonchev, 1971, p. 157).

The first results achieved by systematic study of the morphostructural lineaments on a nationwide scale proved to be reliable (Vaptsarov, Dilinska, 1980; Vaptsarov, Mishev, 1982). This was a suggestion convincingly confirmed by outspace images decoding as well (Mozhaev and others, 1976; Gochev and others, 1984). Having in mind the unquestionable scientific value of the results obtained by using structural-geomorphological method in the studies of lineaments and lineament zones in Bulgaria, the authors of the present paper in collaboration with N. T. Kochneva from the Institute of Geology of Endogenic Mineral Deposits at the USSR Academy of Sciences and with G. Alexiev from the Institute of Geography at the Bulgarian Academy of Sciences, carried out goal-oriented morpholineament investigations on the territory of Bulgaria. They drew a schematic map reflecting the major lineament systems and zones (V. Vaptsarov, N. Kochneva, G. Alexiev, Fig. 1). The lineament network delineation was based on the analysis of differently scaled topographic maps and aerocosmic photographs and on medium-scaled maps of linear tectonic elements. The latter are represented by morphographic escarpments along fault dislocations, actively or passively expressed in the relief, by monoclines, anticlinal or synclinal uplifts in folded regions, by graben depressions and their linear configuration, by rectilinear parts of river valleys, rectilinear low cols perched on the mountain ridges, volcanic dykes, single-oriented volcanic structures, etc. The mountain areas with dissected relief seem to be dominated by tectonic elements while the depressions — by the river valley elements.

Against the background of the national morphostructural lineament network, almost all major fault structures are discernible in Bulgaria, having been outlined by geological methods. Among them are the Pre-Balkan and Sub-Balkan faults, the Stara Planina fore-line, the Marishki, Strumski, Transko-Kosharevski, Pernishki, Kiustendilski faults, etc. Quite often they are local representatives of larger and deeply lineamented zones, well seen in the contemporary relief. The characteristics of these lineamented zones, available on the basis of structural-geomorphological analysis, make it imperative to

add them to the global lineament network which is in compliance with Hobbs' theory. They belong to the four known series of the global lineament orthogonal and diagonal system which are North-Southern (NS), East-Western (EW), North-Western (NW) and North-Eastern (NE). The first two series correspond to Bonchev's meridional and Balkanidna series and the last two — to those of Berkovitsa and Tvarditsa. The Krayshtidna series (160°) is found mainly within South-Western Bulgaria and therefore in Hobbs' classification it is ranked as „local".

Throughout the country the density of morphostructural lineaments is uneven. It is greater in South Bulgaria, especially in the mountain areas (Stara Planina included) in contrast to the Danube epiplatformian plain in Northern Bulgaria.

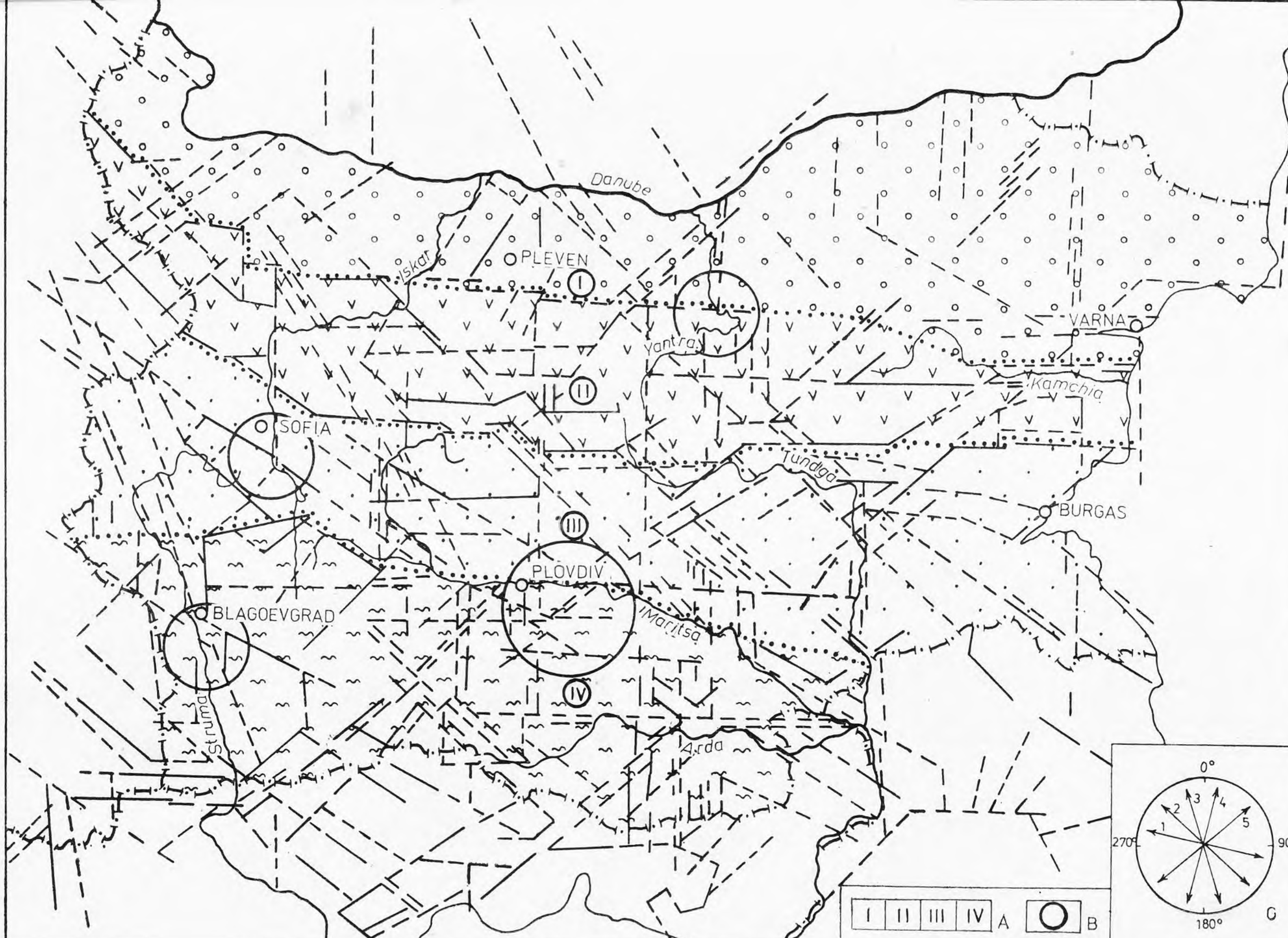
Proceeding from the morphostructural lineament qualitative assessment it is obvious that the diagonal North-Western system of Berkovitsa is prevailing in Bulgaria — a fact that is corroborated by quantitative measurements on lineaments in Europe (Katterfeld, 1984). This system predetermines the basic morphographic features in the Western Stara Planina Mountains westward from the deep Iskar transversal gorge. It is distinctly marked both by the marginal steep faulted escarpments and by the well expressed lineament subparallel linear anomalies in the inner mountain zone. The North-Western morphostructural lineament system includes also many peripheral and inside linear distortions observed in the Rilo-Rhodopy massif's topography (Vaptsarov, Dilinska, 1980). The central part of the country, known as Srednogorie, is remarkable for several outstanding morpholineament zones which can be traced further to the north, crossing diagonally the Stara Planina mountain. Transitional are two additional morpholineaments — those of Panagiurishte--Bebresh and Topolovgrad-Karlovo. Along the whole central axis of South Bulgaria from the Bulgarian-Yugoslav up to the Bulgarian-Greek frontiers there can be established in north-western direction a lineament zone, 30—35 km wide, with numerous densely distributed morphostructural lineaments. It embraces parts of the Western Srednogorie (to the north-west of Sofia), of the Central Srednogorie and Ikhtimanska Sredna Gora, of the Upper Tracian Lowland and the Eastern Rhodopy. The zone coincides with a wide depression rich in lineaments, well seen in the relief: faulted escarpments, subparallel river valley network, monoclinal elevations, etc. By its structural-geological and geophysical characteristics the lineamented zone in question can be assu-

Fig. 1. A schematic map of the morphostructural lineaments in Bulgaria (compiled by I. Vaptsarov, N. Kochneva, V. Alexiev).

A — Morphostructural zones
I — The Danube epiplatformian plain
II — The Stara Planina epigeosynclinal system
III — Krayshtidno-Srednogorska folded-block zone
IV — The Rilo-Rhodopy epiplatformian massif

B — Morphostructural junctions

C — Lineament direction
1 — Marishka, *2* — Berkovska, *3* — Krayshtidna, *4* — Meridional, *5* — Tvardishka


Danube
Iskar
PLEVEN
Yantra
VARNA
Kamchia
SOFIA
Tundiga
BURGAS
PLOVDIV
BLAGOEVGRAD
Maritsa
Struma
Arda
I
II
III
IV
0°
90°
180°
270°
1
2
3
4
5
C
A
B

med to be of first order, stretching itself on the border between two large lithospheric blocks and set deeply into the Earth's crust and the upper mantle (Velchev and co-authors, 1971; Yosifov, 1976).

The remaining three chief series (North-Eastern and the two diagonal ones, i. e. North-Southern and East-Western) have morphostructural lineaments almost equal in number. Relatively poorer development has the North-Eastern lineament series of Tvarditsa. The latter is best represented in South-Eastern Bulgaria: in the Eastern Stara Planina (particularly in Tvarditsa ridge after which it is named) and the Eastern Rhodopy Mountains. In this section the lineaments are most dense. What is more, the series is transitional, i. e. its morphostructural lineaments start from the Aegean Thracia (North Greece), cross the Eastern Rhodopy and jut out through the Eastern Stara Planina in north-eastern direction, thus reaching the western Black Sea coast. There too, the zone is deeply set into the Earth's crust which makes it a first-order linear morphostructure. In the rest of the country the same series consists of single morpholineaments such as Krupnishko-Bachevski and Etropoliski. The first is crossing diagonally the river Struma valley to the south of Blagoevgrad and in the zone between Pirin and Rila, and Rila and Western Rhodopy it passes into rectilinear faulted escarpments.

The East-Western morphostructural lineament series of Balkanidi is well represented in Bulgaria. It specifies the morphographic orientation of the Central and Eastern Stara Planina system. There it follows not only the main mountain axis but assuming the form of marginal and inner escarpments, it runs along the neotectonically activated Pre-Balkan and Sub-Balkan faults or along the Stara Planina Range, setting apart the two morphostructures within the mountain system, i. e. the Pre-Balkan to the north and the fore Balkan Range to the south. Similar is the appearance of this series in the Rilo-Rhodopy massif in South Bulgaria where it also is composed of rectilinear marginal escarpments along activated fault structures or of passively reflected in the relief normal faults, concurring with some of the big Rhodopy river valleys (Vaptsarov, Dilinska, 1980). The Marishki lineament which is developed along South Bulgaria, also falls under the same series. To the west it coincides with a faulted escarpment well expressed on the north periphery of Rila, then from the town of Stanke Dimitrov it strikes the central lowest parts of the Upper Thracian Lowland, cut by the Maritsa river, and continues its way to the east up to the Sakar northern margin. The Marishki lineament, cited in Bulgarian geological literature as a deep-seated fault-suture zone (Bončev, 1971), is one of the typical structural-geomorphological lineaments in Bulgaria of structural-geological and geomorphological importance.

The meridional lineament series (5°—15°) is distinctly expressed in the relief of Bulgaria, too. Its lineaments are shorter and the lineament zones are narrower and more densely situated. During the neotectonic stage they were slightly deformed although somewhere the deformation did not affect them at all. As a consequence, the river network adjusted itself parallel to them and it was in the same direction in which the rocky substratum fell into fragments. In other cases they resemble individualized linear zones extended along faults with low cols around. Elongated linear dyke formations, built of young bazalt Neogene subvolcanic rocks spread alongside. The centre of the meridional lineament series is occupied by a wide lineament zone,

striking north-south, where is developed the Momchilgrad depression just on the boundary between the Western and Eastern Rhodopy in South Bulgaria. It can be traced further to the north, passing through the Stara Planina region and the Danube plain. This series includes the Tundga lineament as well with the Tundga river valley oriented along it from the town of Yambol to the state frontier with Turkey. Analogical are the morphological characteristics observed with the Topolnishki lineament, being cut by the Topolnitsa river in its middle course. Along the Topolnishki lineament there can be distinguished a linear deformation of Late Pliocene denudation terraces, rising up to 400 m westward. Within the Western Rhodopy, well expressed from morphological aspect is the Vatcha lineament, deeply cut by the rectilinear Vatcha river valley.

As it was already mentioned, the Krayshtidi series of morphostructural lineaments (160°) is „local" according to Hobbs' classification. E. Bončev maintained that territorially it was located in the Krayshtidi structural zone in Western Bulgaria, to the south of the Western Stara Planina. Regarding its recent structural elements, it has characteristics of its own. It is a block-faulted morphostructure with various old faults in west-northwestern direction (340°), to which is attached almost the whole river valley network and especially the Struma right tributaries. There are serious grounds to conclude that the region is typical for its highly lineamented relief, the outstanding feature of which is the adjustment of the water divides and river network to the block-faulted structure. The relatively wide Struma morpholineament, set deeply in the Earth's crust, belongs to the Krayshtidi lineament series, too. It runs to the west of Rila and Pirin and to the east of the marginal mountains of Ograzhden and Vlakhina in the vicinity of the Bulgarian-Yugoslav boundary. It has westnorthern strike (345°), and is from 5 to 10 km wide. Neogene-Quaternary depressions are scattered alongside such as those of Stanke Dimitrov, Blagoevgrad, Simitli and Sandanski. The Struma river low course coincides in its direction with the lineament stretch.

To find spatial correlation between the regmatic fault network and the lineament formation in Bulgaria by using structural-geomorphological analysis means to prove the interdependences between the structural-geological composition of the country and the large morphostructural units. This relationship is found in the territorial overlapping of the big structural zones and the basic morphostructures — the Danube epiplatform, the Stara Planina mountain system, the Krayshte-Sredna Gora and Macedonian-Rhodopy ones. Obviously, their formation as individual geomorphological units should be associated with the structural-geological evolution of the Bulgarian lands, especially during the latest neotectonic period when the contemporary, highly differentiated relief came into existence. Taking into consideration Gerasimov and Meshtyarkov's conception (1964) about a certain geomorphological stage of development our country has passed through, the low age of the recent morphostructures in Bulgaria was dated back to the Mesozoic when the compact Thracian massif fragmented, the Misian platform appeared and the fist geosynclinal troughs were inserted into the transitional structural zone of Stara Planina. These were processes controlled by the initial regmatic network of faults which nowadays has a strong impact on the topography, on its general morphographic axes and territorial interrelations. The latter are best illustra-

ted by differently ranked block morphostructures in South Bulgaria and by the chain-like extension of the young Stara Planina morphostructure.

The Neotectonic (Neogene-Quaternary) activity of the morphostructures and morphostructural lineaments is undoubtedly inherited from ancient endogenic processes. However, not all of the old structures (lineament zones included) were subdued to activation. A careful morphostructural analysis shows that neotectonic stage was marked by two opposite tendencies — inherited development and formation of new morphostructures. As for the lineaments, only separate sections of them were activated and the principle of „selectivity" was dictated by the specific geodynamic situation. Their other parts were passively expressed in the relief. The heterogenous dynamic characteristics of morphostructural lineaments in Bulgaria fully and correctly revealed the mechanism of the endogenic geodynamics up to the present days. Such comprehensive historical and dynamic characteristics of the lineaments enabled to register and fix the seismic centres in the country, recently activated. A detailed analysis was carried out on morphostructural lineaments in Bulgaria (Vaptsarov, Mishev, 1982) on the basis of which there were established certain junctions of high endogenic activity at the points of their intersection. Examples in this respect are the Marishki (at the crossing of Marishki and Tvardishki lineaments), the Krupnishki (at the crossing of Strumski and Krupnishko-Bachevski lineaments), the Gornooryahovski (at the crossing of Pre-Balkan and meridional lineaments) junctions and some others of a lower taxonomic rank.

In conclusion, it becomes clear enough that by studying the morphostructural lineaments in Bulgaria we characterise on the one hand more accurately the tectonic processes, and on the other we acquire knowledge that is far deeper and diverse than earlier about the formation and development of the contemporary relief. Geomorphology is faced with the prospect of effectively servicing practice by being involved in tasks of practical applied importance, among which is the problem of seismic and metallogenic zoning of Bulgaria.

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LINEAMENTY A LINEAMENTNÝ RELIÉF V BULHARSKU

Použitie štruktúrnogeomorfologickej metódy pri štúdiu lineamentov a lineamentných zón v Bulharsku prináša so sebou možnosť úplnejšieho zistenia zákonitostí endogénnej dynamiky, ako aj celkového procesu formovania súčasného reliéfu krajiny. Pri analýze priamočiarych bralných svahov pozdĺž starších alebo mladších zlomov, ďalej pri analýze smerov orografických osí, lineárnych prepadlín, riečnych dolín atď. v Bulharsku sa zistilo 5 hlavných smerov: 2 diagonálne (SZ a SV), 2 ortogonálne (V—Z, S—J) systémy a jeden lokálny smer — Krajštidny (160°). Všetky tieto série sa zhodujú s hlavnými smermi regmatickej siete — Berkovským, Tvardišským, Balkanidným, Meridionálnym a Krajštidným, zisteným Bončevom (1963, 1971, 1971a, 1977 a i.). Analýza priestorových vzťahov morfoštruktúrnych lineamentov a siete regmatického rozpojenia poukazuje na úzku korelačnú súvislosť. Táto súvislosť je aj dynamická — neogénnokvartérne geodynamické procesy, ktoré majú hlavnú úlohu v procese formovania súčasného reliéfu, postupne rozvíjajú staršie štruktúrne jednotky alebo v ich dôsledku vznikajú nové štruktúrne prvky, ktoré súvisia s novou geodynamickou situáciou. Pozornosť sa venuje vývoju 5 sérií morfoštruktúrnych lineamentov na území Bulharska. Skúmanie morfolineamentov prináša so sebou možnosti využtia geomorfologickej vedy na aplikované ciele, akými sú sejzmická a metalogenetická regionalizácia a prognózovanie.

Obr. 1. Schematická mapa morfoštruktúrnych lineamentov v Bulharsku. (podľa I. Vapcarova, N. Kočnevovej a G. Alexieva).
A — Morfoštruktúrne zóny
I — Dunajská epiplatformná rovina
II — Staroplaninský epigeosynklinálny systém

III — Krajštidno-Srednogorská vrásovo-zlomová zóna
IV — Rilsko-Rodopský epiplatformný masív

B — Morfoštruktúrne uzly

C — Smery lineamentov
1 — Marišsky, *2* — Berkovsky, *3* — Krajštidny, *4* — Meridionalný *5* — Tvardišsky.

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ЛИНЕАМЕНТЫ И ЛИНЕАМЕНТНЫЙ РЕЛЬЕФ В БОЛГАРИИ

Приложение структурно-геоморфологического метода в изучении линеаментов и линеаментных зон в Болгарии расширяет возможности более полного раскрытия и выяснения закономерностей эндогенной динамики, а также общего процесса формирования современного рельефа страны. При анализе прямолинейных склоновых утесов вдоль древних или молодых сбросов, направлений орографических осей, линейных грабенов, речных долин и т. д. в Болгарии установлено пять главных серий — две диагональной (СЗ и СВ), две ортогональной (В-З, С-Ю) системы и одна „локальная" серия — Крайштидная (160°). Все пять серий совпадают с главными направлениями регматической сети — Берковским, Твардишским, Балканидным, Меридиональным и Крайштидным, установленными Бончевым (1963, 1971, 1971а, 1977 и др.). Анализ пространственных соотношений морфоструктурных линеаментов и сети регматического разрыва показывает тесную коррелятивную связь. Она оказывается и динамической — неогенно-четвертичные геодинамические процессы, которым принадлежит ведущая роль в формировании современного рельефа, постумно развивают древние структурные единицы или создают новые структурные элементы, связанные с новой геодинамической обстановкой. Рассмотрено развитие пяти серий морфоструктурных линеаментов на территории Болгарии. Изучение морфолинеаментов создает возможность для привлечения геоморфологической науки для решения практического и прикладного значения, таких как сейсмическое и металлогенное районирование и прогнозирование.

Рис. 1. Схематическая карта морфоструктурных линеаментов в Болгарии (по И. Вапцарову, Н. Кочневой и Г. Алексиеву).
A — Морфоструктурные зоны
I. — Дунайская эпиплатформенная равнина
II. — Старопланинская эпигеосинклинальная система
III. — Крайштидно-Среднегорская складчато-сбросовая зона
IV. — Рило-Родопский эпиплатформенный массив
B — Морфоструктурные узлы
C — Направления линеаментов
1 — Маришское, *2* — Берковское, *3* — Крайштидное, *4* — Меридиональное, *5* — Твардишское.

Перевод автора