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Geology and morphotectonics of Sredna Gora Mountains (Southern Bulgaria)

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Abstract. The tectonics of Sredna Gora Mts includes three structural complexes: Precambrian, Caledonian-Herzinian and Alpine, in which several structural levels and sub-levels are distinguished. They form the main structures of the Sredna Gora Mts: Ihtimanski anticlinorium, Srednogorie horst-anticlinorium, Bailovo-Panagyuriski synclinorium (Panagyurishte Strip) and the Stara Zagora synclinorium (Stara Zagora Strip). The geological characteristics of the Sredna Gora Mts are a result of their geological development. Some limestones and marls have been formed at the end of the Mesozoic. At the beginning of the Neozoic era (through the Paleogene), the rock layers in the region were folded. The process was accompanied by active volcanic activity, so there were formed andesite, tuffs and tuffites, which in some places created unified volcano-sedimentary complexes. At the same time, the introduction of magma into the Earth's layers led to the formation of intrusive bodies. Older rocks - granites, gneisses, mica shales, have also been discovered in the process of surface formation. After the folding process, younger sedimentary rocks and deposits were formed.

Key words: granitoids, plutons, ore deposits, gold, copper, Srednogorie structural zone.

Introduction

Sredna Gora Mountains (Mts) is part of the Srednogorie Mountain System (Srednogorie). It extends subparallel to the main chain of the Stara Planina Mountains, south of the line of the Sub-Balkan Valleys - Sofiyska, Saranska, Kamarska, Mirkovska, Zlatishko-Pirdopska, Karlovska, Kazanlashka, Tvardishka and Slivenska, and north of the Kraishte, the Rila-Rhodope massif and the Upper Thracian Lowland. The highest peak of Sredna Gora Mts is Bogdan Peak - 1604 m a.s.l. With its relatively low average altitude of only 464 m, Sredna Gora Mts refers to the low mountains (Kopralev *et al.* 2002).

Fig. 1. Sredna Gora Mountains (Source: https://bg.wikipedia.org/).

GEOLOGY

According to its geological structure, morphostructural and morphohydrographic features, the Srednogorie Mountain System is divided into four large zones: Zavalsko-Planska (also called Vitoshko Srednogorie, to which are referred to: Zavalska Planina Mt, Viskyar Mt, Lyulin Mt, Vitosha Mt and Plana Mt), Sredna Gora Mts, Bakadzhitsite Mt and Karnobatsky Hissar Mt. Particularly important are the Svetiiliyskite Vazvishenia Heights, the Manastirskite Vazvishenia Heights, the Cherny Ridge (Karatepe) and the Bosnia Ridge as "transitional" between the Srednogorie Mountain System and the Sakar-Strandzha Mountain Region.

The borders of Sredna Gora Mts, with the exception of the western one, have a clearly pronounced morphostructural and morphological character. In this sense, the western boundary, the Pancharevo Gorge (between Plana Mountain and Lozenska Mountain), is conditional, but it is well known and is officially accepted. The eastern boundary is delineated by the Tundzha River, which, entering the Sliven Valley, sharply changes direction and turns south, tearing off the Bakadzhitsite Mt to the east. The northern boundary is marked by the relatively steep end of the Sredna gora Mts slopes to the Sub-Balkan valley fields and has an almost straight outline, unlike the southern one, which has a complex pattern. To the west, the southern boundary is faulty, but Sredna Gora Mts is tightly squeezed into the Rila Mts, and to the east, the border is a "ruffled" erosion line, along which Upper Thracian Lowland enters with some large "bays" in the mountain (Kopralev *et al.* 2002).

Fig. 2. Location of Sredna Gora Mountains.

Within the boundaries described, Sredna Gora Mts has a straight (aerial) length of 256 km and a width of 40-50 km (in the western part) to 3 km (in the easternmost). It is the third longest in Bulgaria after the Stara Planina Mts and the Sub-Balkans Range. Its area is approximately 6000 km^2, which is about 6% of the country's territory. In addition to the west, where Sredna Gora Mts connects to the mountains of Kraishte structural zone, a series of transverse ridges also connect it to the Stara Planina Mts. Such a connection, though less distinct, is also to the south with the Rila Mts, Rhodope Mts, Sakar Mts and Strandzha Mts. From the west to the east, the transverse thresholds of Negushevsky Ridge, Gulabets Ridge, Koznitsa Ridge, Strazhata Ridge (Krustets) and Mezhdenika Ridge connect Sredna Gora Mts with Stara Planina Mts. Particularly expressive in orographic terms is this connection through the Gulabets Ridge, the Koznitsa Ridge and the Strazhata Ridge (Kopralev *et al.* 2002).

The Shipochansky Ridge and the Schumnatitsa Ridge make the connection between Cherni Ridge from the Ihtimanska Sredna Gora Mts and the Rila Mts in the south. A little to the east, such a connection is made between Golak Ridge (Ihtimanska Sredna Gora Mts) and the transverse ridge Rakovitsa. Further to the east, the Chirpanskite Vazvishenia Hights, elevated to the south in Thracian Lowland, by a wide footstep had a direct connection with the eastern Rhodopes' ridges Dragoina and Mechkovets. This connection, although deeply eroded and torn apart by the Maritza River, also has a clear morphological appearance (Kopralev *et al.* 2002).

Morphotectonic zonation of Bulgaria

The evolution of the ideas concerning morphotectonic zonation of Bulgaria and geomorphological zonation as derived from it, is very well discussed in the review of Zagorchev (2009). As the author emphasizes, the morphotectonics has played an important role in the evolution of geotectonic. Even at the first geological observations, explorers have found out some direct relations between the relief and tectonics, and specifically, between the young fold belts and the mountain chains. So, the first tectonic syntheses have a morphotectonic character as far as they reflect the relationship of the tectonic structure to its surface – a geomorphological expression.

The first tectonic zonation of Bulgaria and the Balkans was published by Cvijic (1904). It represented a morphotectonic zonation based upon five large tectonic and morphological elements: the Bulgarian (later called Moesian) plate (platform), the Carpathian system (mountain range), the Balkan system (mountain range), the Transitional zone and the Rhodope mass. All later morphotectonic (Bonchev 1946, 1971), geomorphological (Galabov 1946) and neotectonic (Tzankov *et al.* 1998) maps are based on this fundamental distinction as stated by Zagorchev (2009).

The differentiation between geomorphological and morphotectonic zonation of Bulgaria has been proposed by J. Galabov and E. Bonchev in 1946 (Zagorchev 2009). Almost 25 years later, Bonchev (1971) introduced two other basic concepts in the morphotectonic zonation: 1) the lineaments and lineament-geosynclinal zones related to deep faulting, and 2) the transversal crypto-lineaments that divide the country into three megablocs: Western, Central and Eastern. Next big step in the evolution of ideas concerning the geotectonic zonation was made by Boyanov *et al.* (1989) and Dabovski *et al.* (2002) which introduced the plate tectonics postulates. These authors implemented also the idea about the consecutive superposition of several Alpine orogens to form the complex Alpine orogenic edifice on the Balkan Peninsula: Late Triassic (Early Cimmerian), Middle Jurassic (Late Cimmerian), Mid Cretaceous (Austrian), Late Cretaceous (Subhercynian and Laramide), Middle Eocene (Illyrian), Late Eocene - Oligocene (Pyrenean) and latest Oligocene - earliest Miocene (Savian). As a result of their studies, the maps produced have a purely geotectonic and geodynamic character, but they have lost almost all links to the geomorphological and morphotectonic zonation (Zagorchev 2009).

In the present structural terms, the morphotectonic picture of Bulgaria is entirely subordinated to the structures of the Alps-Himalayan orogeny. With the emergence of this complex geotectonic structure, the main morphotectonic units in Bulgaria are formed. They differ not only in morphology and tectonic style, but also in the character of the sedimentary, magmatic and metamorphic rocks that build them. The differences are related to the different fate of these areas during the long evolution of our geological space.

The Bulgarian continental microplate is disposed in eastern part of the Balkan Peninsula (South East Europe). The last one covers the territories to the east from the Timok River, South Morava, Pchinya and Vardar River. It includes the territories of Bulgaria and parts from East Serbia, the eastern part of the Republic of Macedonia, the North-East Greece and the North-West Turkey.

According to Tzankov *et al.* (2018), the territory of Bulgaria, as a part from the Balkan Peninsula, is composed by numerous micro morphotextures (Fig. 3). Those continental microplates were separated from the northern passive paleo margin the Gondwana Continent in different moments of the Phanerozoic evolution. Authors explain their movement to the north during the closing of the Tethys Ocean as islands or archipelagos with different geological and tectonic history. These continental fragments were arrived to the south and south west margin of the Paleo-Europe continental massif in the time of the ending of the Tethys oceanic crust subduction (Early Paleogene) where they built the modern southwestern and southern margin of the European continent – Neo Europe. The Neo Europe uniform geotectonic evolution was begun in Early Paleogene but the last more important deformations on the Balkan Peninsula were realized during the Paleocene and Eocene Epochs and the Early Oligocene Age. Main Alpidian tectonic processes were related to deep crust folding and over thrusting deformations, revealing to the end of the Alpidian geotectonic era. The Paleocene-Early Oligocene predominantly low or hill-low mountain relief in the region was connected with intensive volcanic activity (Tzankov *et al.* 2018). That is the reason for the presence of the contemporary mosaic pattern of continental crust (25 microplates) in the southeastern parts of Neo Europe as presented on Fig. 3. Tzankov *et al.* (2018) conceived that the oriental part of the Balkan Peninsula includes the Bulgarian, Halkidikian and southern part from Moesian continental microplates.

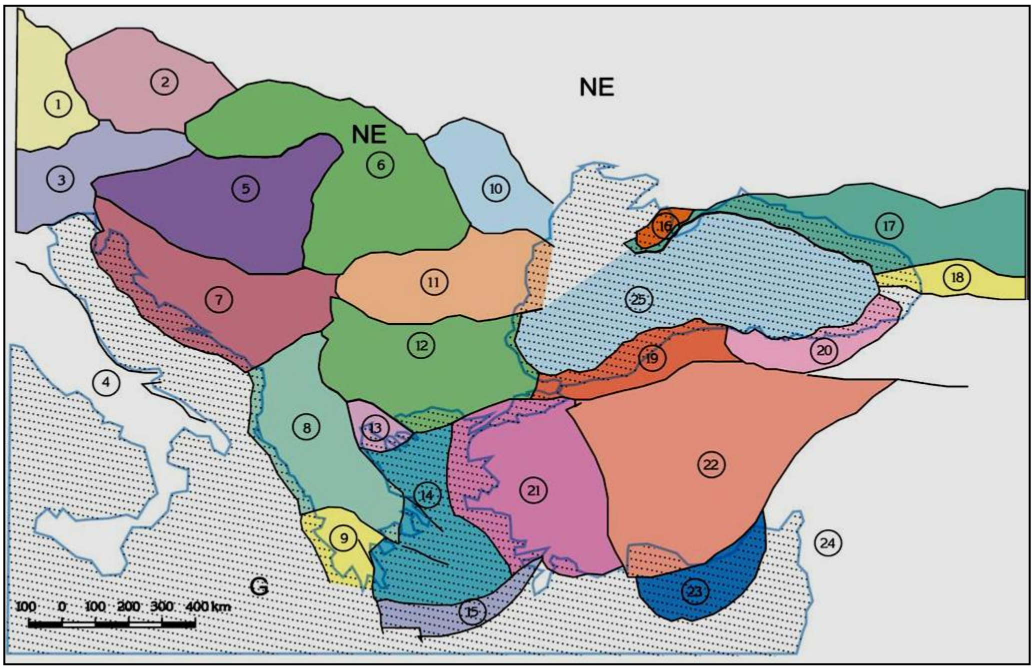

Fig. 3. Mosaic tectonic pattern schematic model of the Neo Europe South-eastern part (after Tzankov and Iliev, 2015, with modification and addition) (Source: Tzankov *et al.*, 2018). G- Gondwana continental macroplate (Continent); NE - Neo Europe continental macroplate. 1-20 - Neo Europe continental microplates: 1-Bavarian, 2-Bohemian, 3-Alpean, 4-Apeninian, 5-Moravian, 6-Carpathian, 7-Dinarian, 8-Pindian, 9-Heladian, 10-Scitian, 11-Moesian, 12-Bulgarian, 13-Halkidikian, 14-Aegean, 15-Cretean, 16-West Pontian, 17-East Pontian 18-West Anadolian, 19-East Anadolian, 20-Cyprian; 21-23, Paleo Europe Continental Microplates: 21-Creamean, 22-Caucasian, 23-Georgian; 24-Arabian Continental Plate; 25, Black Sea Oceanic Microplate.

The Bulgarian continental microplate is composed by the Sub Balkan, Upper Thracian, Strumeshnitsa, Middle Struma, Middle Mesta, West Thracian, Lower Thracian, South Morava, Hemus, Kraishte-Sredna gora, Bregalnitsa, Rila-Rhodope, Sakar-Strandzha and Gradesh-Belasitsa morphostructural zones (Tzankov *et al.* 2018) (Fig. 4).

The Balkanides occupy the central part of the Bulgarian lands. To the south they are bounded by the Marishka Fault and to the north by the Brestnitsa-Preslav Flexure. To the west, they continue to eastern Serbia, and to the east they reach the Black Sea shelf, in whose boundaries they turn south and connect with the Pontids. The rocks that are revealed in their range can be conditionally combined into three structural complexes: lower, middle and upper (Strashimirov & Moev 1988).

The lower structural complex lies in the core of the large positive structures located in the southern reaches of the Balkanides. It is made of high-metamorphic rocks and granitoids with a revealed thickness up to 4 km. It is genetically and spatially linked to the upper part of the Pra-Rhodope complex.

The middle structural complex is revealed most fully in the core of the anticlinoric structures from the central parts of the Balkanides and Strandzha Mountains. Its distribution clearly marks the direction of the Paleobalkanides. It is made of low-metamorphic and diverse sedimentary rocks which make a typical formational order for geosynclinals areas: diabasic-phyllitoid and aspidic (clay) formation of the Early Paleozoic age (Cambrian, Ordovician, Silurian), terrigenous-carbonate and flysch formation of the Devonian and Early Carboniferous and molasses of Carboniferous and Permian ages (bottom-up direction). The total thickness of the complex is about 8 km. The Plutonites of Stara Planina are implemented in the middle structural complex. In this regard, its lower parts are affected not only by regional but also by contact metamorphosis (Strashimirov & Moev 1988).

The upper structural complex is revealed very widely, but in the most complete sections it is preserved in the northern areas of the Balkanides (Pre-Balkan). It covers the Mesozoic and Neozoic groups. It is made of various marine and continental sedimentary rocks. The upper Cretaceous rocks in the southern parts of the Balkanides have specific composition and construction. Upon closer examination, they are clustered into a separate structural complex, characteristic only of the Srednogorie structural zone. In the upper structural complex there are many disagreements and peculiarities that allow it to be broken down into a whole series of structural series and sub-series. Usually they are not sustained over the entire area of the Balkanides and their occurrence is conditioned by the specific behavior of the individual earthquake blocks. Unlike other structural complexes, the upper structural complex constructs the mantles of anticlinoric and entire synclinoric structures. Its thickness varies widely and in some sections exceeds 6 km (Strashimirov & Moev 1988).

Geomorphological zonation of Bulgaria

The geomorphological zonation of Bulgaria also derived from the original morphotectonic zonation of Cvijic (1904), as have discussed by Zagorchev (2009). The most popular geomorphological zonation was proposed by Galabov (1946). He distinguished four morphological regions on the Bulgarian territory: I. Danubian hilly plain; II. Stara Planina zone (IIa. Foothills of Stara Planina (Forebalkan, Pre-balkan), and IIb. Main Stara Planina chain); III. Transitional strip (zone) (IIIa. Sredna Gora with the Cis-Balkan basins (IIIb), the Kraishte (IIIc) and the Thracian plain (IIId)); IV. Rila-Rhodope massif (Rhodopes (IVa), Rila (IVb), Pirin (IVc), Osogovo-Maleshevo Mountains (IVe) and the Sakar-Strandzha Mountains (IVf)). Alternative zonation was proposed by Gerasimov (1957), based on the morphological regions of Galabov (1946) and the geostructural elements of E. Bonchev (1946).

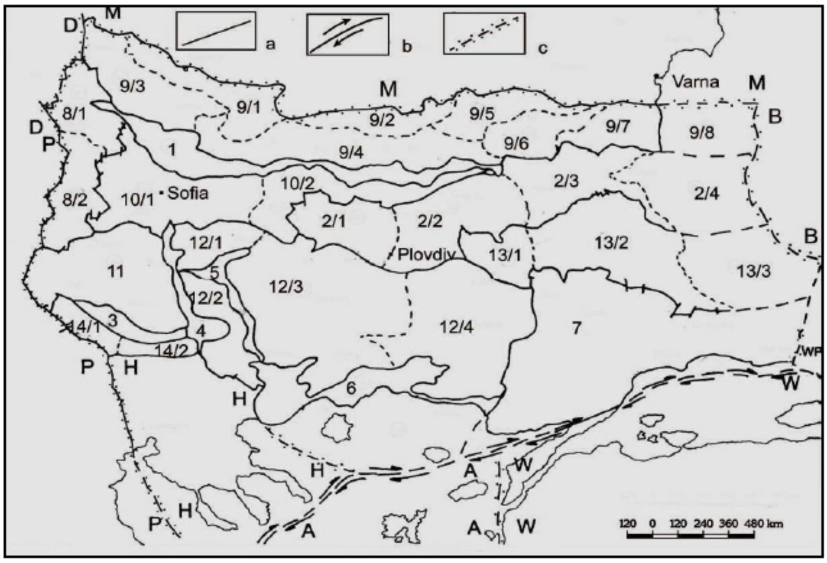

Fig. 4. Bulgarian continental microplate (zones and areas) (after Tzankov et al., 2018)
1- Sub Balkan, 2- Upper Thracian (2.1- Plovdiv, 2.2- Zagore, 2.3- Burgas), 3- Strumeshnitsa, 4- Middle Struma, 5- Middle Mesta, 6- West Thracian, 7- Lower Thracian, 8- South Morava (8.1- Nishava, 8.2- Surdulitsa), 9- Hemus (9.1- Vratsa, 9.2- Veliko Tarnovo, 9.3- Preslav, 9.4- Midzhur, 9.5- Mazalat, 9.6- Udvoy-Matoria, 9.7- Primorsko), 10- Kraishte-Sredna gora (10.1- Kraishte, 10.2- Sredna gora), 11- Bregalnitsa, 12 - Rila-Rhodope (12.1- Rila, 12.2- Pirin, 12.3- West Rhodope, 12.4- East Rhodope), 13- Sakar-Strandzha (13.1- Sakar, 13.2- Strandzha), 14- Gradesh-Belasitsa (14.1- Gradesh, 14.2- Belasitsa).

The geomorphological zonation of Bulgaria has been further developed by Galabov (1982) and Kopralev *et al.* (2002). Authors accept as a base the morphostructural analysis of the relief, the principal stages in the geologic evolution, the planation surfaces, the valley network and terrace spectra, loess, karst relief and the Black Sea shelf, similarly to the findings of Zagorchev (2009). The proposed zonation includes four big geomorphological regions which coincide with the principal morphographic regions (Fig. 5).

Zagorchev (2009) emphasizes also that that the Neogene evolution and the development of the relief are controlled mostly by vertical tectonic movements in extension conditions, so the geomorphological regions and subregions are closely related to the young tectonic evolution. Par example, some geomorphological and neotectonic studies in Bulgaria and on the Balkan Peninsula demonstrated that the planation surfaces (the initial peneplain formed in Early Miocene to early Middle Miocene times, and subsequent younger surfaces) in the mountain horsts show a step-wise distribution, and their altitude is dependent on the amount of uplift posterior to their formation (Zagorchev 1992, 2009). In some cases, it is possible to correlate some of the surfaces with corresponding stagnation levels in the neighbor sedimentary basins. Alternatively, destruction of some surfaces during intense uplift and erosion is correlated with very coarse sediments (megabreccia, coarse conglomerate) that form fans within adjacent grabens, some of which are buried by younger sediments (Zagorchev 2009).

Fig. 5. Map of the geomorphological zonation of Bulgaria (according to Kopralev *et al.* 2002; redrawn in color by Zagorchev 2009) (Source: Zagorchev 2009).

A – Region of Moesian (Danube) plain: Ab – Subregion of Pleven-Pavlikeni; Ac – Ludogorie-Dobrudzha Subregion (Ac1 – Ludogorie-Dobrudzha plateau; Ac2 – Shumen-Provadiya plateau; Ac3 – Peri-Black Sea low plateau and lowlands; Ac4 – Danube low plateau and lowlands); B – Stara Planina Region: Ba – Subregion of Pincipal Stara Planina Range; Bb – Fore-Balkan Subregion (Bb1 – Belogradchik-Veslets hilly area; Bb2 – Teteven-Elena hilly area; Bb3 – Preslav-Gerlovo hilly area); C – Kraishte-Sredna Gora Region: Ca – Kraishte-West Srednogorie Subregion (Ca1 – Kraishte area; Ca2 – West Srednogorie area); Cb1 and Cb2 – Sredna Gora range; Cc1 – Sofia basin; Cc2 – Cis-Balkan basins; Cd – Upper Trace-Middle Tundzha Subregion (Cd1 – Plovdiv and Stara Zagora basins; Cd2 – Middle Tundzha lowland and hilly area; Cd3 – Burgas lowland); Ce – Sakar-Strandzha Subregion (Ce1 – Sakar area; Ce2 – Strandzha area); D – Macedonian-Rhodope Region: Db – Subregion of Osogovo-Belasitsa (Db1 – Osogovo-Ograzhden mountain area; Db2 – Struma graben area); Dc – Subregion of Rila, Pirin and Mesta basins (Dc1 – Rila-Pirin high mountain area; Dc2 – Mesta graben area); Dd – East Rhodope Subregion (Dd1 – Middle Arda hilly area; Dd2 – Maglenitsa hilly area; Dd3 – Haskovo low mountain step).

Morphotectonic zonation of Sredna Gora Mts

The tectonics of Sredna Gora Mts are closely related to the Srednogorie structural zone, which has a long and complex geo-historical development. The ideas about the place of the Sredna Gora Mts in the tectonic scheme of Bulgaria, its relative independence or belonging to one or another tectonic zone also undergo a long and complex evolution.

Considering the first tectonic division that was made by the Serbian geomorphologist Cvijic in 1904, the unfinished scientific debate has been going on for more than a century. According to some researchers and authors, the Srednogorie zone belong to the Rhodope Massif (Rila-Rhodope Massif, Macedonia-Rhodope Massif) and, according to others, to the Balkanides or the Alpine folded system. Researchers who distinguish it as a separate tectonic unit are no exception. Among the last are the great Bulgarian geologists Acad. J. Galabov and Acad. E. Bonchev. Either way, the dispute continues. So far, the only undisputed thing is that Sredna Gora Mountain is part of the Srednogorie structural zone.

The boundaries of the Srednogorie structural zone are determined by the Marishky and Pernik rifts in the south and Sub-Balkan rift in the north. To the west and east, the zone continues beyond the borders of Bulgaria. Within this range, specific cretaceous rocks with a volcanic-sedimentary character and a thickness of 1 to 5 km have been developed. For these reasons, it is also known as the Central Bulgarian Volcanic Belt. It originated on a heterogeneous basis and slightly oblique to the Paleobalkanides and Mesobalkanides. On the upper Cretaceous complex are deposited thick molassoid sediments, which are located in separate depressions and grabs. Because of its specific construction, many authors have tried to view it separately from the Balkanides, such as a separate geosyncline space, called the tafrogeosyncline, the lineament-geosyncline, the continental rift, etc. Such a solution encounters serious difficulties in interpreting the neotectonic development of Balkanides and the Plate-tectonic reconstructions of our lands (Strashimirov & Moev 1988).

According to Tzankov *et al.* (2019), the origin of the Sredna Gora morphostructural area should be referred to the Late Pleistocene-Holocene, after the full destruction of the post Early Pleistocene orthoplain. The authors revealed that the new build positive morphostructures belong to one older Late Pleistocene generation and one younger Late Pleistocene-Holocene generation. The first one is presented today through the more or less partial conserved traces of the eroded morphounits. The second generation morphostructures build the modern complete regional morphostructural plan of the area (Tzankov *et al.* 2019).

According to Tzankov *et al.* (2019), the geodynamic genesis of the Sredna Gora morphostructural zone is connected with the Early Paleogene saturation between the Moesian and Balkan Continental Microplate during the building of New Europe Continental massif. The morphotectonic position of the Sredna Gora morphostructural zone corresponds with the first-order regional morphostructural threshold – the Srednogorie Threshold. It separates the Tsaribrod-Tvarditsa Complex morphostructural passage (Sub Balkan morphostructural zone) from the Thracia Complex morphostructural passage (Upper Thracian morphostructural zone) between Iskar River and Tundzha River (Fig.6).

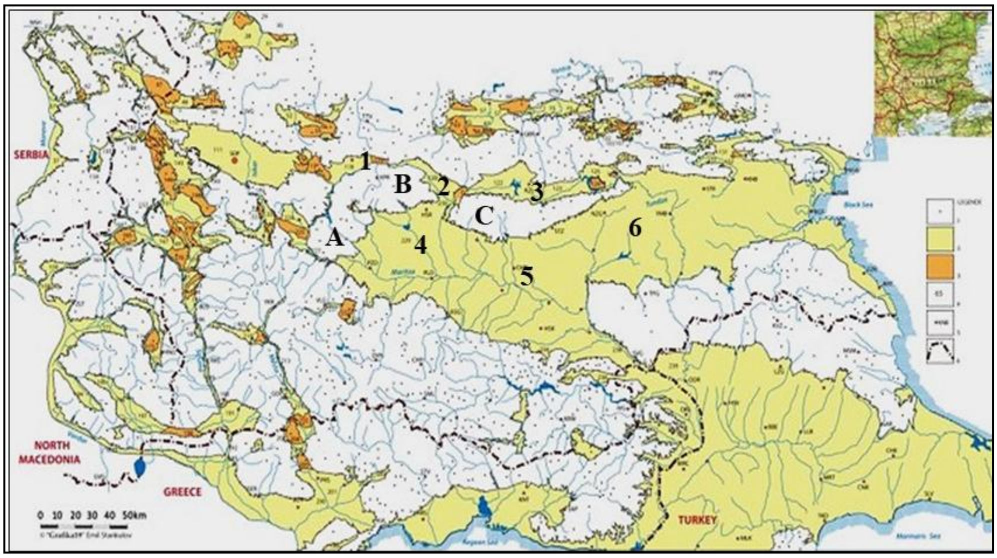

Fig. 6. Morphotectonic position of the Sredna Gora morphostructural area in the east part of the Balkan Peninsula (Source: Tzankov *et al.* 2019).

1-3-east part of the Tsaribrod-Tvarditsa Complex morphostructural passage (Sub Balkan morphostructural zone): 1-Zlatitsa Valley morphostructure; 2-Karlovo Valley morphostructure; 3 -Kazanlak Valley morphostructure; 4-6-west part of the Thracia Complex morphostructural passage (Upper Thracian morphostructural zone): 4-Plovdiv Lowland morphostructure; 5-Spassovo morphostructural threshold; 6-Zagore Lowland morphostructure; A-Eledzhik Morphostructural Region (Babuhnitsa-Vitosha morphostructural area); B-C-Sredna Gora morphostructural area: B - Panagyurishte and Hisarya Morphostructural Regions, C-Sarnena Sredna Gora Morphostructural Region.

In the transitional direction, the Srednogorie structural zone is divided into Western, Central and Eastern zone (Strashimirov & Moev 1988).

Western Srednogorie zone is also known as Sofiysko Srednogorie. The Etropole diagonal crypto-fault is considered to be its eastern border. To the east, the Upper Cretaceous complex is buried by the Paleogene sedimentary rocks of the Pernishki graben and the Pliocene deposits of the Sofiyski graben. Between them remains highly elevated Vitosha central-magmatogenic structure (Strashimirov & Moev 1988).

Central Srednogorie zone covers the lands between the Etropole crypto-fault and the Tvardishki strait. It develops several positive and negative structures, which were formed during the late Alpine structure. In the western part of the Central Srednogorie zone is the Ihtimanski horst block, built mainly by the high-metamorphic rocks of the lower structural complex. It is surrounded by grabens with different size and time of formation. In the northern part of the Central Srednogorie zone is the Srednogorie horst anticlinorium, which in orographic terms encompasses Sashtinska and Surnena Sredna Gora. At its core are revealed the high-metamorphic rocks of the Balkanides' lower structural complex, which are strongly fragmented and assimilated by granitoid intrusions. Immediately south of the Srednogorie anticlinorium are the Bailovo-Panagyurishte and the Stara Zagora structural strip. They are long and narrow syncline structures that are composed of intricately folded and dislocated Triassic, Jurassic and mainly Upper Cretaceous rocks. The southern part of the Central Srednogorie zone is occupied by the Upper Thracian complex trench. Its borders include the Plovdivski graben and Zagorski graben, and the Chirpanski threshold separating them. The grabens are filled with Paleogene, Neogene and Quaternary deposits. Relatively smaller ridges have developed along the boundary faults of the structural zone, which are filled mainly with Pliocene and Quaternary sediments. There are the Zlatitsa, Karlovski, Sheinovski and Kazanlashki grabens to the north, and the Palakariyski, Kostenetski, Uzundzhovski grabens to the south (Strashimirov & Moev 1988).

Eastern Srednogorie zone comprises two first-class structures: the Strandzha anticlinorium and the Burgas synclinorium. Some authors view these structures as separate zones or sub-zones (Strashimirov & Moev 1988). The Strandzha anticlinorium begins east of the Zagora graben and continues east-southeast in Turkey. In the modern structural plan there are clearly several second-order fold structures, of which the Central Strandzha anticlinorium is the most expressed. Of the syncline structures, the most significant sizes have Stoilovski and Topolovgradski synclinorium. The Burgas synclinorium begins in the region of Nova Zagora, expanding and deepening in the east. To the south it reaches the North Strandzha flexure, and to the north - to the Aytos anticlinorium. It is filled with a variety of sedimentary, volcanic and intrusive rocks of Early Cretaceous, Paleogene and Neogene age (Strashimirov & Moev 1988).

Fault tectonics determines the block-mosaic structure of the Sredna Gora Mts, especially pronounced in the Ihtimanska Sredna Gora Mts, and play an important role in its neotectonic geomorphological development when shaping the actual landscape.

Geological characteristics of Sredna Gora Mts

Sredna Gora Mts includes rocks and rock complexes of different types, composition and age. Almost all major rock species are represented here: magmatic - plutonic (intrusive) and volcanic, sedimentary, metamorphic. Their age spans a huge range, from the Precambrian to the Quaternary, i.e. more than 2 billion years. The oldest rocks that are now being discovered in Sredna Gora Mts are metamorphic (various types of gneisses, schists, gneiss-schists, etc.) and have a Precambrian age. They, together with the slightly younger (Paleozoic) granitoids, make up about 75% of the Sredna Gora Mountains and play a major role in its geological features (Valev & Filipov 1983).

Granitoids (granites, granodiorites, gabbro, etc.) make plutons of varying size (rocks whose magma, unlike volcanic rocks, has stuck in the Earth's interior, subsequently discovered by denudation processes). The more famous such plutons in Sredna Gora are: Vershilski, Gutsalski and Boshulski plutons (Ihtimanska Sredna Gora Mts) (Dabovski *et al.* 1965; Georgiev *et al.* 2009), Poibrenski, Panagyuriski, Koprivshtenski, Hisarski plutons (Panagyurska Sredna Gora Mts) (Valchev & Nikolova 2017), Bratanski, Pustrovski, Zmeyovski plutons (Sarnena Sredna Gora Mts) (Valev & Filipov 1983).

The Mesozoic and Neozoic sedimentary rocks (various types of limestone, dolomites, marls, sandstones, conglomerates, etc.) are also widespread and play important role in the geological structure of the Sredna Gora Mts. Essential for the geomorphology are also volcanic and volcano-sedimentary rocks - andesite, andesite lava breccia, tuffs - the result of intense underwater volcanism which occurred during the Upper Cretaceous especially intense in Panagyurska Sredna Gora Mts and Sarnena Sredna Gora Mts (Fig. 7) (Vangelov *et al.* 2019).

The Pliocene is relatively widespread in the southern parts of the Sarnena Sredna Gora Mts where is represented by lake-type sediments. There are two main facies that differ horizontally. One of them is external, coastal, consisted of coarser gravels and boulders. The other one is an internal, comparatively finer, made up of clayey-sandy sediments. The transition between the two facies is gradual, and the differences in the size of the material are due to the dynamic environment during their formation (Valev & Filipov 1983).

The Quaternary in the Sarnena Sredna Gora Mts is represented by Pleistocene, Holocene and other genetic types of Quaternary deposits. To the Pleistocene are related the coarse sedimentary materials of some deluvial cones northeast of the village of Rozovets, as well as the gravel-boulder deposits around the village of Chehlare, Turiya, Gorno Novo selo. The Holocene is widespread mainly in the valleys of almost all larger and smaller rivers. the materials that build it are developed in boulder-gravel and sandy-gravel facies, without any particular differentiation (Valev & Filipov 1983).

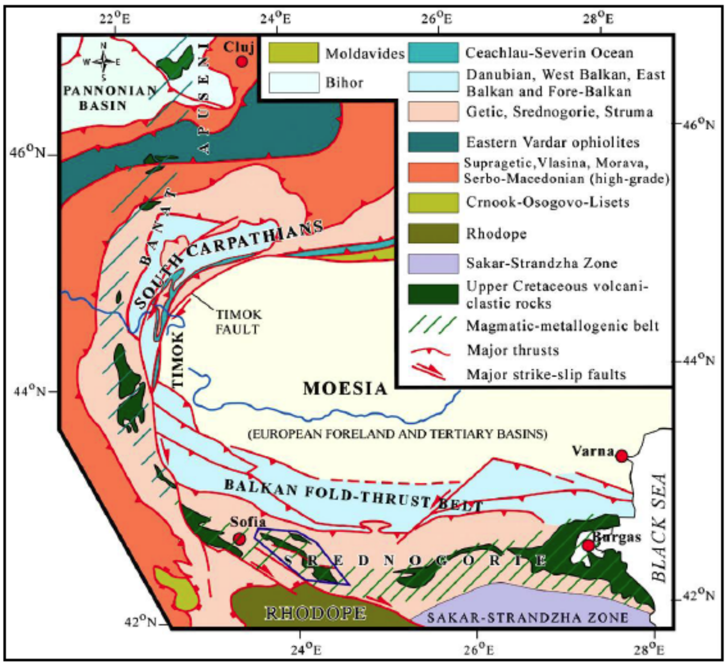

Fig. 7. Regional sketch map of the Apuseni-Banat-Timok-Srednogorie magmatic and metalogenic belt (after Knaak *et al.*, 2016, modified by Vangelov *et al.* 2019) (Source: Vangelov *et al.* 2019).

Stratigraphy of Sredna Gora Mts

Sredna Gora Mts is a small fragment of the giant Rhodope Massif, the oldest "land" and an indisputable morphological core in the Balkans. Many studies have proved that Sredna Gora zone is a part of a complex, elongated Late Cretaceous-Tertiary magmatic arc that can be traced from the Apuseni Mountains in Romania to Iran (Bergougnan & Fourquin 1980, Sandulescu 1984, Mitchell 1996, Jankovic 1977, 1997, Berza *et al.* 1998, Stampfli & Mosar 1999, Neubauer, 2002). According to some authors, this zone could be regarded as a volcanic island arc (Boccaletti *et al.* 1974, 1978), back-arc basin (Hsu *et al.* 1977) or intra-arc basin with submarine volcanism (Nachev 1978), or even as an intracontinental rift, which originated in connection with the Vardar subduction (Dabovski 1980). Widespread in the Sredna Gora zone are intrusive and volcanic rocks, the products of Upper Cretaceous magmatic activity (Georgiev *et al.* 2009).

During the Paleozoic (about 300 million years ago), this protomorphostructure (over 2-3 billion years old) begins to disjoint and disintegrate. From then until the Upper Cretaceous-Paleogene stage (60-70 million years ago), the area of present-day Sredna Gora Mts is an arena for the introduction of granitoid plutons (Upper Paleozoic and Upper Cretaceous), supplemented by contact metamorphic changes, long-standing regional metamorphism, multiple transgressions (invasion of sea basins), underwater volcanism and emersion - "floating" over the waters and intense destruction (Strashimirov & Moev 1988).

The Upper Cretaceous sedimentary successions in the western part of the Central Srednogorie tectonic subzone crop out in the so called Chelopech and Panagyurishte strips (Fig. 8). As a whole, both strips show similar structure and composition: basal siliciclastic sediments, an interval including magmatic rocks, followed by a volcaniclastic and epiclastic deposits, covered by white, red and green limestones (regionally developed in peri-Tethyan realm facies), with fast transition to sandy low-density turbidities. The crystalline basement of the Srednogorie zone consists of Cadomian and Palaeozoic high-grade metamorphic rocks intruded by granitoids with different age, whereas, in the southern slopes of the Stara Planina Mts (along the northern rim of the Chelopech strip), mostly lower Palaeozoic low-grade metasediments are exposed (Iliev & Katskov 1990, Velichkova *et al.* 2004).

Permian and Triassic clastic and carbonate rocks are locally preserved in both strips (Antonov *et al.* 2010). The findings of Tzankov (1961), Iliev & Katskov (1990) revealed that Carboniferous, Permian, Triassic and Jurassic rocks in the western part of the Panagyurishte strip are also part of the pre-Upper Cretaceous basement (Fig. 8). The heterogeneity of the basement lithology is a result of the intensive Early Alpine orogeny, during which different levels of exhumation and erosion were achieved, the most prominent being those in the Central Srednogorie tectonic subzone, as summarized by (Vangelov *et al.* 2019).

The Upper Cretaceous stratigraphy in the Eastern Sredna Gora zone is based mainly on the results of the systematical field descriptions (cited above) as well as on the studies of microfaunistic associations (Petrova *et al.* 1980, Nachev & Dimitrova 1995). In the Eastern Sredna Gora zone there is Lower Cenomanian conglomerates, calcareous-sandy, siltstone, quartzite-sandstone, and sandy-limestone horizon, Turonian basal conglomerate-sandstone, shale, coal, supra-coal horizons and flysch-like series as well as Maastrichtian basal breccia-conglomerate, tuffic-volcanogenic, marl-limestone with tuffs, volcanogenic and limestone horizons (Tzankov *et al.* 1962, Tzankov 1968).

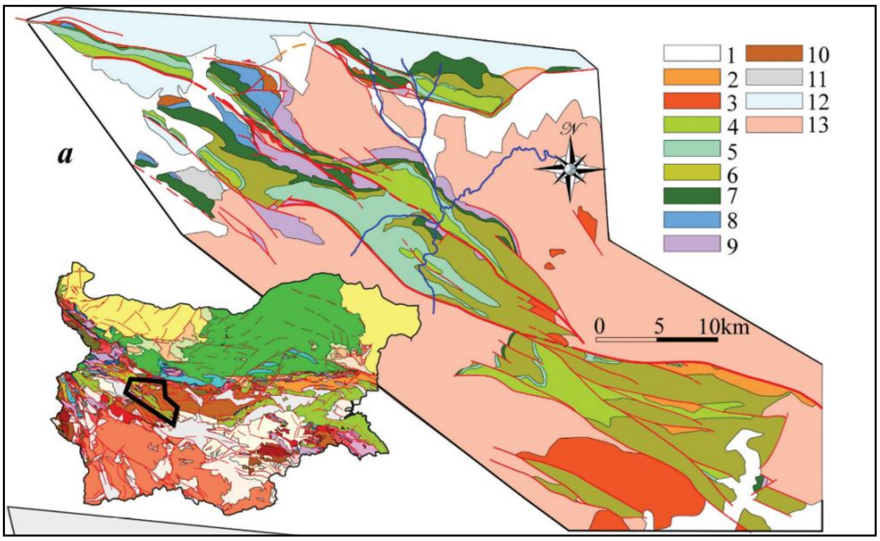

Fig. 8. Geological sketch map of the studied area (modified from Iliev & Katskov 1990, and Antonov *et al.* 2010, modified by Vangelov et al., 2019) (Source: Vangelov *et al.* 2019)
1 – Neogene–Quaternary; 2 – Paleocene; 3 – Upper Cretaceous plutons; 4 – Chugovitsa Formation; 5 – Mirkovo Formation; 6 – volcano-terrigenous complex; 7 – basal terrigenous unit; 8 – Jurassic; 9 – Triassic; 10 – Permian; 11 – Upper Carboniferous; 12 – Paleozoic low-grade metamorphites; 13 – Paleozoic high-grade metamorphites.

Gradishte Formation occurs as a stripe to the west of Sliven Town with a height of 90 m up to 130 m. The rocks of the Formation lie with a transition (sub flysch) over black shales, calcareous shales and argillaceous limestones of the Cerovska Formation (Petrova et al., 1980). Fossils in Gradishte Formation are extremely rare and represented by *Globotruncana linneiana* (d'Orbigny), *Hedbergella* sp., Heterohelicidae and *Lenticulina* sp. (Nachev & Dimitrova 1995). The age of the formation is considered as Coniacian-Campanian (conditionally). A part of the flysch provisionally is referred to the Turonian (Tzankov 1968, Kunchev 1971, Kulaksazov 1974).

Glushnik Formation is named after the Glushnik Village, located at 15 km east of the town of Sliven. The thickness of the rocks there is rising from 10 m up to 200 m (Nachev & Dimitrova 1995). The features of the Glusnik Formation are related to the presence of grey up to reddish micritic and argillaceous limestones which are partly ironized. They contain also silicate concretions, bedded quartz (jasper) and manganese ores. As described by Nachev & Dimitrova (1995), the rocks of the Glushnik Formation lie over the Sinemorec Formation with a sharp contact, locally with a submarine erosion. Fossils of Glushnik Formation are presented mainly by planktonic foraminifers and microfossil associations. The following taxa have been determined: *Globotruncana tricarinata* (Quereau), *Globotruncana bulloides* Vogler, *Contusotruncana fornicate* (Plummer), *Rugoglobigerina rugosa* (Plummer) and *Pseudotextularia elegans* (Rzehak). The age of the Glushnik Formation is Campanian (Nachev & Dimitrova 1995).

During the Paleogene, Sredna Gora Mts begins to "float", rising above the surrounding water basins (seas). And then one of the most important geotectonic events happens - huge masses gravitationally slip into the Paleogene Sea to the north, from where the Stara Planina Mts was born. The Central Balkan uplift is formed and whose fragment, the Botevvrashka part, is a classic example in the tectonics of the Balkans. The highest peaks of the Kalofer Mts are made of allochthonous (alien) rocks, ie. from Srednogorie granitoids (Strashimirov & Moev 1988).

Mineral and ore deposits

Sredna Gora Mts can be described as rich in minerals and ore deposits. The most famous one is the Panagyurishte ore region, whose copper deposits are noted in the world copper almanac. In addition to the well-known deposits, there are dozens of indications of various ore, non-metallic and other minerals that have been found in Sredna Gora Mts. There were also deposits of polymetallic minerals, manganese, titanium-manganese, manganese-iron, hematite ores, molybdenum, and especially gold-containing ores. Many of them were subject to extraction and production in the distant past, when the ancient miners have followed their amazing talent and have shown excellent knowledge.

The history of gold mining in Bulgaria, the Balkans and Europe is closely related to Sredna Gora Mts. Information about the prehistoric and antique ore production in Bulgaria, and more precisely, in the Srednogorie Region, can be found in a number of publications (Skorpil 1882, 1884, 1888, Karaoglanov 1924, Radoslavov 1934, Peev 1975, 1980, 1990, Georgiev 1978, 1987, Cernykh & Raduncheva 1972, Cernykh 1978, Kovachev 1994, Nenov 1994, 1997, Nenov & Nenov 2008a, b, Avdev 2005). Another data on mining activities in the region are given in the notes of many travelers, in chroniques and historical documents (Nenov 2008). The study of Cernykh (1978) has proved that the oldest copper mines in Europe have been located in Sarnena Sredna Gora Mts. Traces of them can be found near the villages of Hrishteni and Rakititsa, the village of Mineral Baths, in the area “Mechi Kladenets” (“Ai Bunar”), “Tumyanka” and other places in the Stara Zagora Region. Their age could be attributed to the Chalcolithic period (5000-4000 BC). The copper ores in the region have been with high gold content – only in the “Mechi Kladenets” area it has been estimated that over 300 kg of gold have been produced (Cernykh 1978). There was found an evidence for the application of “fire” method in ore production which age is about one hundred years before the same practice in the Pyrenean Peninsula (Avdev 2005).

Another significant evidence for the ancient ore production in Sarnena Sredna Gora Mts is the unique archaeological monument “Kutela” (the “Mortar”) at the Southern slope of Bratan Peak (Fig. 9). It has been modelled from a granite block with thickness of the walls 0.40 m, depth 1.00 m, inside diameter from top to bottom 1.30-0.50 m, outside perimeter 4.30 m, and with two stone “handles” of 0.55 x 0.25 x 0.15 m. As Nenov (1997) emphasizes, its close location to gold and gold-bearing occurrences and deposits is remarkable - only around the mountain area of Bratan-Kavakliika can be traced over 150 ancient ore production sites and two shafts (near the villages of Kolio Marinovo and Gorno Novo Selo), as well as many traces of washing placer gold. This evidence gives the opportunity to accept its relation to the ancient ore production and not as monument of a cult character (Nenov, 2008).

Fig. 9. The unique geoarchaeological monument “Kutela” below the Bratan Peak in Sarnena Sredna Gora Mts (granite) (Source: Nenov, 2008).

There are both autochthonous (endogenous) and placer (river, alluvial) deposits and manifestations of gold, which have been the subject of extraction of the most ancient times until the present day. The indigenous gold deposits are the gold-containing copper deposits “Assarel”, “Medet”, “Radka”, “Elshitsa”, “Tsar Assen”, “Vaykov Peak”, “Petelovo” in the Panagyurishte ore region, gold-bearing deposits and manifestations in the Ihtimanska Sredna Gora Mts (around Golyama Rakovitsa and Verinsko), in the Sarnena Sredna Gora Mts (around the villages of Svezhen, Osetenovo, Chehlare, Slavyanin, Kolyu Marinovo, Gorno Novo Selo, etc.) (Valev & Filipov 1983, Nenov 2008).

The deposits of many rivers in Sredna Gora Mts contain placer gold, ie. "native" gold released from the parent rock (Nenov 2008). The river beds and river terraces of the Stara Reka River, the river valley of the Topolnitsa River and its middle tributaries (especially the Mechenska River and Panagyurska Luda Yana River), the left tributaries of the Maritza River (Rahmanliyska River, Omurovska River, Sazliyka River), the tributaries of the Tundzha River (flowing from the massifs of Bratan, Cavakliyka and Moruley) are gold-bearing. During antiquity the gold production has been well developed by washing (panning) of placer gold from young Quaternary placers. Material traces of this activity are mounds of washed pebble materials, which are rarely found. They have been periodically destroyed by the high waters of the rivers or as a result of anthropogenic activity. Nevertheless, such mounds have been preserved along the Topolnitsa River (near the village of Chavdar), Saplama River, Turiiska River, Golyamata Reka River, and near the villages of Chehlare, Slavyanin and Medovo. Such mounds have been known also along the Sazliika River, but now they are under the waters of the Chatalka Dam. Some ancient shafts for gold production were found during recent digging for a channel near the village of Pancharevo – in Pliocene (more probably in Pleistocene) gold bearing conglomerates. In many of them, there is an amateur production and nowadays (Nenov 2008).

The uranium deposits in the adjacent parts of the Upper Thracian Lowland to the Sredna Gora Mts represent a significant resource. With proven reserves of such ores, Bulgaria occupies one of the first places in Europe, but after 1989 their production in Bulgaria is closed. The deposits of asbestos, talc and vermiculite around the town of Ihtiman, pegmatites and pegmatite fields for the production of feldspar, muscovite, kyanite were noted from the non-metallic minerals. The largest barite deposit (with gold content) in Bulgaria, now closed, is located in Sarnena Sredna Gora Mts (around the city of Stara Zagora). In Chirpan region, there are also manifestations of gypsum and various types of clay, including bentonite (Ruseva & Grozdanov 1983).

Conclusion

The tectonics of Sredna Gora Mts includes three structural complexes: the Precambrian, the Caledonian-Herzinian and the Alpine, in which several structural levels and sub-levels are distinguished. They form the main structures of the Sredna Gora Mts: Ihtimanski anticlinorium, Srednogorie horst-anticlinorium, Bailovo-Panagyuriski synclinorium (Panagyurishte Strip) and the Stara Zagora synclinorium (Stara Zagora Strip). To the west and east, these large structures are bounded respectively by the Sofia and Burgas synclinories (which in tectonic terms refer to Srednogorie zone), and to the north and south by a series of imposed depressions (grabens), on whose expand the valleys. From the north these are: Sofiyski, Saranski, Dolno Kamarski (Mirkovski), Pirdopski, Karlovski, Sheinovski, Kazanlashki, Gurkovsko-Tvardishki and Belenski grabens, and from the south - Kostenetski graben and Upper Thracian depression. Internal to the zone are the Rakitski (Gabrenski, Chukurovski) and Ihtimanski grabens.

The geological characteristics of the Sredna Gora Mts are a result of their geological development. It is connected with the development of the Srednogorie geosynclinorium which was formed at the end of the Mesozoic. Some limestones and marls have been formed at its bottom. At the beginning of the Neozoic era (through the Paleogene), the rock layers in the region were folded. The process was accompanied by active volcanic activity, so there were formed andesite, tuffs and tuffites, which in some places were mixed with sedimentary rocks, thus forming a unified volcano-sedimentary complex. At the same time, the introduction of magma into the Earth's layers led to the formation of intrusive bodies. Older rocks - granites, gneisses, mica shales, have also been discovered in the process of surface formation. After the folding process, younger sedimentary rocks and deposits were formed.

The area of the Sredna Gora Mts is rich in minerals and ores. Significant deposits of copper ores have been discovered in Sashtinska Sredna Gora Mts, in the region of Panagyurishte Town. Polymetallic ores containing copper, lead, zinc and some other metals were found in Bakadzhitsite, while the valleys of the Topolnitsa rivers (around the town of Zlatitsa) and Luda Yana (near Strelcha and Panagyurishte) are rich in placer gold.

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