THE URANIUM-POLYMETALLIC DEPOSITS IN THE SLIVEN-TVARDITSA ORE REGION IN THE WEST BALKAN METALLOGENIC ZONE, BULGARIA

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ABSTRACT. Late Cretaceous hydrothermal uranium deposits are found in the West Balkan Metallogenic Zone. Sliven-Tvarditsa Ore Region is outlined in the Central Balkan Mountain, in which the Sliven and Shivachevo Ore Fields and the Yavorovets ore occurrence are distinguished. The ore bodies are bed-like, metasomatic, in Triassic and Upper Cretaceous carbonate rocks or in interbedding breccia. Besides, vein ore bodies are developed along the faults in the Paleozoic basement rocks. The ore mineralization is hydrothermal in type, medium to low temperature. The main ore minerals are pitchblende, galena, sphalerite and chalcopyrite, and the non-ore are quartz and to a lesser extent dolomite, calcite and barite. Pyrite, arsenopyrite, chalcocite, hydro pitchblende, chalcanthite, renardite, anglesite, uranospinite, torbernite, cerussite, malachite, azurite, autunite, uranophane, hematite and limonite are more rarely observed. Bornite, chalcocite, hydro pitchblende, uranium soot, chalcanthite, renardite, anglesite, uranospinite, torbernite, cerussite, malachite, azurite, autunite, uranophane, hematite and limonite are hypergenous. The hydrothermal alterations are represented by sericitization, advanced argillization, pyritization, kaolinization and carbonization. The ore deposits are formed in the frame of a non-volcanic island chain, adjacent to the Srednogorie Zone from the Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt.

Keywords: Uranium deposits, Upper Cretaceous West Balkan Metallogenic Zone.

УРАНОВО-ПОЛИМЕТАЛНИТЕ НАХОДИЩА В СЛИВЕН-ТВЪРДИШКИЯ РУДЕН РАЙОН ОТ ЗАПАДНОБАЛКАНСКАТА МЕТАЛОГЕННА ЗОНА, БЪЛГАРИЯ

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РЕЗЮМЕ. В Западнобалканската металогенна зона са установени къснокредни хидротермалниуранови находища. В Централния Балкан се оконтурва Сливен-Твърдишки руден район, в който се отделят Сливенското и Шивачевското рудни полета, както и рудопроявление Яворовец. Рудните тела са пластообразни, метасоматични, в триаски и горнокредни карбонатни скали или междупластови брекчи. Освен това са развити жилообразни рудни тела в разломите от палеозойски скали от фундамента. Рудната минерализация е от хидротермален тип, средно- до нискотемпературна. Главните рудни минерали са настуран, галенит, сфалерит и халкопирит, а нерудните – кварц и по-малко доломит, калцит и барит. По-рядко се срещат пирит, арсенопирит, халкозин, тенантит, тетраедрит и борнит. Хипергенни са борнит, халкозин, хидронастуран, настуран, уранови чернилки, халкантит, ренардит, англезит, ураноспинит, торбернит, церусит, малахит, азурит, отонит, уранофан, хематит и лимонит. Хидротермалните промени са представени от серицитизация, окваряване, пиритизация, каолинизация и карбонатизация. Рудните находища са образувани в рамките на невулканска островна верига, прилежаща към Средногорска зона от Апусени-Банат-Тимок-Средногорския магматичен и металогенен пояс.

Ключови думи: уранови находища, горнокредна Западнобалканска металогенна зона.

Introduction

The geological setting in Bulgaria is determined by the Balkan and Carpathian Systems of the Alpine Orogeny and the adjacent Moesian Platform. The sub latitudinal Balkan, Srednogorie and Morava-Rhodope Zones are distinguished from North to South in the Balkan System (Zagorchev et al. (ed.), 2009). The evolution of the Balkan System is a result of consecutive geotectonic events, as intracontinental rifting, ocean spreading, subduction, Austrian collision, Upper Cretaceous rifting, Illyrian collision and post-collisional orogenesis (Popov, 1981; Popov, 1996; 2002). The Balkan Zone covers the outer parts of the orogeny, as it is overthrust on the Moesian Platform and part of the Southern Carpathians to the North, and it borders on the Srednogorie Zone to the South. The Balkan Zone section is represented by Mesozoic and Paleocene – Middle Eocene sediments with numerous hiatuses and compressional deformations (Zagorchev et al. (ed.), 2009).

The ore forming processes are manifested during the Late Cretaceous events in the Balkan Zone, and differentiate the West Balkan Metallogenic Zone. This zone covers the major part of Western and Central Stara Planina Mountain, from the Eastern parts of Serbia in the west, to the town of Sliven in the east (Fig. 1) (Popov, 1985; 1989; Popov, 1995). According to the scheme by Dabovski, Zagorchev (Zagorchev et al. (ed.), 2009) it includes the West Balkan, Central Balkan and part of the Fore Balkan units from the Balkan Zone, as well as parts from the Srednogorie and SW Bulgaria.

The West Balkan Metallogenic Zone position during the Upper Cretaceous is of great significance. To the South it borders to the Srednogorie through which it is part of the Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt (Popov et al., 1978; Popov et al., 2002), where intensive sedimentation and volcanic activity are observed. At the same time, a shallow epicontinental sea is formed over the Moesian

Plate to the North. The analyses by different authors (Bonchev, 1955; Nachev, 2003) show that the studied territory is above the sea level during this period and represents a non-volcanic island chain. It includes part of the Austrian fold-overthrust belt, uplifted during the Late Cretaceous rift forming. The noted West Balkan Metallogenic Zone position supposes that the ore forming processes are result of hydrothermal activity, controlled by the Upper Cretaceous magmatism in the Srednogorie area (Popov, 1985; 1989).

The West Balkan Metallogenic Zone is characterized by series of endogenous mineral deposits, compounds of lead, zinc, copper, uranium, barite and rarely iron, antimony and molybdenum ores in different proportions. Stratiform and less vein or vein-like deposits predominate. The Sliven-Tvarditsa Ore Region is marked by the development of uranium-polymetallic ores and it is differentiated in part of the Central Stara Planina Mountain, within the frame of the metallogenic zone.

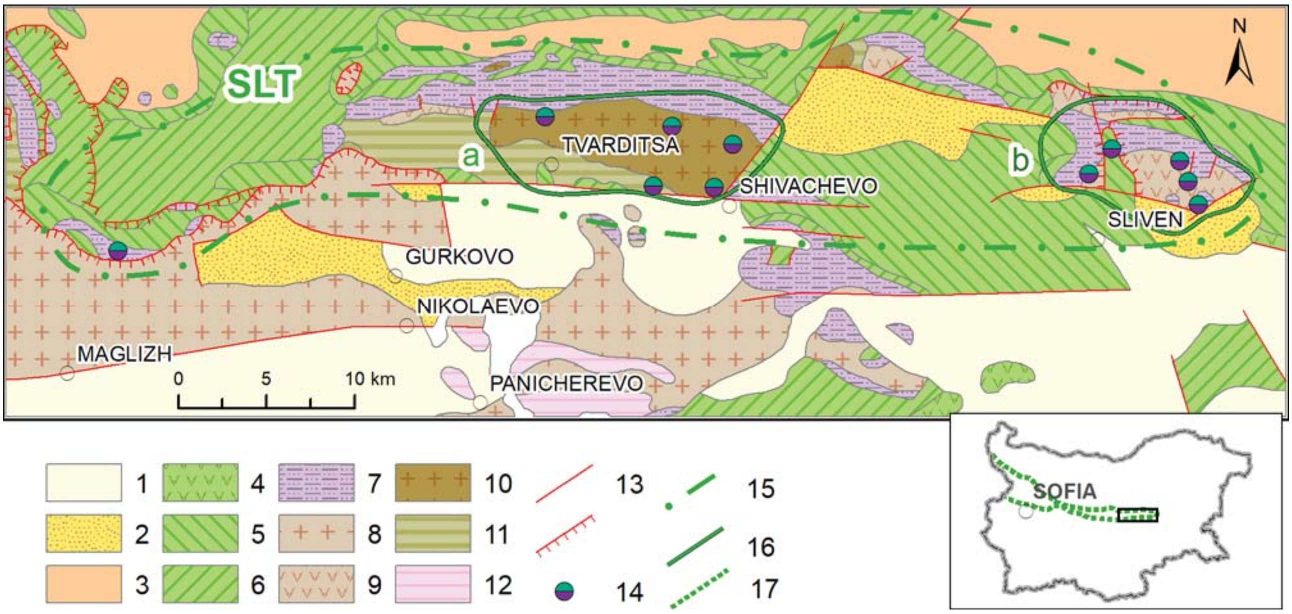

Fig. 1. Geological map of the Sliven-Tvarditsa Ore Region.
1 – Quaternary sediments; 2 – Upper Eocene – Pliocene sediments; 3 – Paleocene – Lutetian sediments; 4 – Upper Cretaceous volcanic rocks; 5 – Coniacian – Maastrichtian sediments; 6 – Cenomanian – Turonian sediments; 7 – Triassic sediments; 8 – Srednogorie Upper Paleozoic granitoid; 9 – Upper Paleozoic volcanic rocks; 10 – Stara Planina granitoid (Devonian – Lower Carboniferous); 11 – Neoproterozoic – Cambrian metamorphic rocks; 12 – Neoproterozoic metamorphites; 13 – fault and overthrust; 14 – uranium-polymetallic deposit; 15 – Sliven-Tvarditsa Ore Region (SLT); 16 – Ore Fields (a - Shivachevo, b - Sliven); 17 – West Balkan Zone (on the overview map).

Geology

The Sliven-Tvarditsa Ore Region covers the southern slopes of the Central Stara Planina Mountain, including parts of Tryavna, Elena-Tvarditsa and Sliven Mountains. It is traced north of the towns of Maglizh, Gurkovo, Tvarditsa, Shivachevo and Sliven, to the village of Sotirya (Fig. 1). Pre-Alpine basement is outcropped in the region, and represented by Neoproterozoic and Cambrian metamorphic rocks, Middle and Late Paleozoic granitoids and Late Paleozoic volcanites. Triassic terrigenous and carbonate sediments are observed at the Alpine section base. They are differently preserved in the separate areas due to the erosion. The Jurassic and Lower Cretaceous sediments are completely eroded. The Upper Cretaceous sediments are represented by terrigenous, coal-bearing, limestone, flysch and other sequences from the Cenomanian to the Maastrichtian. Late Cenomanian to Campanian of age volcanic rocks are also included within the limestone and flysch formations. Hiatuses between the Cenomanian and Turonian as well as between the Turonian and Coniacian sediments are observed at some places. Paleocene – Lutetian sediments are traced north of the area. Upper Eocene – Quaternary terrigenous and terrigenous-carbonate sediments are developed in the southern margins of the region (Zagorchev et al. (ed.), 2009).

The limited presence of Triassic and the complete lack of Jurassic and Lower Cretaceous rocks hinder the determining of the character of the Early Cimmerian and Austrian tectonic structures. The later deformations allow to differentiate from west to wast the Shipka anticline, the Borushtitsa structure, the Tvarditsa anticline, the Kachulka structure and the Predela anticline with Sliven overthrust, which are allochthonous in position (Bonchev, 1986, Kanchev, 1995, Kanchev et al., 1995, Popov 1971, Valchanov, 1974, Popov et al., 1980, Paskalev, 1983). The setting of the region is complicated due to the imposition of different in character and age deformations. The Sub-Hercynian deformations are quite distinct, as they are marked by standing and overturned Cenomanian – Turonian beds, overlaid by Early Senonian carbonate sediments in the town of Tvarditsa area (Kanchev, 1962). This is confirmed by the transgressive position of the Early Senonian sediments over different older rocks in the town of Sliven area (Popov et al., 1980). The Laramian structures manifestations are not clarified. Popov et al.. (1980) assume that the Sliven overthrust is Laramian, while Paskalev (1983) and Tzankov et al. (1991) define it as Illyrian. The presence of numerous olistoliths within the Upper Cretaceous sediments should be noted (Ivanov, Moskovski, 1974, Nachev, 1977, Paskalev 1989). The presence of the Illyrian structures is demonstrated by the Luda Kamchiya synclinorium, compounded by Senonian – Lutetian sediments. It is overthrust from the south on the rocks from the Sub-Hercynian structures. The Stara Planina overthrust is observed along the southern margins of the region. It is compounded mainly by Neoproterozoic, Paleozoic and Triassic rocks, which partially overlay the above-mentioned rocks (Kanchev, 1962, 1995; Kanchev et al., 1995; Tsankov et al., 1995a). The post-collisional processes form the Stara Planina horst system and the Back Balkan graben system (Gurkovo-Tvarditsa, Belenski, Sotirya and other grabens), filled with Upper Eocene – Quaternary sediments (Kanchev, 1995, Kanchev et al., 1995; Tsankov et al., 1995a,b).

Metallogeny

The metallogenic processes in the Sliven-Tvarditsa Ore Region are marked by the forming of uranium-polymetallic Sinite Kamani and Sborishte deposits and numerous ore occurrences. These ore mineralizations are localized within the Pre-Alpine basement rocks or in the Triassic and partially Upper Cretaceous sediments. The spatial and structural position of the ores outlines the Sliven and Shivachevo ore fields as well as the separate Yavorovets ore occurrence.

Sliven Ore Field

The Sliven Ore Field is located north f the town of Sliven, in the Sliven part of Stara Planina Mountain. The oldest outcropped rocks are Permian volcanites, represented by quartz-porphyry, quartz-porphyry lava breccia, granophyre and granite porphyry (Popov, Tsanova, 1967). They are transgressive, overlaid by Lower Triassic sandstone, siltstone, rarely conglomerate, with thickness from 0 to 30 m. Upwards Middle – Upper Triassic limestone, dolomitic limestone, dolomite and rarely calcareous argillite cover them or the Permian volcanites. Cenomanian coal-bearing sediments, sandstone, marl and Turonian terrigenous flysch are transgressive, deposited with hiatus, as they are outcropped at the western margins of the ore field. Insufficiently studied Senonian (Upper Turonian – Senonian) limestone, clayey limestone and flysch, with volcanic lava and tuff at some places, and with transition to Paleocene-Lutetian flysch to the North (Zagorchev et al. (ed.), 2009), are deposited with new hiatus. The trachiandesite and quartz latite lava and pyroclastic rocks manifestations in the southeastern part of the ore field should be mentioned as well (Pashov et al., 1966f). Upper Eocene molasse sediments are deposited in the southern border of the region (Fig. 2).

The Triassic and Upper Cretaceous sediments set up the Predela (southern) and the Karakyutyuk (northern) anticlines, with cores of Permian volcanic rocks (Popov, 1971). These antiform structures are allochthonous in position, as they are included in the Sliven overthrust (Popov, 1971; Valchanov, 1974; Popov et al.., 1980; Paskalev, 1983). The last one represents the eastern part of Sliven-Shipka overthrust, described by Kockel (1927) (Fig. 2). Field and drill data show that the allochthone, set up by the Predela's anticline overturned northern bed, lie over Campanian – Maastrichtian sediments. Its interrelations with the Paleocene – Lutetian sediments from the upper section levels outcropped to the North have not been determined till now. Accordingly, the overthrust is described as Laramian by Popov et al. (1980), and as Illyrian by Paskalev (1983) and Kanchev (1995). It should be noted that the sediments below the overthrust are assigned by Kanchev (1995) to the Paleocene, and during the later revisions by Sinyovski (Zagorchev et al. (ed.), 2009) these rocks are referred to the Campanian – Maastrichtian.

Intensive faulting is observed in the studied region (Popov, 1970; 1971). Sub-Hercynian normal faulting along the sub latitudinal Daula fault in the ore field's northwestern part and slip faulting along diagonal ruptures are determined. The later deformations are significantly more intensive, while allochthonous Predela and Karakyutyuk anticlines are cut by sub latitudinal (90-100°), NE (40° – Sotira, Tepavitsa, etc.) and NNW (160° – Ablanovo, Rogovets, Golyama Chatalka, etc.) faults and the so called Ablanovo graben is formed. As a result of the tectonic deformations 0.5-10 m thick breccia is formed along the contact between the Paleozoic core and the Triassic or Upper Cretaceous sediments.

The Sinite Kamani deposit and Tyulbeto-West, Tyulbeto-East, Zmeyovi Dupki, Golyama Chatalka, Karakyutyuk and Ablanovo ore occurrences are found within the Sliven Ore Field (Fig. 2).

The Sinite Kamani deposit is located about 3 km northwestern from the town of Sliven. Permian volcanic rocks covered by Lower Triassic terrigenous, Middle Triassic carbonate and Senonian clayey carbonate rocks are observed here. The Lower Triassic rocks are often missing in the section, as the Upper Cretaceous sediments overlay directly the Permian volcanites in some places. The Mesozoic rocks are part of the Predela anticline's southern bed. Series of sub latitudinal, NE and NNW faults are differentiated. Pre-Senonian movements are accomplished along some faults, which is documented by the different thickness in the separate blocks of the Triassic rocks, covered by the Senonian sediments (Fig. 2). The breccia between the Permian volcanic rocks and the covering different Mesozoic rocks is well developed. The Sliven overthrust possesses ore conductive role, as it is probably connected with the latitudinal fault zone delimiting the Srednogorie and Balkan regions. The diagonal faults have ore distributing role, as they connect the overthrust zone with the ore controlling and hosting zone of the breccia between the rock formations (Pashov et al., 1966f). The low permeable Senonian clayey carbonate rocks and the slightly cracked Triassic carbonates are sealed both in structural and in geochemical aspect.

Complex uranium-lead-zinc-copper ores are found in the Sinite Kamani deposit. The uranium content in the ore reaches 3.5%, the lead is up to 6.28%, the zinc is up to 3.7% and the copper is up to 0.86% in some nests. Only the uranium was mined. The ore mineralization set up mainly bed-like ore bodies with highly meandering contours in plane. They are formed predominantly in the brecciated zone between the rock formations, formed along the contact between quartz porphyry and the Triassic carbonate rocks, and dipping 20-30° to the

South. Five main ore bodies are determined in the deposit. The ore body № 1 is more than 400 m in length and has thickness from 0.17 to 2.2 m. The ore bodies № 2, 3 and 4 are analogous in character but much smaller in size. The ore mineralization metasomatically replaces the brecciated dolomitic limestone or cements the tectonic breccia. In the areas, were the Lower Triassic sediments are preserved, the ore is developed in the permeable sandstone beds, usually below clayey layers. The ore is partly formed in the brecciated quartz porphyry, where it is mainly veinlet-disseminated in type.

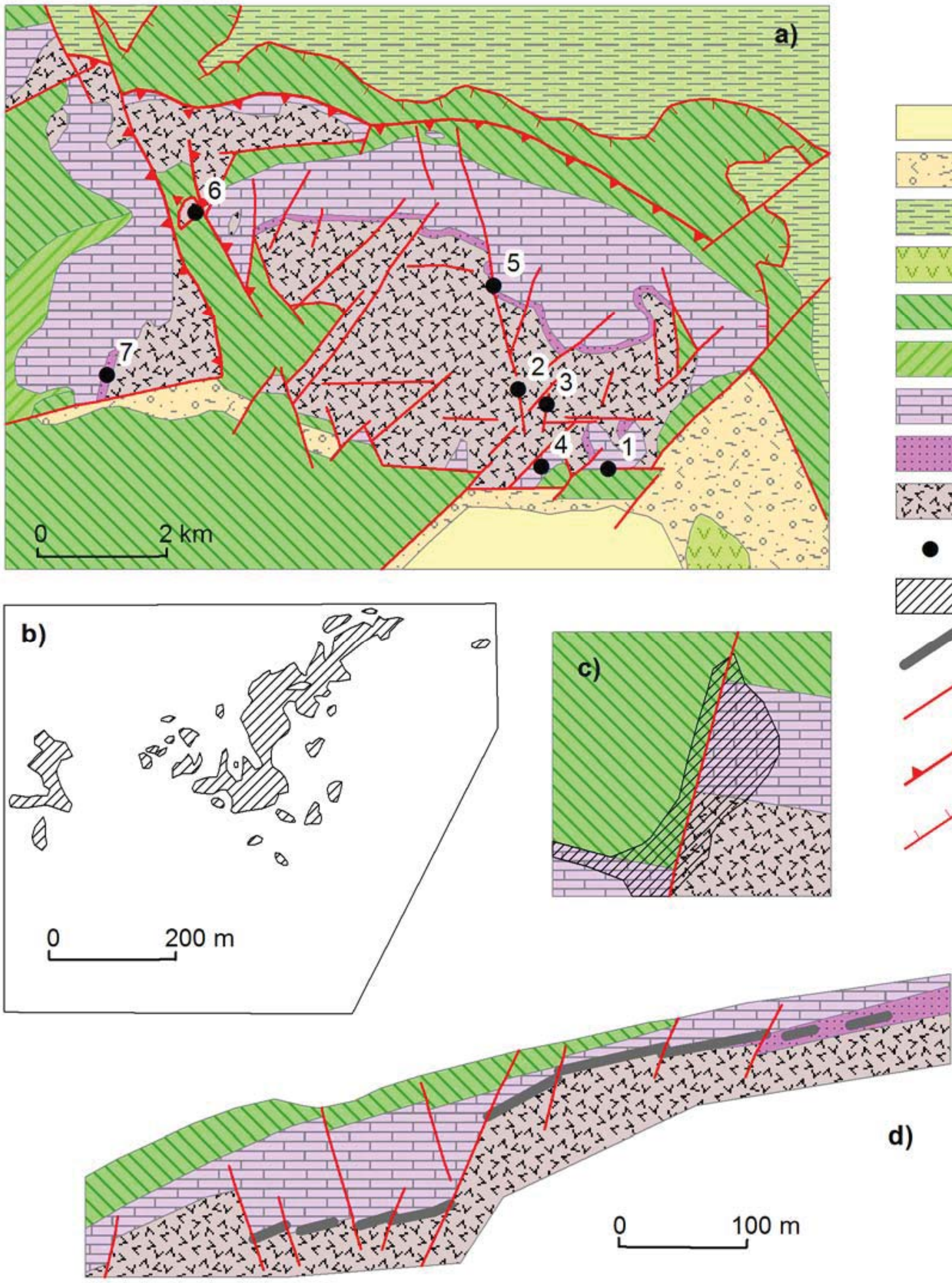

Fig. 2. Geological map of the Sliven Ore Field (a), plane of the ore bodies in Sinite Kamani deposit (b), fragment from the uranium ore body in Adit 7 area (c), geological section across Sinite Kamani deposit (d).
1 – Quaternary sediments; 2 – Upper Eocene sediments; 3 – Campanian – Maastrichtian flysch; 4 – Upper Cretaceous volcanic rocks; 5 – Coniacian – Campanian (?) clayey limestone and volcanites; 6 – Cenomanian – Turonian sediments; 7 – Middle – Upper Triassic carbonate sediments; 8 – Lower Triassic terrigenous sediments; 9 – Upper Paleozoic (Permian) volcanic rocks; 10 – ore deposits and occurrences on (a) (1 – Sinite Kamani, 2 – Tyulbeto-West, 3 – Tyulbeto-East, 4 – Zmeyovi Dupki, 5 – Golyama Chatalka, 6 – Karakyutyuk, 7 – Ablanovo); 11a – ore bodies on (b) and (c); 11b – ore bodies on section (d); 12a – fault; 12b – reverse slip fault; 12c – overthrust.

The ore bodies' position is controlled by the diagonal faults, as the ore is developed along them. Besides, in the intervals where the faults cut the contact between Triassic and Paleozoic rocks, the ore is developed within the faults as well, forming vein-like bodies (ore shear zone). Usually these vein-like bodies are component of the bed-like ones, as they form kind of root-like apophyses in the volcanic rocks, down to 30-40 m below them, and much less in the overlaying Mesozoic sediments. Thus, the ore bodies are complicated step-like in structure, sometime additionally complicated by the after ore forming faulting. It should be noted that in the places, where the Upper Cretaceous clayey carbonate rocks directly overlay the Permian volcanites, the ore is developed in the breccia between them and insignificantly in the clayey limestone near the feeding diagonal faults, which is observed in the mining works (Pashov et al., 1966f). The ore bodies are nest-like or irregular in shape. Ore mineralization in the Upper Cretaceous rocks is also found in some drills (Pashov, 1965f). No doubt, these facts confirm the Upper Cretaceous age of the deposit.

The position of the small ore body № 5 from the eastern deposit's part is different as it is concordant to the planar parallelism in the Permian volcanic rocks.

The ore forming process starts with the pneumatolytic deposition of magnetite with less specularite, martite and the non-ore quartz and little tourmaline. The hydrothermal mineral forming is most important, as the main minerals are represented by nasturan (pitchblende), galena, sphalerite and chalcopyrite and the subordinate pyrite, arsenopyrite, chalcocite, tennantite, tetrahedrite and bornite. The gangue minerals are quartz mainly and less dolomite, calcite and barite. Bornite, chalcocite, hydro nasturan (hydro pitchblende), uranium soot, chalcanthite, renardite, anglesite, uranospinite, torbernite, cerussite, malachite, azurite, autunite, uranophane, hematite and limonite are formed during the hypergenous stage (Пашов, 1965ф). The hydrothermal rock alterations are expressed by sericitization, advanced argillization, pyritization, kaolinization and carbonization (Pashov et al., 1966f).

The Zmeyovi Dupki, *Ablanovo and Karakyutyuk ore occurrences* are similar to the Sinite Kamani deposit, as they are developed near the contact between the Mesozoic sediments and the Permian volcanic rocks. At the same time *the Tyulbeto-West, Tyulbeto-East and Golyama Chatalka ore occurrences*, located northwestern from the Sinite Kamani deposit (Fig. 2), are formed in fault structures in the Permian volcanites and are ore-bearing fault (shear zone) of type (Pashov et al., 1966f).

Shivachevo Ore Field

The Shivachevo Ore Field covers part of the southern slopes of the Elena-Tvarditsa Stara Planina Mountain, in the towns of Tvarditsa and Shivachevo area (Fig. 3). The Pre Alpine basement is compounded by Neoproterozoic – Cambrian metamorphic rocks and Devonian – Lower Carboniferous granitoid. The metamorphic rocks are described as "Shivachevo Complex" (Ivanov et al., 1974; Statelova, Machev, 2005) compounded by schist, granitic gneiss, etc. The granitoid rocks set up the Tvarditsa pluton (Ivanov et al., 1974). Lower Triassic sandstone, conglomerate, siltstone and argillite cover the granitoid and are overlaid by Lower – Upper Triassic carbonate sediments, as the dolomite predominates. The Upper Cretaceous formations lie transgressive upward in the section (Kanchev et al., 1995; Kanchev, 1995). Turonian and Lower Senonian flysch and flysch-like formations are observed at the ore field's southern and eastern margins, as they are overhtrust in certain degree over the basement rocks. Allochthonous fragments of Late Paleozoic granite, metamorphites and Triassic rocks are found at the southern margin. Neogene and Quaternary sediments are also deposited to the South.

The Triassic and Cenomanian – Turonian sediments from the region set up the Tvarditsa anticline's northern bed. These rocks are with overturned bedding and are in allochthonous position in certain degree, which is marked by the Sub-Hercynian deformations. The Senonian – Lutetian beds of the Luda Kamchia synclinorium overlay them to the North (Kanchev et al., 1995; Kanchev, 1995). The southern bed is almost eroded. To the East, the Tvarditsa structure is limited by the Tvarditsa lineament sheaf (Bonchev, 1986). Faults with 100-120° direction and slant dip to the south, as well as steep faults with sub meridional, NE or NW direction are observed in the Paleozoic granitoid.

The metallogenic aspect of the Shivachevo ore field is defined by the development of Sborishte uranium-polymetallic deposit and several ore occurrences as Osenov Rat, Chakaloto, Krivata Cheshma, Kichesta, Domuz Dere, Kashla Dere and Sap Dere (Fig. 3).

The Sborishte deposit is located about 2 km NNE from the Sborishte village. Here the area is set up by the Devonian – Lower Carboniferous granitoid intruded in the Riphean – Cambrian metamorphic rocks. Partially preserved Turonian flysch and Campanian – Maastrichtian marl-limestone sediments are observed along the southern boundary. All these rocks are covered by Quaternary and Tertiary sediments to the south. Series of close, meridional, steep faults is developed in the deposit's area. They represent zones of intensive cracking, brecciating and cataclasis, which cut the high grade metamorphic rocks and the Tvarditsa pluton.

The ore mineralization is located in the sub meridional faults. The ore bodies are ore-bearing fault (shear zone) of type. Lens-like or nest economic ore bodies are traced within the ore hosting faults. The uranium-polymetallic ore is determined down to 150-200 m in depth. Small ore bodies are rarely found in equatorially oriented faults as well. The ore hosting rocks are consecutively altered by potassium and sodium metasomatism, sericitization, chloritization and hematitization. The ore mineralization is represented mainly by nasturan (pitchblende) and chalcopyrite and less pyrite, marcasite, sphalerite, galena, antimonite, tennantite, rammelsbergite, and the non-ore minerals are quartz and less calcite and dolomite. The secondary mineralization is well developed and represented by uranium soot, autunite, torbernite, etc. (Stoyanov et al., 1989f).

The ore occurrences in the ore field are similar in geological and mineralogical features to the Sborishte deposit. Ore bodies localized in sub meridional faults predominate (Osenov Rat, Chakaloto, Kichesta, Kashla Dere, Sap Dere mineralizations). Besides, northwestern (Krivata Cheshma, Domuz Dere mineralizations) and northeastern (Kichesta and Domuz Dere occurrences) ore hosting faults are also observed. The ores are developed mainly within the granitoid rocks, but the Kashla Dere ore occurrence is in the metamorphites, while in the northern parts of Krivata Cheshma occurrence the ore mineralization affects the Triassic rocks as well.

Yavorovets ore occurrence

The Yavorovets ore occurrence is located about 2.5 km NE from the Yavorovets railway station, the town of Kazanlak area, at the eastern margin of Shipka anticline. Neoproterozoic and Paleozoic rocks, Lower Triassic terrigenous and Middle Triassic carbonate sediments and sequence of Upper Cretaceous formations are outcropped in this area. The Mesozoic beds are overturned, as a sheaf of North-vergent overthrustings are observed. Ivanov, Moskovski (1974) noted Triassic olistoliths included in the Upper Cretaceous sediments. The Upper Paleozoic Srednogorie granite and the Neoproterozoic metamorphites from the Stara Planina overthrust lie at the top (Kanchev et al., 1995).

Yavorovets ore occurrence is characterized by the uranium-polymetallic mineralization, developed within olistoliths from Triassic rocks. Geological explorations outlined numerous small ore bodies, which are located in several sites: Mostov Dol, Vrabnitsa, Stoykov Most, Yavorovo Dere and Ralevska Reka. These ore bodies are formed near the Lower Triassic sandstone contact with the Middle Triassic carbonate rocks. The ore mineralization is developed most often in the highly cracked limestone and dolomite, rarely in the sandstone. Ore bodies in hard, coarse grained sandstone are also found. Secondary mineralization is rarely observed, along the sandstone bedding surfaces. The ore hosting rocks are sericitized, silificated, and less chloritized, kaolinized and dolomitized. Uranium, lead, zinc and copper are the main ore elements. The determined maximum contents are 0.557% uranium, 3.8% lead, 1.85% zinc and 2.6% copper. Silver, cobalt, nickel, etc. show increased contents. Varied association of primary and secondary ore minerals is formed (Krastev, Dzhelepov, 1974f).

It should be noted that the ore hosting Triassic rocks are included in the flysch-like formation by Kanchev et al. (1995). The same formation is nominated by Sinyovski as "limestone formation" with Coniacian – Campanian age (Zagorchev et al., (ed.), 2009).

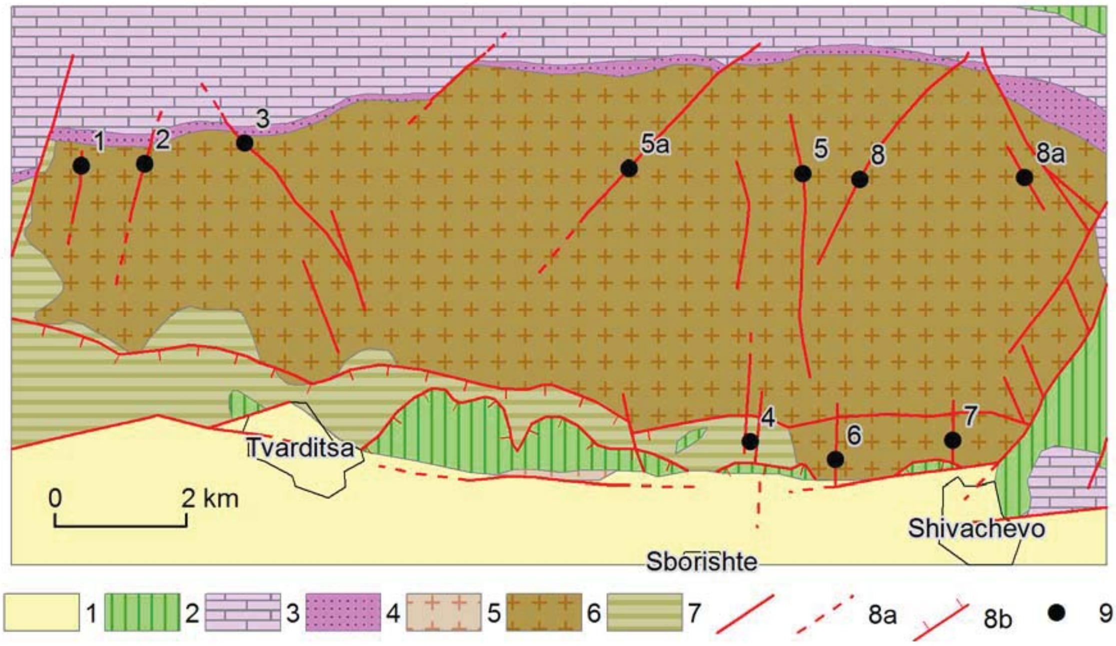

Fig. 3. Geological map of the Shivachevo Ore Field (based on data by Kanchev et al., 1995; Kanchev, 1995; Stoyanov et al., 1989f).
1 – Quaternary sediments; 2 – Upper Cretaceous sediments; 3 – Middle – Upper Triassic carbonate rocks; 4 – Lower Triassic terrigenous sediments; 5 – Upper Paleozoic (Srednogorie) granite; 6 – Devonian – Carboniferous Stara Planina granitoid (Tvarditsa pluton); 7 – Neoproterozoic – Cambrian metamorphic rocks; 8a – fault; 8b – overthrust and upthrust; 9 – uranium deposits and occurrences (1 – Osenov Rat, 2 – Chakaloto, 3 – Krivata Cheshma, 4 – Sborishte, 5 – Kichesta, 6 – Kashla Dere, 7 – Sap Dere, 8 – Domuz Dere).

Conclusions

The Sliven-Tvarditsa Ore Region covers the eastern part from the West Balkan Metallogenic Zone. The region is marked by the development of uranium-polymetallic ores, which are determined in the Sliven and Shivachevo Ore Fields and the Yavorovets ore occurrence. The ore mineralizations are localized in the Triassic and partially in the Upper Cretaceous sediments, as well as in the Pre-Alpine basement rocks such as Permian volcanites, Devonian – Lower Carboniferous granitoids and Neoproterozoic – Cambrian metamorphites.

The ore bodies are formed in the breccia between Mesozoic sediments and Paleozoic basement rocks, as well as in the brecciated Lower Triassic siltstone and argillite or Middle Triassic or Senonian carbonate rocks. Besides, "ore breccia" type ore bodies are found in the NW, sub meridional or NE faults in the basement. Ores in olistoliths from Triassic rocks are also noted.

The ore mineralization is of hydrothermal type. The main ore minerals are pitchblende, galena, sphalerite and chalcopyrite, and the non-ore are quartz and less dolomite, calcite and barite. Pyrite, arsenopyrite, chalcocite, hydro pitchblende, chalcanthite, renardite, anglesite, uranospinite, torbernite, cerussite, malachite, azurite, autunite, uranophane, hematite and limonite are more rarely observed. The hydrothermal alterations are sericitization, advanced argillization, pyritization, kaolinization and carbonization.

The presented data show that the ore mineralizations are of hydrothermal type, medium to low temperature, as they are not related to concrete magmatic activities. The ore manifestations within the Upper Cretaceous rocks, as well as the development of Upper Cretaceous rocks in the region point that the ore forming is controlled by the Upper Cretaceous magmatism. However, concrete volcanic structures are known at 10-15 km south of the region. This indicates that the examined ore deposits are formed in the frame of the noted non-volcanic island chain, adjacent to the Srednogorie Zone from the Apuseni-Banat-Timok-Srednogorie Magmatic and Metallogenic Belt.

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