LITHOSTRATIGRAPHY OF THE LATE CRETACEOUS ROCKS IN THE PANAGYURISHE ORE REGION

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ABSTRACT. The Late Cretaceous magmatism controls the evolution of the metallogenic processes in the Panagyurishte ore region. The Upper Cretaceous sedimentary and volcanic rocks transgressively overlay the basement of different older rocks. Turonian terrigenous complex, Panagyurishte volcano-sedimentary Group and Popintsi sedimentary Group are distinguished in the Upper Cretaceous section. The coal-bearing and sandstone suites are determined in the Turonian terrigenous complex. The Panagyurishte volcano-sedimentary Group is divided on Chelopech, Vozdol, Petelovo, Vrankamik, Assarel, Ovchepoltsi, Elshitsa and Pesovets Formations. The Popintsi sedimentary Group is compound by the known Mirkovo and Chugovitsa Formations. The paleontological data about the age of the quoted lithostratigraphic units are shown, as well as the data for their absolute age.

Introduction

The Panagyurishte ore region is part of the Apuseni-Banat-Timok-Srednogorie magmatic and metallogenic belt (Popov et al., 2002). It is located 55-95 km eastern from the city of Sofia. It covers an area of about 1500 km² that includes part of the Central Srednogorie and Stara Planina (Balkan) Mountains, between the towns of Pazardzhik and Etropole. The position of region is determined by the area of intensive Late Cretaceous magmatic activity and associated ore deposits (Popov and Popov, 1997, 2000). The porphyry copper and epithermal massive-sulphide ore deposit predominate. Small gold, gold-base-metal, barite, lead-zinc and manganese deposits and are found as well.

The main features in the geological structure of the Panagyurishte ore region, which control the metallogenic processes in space and time, are determined by the character of the complex of Upper Cretaceous magmatic and sedimentary rocks and the associated tectonic structures (fig. 1). That is why the subject of this paper is the lithostratigraphy of the Late Cretaceous effusive rocks. It is the necessary base for the delimitation of the individual magmatic complexes with a view to their metallogenic significance.

The Upper Cretaceous sedimentary and effusive rocks overlay transgressively the basement of different Precambrian high metamorphic rocks and Late Paleozoic South Bulgarian (Srednogorie) plutons mainly (Fig. 1), and in the northern areas – of Middle Paleozoic Stara Planina granodiorite-granite complex. The Stephanian-Permian and Triassic sediments are preserved in small areas.

The earlier geological investigation in the middle and second half of the 19th century do not give a clear data of the Upper Cretaceous rocks in the Panagyurishte region. First of all Zlatarski (1893) mentioned the presence of the Upper Cretaceous sedimentary rocks in this territory. This author determined the Campanian age of these rocks and he delimit marl-limestone and flysch facieses (Zlatarski, 1910). Besides, Bonchev (1909) confirm the Cretaceous age of the young volcanic rocks. Later Pushkarov (1927) differentiated the littoral sedimentary rocks in the base of the Upper Cretaceous section, which he assign to the so called Gossau facies of the Upper Senonian, and Kamenov (1936) (by lithological analogy) supposed that they are Turonian. The Turonian age of these rocks is defined on the base of paleontological data by Dimitrov (1936) for the area west of Mirkovo village, and by Nikolaev (1947) for the area around Chelopech village.
More detail investigations in the western part of the region are carried out by Landzev (1940), Mandev (1940), Boyadziev (1940), and Bonchev (1940), which traced out the spatial development of the Upper Cretaceous rocks and their stratigraphic differentiation. Two lithological units (they call them “horizons”) are usually distinguished in the Turonian section by these authors. They subdivided the Senonian section into three horizons: first - andesitic tuff, andesite, marls, and clayey limestone; second – red marls, and clayey limestone; third – alternating sandy marl and sandy-carbonate argillite, rare andesitic tuff (Fig. 2). This stratigraphic model was adopted in the later studies of Nikolaev (1947) in the area around the village of Chelopech, as well as by Dimitrov and Kostov (1954), Hristov (1957, 1960) and Boyadzhiev (1965) in the area southern from the town of Panagyurishte. This model is the basis for the later elaborations of Vrublyanski et al.

Fig. 1. Geological map of the Panagyurishte ore region

Fig. 2. Stratigraphic model of the Panagyurishte ore region.
(1961), Karagyuleva et al. (1974), Moev and Antonov (1978), Dimitrova et al. (1984). Vrublyanski et al. (1961) separated the first horizon into two horizons: first – grey marl and an andesite; second – andesite and tuff-marl complex, and suggest that the age of the whole section is Maastrichtian. Karagyuleva et al. (1974) divided the first horizon into two suites: sedimentary-volcanic and tuffitic. More different stratigraphic model of the Senonian rocks suggests Dimitrova et al. (1984). These authors described the following suites in the Senonian section: limestone-marl, tephroide, tuff, flysch, and conglomerate (Fig. 2). The first three suites interfinger laterally and the last (conglomerate) according others authors belongs to the Paleogene. Chipchakova (1970) suggested a model of rhythmic development of the magmatic activity, which is interrupted by sedimentation periods. As a number of authors mentioned (Bogdanov et al., 1974; Karagyuleva et al., 1974; Dimitrov, 1983), this model is based on the incorrect interpretation of the stratigraphic position of the known sedimentary units and it is not confirmed by their real relationship in the field.

On the basis of the data from mentioned publications, as well as by the result of author’s study on the composition, spreading and relationships of the Upper Cretaceous sedimentary and effusive rocks, here is suggested to differentiate the column on three clearly remarkable lithostratigraphic groups, which was suggested by K. Popov (2001) (Fig. 1-3). The Turonian terrigenous complex builds the lower part of the section. The Lower Senonian Panagyurishte volcano-sedimentary Group covers it transgressively. Numerous subvolcanic and hypabyssal intrusions and dikes are associated with the second group. The Upper Senonian Popintsi Group is developed the uppermost part of the section, where flysch-type rocks predominate. The features of the composition and structure of the individual groups mark the changes of the character and conditions of the sedimentary and volcanic processes.

### Turonian terrigenous complex

The Turonian terrigenous complex builds the lower part of the Upper Cretaceous profile. It marks the beginning of the Late Cretaceous sedimentation cycle in the region after the Austrian tectonic processes. It contains two suites: coal-bearing and sandstone.

#### Coal-bearing suite

The Coal-bearing suite was named by Moev and Antonov (1978). Earlier it was designated by Vrublyanski et al. (1961) as “littoral-clastite unit” and by Karagyuleva et al. (1974) – as “molassa suite”. It is not developed everywhere in the base of the Turonian section.

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### Fig. 2. Comparative scheme of the Upper Cretaceous stratigraphic division in the Panagyurishte region by different authors

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<td>Third horizon</td>
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<td>Sedimentary - volcanogenic suite</td>
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<td>Turonian</td>
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<td>Sandstone suite</td>
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<td>Elshitsa suite</td>
<td>Svoboda-Osvihulm and Assarel suites</td>
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<td>Mirkovo Formation</td>
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Fig. 3. Lithostratigraphic column of the Panagyurishte Ore Region
The Coal-bearing suite overlies the Pre-Cambrian, Early Paleozoic and Triassic rocks transgressively and discordantly. It contains polygenic breccia-conglomerate and conglomerate disposed mainly in the base of the section and predominantly polymictic sandstone. Aureolite, argillite, sandy-coal-bearing schist and thin coal intercalation are rare. Most of the authors mentioned the presence of vegetable fossils pieces. Evidently, these sediments are formed in continental-littoral environment (Vrublyanski et al., 1961). Its thickness varies from 0 to 100-200 m in different areas of the region.

By drill data, in small place in the Vozdol area (northern from Chelopetch village), an olistostrome packet with thickness of 300 to 350 m was formed in the base of the section (Popov et al., 1983). This packet consists of olistoliths of Pre-Cambrian metamorphite mainly, which are included in matrix of conglomerate, gritstone and hetero-granular sandstone. Usually the olistoliths have a size of several meters, but blocks up to 120 m in diameter are found too. The development of the olistostrome packet is limited to the north by Mechita fault. Besides, the sandstones of the higher level of the Turonian section are developed in the both sides of this fault without displacement. These interrelations mark the sin-sedimentary dislocation along the fault with uplifting of the northern block.

Sandstone suite

The Sandstone suite is named by Karagyuleva et al. (1974), which is adopted by the other authors (Moev and Antonov, 1978; Cheshitev et al., 1995; Katskov and Iliev, 1993). It gradationally overlay the Coal-bearing suite, as it lies transgressively above older rocks in some areas (Karagyuleva et al. 1974; Moev and Antonov, 1978; Dimitrova et al., 1984; Katskov and Iliev, 1993). It consists of submarine polymictic arkose or mica sandstone, aureolite, and less of argillic sandstone, sandy limestone, marl, and calcareous-sandy argillite. Its preserved thickness varies from 20-50 m up to 300 m in different areas.

The age of both coal-bearing and sandstone suites is determined as Turonian by paleontological data. Vrublyanski et al. (1961) provide most detailed descriptions of the fauna, mainly from the Sandstone suite. These authors designated the whole suite to the Upper Turonian without sufficient reasons. Karagyuleva et al. (1974) and Moev and Antonov (1978) suggest that the lower suite is lower Turonian and Dimitrova et al. (1984) suggest that it is Cenomanian. The fossils found by these authors (in both suites) include Exogyra columba var. major Jourd.; Mammites reverlieranus Jord.; Natica (Ampulina) bulbiformis Sow.; Natica subchercinica Freuch.; Pecten decemcostatum Munster.; Cuculea chimensis Gumbel; Inoceramus labiatus Schloth.; Inoceramus cf. andinus Wichel., etc., which without doubt fix the age as Turonian. The delimitation of the Lower and Upper Turonian and the assignment of the Coal-bearing suite to the Cenomanian are not reasonable for the time being.

Panagyurishte volcano-sedimentary group

The Panagyurishte volcano-sedimentary Group is distinguished by K. Popov (2001). It is named to Panagyurishte – a town located in the center of the area of its spreading. The definitive features of this group are the wide spreading of the volcanic and associated volcano-sedimentary and sedimentary rocks. The group is compound by Chelopetch Formation of Moev and Antonov (1978) and several effusive formations, which are discussed below. This group is stratigraphic analog of the first Senonian horizon by Landzev (1940), Mandev (1940), Bojadziev (1940), Boncev (1940), Nikolaev (1947), Dimitrov and Kostov (1954), Hristov (1957, 1960) and Boyadzhiev (1965), or the first and second Maastrichtian horizon by Vrublyanski et al. (1961), or sedimentary-volcanogenic and tuffite suite by Karagyuleva et al. (1974), or the Chelopetch Formation by Moev and Antonov (1978) (fig. 2). The Panagyurishte group transgressively overlies various Turonian levels or even older rocks in some areas (Vrublyanski et al., 1961; Karagyuleva et al., 1974; Moev and Antonov, 1978). Moreover, the Senonian effusive rocks cover Pre-Cambrian metamorphic rocks in the southern part of the region (Boyadzhiev and Chipchakova, 1963; Bogdanov et al., 1970). At the same time, the post-volcanic rocks of the Popintsi Group transgressively overlie the Panagyurishte Group.

The aspiration of the authors to make a general stratigraphy of the volcanicogenic rocks, which is valid of the whole territory of the region, is common disadvantage of the stratigraphic schemes mentioned above. These schemes do not recognize the differences in the composition and spreading of the volcanic rocks, which are formed as a result of the activity of different volcanoes, and which have complicated interrelations between each other and with the sedimentary rocks of the same age. Besides, some of the authors presume that the volcanic activity took place during the whole Senonian, which is based on the presence of the tuffite rocks in the so called third horizon. Dimitrov and Kostov (1954) and Karagyuleva et al. (1974) emphasize that these rocks was formed as a result of re-sedimentation of the volcanogenic material, which is confirmed by author's observations also. The investigations after 1980 in the separate parts of the region demonstrate the petrological differences of the rocks, which are result of the individual evolution of the particular volcano-intrusive complexes (Popov, 1989; Ignatovski and Bayraktarov, 1996; Popov and Popov, 1997, 2000: K. Popov, 2001). These circumstances determine the very complicated structure of the Panagyurishte volcano-sedimentary Group in vertical and horizontal direction. The sedimentary and volcano-sedimentary rocks predominate in the section from the westernmost part of the region (western from Oborishte village and in the area of Mirkovo village) where the effusive rocks are rare. Similar section is observed to the east, in the area of Dyulevo and Smilets villages, as well as southern of Orchepoltsi village, where the volcanic-sedimentary rocks and pelite-psamitic tuff predominate. Beside, this complex comprises of effusive rocks predominantly eastern of Oborishte village, southern from Panagyurishte town, in the areas of Buta, Popintsi, Svoboda, and Elshtitsa villages and Obchite Hulmove hills, as well as northern form Chelopetch village. This variability of composition is a result of continued and in different time effusive activity of numerous volcanoes, accompanied by sedimentary and re-sedimentary processes (Popov and Popov, 1997, 2000). It is very difficult to make a detailed and reliable correlation between the sections in the separate areas because of the different block displacement and the affiliation of the rocks to individual volcanoes. The development of lava sheets and agglomerate and block tuff around the volcanic centers is typical in general. The so called tephroide flisch (Nachev and
Soultanov, 1991), which is composed mainly of tephroide rocks, marl, clayey limestone and rarely other rocks, prevail in horizontal and vertical direction, away from the volcanic centers. Limestone, marl, calcareous sandstone and sandy limestone are formed in the outermost areas as well as during the decreasing or absence of effusive activity.

The data from the investigation in the last ten years, as well as the publications and geological reports about the areas of Chelopech (Moev and Antonov, 1978; Popov and Moutafchiev, 1980; Popov et al., 1983, 2000a, 2001), Assarel (Popov and Petkov, 1994; Popov et al., 1996, 2000b), as well as Dimitrov (1983) and Ignatovski and Bayraktarov (1996) give the opportunity to suggest a new lithostratigraphic model of the volcano-sedimentary rocks from the Panagyurishte Group, which was published for the southern part of the region (K. Popov, 2001a). The base criteria for the lithostratigraphic subdivision are the petrographic features of the effusive rocks. The petrographic distinctions of the rocks are determined by the circumstance that they are formed as a result of activity of individual volcanoes or complex of neighboring volcanoes with identical rocks' composition. The spreading of these specific effusive rock associations can be traced very well, as it coincides to a great extent with the areas of the individual or complex volcanoes. Numerous effusive formations are delimited on the basis of these features, which are identical rocks' composition. The spreading of these specific formations possesses comparatively clear lower and upper boundaries in the areas where they are outcropped. Besides, their delimitation in horizontal direction is provisional to a great extent, because of the lateral interfingering between the rocks, which are products of different volcanoes. The effusive formations associate with co-magmatic subvolcanic, subvolcanic-hypabyssal and hypabyssal intrusives and dikes, and together they form several uniform volcano-intrusive (volcano-plutonic) complexes.

Chelopech Formation

The Chelopech Formation is developed mainly in the eastern and western periphery of the Panagyurishte ore region. It was determined by Moev and Antonov (1978) in the northern part of the region, in the Chelopech village area. Karagyuleva et al. (1974) described part of these rocks as tuffite suite southern from Panagyurishte town. Earlier authors designated it as the first Senonian horizon (Landzev, 1940; Mandev, 1940; Bojadziev 1940; Bonchev, 1940; Nikolaev, 1947) or as the first and second Maastrichtian horizon (Vrublyanski et al., 1960). The name of Chelopech Formation is adopted for the whole Panagyurishte region at present (Katskov and Iliev, 1993). It transgressively overlay Turonian or older rocks, but it overlies with gradual transition the Turonian sandstone suite in the northeastern part of the region, around the Mirkovo and Petrich villages.

The Chelopech Formation is formed in the areas away from the volcanic centers, where the combined deposition of hemipelagic and terrigenous materials, volcanic pyroclastics as well as reworked, resedimented tephra occurs. Typical tephroide flysch, described by Nachev (1978), is formed in some levels of the section, mainly in the marginal parts. The volcano-sedimentary section intercalates in lateral direction with the sections of the individual volcanoes, which form the corresponding effusive formations. The boundaries between them and the Chelopech Formation are not very clear.

The Chelopech Formation is stratigraphic equivalent of all effusive formations, as in some sections it shows variations in the composition, time, and source of constituent material. The section of the Chelopech Formation is subdivided into three packets in the area western from Chelopech village (Moev and Antonov, 1978). The first packet from the lower part of the section is presented by sandy and aleurolitic marl, rarely aleurolitic and calcareous argillite. They are intercalated to the east with tuff and tuffite, rarely with lava sheets. The second packet predominantly consists of medium to coarse grained polymictic sandstone, rarely fine-grained clayey sandstone. They intercalate with polygenic breccia, tuffite, tuff and single lava sheets. The lithoclasts in psammitic and psephitic rocks are predominantly from Pre-Cambrian metamorphite, as clasts of volcanic rocks occur as well. The quantity of the volcanic products increases to the east, oncoming to the Chelopech volcano. The third packet includes the uppermost part of the section. It almost only consists of light grey polymictic sandstone and rare layers of fine-grained clayey sandstone. In the Vozdol area it intercalates with volcaniclastic rocks from the Vozdol mono-volcano. The thickness of this packet is 30 to 40 m, as it reaches up to 230 m near Vozdol river valley. The whole thickness of the Chelopech Formation varies from 300 m in the northwestern areas to 700 m near the Chelopech volcano. It should be mention that this rock sequence is not valid for the whole territory of the Panagyurishte region, which involves the necessity for description of additional reference sections in other development areas of the Chelopech Formation.

Vozdol effusive Formation

The Vozdol effusive Formation was determined by Moev and Antonov (1978) as Vozdol member of the Chelopech Formation. The rank of this lithostratigraphic unit is changed from member to formation in this paper, because of its isolation, big size and genetic features. This is done in conformity with the accepted here lithostratigraphic model for the rest of effusive formations from the Panagyurishte volcano-sedimentary Group.

The Vozdol effusive Formation is developed in the area of Chelopech village in the northernmost part of the
Panagyurisht region. It is presented by the effusive rocks, which form the accumulative cone of the Chelopech stratovolcano (Popov and Moutafchiev, 1980), and the satellite Vozdol mono-volcano. The section of the formation is preserved from the erosion in the central and western part of the volcanic cone only. It is well outcropped along the Vozdol river valley and along the northern slope of Frunkaya peak. The deeper levels of the section are explored in depth by numerous drills. The Vozdol Formation transgressively overlies different levels of the Turonian section or outcropped areas of the earlier subvolcanic intrusives. It is covered by the uppermost levels of the Chelopech Formation represented by polymictic sandstone. The sedimentary rocks of the Mirkovo Formation lie above them, as the boundary is transgressive in the central part of the volcano. The formation is laterally interfingered with the Chelopech Formation to the west. The thickness of the Vozdol Formation is up to 1200 m (by drill data) in the central part of the volcanic cone and it gradually decreases to 700-800 m to the periphery.

The volcanic rocks are andesite, latite to dacite, and trachyandesite in composition (Stoykov et al., 2003). The section of the Vozdol Formation is formed by block, agglomerate and lapilli tuff, and rarely by lava flows and lava breccia, which emphasizes the explosive character of the volcanic activity (Popov et al., 2001). The psamitic and pelitic tuffs are very rare. These rocks are formed predominantly around the vent funnel, as their sequence is irregularly along the section. The sizes of the pyroclastic pieces gradually decrease to the west, and more often they alternate with the volcano-sedimentary rocks from the Chelopech Formation. As Moutafchiev (1967) noted, the pieces from earlier subvolcanic light green quartz-bearing amphibole-biotitic andesite to latite, rarely trachydacite (dacite-andesite by Moutafchiev) are often observed in the rocks of the Vozdol Formation.

The volcanic neck and several lava sheets and tuff beds are outcropped in the Vozdol river valley, northern from Chelopech village. They intercalate with the polymictic sandstone from the uppermost levels of the Chelopech Formation. These rocks are amphibole-biotitic andesite, andesite-basalt and latite. They are of later eruption along lateral vent funnel and set up the Vozdol subordinate volcano. The rocks of Vozdol volcano are part of the Vozdol Formation and they are an integral part of the Chelopech stratovolcano. It should be mentioned that numerous ore pieces and pieces of hydrothermally altered rocks are included within the rocks of Vozdol volcano (Moutafchiev and Chipchacova, 1969; Popov and Moutafchiev, 1980), which indicates that it is formed after the ore-forming processes.

The Vozdol Formation (and the Chelopech volcano respectively) spatially associates with numerous comagmatic subvolcanic and subvolcanic-hypabyssal small intrusive bodies and dikes. Part of them has been formed before and other – after the effusive activity, which will be discussed below.

**Petelovo effusive Formation**

The Petelovo effusive Formation is outcropped southern and southeastern from the town of Panagyurisht and it is traced to the east and southeast to the villages of Dyulevo, Smilents and Ovchepoltsi, as well as to the northwest from Banya village (fig.1). The Petelovo effusive Formation is introduced for the first time in this paper. It is named on Petelovo peak, which is located about 8 km southeastern from the town of Panagyurisht. The earlier authors assigned the rocks from the Petelovo Formation to the first Senonian horizon and Karagyuleva et al. (1974) – to the Senonian volcano-sedimentary suite. Later Ignatovski and Bayraktarov (1996) described these rocks as Krasen-Petelovo complex and K. Popov (2001) – as Krasen-Petelovo effusive suite.

The rocks from the Petelovo effusive Formation are product of several spatially close, linearly aligned volcanoes (Petelovo, Tangur, Smilents, etc.) which are laterally interfingered. The definitive features of the Petelovo Formation are determined by the development of effusive rocks, which are andesite to basalt-andesite in composition. The lava rocks are mainly grey to green-grey amphibole and amphibole-pyroxene andesite. Dark-grey to black amphibole, pyroxene-amphibole or pyroxene andesite-basalt are rare, and light-grey biotite-amphibole quartz-bearing andesite is very rare. The section of the formation is very variable. It mainly consists of lava sheets, lava-breccia and rudaceous agglomerate tuff around the volcanic centers. Furthermore, better sorted agglomerate, lapilli, rarely psamitic to pelitic tuffs are observed in the periphery of the volcanoes. Lapilli and psamitic-pelitic tuff predominate in the outermost areas, as it is southern from the Ovchepoltsi village. The thickness of the formation varies from about 2000 m in the area of the Petelovo volcano to 500 m in the most peripheral areas.

The slopes of the Petelovo and Tangur peaks, the section along the road southern from the town of Panagyurishte to the town of Pazardjik, as well as the section around the road southern from Ovchepoltsi village should be indicated as a type places for characterization of the Petelovo Formation.

The Petelovo effusive Formation set up the lower levels of the section of the Panagyurisht region in indicate area. Its approximate stratigraphic analogues are the rocks of the Vozdol Formation from the northern part of the region and the Vrankamik Formation developed western from the Oborishte village. It transgressively overlies different levels of the Turonian section as well as the basement rocks in separate areas, which is observed southern from Ovchepoltsi village, western from Blatnitsa village and northwestern from Banya village. The Petelovo Formation is covered by the rocks from Ovchepoltsi Formation near the villages of Smilents, Svboda, and Ovchepoltsi, and northwestern from Banya village, by the Pesovets Formation near the Krasen ore deposit, and by the Mirkovo Formation in the rest parts between the town of Panagyureshite and Dyulevo village.

The effusive rocks from the Petelovo Formation associate with numerous subvolcanic bodies and dikes, which are andesite to dacite in composition. Besides, the subvolcanic-hypabyssal Petelovo intrusive and several smaller intrusives and dikes are emplaced in them.

**Vrankamik effusive Formation**

The Vrankamik effusive Formation is developed western from Ovchepoltsi village. It forms the debris cone of the Vrankamik volcano, defined by Ignatovski and Bayraktarov (1996). The formation is determined here for the first time. It is named on the Vran Kamik peak, which is situated about 5 km...
north-northwestern from the Oborishte village. In the past these rocks are included in the first Senonian horizon (Landzev, 1940; Boncev, 1940), in the Senonian sedimentary-volcanic suite (Karagyuleva et al., 1974), and Ignatovski and Bayraktarov (1996) described them as Vrankamik complex.

The definitive features of the Vrankamik Formation are determined by the predominantly presence of gray to black pyroxene, pyroxene-amphibole or amphibole andesite and andesite-basalt. A lava flow of light gray dacite outcrops rarely. The lava rocks form about 20% from the section. The pyroclastic rocks prevail, and they are presented mainly by agglomerate or lapilli-agglomerate tuff. The fine-grained varieties are developed in the periphery of the volcanic cone mainly. The block tuffs are well presented near to the vent funnel. The thickness of the section is 1000 to 1200 m in the central part of the volcano and 400 to 500 m in the periphery.

The definitive features of the Assarel Formation are the slopes of the Vran Kamik peak. The formation overlies Turonian and Triassic rocks. It is gradually replaced by the volcano-sedimentary rocks of the Chelopech Formation to the west. In the same direction it is covered by the rocks of the Mirkovo Formation or by the uppermost parts of the Chelopech Formation. The upper levels of the Vrankamik Formation intercalate with the lower levels of the Assarel Formation and they are covered by the upper levels of the Assarel Formation to the north.

The type area for characterization of the formation includes the slopes of the Vran Kamik peak. The formation overlies Turonian and Triassic rocks. It is gradually replaced by the volcano-sedimentary rocks of the Chelopech Formation to the west. In the same direction it is covered by the rocks of the Mirkovo Formation or by the uppermost parts of the Chelopech Formation. The upper levels of the Vrankamik Formation intercalate with the lower levels of the Assarel Formation and they are covered by the upper levels of the Assarel Formation to the north.

Assarel effusive Formation

The Assarel effusive Formation is developed northwestern from the town of Panagyrishite and northern form Oborishte village. It is set up by the effusive rocks, formed as a result of the activity of the Assarel volcano, described by Popov and Petkov (1994). The formation is determined as official unit here at first. It is named on the Assarel River, which pass through this area. In the past it was described as the first Senonian horizon, the Senonian sedimentary-volcanic suite (Karagyuleva et al., 1974), and as Razslatitsa complex by Ignatovski and Bayraktarov (1996).

The definitive features of the Assarel Formation are determined by the presence of amphibole-biotite or amphibole andesite to latite, very rarely dacite. They are mesocratic, grey-green, grey to deep grey. The entire section is set up by irregularly alternated lava sheets and beds of block-agglomerate to lapilli, very rarely psamitic tuffs. The quantity of the lava and pyroclastic rocks is approximately equal, as the lava sheets predominate around the neck, and the pyroclastites are dominant to the west in the periphery of the volcano. The thickness of the section is more than 1200 m in the central part of the volcano.

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The type area for characterization of the Assarel Formation is the western slope of the former Razslatitsa peak, which is destroyed by the Assarel open pit, towards to Panova river valley.

The formation overlies the Turonian rocks near Petrich village to northwest and the Pre-Mesozoic basement rocks near Razslatitsa peak. However, it overlies the Petelovo Formation western from the town of Panagyrishite as well as the Vrankamik Formation northern from Oborishte village. It is most likely that in the latter areas its lower levels interfinger with the uppermost levels of the sections of the Petelovo and Vrankamik Formations respectively. The Assarel Formation laterally interfingers with Chelopech Formation to the northwest. There it is covered by the uppermost levels of the Chelopech Formation or by Mirkovo Formation.

Volcanic neck facies with numerous apophyses are developed in the area of Razslatitsa peak (now Assarel open pit). They are analogous in composition as the effusive rocks, but they are better crystallized and discordant to the bedding. Numerous subvolcanic, subvolcanic-hypabyssal (Assarel and Lisa Mogila) and hypabyssal (Medet) intrusives associate with the effusive rocks.

Ovchepoltsi effusive Formation

The Ovchepoltsi effusive Formation is developed in the southeastern part of the region, near the villages of Ovchepoltsi, Svoboda and Smiletts and southeastern from Popintsi village. The effusive rocks northwestern from Banya village are probably assigned to this formation as well (fig. 1). It is set up by the effusive accumulative cones of the Svoboda and Ovchihulm volcanoes.

The Ovchepoltsi effusive Formation is defined here at first. It is named on the village of Ovchepoltsi, Pazardjik area. Earlier it is described as Svoboda-Ovchihulm effusive suite (K. Popov, 2001), but in the older publication is included in the first Senonian horizon. The rocks from Chobanitsa and Pesipo volcanics complexes, described by Ignatovski and Bayraktarov (1996), are combined in this formation.

The definitive features of the Ovchepoltsi effusive Formation are determined by the prevalent presence of sub-alkaline rocks, represented mainly by pyroxene-amphibole latite and shoshonite, dark grey to black in color with brown nuance, as well as rarely by light grey to beige-pink amphibole-biotite to amphibole-biotite-pyroxene trachydacite. It is possible to distinguish several members within the formation with more detailed studies, according to the petrographic features of the rocks and their affiliation to individual volcano.

The areas of the Ovchite Hulmove hills and the section near the Ovchepoltsi village to the Blatnitsa village, as well as the area around the Svoboda village are assumed as the type areas for characterization of the Ovchepoltsi Formation. The unit overlies the rocks from different levels of the Petelovo Formation, which interrelations are observed southern from Ovchepoltsi village, eastern from Svoboda village and western from Banya village. The rocks from the Assarel volcano could be regarded as the most probable stratigraphic analogue to it. The formation laterally interfingers with the volcano-sedimentary rocks from the Chelopech Formation to the east, near the Smiletts village. The Ovchepoltsi Formation is covered by the rocks from the Elshitsa Formation near the village of Tsar Asen, by the Pesovets Formation near the villages of Svoboda and Popintsi, and directly by the Mirkovo Formation northwestern from Banya village.
The Ovchepoltsi effusive Formation mainly consists of agglomerate to lapilli tuff, which intercalates with lava sheets or flows. Block tuffs are observed around the vent channel, along the ridge of Ovchite Hulmove hill. Psamitic and pelitic tuffs are rarely observed. They are well represented in the eastern areas (eastern from Smilets village) where they alternate with the rocks form the Chelopech Formation. The lava sheets and flows are widespread in the area of the Ovchite Hulmove hill and around the Svoboda village, where the respective volcanic centers are located. The quantity of lava rocks gradually decrease away from the volcanic centers. The lava sheets are relatively well present western of the Buta village also, which mark probable presence of a third volcano.

Shoshonite rocks are mainly developed in the base of the section. Upwards latite rocks are mostly imposed and they are most widespread in the area. Trachydacite rocks are presented in the uppermost part of the section. They are described as dacite and rhyodacite in older publication and geological reports, and as latirhyolite by Dimitrov (1983). Trachydacite rocks outcrop between the villages of Ovchepoltsi and Blatnitsa, as well as to the west in the area northern of Tsar Asen village. The necks of the mentioned volcanoes are determined in the high parts of the Ovchite Hulmove hills and western from the Svoboda village. The thickness of the rocks in the areas of Svoboda village and western from Banya village is 1500 m at least. The thickness between the Ovchite Hulmove hills and Blatnitsa village can not be well estimated by reason of partial coverage by young sediments, but it is more than 1000 m.

Numerous subvolcanic and subvolcanic-hypabyssal small intrusions and dikes associate with the effusive rocks from the described formation. They are located near volcanic centers predominantly.

**Elshitsa effusive Formation**

The Elshitsa effusive Formation is developed in the southernmost part of the Panagyurishte region. It is composed by the effusive rocks from the Elshitsa volcano. At present they are preserved in two strips: Radka and Elshitsa. The first strip starts southern from Buta village, passes southern from Popintsi village and reaches to Tsar Asen village. The second strip is traced southern from the villages of Elshitsa and Borimechkovo (fig. 1).

The Elshitsa effusive Formation is defined as official lithostratigraphic unit here. It is named on the village of Elshitsa. Before it is described as Elshitsa effusive suite (K. Popov, 2001), as well as first Senonian horizon in the mentioned older publications. The rocks of the Elshitsa and Radka volcanic complexes by Ignatovski and Bayraktarov (1996) are combined in the formation.

The definitive features of the Elshitsa Formation are determined by the presence of grey-green amphibole-pyroxene andesite and light grey-green biotite-amphibole dacite to rhyolite, and associated pyroclastic rocks of the same composition. It consists of two members: Tsar Asen and Shiligarnika, which are introduced here as well. The Tsar Asen member set up the lower part of the section, and it is composed by andesite to andesite-basalts or quartz-andesite.

The Shiligarnika member consists of dactitic to rhyolitic rocks, and it set up the upper part of the section. They are respectively named on the Tsar Asen village and on the place of Shiligarnika, southeastern from the Elshitsa village. Up to now they are described as andesitic and dactitic packets (K. Popov, 2001) or facieses (Boyadzhiev and Chipchakova, 1963).

The high variability of the horizontal and vertical development of the effusive rocks, as well as their incomplete outcropping do not permit to characterize a type section. The places south-southeastern from Elshitsa village, near Radka mine (southern from Popintsi village) and western from Tsar Asen village can be pointed as type areas. Numerous exploration drills were carried out in these areas, which give good information.

The formation, and the Tsar Asen member respectively, overlies the Pre-Mesozoic basement rocks southern from Elshitsa village according to Boyadzhiev and Chipchakova (1963) and Bogdanov et al. (1970) (by drill data). Besides, it covers the upper levels of the Ovchepoltsi Formation near Tsar Asen village, which is confirmed by drilling (K. Popov, 2003). The rocks of Shiligarnika member (dactitic packet) are preserved southern from Popintsi village (Radka stripe) and in the northern parts of the Elshitsa stripe. The boundary between the two members is comparatively sharp, according to field observations and drill data, or there is a narrow alternation zone of andesite and dactite rocks in some places.

The Tsar Asen and Shiligarnika members of the Elshitsa Formation are set up by massive lava sheets or flows and lava breccia which alternate irregularly with beds of agglomerate, lapilli, rarely ash tuffs. Thin layers of marls and tuffite are observed very rare. The individual sheets or beds are very inconsistent in strike and dip. The lava rocks and coarse-grained pyroclastites are gradually replaced by lapilli and psamitic tuffs to the east and west (Bogdanov et al., 1970).

The biggest part of the section is outcropped in the area of Radka mine on the surface and by drills. Here the thickness of the Tsar Asen and Shiligarnika members is more than 950 m and 850 m respectively.

The rocks of the Elshitsa Formation are overlaid by the Pesovets effusive Formation western from Popintsi village. Besides, it is covered by the sedimentary rocks of Mirkovo Formation southern from the villages of Svoboda and Buta.

Numerous comagmatic intrusive bodies such as the hypabyssal Elshitsa pluton, subvolcanic-hypabyssal Tsar Asen, Vlaikov Vruh and Popovo Dere intrusives and subvolcanic bodies and dikes associate with the effusive rocks from the Elshitsa Formation. They were intruded within the effusive rocks from the formation as well as in the basement rocks. Besides, the subvolcanic intrusive bodies cut the rocks from Ovchihulm volcano in the area of Ovchepoltsi village.

**Pesovets effusive Formation**

The Pesovets effusive Formation is developed southern from the town of Panagyurishte, near the villages of Buta, Popintsi, Svoboda and Smilets. It includes the rocks, which form the accumulative cone of Pesovets volcano. This formation is defined as official lithostratigraphic unit here. It is named on the
Pesovets peak, which is located about 8 km southeastern from the town of Panagyurishte. Earlier it was described as Pesovets effusive suite (K. Popov, 2001), as Pesovets complex (Ignatovski and Bayraktarov 1996), and as first Senonian horizon in the older publications.

The definitive features of the Pesovets Formation are determined by the presence mainly of brown-black two-pyroxene andesite-basalt and andesite, and very rarely dacite, as well as pyroclastites of the same composition. The type area for the formation is the place around Pesovets peak, where the section is best well preserved. Here the Formation is set up predominantly by agglomerate to lapilli, rarely block, and very rarely ash tuffs. Lava sheets and flows comprise 20 to 25% of the section. They are presented by massive to amygdaloidal lava rocks or lava-brecia. The preserved thickness of the section in this place is 250 m at least. The volcanic neck outcrops along the western slope of Pesovets peak, as the rocks are intensively hydrothermally altered. Away from the volcanic center, to the west and east, the quantity of the lava sheets and agglomerate tuffs in the section gradually decrease versus the quantity of the psamite-pelitic tuffs and tuffites. The formation’s rocks interfere with the uppermost levels of the volcano-sedimentary Chelopech Formation in the easternmost areas.

The Pesovets effusive Formation set up the uppermost levels of the Panagyurishte Group. It overlies different levels from the older volcanic rocks. It overlies the Petelovo Formation northeastern of Buta village, the Elshitsa Formation between the villages of Buta and Popintsi, and the Ovchepoltsi Formation near the villages of Popintsi and Svoboda. The post-volcanic sediments of the Mirkovo Formation cover the Pesovets Formation. The lower boundary of the Formation outcrops in the type area along the northern foot of Chervena Mogila peak (SW of Pesovets peak), and the upper boundary is observed northeastern from Pesovets peak.

At the contemporary erosion level the intrusives, associated with the effusive rocks, are presented by several small subvolcanic bodies western from Popintsi village and eastern from Buta village.

It is necessary to emphasize, that the Campanian-Maastrichtian post-volcanic sediments of the Popintsi Group transgressively overlie the rocks of different effusive formations, which have different stratigraphic position, as well as the Chelopech Formation. Such interrelations are determined between some of the effusive formations as well. As it was mentioned, the Pesovets Formation overlies the Petelovo, Ovchepoltsi and Elshitsa Formations in the different areas. The Elshitsa Formation overlies the Ovchepoltsi Formation to the north, and the Pre-Cambrian basement to the south. These facts indicate for significant intra-Senonian vertical block movements as in the time of volcanic activity, as well as after its finishing, which are accompanied by denudation of separate parts from the sections of the individual volcanoes.

The age of the rocks from the Panagyurishte volcano-sedimentary Group has been determined in earlier works as Senonian (Landzev, 1940; Mandev, 1940; Bojadziew, 1940; Boncev, 1940). Later Vrublyanski et al. (1961) assigned the whole section as Maastrichtian. Karagyuleva et al. (1974) found micro fauna association near the villages of Dyulevo and Banya, which indicates Coniassian-Santonian age. This is confirmed by Moev and Antonov (1978) for the area near the villages of Chelopech and Mirko, as well as by Dimitrova et al. (1984). Zhelev et al. (1999f) present new data from their study of nanno fossils. Based on these data it could be concluded that in different parts of the section of the Chelopech Formation the fossil macro fauna is represent by *Inoceramus inconstans* Woods.; *Pecten fajasi* Debr., *Nowakites cf. carezi* Gross., etc., micro fauna is presented by *Globotruncana angusticarinata* Gondolfi; *Globotruncana coronata* Boll; *Globotruncana marginata* (Reuss); *Globotruncana renzi* Gondolfi; *Globotruncana concavata carinata* Pesagno; *Globotruncana concavata* Broten; *Vaccinites inaequicofastus* (Munster), etc., as well as nanno fossils *Micina decustata* Vekshina; *Lithastrinus floralis* Stradner, etc., (Vrublyanski et al., 1961, Karagyuleva et al., 1974; Moev and Antonov, 1978; Dimitrova et al., 1984; Zhelev et al., 1999f). This fauna, no doubt, determine the age of the Chelopech Formation as Coniassian-Santonian. The age of the effusive rocks is the same as of the Chelopech Formation, as far as they are laterally interfingered by the Chelopech Formation. This age is also confirmed by the fact that the effusive rocks overlie the Turonian sandstone suite and they are covered by the Mirko, Formation of Santonian-Campanian age. Therefore, according to the biostratigraphic data, the Late Cretaceous magmatic activity in the Panagyurishte ore region was accomplished in a short period of time – about 5-6 Ma (88 - 83 Ma).

According to the K-Ar age dating of 23 samples Lilov and Chipchakova (1999) determined the duration of the magmatic events in the Panagyurishte ore region in the range from 91 to 65 Ma, as the non-sampled oldest rocks are assumed as older than 91 Ma. The authors bind these data with the presence of four stages in magmatic activity, based on the earlier model of Chipchakova (1970). But, as it was mentioned, this model does not take into account the real facts. Based on these data, the authors accept the period of magmatic activity from Cenomanian to Maastrichtian including, which contradicts to the known relations observed in the field, as well as with the age of paleontologically well dated sedimentary rocks. These four stages of the magmatism, suggested by Chipchakova (1970), do not account the circumstance that the effusive rocks in the individual areas are clearly different by their petrologic and petrochemical features and that they are products of separate volcanoes.

The absolute age dating of the magmatic rocks mainly, which was done in last time by different methods (table 1) can be summarized as follows: by $^{26}$Ar/$^{39}$Ar method the age of the Elatsite intrusive is determined as 91.72±0.70 to 90.78±0.44 Ma, the age of Vozdol neck (north from Chelopech) is 89.95±0.45 Ma, the age of Medet intrusive is 90.40±0.90 to 85.70±0.35 Ma and the age of andesite from St. Nikola peak (south from Panagyurishte town) is 80.21±0.45 Ma (Hander et al., 2002; Lips et al., 2004). According to $^{206}$Pb/$^{238}$U zircon dating, the age of the intrusive rocks in Elatsite is dated as 92.1±0.3 to 91.84±0.31 Ma (Vondr et al., 2002), the age of the Elshitsa granite is 86.62±0.02 Ma, the age of the Elshita subvolcanic dacite is 86.11±0.23 Ma (Peycheva et al., 2003). Besides, $^{206}$Pb/$^{238}$U zircon age of the early subvolcanic...
The stratigraphic relations observed on the field allow the forming of described effusive lithostratigraphic units and associated intrusive bodies to be delimited on four stages, which is mentioned by Popov and Popov (1997, 2000) and K. Popov (2001). The Chelopech, Vozdol, Petelovo and Vrankamik Formations are formed during the first stage. The forming of Assarel and Ovchihulm Formations is assigned to the second stage. The third stage is marked by the forming of the Elshitsa Formation in the southern parts of the region. The forming of the Pesovets Formation is referred to the fourth stage. Moreover, the migration of magmatic activity from the north to the south is clearly determined (Fig. 1). The last circumstance is confirmed by the data about the absolute ages of the rocks as well.

The Panagyurishte volcano-sedimentary Group is developed within the boundaries of the described Panagyurishte ore region. Volcanogenic section gradually pinches out to the west, near the Topolnitsa river valley in the area of Petrich village. Obviously it is separated from the volcanicogenic complex developed in the West Srednogorie by considerable territory without important effusive activity, where the sedimentary processes predominate. The volcanic rocks are eroded to the east, around the Blatnitsa village, and they are covered by Neogene sediments southeastern from Ovchepoltsi village. It should be accepted that the Panagyurishte Group pinch out to the east as well, which is confirmed by the absence of considerable manifestations of volcanic rocks in the Upper Cretaceous section in the area of Stara Zagora town. The volcanicogenic complex pinches out to the north, as it was mentioned, around the ridge of the Etropole area of Stara Planina Mountain. The Panagyurishte Group is eroded or covered by Neogene sediments to the south. It is not clear are the Late Cretaceous intrusives in this area mark deep parts of the volcanic-intrusive complexes or they are individually formed.

**Table 1**

Isotope age data of magmatic rocks and ore mineralization in the Panagyurishte Ore Region

<table>
<thead>
<tr>
<th>Object</th>
<th>Method</th>
<th>Age, Ma</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elatsite intrusive</td>
<td>40Ar/39Ar biotite</td>
<td>91.72±0.70</td>
<td>Hander et al., 2002</td>
</tr>
<tr>
<td>Elatsite intrusive</td>
<td>40Ar/39Ar amphibole</td>
<td>90.78±0.44</td>
<td>Hander et al., 2002</td>
</tr>
<tr>
<td>Elatsite intrusive</td>
<td>40Ar/39Ar amphibole</td>
<td>91.20±0.60</td>
<td>Lips et al., 2004</td>
</tr>
<tr>
<td>Elatsite intrusive</td>
<td>206Pb/238U Zircon</td>
<td>92.10±0.30</td>
<td>Von Quadt et al., 2002</td>
</tr>
<tr>
<td>Elatsite intrusive</td>
<td>206Pb/238U Zircon</td>
<td>91.84±0.31</td>
<td>Von Quadt et al., 2002</td>
</tr>
<tr>
<td>Elatsite intrusive</td>
<td>37Ar/39ArSr, 39Rb/87Sr – Bi, feldspar</td>
<td>90.55±0.80</td>
<td>Von Quadt et al., 2002</td>
</tr>
<tr>
<td>Elatsite intrusive – altered rocks</td>
<td>40Ar/39Ar white mica</td>
<td>79.40±0.70</td>
<td>Lips et al., 2004</td>
</tr>
<tr>
<td>Elatsite intrusive – altered rocks</td>
<td>40Ar/39Ar white mica</td>
<td>79.90±0.70</td>
<td>Lips et al., 2004</td>
</tr>
<tr>
<td>Elatsite ore deposit – ore mineralization</td>
<td>Re-Os molybdenite</td>
<td>93.10 to 92.30</td>
<td>Zimmermann et al. 2003</td>
</tr>
<tr>
<td>Early subvolcanic intrusive – Chelopech</td>
<td>206Pb/238U Zircon</td>
<td>92.30±0.50</td>
<td>Stoykov et al., 2004</td>
</tr>
<tr>
<td>Lava flow rocks - Chelopech</td>
<td>206Pb/238U Zircon</td>
<td>91.30±0.30</td>
<td>Stoykov et al., 2004</td>
</tr>
<tr>
<td>Vozdol neck</td>
<td>40Ar/39Ar biotite</td>
<td>89.95±0.45</td>
<td>Hander et al., 2002</td>
</tr>
<tr>
<td>Vozdol neck</td>
<td>206Pb/238U Zircon</td>
<td>91.30±0.30</td>
<td>Stoykov et al., 2004</td>
</tr>
<tr>
<td>Altered and ore mineralized rocks-Chelopech</td>
<td>206Pb/238U Zircon</td>
<td>91.47±0.15</td>
<td>Moritz et al., 2003</td>
</tr>
<tr>
<td>Medet intrusive</td>
<td>40Ar/39Ar amphibole</td>
<td>85.70±0.35</td>
<td>Hander et al., 2002</td>
</tr>
<tr>
<td>Medet intrusive</td>
<td>40Ar/39Ar biotite</td>
<td>90.40±0.90</td>
<td>Lips et al., 2004</td>
</tr>
<tr>
<td>Medet intrusive – altered rocks</td>
<td>40Ar/39Ar white mica</td>
<td>79.50±0.80</td>
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<td>Medet intrusive – altered rocks</td>
<td>40Ar/39Ar white mica</td>
<td>79.00±0.80</td>
<td>Lips et al., 2004</td>
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<tr>
<td>Medet intrusive – altered rocks</td>
<td>40Ar/39Ar white mica</td>
<td>79.40±0.60</td>
<td>Lips et al., 2004</td>
</tr>
<tr>
<td>Lava flow rocks - St. Nikola peak</td>
<td>40Ar/39Ar amphibole</td>
<td>80.21±0.45</td>
<td>Hander et al., 2002</td>
</tr>
<tr>
<td>Elshitsa pluton - granite</td>
<td>206Pb/238U Zircon</td>
<td>86.62±0.02</td>
<td>Peycheva et al., 2003</td>
</tr>
<tr>
<td>Elshitsa subvolcanic dacite</td>
<td>206Pb/238U Zircon</td>
<td>86.11±0.23</td>
<td>Peycheva et al., 2003</td>
</tr>
<tr>
<td>Vlaikov Vruh – hydrothermal rutile</td>
<td>206Pb/238U Zircon</td>
<td>85.66±0.15</td>
<td>Peycheva et al., 2003</td>
</tr>
<tr>
<td>Vlaikov Vruh – ore mineralization</td>
<td>Re-Os molybdenite</td>
<td>82.00±0.60</td>
<td>Kouzmanov et al., 2001</td>
</tr>
</tbody>
</table>

intrusion northern from Chelopech village is 91.3±0.3 Ma, the age of the lava flow rocks of the Chelopech volcano is 91.3±0.3 Ma, and the age of the Vozdol neck is 91.3±0.30 Ma (Stoykov et al., 2004). Isotope data for the age of hydrothermal activity can be summarized as follow: by 40Ar/39Ar method the age of the hydrothermally altered rocks from the Elatsite intrusive is 79.90±0.70 to 79.40±0.70 Ma, and the age of the hydrothermally altered rock from the Medet intrusive is 79.50±0.80 to 79.00±0.80 Ma (Lips et al., 2004), by the 206Pb/238U zircon method the age of the hydrothermally altered rock in the Chelopech mine is 91.47±0.15 Ma (Moritz et al., 2003), and the age of the high-temperature hydrothermal rutile in Vlaikov Vruh ore deposit is 85.65±0.15 Ma (Peycheva et al., 2003). According to the Re-Os molybdenite dating the age of the ore mineralization in the Elatsite ore deposit is 93.10 to 92.30 Ma (Zimmermann et al. 2003), and in Vlaikov Vruh ore deposit is 82.00±0.60 Ma (Kouzmanov et al., 2001). Obviously, the isotope data suggest slightly older ages than the palaeontological dates.

The Popintsi sedimentary Group

The Popintsi sedimentary Group consists of Upper Senonian rocks, formed after the end of effusive activity. In some areas it transgressively covers different levels from the section of the Panagyurishte volcano-sedimentary Group. It is most likely that these relationships are result of the erosion of the indented volcanic topography. The group includes the Mirkovo and Chugovitsa Formations, defined by Moev and Antonov (1978) (Fig. 2).
Mirkovo Formation

The Mirkovo Formation is widespread in the whole Panagyurishte region as well as outside of its territory. It overlies transgressively the rocks from Chelopech Formation or the different effusive formations. It is covered by the rocks from the Chugovitsa Formation everywhere.

According to Moev and Antonov (1978) and Karagyuleva et al. (1974), the Mirkovo Formation is composed mainly of red to variegated clayey limestone and thin intercalation of marl. The limestone is average bedded, organic or cryptocrystalline, with aeolopelitic to fine-grained psammitic admixtures. Polymictic or volcanoclastic calcareous sandstone and polyygine breccia conglomerate with thickness up to 30 m are frequently observed in the lower levels of the section. The pieces from hydrothermally altered and mineralized volcanic rocks are rarely found in the conglomerate. The thickness of the formation ranges from 1 to 250 m in the different parts of the region.

The following fossil fauna are found in the rocks of the Mirkovo Formation: Globotruncana corona (Bolli), Globotruncana elevata Broten, Globotruncana gagnebini (Carsey), Globotruncana marginata (Reuss), Globotruncana rosseta (Carsey), Globotruncana rugosa (Marie), Sigalina carpatica Salaj & Samuel, Pseudotextularia elegans (Rzehak), etc. (Karagyuleva et al., 1974; Moev and Antonov, 1978; Dimitrova et al., 1984). These fauna, no doubt, determine the Santonian-Campanian age of the Mirkovo Formation, as the quoted authors accept.

Chugovitsa Formation

The Chugovitsa Formation is widespread in the Panagyurishte region and outside of its boundary as well. It is preserved in the cores of the synclines at present (fig. 1). It overlies the Mirkovo Formation with a rapid and smooth transition. The uppermost levels of its section are not preserved. The Paleogene sediments overlie it in restricted areas.

The Chugovitsa Formation, according to data by Moev and Antonov (1978) and Karagyuleva et al. (1974), mainly consist of polymictic sandstone, calcareous sandstone, marl, clayey limestone, sandy-calcareous aleurolite, calcareous argillite and re-sedimented volcanic material, rarely by sandy limestone, which are differently represented in the separate areas. These rocks are developed as typical terrigenous-carbonate flysch alternation, with thickness of the sedimentary rhythms usually from 10 to 40 cm, rarely up to 2 m. The well sustained sandstone beds are observed in some parts of the section. The thickness of the formation reaches to 500-700 m in the most preserved parts of the section.

As the conclusion it should be underlined that the analysis of the stratigraphy of volcanic and volcano-sedimentary rocks in the studied region, combined in the Panagyurishte Group, shows that their forming is result of the activity of distinctly differentiated central type volcanoes or groups of linearly located central volcanoes. This is marked by the differences in the petrologic features of the rocks, which set up individual volcanoes, as well as by their different position in space and time. The rock’s composition indicates to the high explosive coefficient of the volcanism. As a rule, the effusive rocks associate with cross-cutting comagmatic intrusive bodies, with which they form integrated volcano-intrusive complexes.

Moev and Antonov (1978) determined an individual Voden member in the lower part of the Chugovitsa Formation, in the northwestern parts of the region, northern from Mirkovo village. It consists of calcareous argillite and rarely clayey-calcareous or sandy-clayey aleurolite. The member pinches out to the east, as its thickness varies from 0 to 220 m.

The abundant fossil fauna is contained in the rocks of the Chugovitsa Formation (Vrublyanski et al., 1960; Karagyuleva et al., 1974; Moev and Antonov, 1978; Dimitrova et al., 1984; Zhelev et al., 1999). The following fossil macro fauna are found: Inoceramus balticus Bohm., Inoceramus regularis d’Orb., Inoceramus regularis d’Orb. var. baltica Behm., Pachydiscus gallevillensis (d’Orb.), Pachydiscus gallevillensis neubergicus (Haeuer), etc. The micro fauna is presented by Heterohelix globulosa (Ehrenberg), Rugoglobigerina rugosa (Plummer), Globotruncana gagnebini Tiley, Globotruncana rosseta (Carsey), Globotruncana stuartiformis (Dalbiez), and other stratigraphically widespread species. The abundant association of calcareous nanoplankton is found, such as Aspidolithus parcus (Stradner) ssp. constrictus Hattner et al., Ceratolithoides aculens (Stradner) Eiffelliolithus exminus (Stover), Micula murus (Martini), Lithraphidites quadratus Bramlette & Martini, Markalius inversus Deflandre, etc. These fauna determine Campanian-Maastrichtian age of the Chugovitsa Formation in general. The presence of Micula murus (Martini), Lithraphidites quadratus Bramlette & Martini and Markalius inversus Deflandre in the uppermost levels of the section defines its Maastrichtian age. Besides, the presence of Aspidolithus parcus (Stradner) constrictus Hattner et al., Ceratolithoides aculens (Stover) Eiffelliolithus exminus (Stover) in the Voden Member from the Chugovitsa Formation determine the Upper Campanian age of the lower levels of the section (Zhelev et al., 1999).

Big part of the Panagyurishte region is covered by Paleogene, Pliocene, and Quaternary sediments at present, which transgressively overlie different levels of the Upper Cretaceous section or the basement rocks (Fig. 1).

References


Bonchev, E. 1940. Über die Geologie des Bajovo Teiles der Panagjuriste-Zone der Srednogorie unter


