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Stratigraphic implications of the Middle Miocene of the Despotovac area: recognition of two geological formations

KATARINA BRADIĆ-MILINOVIĆ[1] & SRĐAN VUKOVIĆ[2]

Abstract. The Middle Miocene of the Despotovac area contains sediments of the lower Middle Miocene (Badenian) and upper Middle Miocene (Sarmatian). The Middle Miocene deposition shows different local variations, but generally fits the evolution of the Central Paratethys. The Miocene sediments were analyzed using paleontological and sedimentological methods. Based on the results of these investigations, the Golubac Formation (Badenian) and the Kamenovo Formation (Sarmatian), which had previously been defined and documented on the Kučevo sheet, were recognized for the first time within the sediments of the Middle Miocene study area on the sheet Lapovo 4.

Key words: *Badenian, Sarmatian, Golubac Formation, Kamenovo Formation, Central Serbia.*

Апстракт. Средњи миоцен подручја Деспотовца је представљен седиментима старијег средњег миоцена (бадена) и млађег средњег миоцена (сармата). Таложење седимената средњег миоцена показује различите локалне варијације, али генерално одговара еволуцији Централног Паратетиса. Миоценски седименти су анализирани палеонтолошким и седиментолошким методама. На основу резултата ових истраживања у оквиру седимената проучаваног подручја средњег миоцена на листу Лапово 4 су по први пут препознате: Формација Голубац (баденски кат) и Формација Каменово (сарматски кат), претходно дефинисане и документоване на листу Кучево.

Кључне речи: *баден, сармат, Формација Голубац, Формација Каменово, централна Србија.*

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Introduction

In contrast to numerous investigations of Miocene sediments in the area of the southern rim of the Pannonian Basin in the last 20 years (e.g. Marović et al., 2007; Krstić et al., 2012; Ganić et al., 2016; Rundić et al., 2019; Jovanović et al., 2021; Bradić-Milinović et al., 2019, 2021), the area of central Serbia (near Despotovac) has been insufficiently investigated.

In the middle of the last century, the Despotovac basin was described in several studies and encompasses the Badenian (Žujović, 1893; Pavlović, 1922; Petković, 1948; Laskarev, 1949; Petronijević, 1953; Čičulić & Džodžo, 1960; Dolić, 1963, 1967; Stevanović, 1967) and the Sarmatian deposits (Veselinović & Maksimović, 1952; Pantić, 1953; Spajić-Miletić, 1953, 1959, 1962, 1969; Čičulić, 1962; Stevanović, 1967; Dolić, 1963, 1967; Dolić & Lončarević, 1977). In Serbia, work on the project "Geological Map of the Neogene of Serbia 1:200,000" and on the definition of the various Neogene formations was published at the beginning of this century (Bojić & Tanasković, 2003). While all the studies mentioned above confirmed the importance of these studies for solving stratigraphic, paleogeographic, paleoecological and paleotectonic problems, knowledge about the Badenian and Sarmatian sediments from the Despotovac Basin is still insufficient.

The aim of our research and this study is to provide an insight into the stratigraphic relationships in this area, and to identify and document newly isolated formations from Middle Miocene sediments.

The work is based on the results of field work in the period 2021–2023, carried out by researchers of the Geological Survey of Serbia, during the preparation of the Basic Geological Map RS 1:50,000, sheet Lapovo 4.

Geological setting

The study area is located in the Despotovac-Mlava basin, i.e. in the area of the settlements of Vezičevo and Bogava (Fig. 1). The mentioned basin belongs to the "Moravian Bay", which is part of the southeastern Pannonian Basin. Various geological-tectonic units with diverse lithological compositions and structural units are distributed across the study area (Fig. 1). The oldest Paleozoic formations are represented by volcano-sedimentary rocks, in which there are intrusions of igneous rocks in the green schist facies, located in the northern part of the study area (Vujisić et al., 1977). They are represented by acidic metavolcanites, metapelites, metapsamites, quartzites and metadiabases. The Carboniferous is represented by sandstones and conglomerates, as well as carbonaceous black shale with coal occurrences. The Upper Carboniferous lies transgressively above the older Palaeozoic and passes upwards into the Permian red sandstones. The Permian red sandstones lie transgressively above the Paleozoic formations or are concordant with the Carboniferous sediments (Vujisić et al., 1977). In most of the distribution area, they form the base with Mesozoic carbonates. The Mesozoic is represented in the east and in part of the study area and consists of Triassic and Jurassic limestones, dolomitic limestones, dolomites and sandstones (Vujisić et al., 1977). The carbonates were formed mainly under shallow water conditions. The Neogene sediments cover the largest part of the study area. They were deposited in the Velika Morava tectonic basin, which is filled with marine, freshwater lake and terrestrial sediments. According to Vujisić et al. (1976) the Neogene sediments date from the Middle and Late Miocene with the Middle Miocene comprising the following members:

- Lacustrine sediments of undefined age from the Middle Miocene ($^{2}M_{2}$),
- lacustrine-continental sediments of undefined age from the Middle Miocene($^{3}M_{2}$),
- marine sediments of the Badenian stage (M_{2}^{1}),
- brackish sediments of the Sarmatian stage (M_{2}^{1})

The oldest, late Middle Miocene ($^{2}M_{2}$) is represented in the south-eastern part of the study area along the edge of the Mesozoic formations, between Plažan, Despotovac and Medar and is represented by two facies (Vujisić et al., 1976). The older facies, with freshwater character consists of white marls, marls and sandy clays, sands and very rarely sandy limestones, while the younger facies with carbonaceous layers, coarse-grained sandstones and sandy

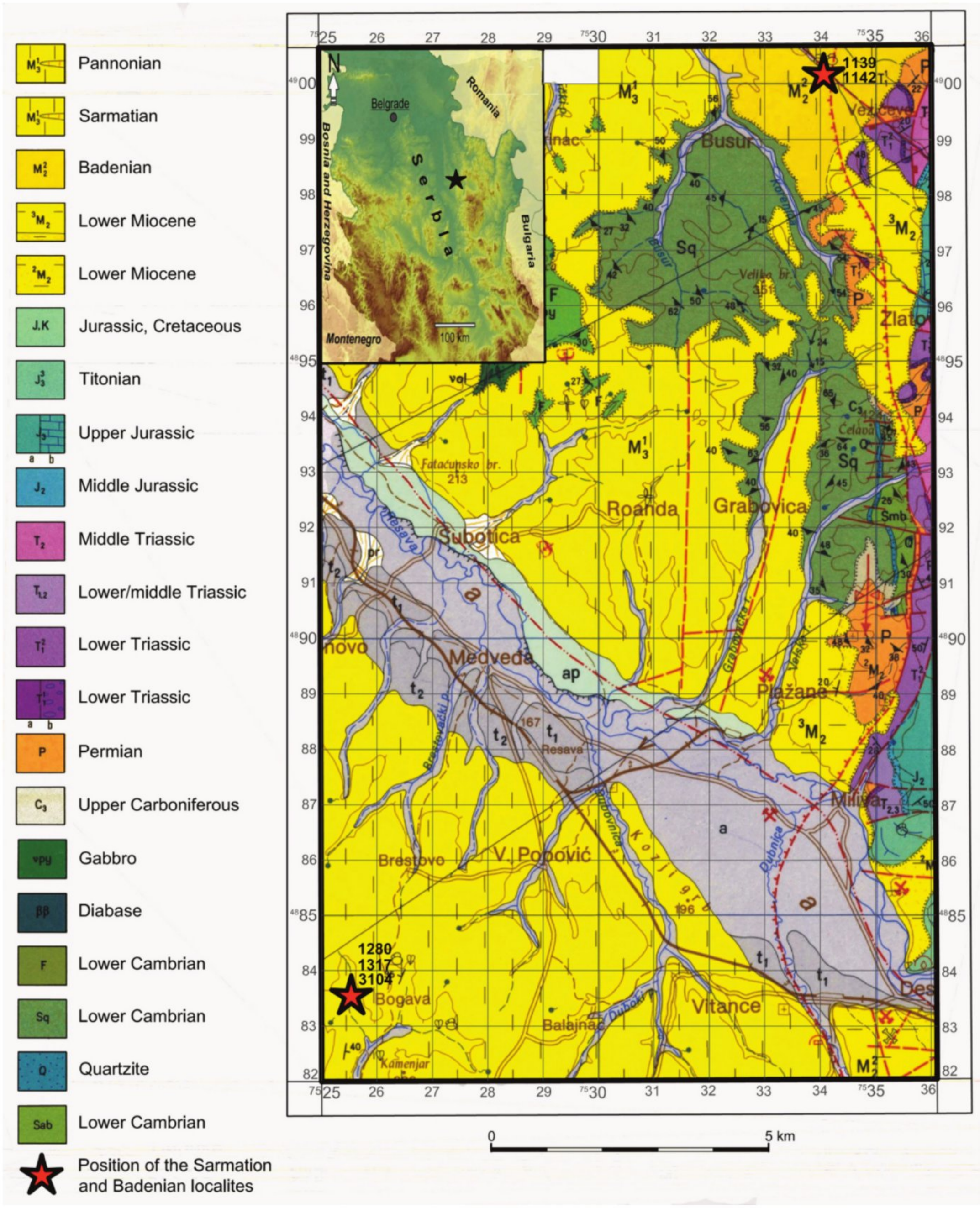

Fig. 1. *Geographic position of the study areas, according to the Basic Geological Map (sheet Lapovo 1:100 000; Vujisić et al., 1976).*

carbonaceous clays probably reflects the sedimentation conditions of a swamp (Fig. 2). Remains of mammals were found in these younger coal-bearing layers.

The lacustrine-continental Middle Miocene ($^3M_2$) is represented by a clastic, continental series deposited under arid conditions and periodic fluvial sedimentation (Vujisić et al., 1977). They are represented in the southeastern part in the Plažan area and south of Despotovac. In terms of lithology, sandstones and loose sands dominate, less frequently conglomerates (Fig. 2). The sedimentary matrix consists of clayey and sandy material in predominant cross-bedding stratification.

The marine Badenian (M_2^1) has a very small areal distribution and is only observed in the northern parts of the study area (Vujisić et al., 1977). It is embedded between the clastic Middle Miocene above and the Sarmatian below. From a lithological point of view, these are predominantly sandy clays alternating with sands and sandstones (Fig. 2). Limestone intercalations are rare. Coal is also present in three or four horizons up to 3 m thick (Vujisić et al., 1977). The environment is predominantly marine, with occasional freshwater intervals in the coal-bearing horizons. The Sarmatian sediments of the upper Middle Miocene extend north and south of Resava in the research area. They lie

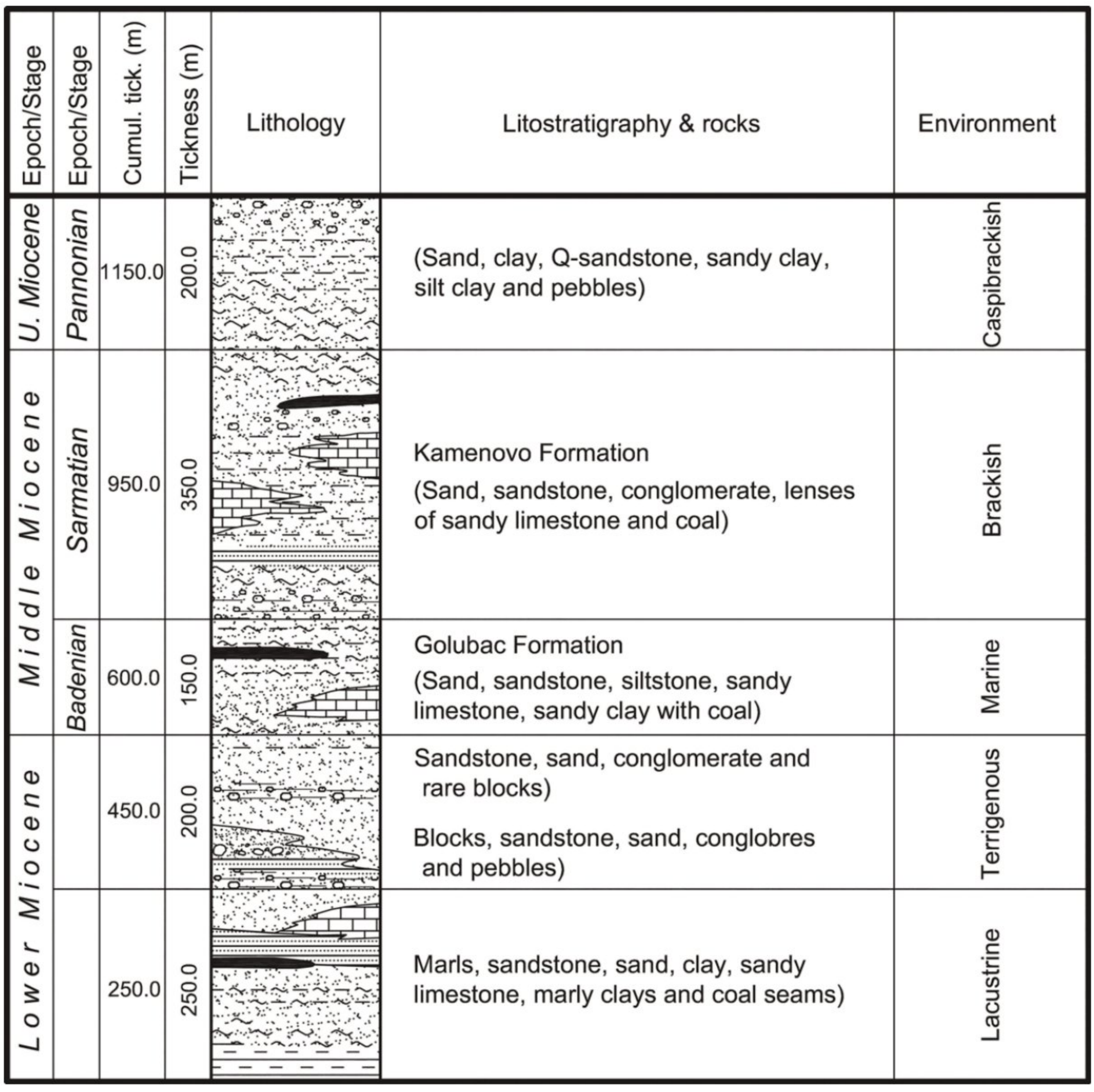

Fig. 2. *Stratigraphic summary column of the Middle Miocene of the study area and the Golubac Formation and Kamenovo Formation (modified after Vujisić et al., 1976).*

above the marine Badenian (M_2^1) or transgressively above older formations (Vujisić et al., 1977). The lithological composition and the occurrences of coal indicate the brackish character of the depositional environment, which also includes sintered rocks. The higher parts consist of finer-grained sediments such as siltstones, fine-grained marly sandstones, porous sandy limestones, sandy clays, carbonate sand-stones and conglomerate lenses (Fig. 2). Most parts consist of yellow sands, sandy clays, clayey carbonate siltstones, less often sandy limestones and carbonaceous clays. Three coal layers with a maximum thickness of 3.6 m were found in the area west of the town of Miliva (Vujisić et al., 1977).

Quaternary formations occupy a significant part of the research area and are represented by fluvial and slope sediments (Vujisić et al., 1977). The fluvial processes are caused by the action of constant linear flows and are particularly pronounced in the Resava valley.

From a geotectonic point of view, the study area comprises the eastern part of the Moravian Corridor, which was part of the Pannonian Basin, in which Tertiary formations of different lithological composition were formed. The sequence is generally tectonically disturbed. These areas are characterized by the development of a coal-bearing productive series caused by tectonic deformations. The study area is also located near the overthrust zone of the Supragetik and the Getik (Kalenić & Hadži-Vuković, 1973; Schmid et al., 2008). According to the classification of Krautner & Krstić (2002), these areas comprise the Supragetik, i.e. the Lužnička Zone (Golubačka Zone). Above these large tectonic units is the complex unit of the Great Moravian Graben, which consists of Neogene and Quaternary sediments. In the extreme east of the study area, there are carbonate rocks of Mesozoic age belonging to the Carpatho-Balkanides, i.e. the Getic (Grubić, 1980). The Supragetic system consists of Palaeozoic volcano-sedimentary rocks formed under the greenschist facies conditions, in which occur the gabbro intrusions and Permian red sandstones. The Getic unit in the east is made up of carbonates from the western limestone belt of eastern Serbia (Antonijević, 1954) ("Ravanički limestones"), while red Permian sandstones are found in the core. As already mentioned, the research area is located near the main Supragetic and Getic traction system. Statistical analysis indicates a slight to steep southwest dipping stratification, which most likely indicates an alpine trend. This slightly altered trend (to the southwest) can also be interpreted as a deviation along the surface layer. The folding itself can be interpreted as eastward pinched to isoclinal folding, but also as a result of repeated thrusting ("flat-ramp geometry"; Krstekanić et al., 2017). At observation point 1139, layer elements with values of ss 250/12 were measured in the overlying Badenian sediments, which should fit the trends of the above-mentioned statistical analyzes in the belt of the eastward folding system.

Material and methods

All samples were collected as part of the project The Basic Geological Map 1:50,000, sheet Lapovo 4, under the auspices of the Geological Survey of Serbia. The field investigation was carried out in the period from 2021 to 2023.

The studied material was collected from several outcrops: two from the Badenian and three from the Sarmatian units. The Badenian sites are located in the north–eastern part of the sheet Lapovo 4, and are labelled with the internal numbers 1139 (7534702; 4900379) and 1142 (7534743; 4900136). The Sarmatian sites are located in the southwestern part of the sheet Lapovo 4, and are internally numbered 1280 (7525299; 4883411), 1317 (7525356; 4883405) and 3104 (7525444; 4883344). At point 1139, 14 samples were collected: 1139/1, 1139/2A, 1139/2A/1, 1139/2Б, 1139/2Ц, 1139/2Д, 1139/2E, 1139/2Ф,1139/3, 1139R/2, 1139R/A, 1139R/B, 1139R/C and 1139R/D. One sample with the collection number 1142R was taken from point 1142. From point 1280 three samples with the collection numbers 1280/1, 1280/2A and 1280/2B were taken. Four samples with the collection numbers 1317/1, 1317A, 1317B and 1317C were taken from point 1317. From point 3104, three samples with the numbers 3104/2, 3104/3 and 3104/4 were taken. The weight of each bulk sample was approximately 1.5 kg. The sediment samples were taken for

the following purposes: paleontological and sedimentological studies (granulometric analyses and sedimentological standard preparations (thin-sections of compact sediments)). Two methods of sediment processing were used for this purpose: Standard washing and sieving and preparation of standard petrographic thin sections (cutting, grinding and polishing). Fossil associations of molluscs, foraminifera and ostracods were extracted and used for the biostratigraphic analysis and the recognition of the geological formations of the Middle Miocene units. All samples were processed in the Laboratory of the Geological Survey of Serbia.

The photographs were taken with the *Leica* S9i microscope. Individual photos of each object were taken at different depth ranges and then digitally stacked to create uniformly focused photos using Helicon Focus software.

All samples (samples of residual sediments, micropaleontological samples and thin-sections of sedimentary rocks) are housed at the Geological Survey of Serbia.

Results and discussion

The Golubac Formation (Badenian stage) and the Kamenovo Formation (Sarmatian stage) are defined here on the basis of field research, the collection and processing of sediments, which required a multi-disciplinary approach.

Golubac Formation – The Middle Miocene (Marine Badenian)

Sediments of the earlier Middle Miocene (Badenian age) are positioned on the map in the north-eastern region. The Badenian stage is confirmed in two localities along the Crvenac stream (1139 and 1142). According to data from the literature (Petronijević, 1953; Pantić, 1953, Čičulić & Džodžo-Tomić, 1960; Dolić, 1966) they were also found in the vicinity of Despotovac, but this was not confirmed within the scope of these investigations. From a lithological point of view, the sediments of Badenian are represented by weakly bound yellow sands, sandy clays, sandstone and sandy limestones (Fig. 3).

The first geological site is located in the Crvenac stream (point 1139), about 7–8 m above the stream level (Fig. 4. 1,2). In the lower part, the sediments consist of red massive Permian sandstone (Fig. 3) with a thickness of approximately 2 m. The Permian sandstones are transgresivelly overlain by grey limestones rich in mollusc fauna (Fig. 3). Various macrofossils were collected from this limestones, including remains of bivalves, gastropods, corals and echinoids. Bivalves are mostly present in the form of imprints or shell hash: G*lycymeris* sp., *Pecten besseri* Andrzejowski (Fig. 4.4), *Tellina* sp., etc. The fossil echinoid was damaged during extraction from the compact rock material, but could still be determined as *Clypeaster* sp. (Fig. 4.5). The investigated sediments contain isolated parts of colonial corals which were identified as ?*Stylophora* sp. indet. (Fig. 5).

The overlying sediments are composed of yellow, fine-grained, loose sands up to 0.5 m thick. In all samples (1139/2D, 1139/3 and 1139R) from this yellow sand, microfossil assemblages were identified, represented by numerous foraminifera and ostracods. These are overlain by gray sandy limestones up to 2 meters thick. Foraminifera, both planktonic and benthic, are more abundant and better preserved than ostracoda. Benthic forms of foraminifera are the most numerous and diverse. The most abundant benthic taxa of foraminifera belong to elphidiids (*Elphidium*, *Porosononion*); anomalinids (*Anomalinoides, Heterolepa,*); buliminids (*Bulimina*).

The identified species of foraminifera are: *Globigerina bulloides* d'Orbigny, *Heterolepa dutemplei* (d'Orbigny), *Bulimina elongata* d'Orbigny, *Cibicoides austriacus* (d'Orbigny), *Anomalinoides badenensis* d'Orbigny, *Elphidium macellum* (Fichtel & Moll), and individual specimens of *Elphidium aculeatum* (d'Orbigny), and *Ammonia beccarii* (Linne) (Fig. 4.3). Only a small number of ostracods have been preserved. The ostracod fauna is represented with the following species: *Loxoconcha punctatella* (Reuss) and *Aurila cicatricosta* (Reuss).

During the field research, gastropod shells were found in these sands including the index species for this period: *Ptychidia* sp. (Fig. 4.6).

Epoch/Stage	Cumul. tick. (m)	Tickness (m)	Lithology	Packages	Samples	Litostratigraphy & rocks
Badenian	10.5	3.0		4	1142R	Yellow fine/medium grain sand with rich fauna foraminiferas, ostracods and moluscs: *Elphidium grill, E. crispum, E. macellum, Poro sononion granosum*, *Ammonia beccarii*, *Heterolepa dutemplei, Cibicoides austiacus, Anomalinoides* sp. and *Anomalinoides* badensis. *Fauna* ostracods*: Loxoconcha punctatella* and *Aurila cicatricosta.* Fauna gastropods:*Tritia serraticosta, Nassarius* sp. and *Archimediella* sp.
	7.5	2.0		2	1139/2D 1139/2E 1139/2F	Sandy limestone breccias grey color with fauna foraminiferas: *Globigerina bulloides, Heterolepa dutemplei, Bulimina elongata, Cibicoides austiacus, Anomalinoides badenensis, Elphidium macellum Elphidium grill* and *Ammonia beccarii. Fauna* ostracods: *Loxoconcha punctatella* and *Aurila cicatricosta. Fauna of microbivalves: Acanthocardia* sp. juv.
	5.5	0.5		3	1139/3	Yellow fine grain laminated sand, limonitised
	5.0	3.0		2	1139/2A 1139/2A/1 1139/2B 1139/2C 1139R	Sandy limestone breccias, grey to dark grey color with fauna, shells: *Anadara* sp., *Glycymeris* sp., *Pecten besseri* and *Tellina* sp., fossil echinoid: *Clypeaster* sp. Fauna gastropods is represented by the type species for this period: *Ptychidia* sp. Parts of colonial corals ? *Stylophora* sp. indet.
Permian	2.0	2.0		1	1139/1	Red Q-sandstone, massive

Fig. 3. *Badenian stratigraphic local column of the Crvenac stream and the Golubac Formation.*

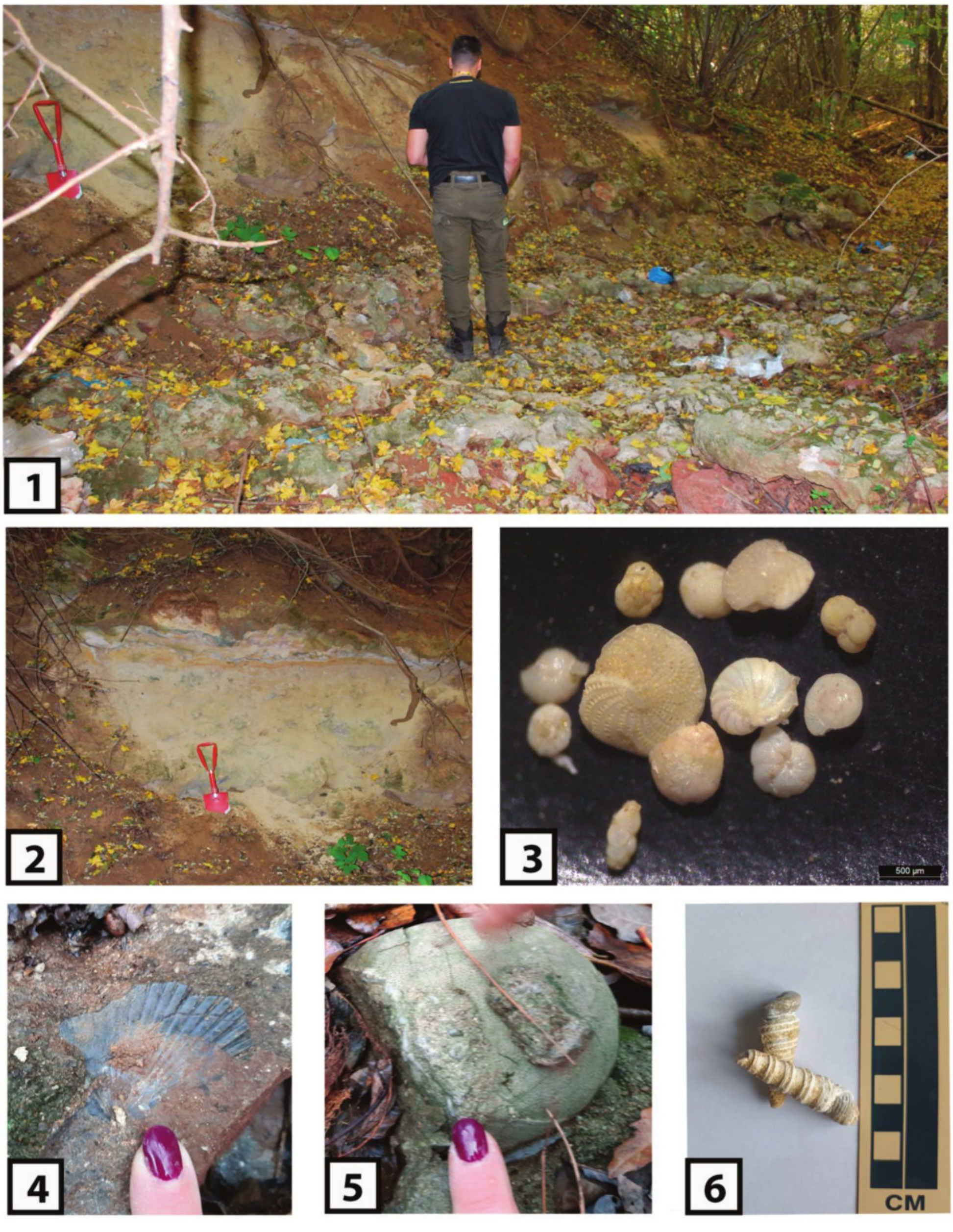

Fig. 4. *Badenian sediments in the bed of the Crvenac stream (**1** and **2**), typical microfossil assemblage for Late Badenian stage (**3**) and macrofossil Pectenbesseri* Andrzejowski *(**4**); Clypeaster* sp. *(**5**); Ptychidia* sp. *(**6**).*

Downstream of the previous outcorp, the second point (1142) is locatedin the bed of the Crvenac stream, near the previous point (about 20 m). The sediments are composed of yellow fine-grained sand with a thickness of about 3 m. Microscopic analysis revealed that this sediment contains a rich fauna of

Fig. 5. *Corals colony (?Stylophora* sp. indet.*) from the yellow sand of the Late Badenian stage of the Crvenac stream.*

foraminifera and, to a lesser extent, ostracods and molluscs (gastropods and individual bivalves). The foraminifera are represented by benthic forms with most species belonging to the elphidiid group. The Foraminifera association contained the following species: *Elphidium aculeatum* (D'ORBIGNY), *E. crispum* (LINNE), *E. macellum* (F.-M.), *Porosonoion granosum* (D'ORBIGNY), (single shells), *Ammonia beccarii* (LINNE), (rare), *Heterolepa dutemplei* (D'ORBIGNY), *Cibicoides austriacus* (D'ORBIGNY), and *Anomalinoides* sp. (Fig. 6). The ostracods are represented by the same species as in the previous point, namely: *Loxoconcha punctatella* (REUSS) and *Aurila cicatricosta* (REUSS) (Fig. 6).

Molluscs are mainly represented by gastropods, whose shells are more or less damaged, and only the following species are recognized: *Tritia serraticosta* (BRONN), *Nassarius* sp. and *Archimediella* sp. Bivalves are represented only in the form of shell remains, predominantly by *Acanthocardia* sp. juv.

The rich fossil fauna is represented by various shallow water organisms such as echinids, corals, benthic foraminifera, ostracods, bivalves and snails. The environment at the time of deposition provided favourable conditions for the development of a small coral reef on which various shallow-water organisms started to develop.The observed fossils pecies are indicative of a shallow water environment (KOVAČ et al., 2007). They are also stenohaline marine organisms (e.g. echinoid and coral) that do not tolerate changes in salinity and thus indicate a marine environment with normal salinity. The presence of coral communities is evidence of a warm, well-aerated environment rich in oxygen. Corals are among the most paleoecologically sensitive marine organisms and therefore cannot compensate for fluctuations in the parameters mentioned (salinity, temperature, depth) in this environment.

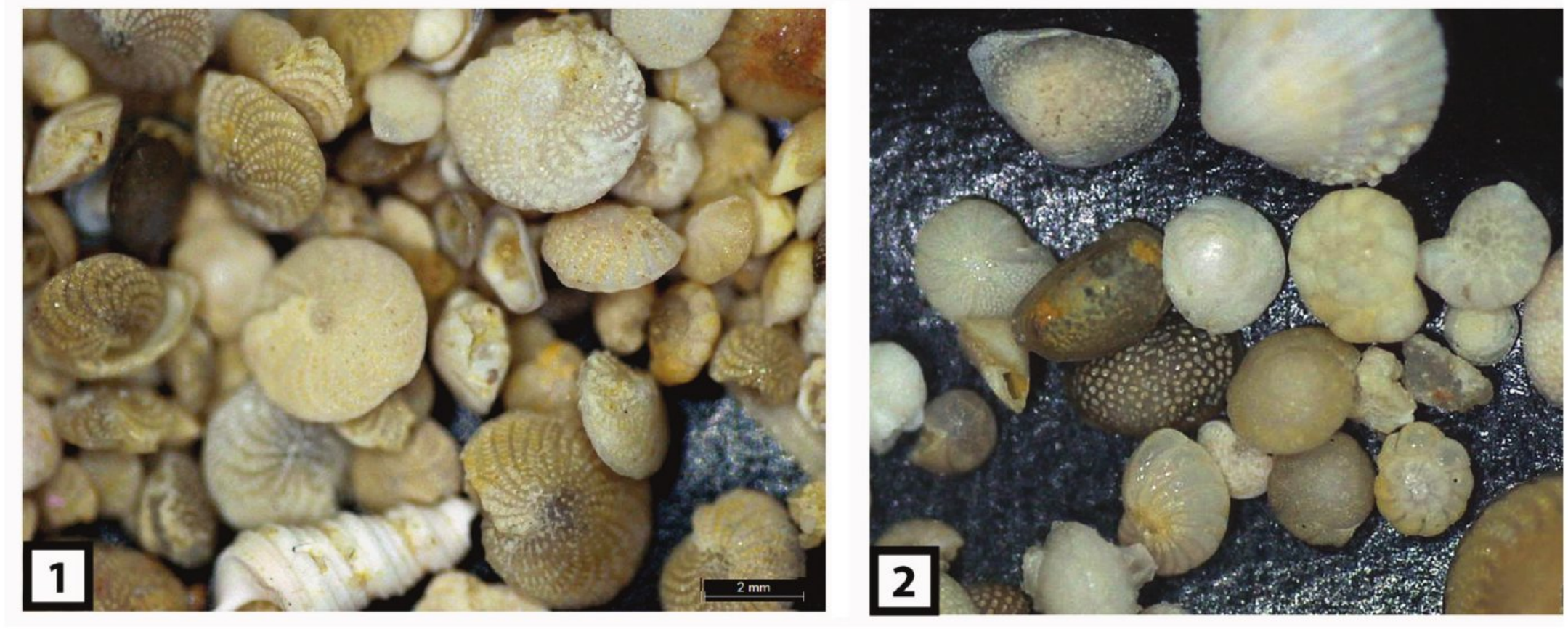

Fig. 6. *Microfossil assemblages from the yellow sand of point 1142:* ***1****) Foraminifera association, mainly represented by elphidiids and* ***2****) Fossil assemblage of foraminifera and ostracods, characteristic of the late Badenian age.*

Kamenovo Formation – Middle Miocene (Marine-brackish Sarmatian)

The Sarmatian formations have the greatest regional distribution of all geological units in the studied area and cover about 50% of the area of Lapovo 4 sheet. Sarmatian sediments are distributed in the eastern and central part of the terrain, e.g. in the Resava and V. Morava valleys. Sarmatian sediments were also confirmed in the vicinity of Bogava, which is positioned in the SW part of the investigation area. Sarmatian sediments have been studied in detail in two localities (1280 and 1317). Sediments from a third locality (3104) did not contain suitable microfossils for a detailed assessment. Sarmatian sediments are represented in the lower parts of the sequence by loosely bound conglomerates with quartz and green schist from the foothills, sandstone, then sands and sandy clays (Fig. 7). In the higher parts of the sequence, they are represented by silty sands, fine-grained marly sandstones, porous limestones, sandy clays and lenses of conglomerate (Fig. 7).

The first point (1280) is located in the vicinity of the Bogava.The section is located in a cut along the Stara Bogava stream and is about 50 meters long. In the lower part of the section there are ochre-colored clayey sands about 1.5 m thick, overlain by gray marly siltstones with a thickness of about 1.5 meters, which in turn are overlain by yellow medium sands with lenses of micro-conglomerate up to 2.5 m (Fig. 8). The sequence is overlain by light yellow limestones with dissolution porosity about 1.5 meters thick (collected sampels: 1280/2A and 1280/2B) and finally by coarse-grained gravelly sands of ochre-gray color with a thickness of 1.5 meters (Fig. 8).

A microfossil association of benthic foraminifera was recognized in the yellow limestone with dissolution porosity. Cross-sections of mollusc shells were also recognized. The foraminifera fauna is numerous but uniform, mainly represented by the species *Quinqueloculina akneriana* d'Orbigny, *Quinqueloculina* sp. (Fig. 9.2) and *Elphidium sp.* (Fig. 9.1). The *Quinqueloculina* spp. association occurs in the recent Mediterranean Sea in shallow-marine environments (2–65 m), temperate to warm waters (10–25 °C) and slightly elevated salinity (37–39‰) (Peryt & Jasinowski, 2012).

The second point (1317) is located about 200 m further downstream along the Crvenac stream in an outcrop of about 4m in height. In the lower part of the outcrop, there are ochre-colored clayey sands with a thickness of about 1.5 meters. They are overlain by 30–40 cm thick gray clays (Fig. 10.1). Above this are ochre-yellow fine-grained sands with a thickness of about 3 meters. The bedrock contains coarse-grained gravelly sands of ochre gray color, which are about 1.5 m thick. The grains in the gravels are up to 3 cm in diameter. A sample (1317/1) was taken from gray-yellow argillaceous siltstone at about 3 meters above the base of the outcrop (1317A, 1317B and 1317C).

Studied thin-sections (1317A, 1317B and 1317C) of yellow limestone are rich in microfossils. Fragments of mollusc shells (Fig. 10.4), cross-sections of ostracod shells and foraminifera were identified microscopically in the thin sections. Foraminifera are represented by benthic forms dominated by *Quinqueloculina* sp. and occasionally *Anomalinoides* sp. (Fig. 10.3).

Microfossils extracted from the gray-yellow argillaceous siltstone contain ostracods and foraminifera. The foraminifera are benthic forms and the following species were identified: *Quinqueloculina akneriana* d'Orbigny, *Varidentella reussi* (Bogdanovich) and *Anomalinoides dividens* Luczkowska (Fig. 9.2). Ostracoda are rare and represented by a single species: *Cytheridea hungarica* (Zalanyi) (Fig. 9.2). *Anomalinoides dividens* Łuczkowska is considered as an index taxon for the regional biostratigraphy of the Paratethyan area. The *Anomalinoides dividens* Biozone was introduced in order to trace the boundary between Badenian and Sarmatian deposits (Filipescu, 2004; Filipescu et al., 2014). Low ostracods diversity indicates unfavorable conditions (Holcova & Zagoršek, 2008; Peryt et al., 2024).

A small outcrop (point 3104) was found about 100 m from the two aforementioned locations in a cut about 20 m long. This small outcrop contains the upper part of this stratigraphic section, which is represented by gray clay and yellow sand. Samples were taken from these two stratigraphic units, but no fossils were found.

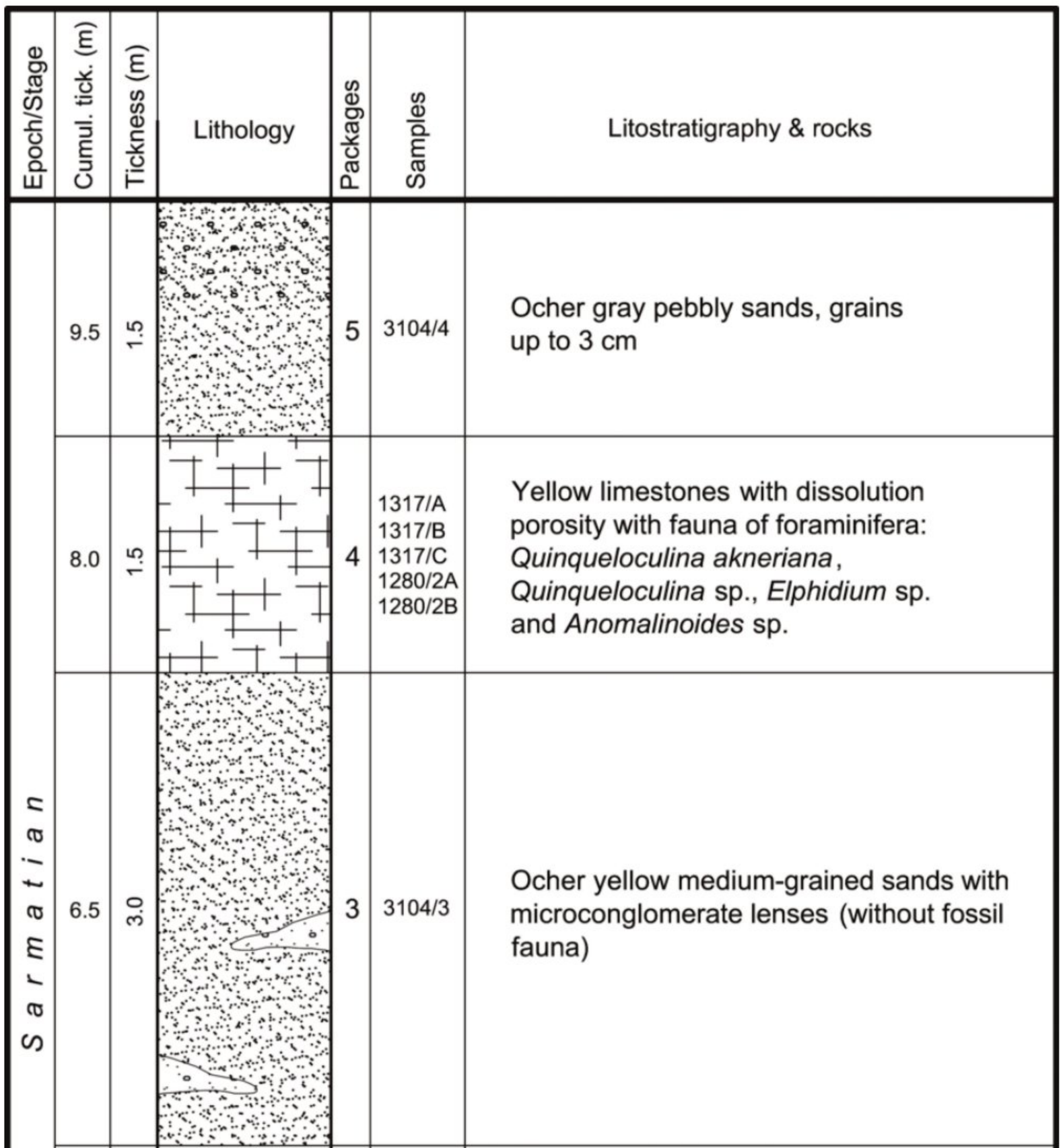

Fig. 7. *Sarmatian stratigraphic column of the vicinity of Bogava and the Kamenovo Formation.*

During the Sarmatian (Late Seravallian) the Paratethys represented a palaeobiogeographically uniform entity, based on the occurrence of similar fossil assemblages from the Vienna Basin to the Caspian Basin (e.g., Rögl, 1998; Harzhauser & Piller, 2007; Piller & Harzhauser, 2023). The Central

Paratethys, during the Sarmatian, was generally interpreted as transition from the marine Badenian sea to the temperate-freshwater environments of Lake Pannon (e.g., Harzhauser et al., 2007; Magyar & Geary, 2012).). Stable bottom-water temperatures (~ 15 °C) and variable salinities (20–32 ‰) are estimated for the Early Sarmatian Sea (Tóthet al., 2010).

In this fossile assemblage, the distribution of the foraminifera is represented by the miliolids group. Miliolids are characteristic for high salinity and shallow environments (Filipescu et al., 2014). *Cytheria hungarica* is species characteristic of brackish to normal marine paleoenvironments (Filipescu et al., 2014).

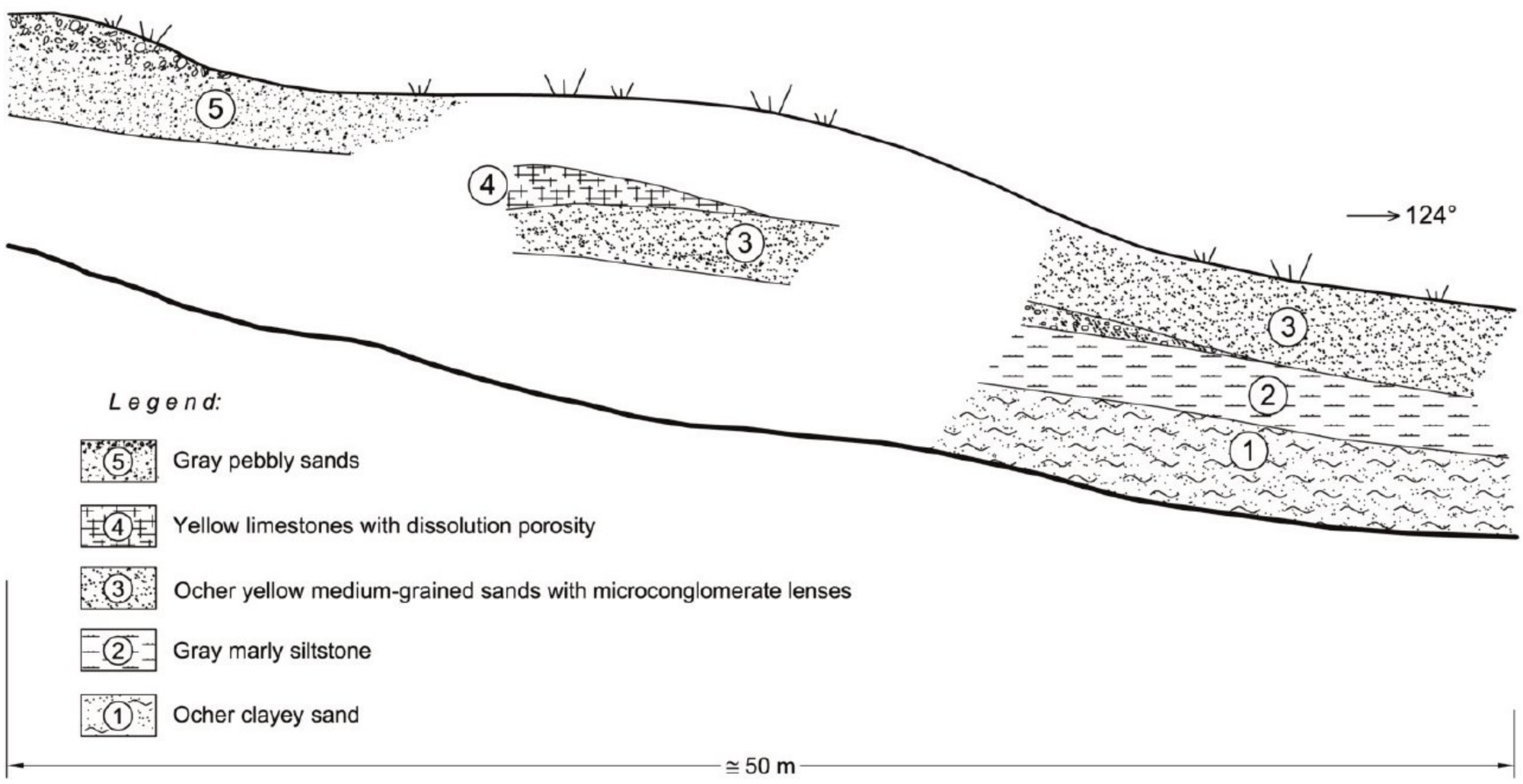

Fig. 8. *Schematic geological sketch of Sarmatian sediments near the settlement of Bogava (point 1280).*

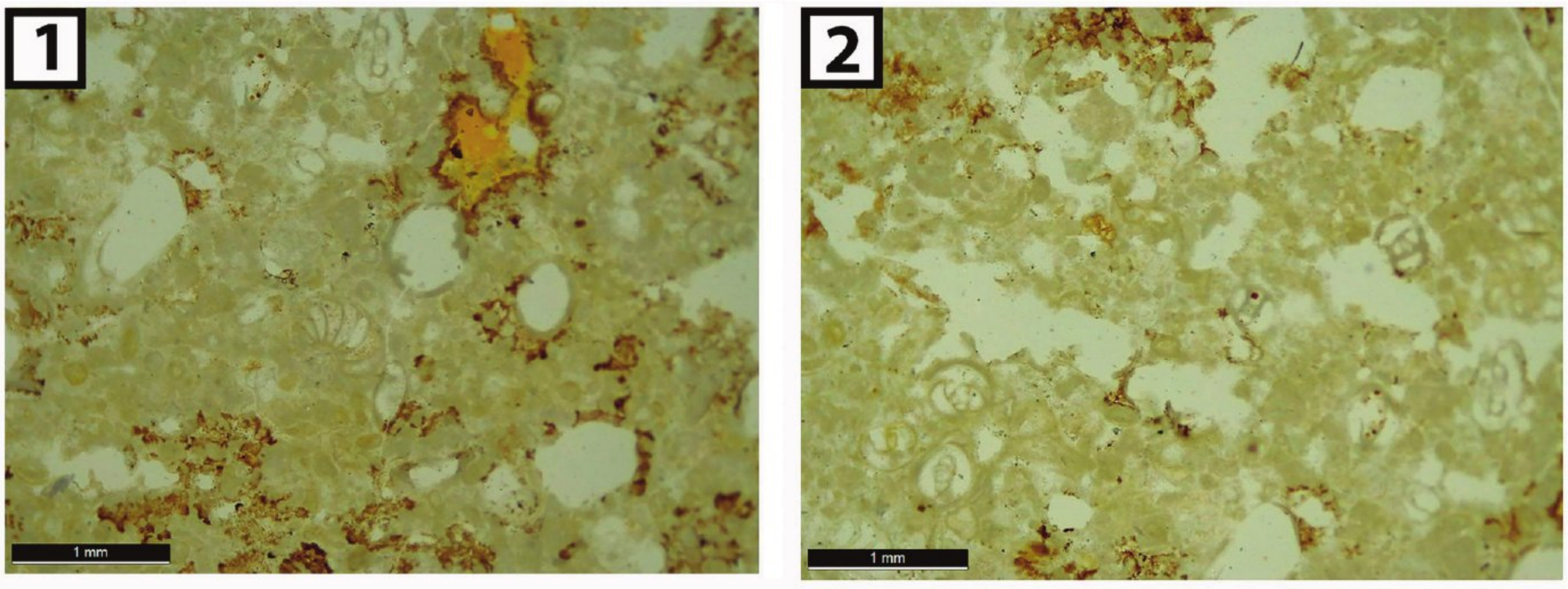

Fig. 9. *Sarmatian yellow sucrosic limestone from point 1280 with representative foraminifera association:* ***1****) mainly represented by elphidiids and* ***2****) species of the genus Quinqueloculina.*

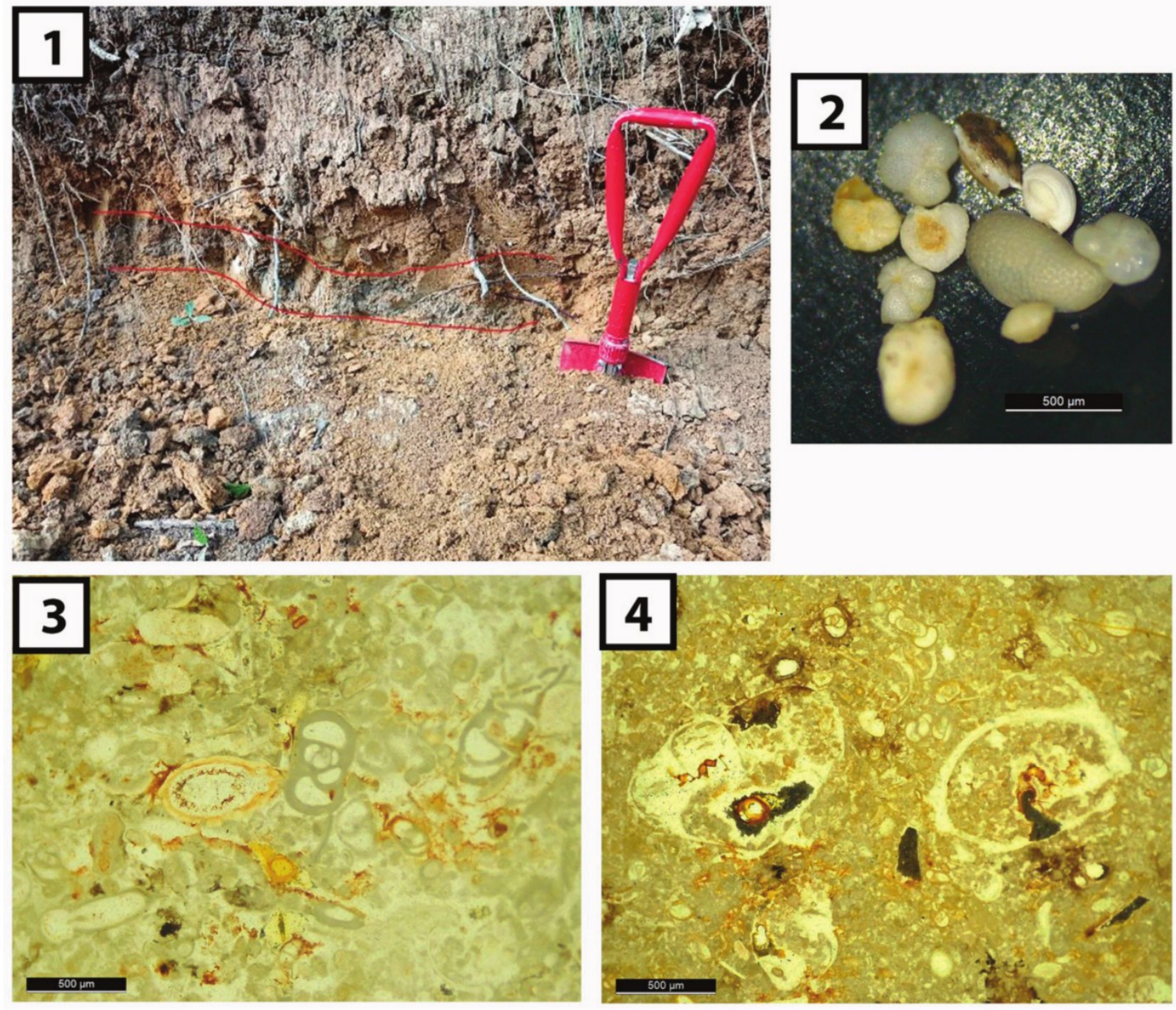

Fig. 10. *Sarmatian gray-yellow argillaceous siltstone (marked with red lines,* ***1****), with extracted microfauna of foraminifera and ostracods (Quinqueloculina akneriana* D'ORBIGNY, *Anomalinoides dividens* LUCZKOWSKA, *Cytheridea hungarica* (ZALANYI) *etc.,* ***2****); and thin-sections from Sarmatian yellow limestone with cross sections of foraminifera (****3****,* ***4****) and microgastropods (****4****).*

Overview and correlations studied area with type localities of Formations

The Golubac Formation is described for the first time in the vicinity of Golubac, with the type locality on the right bank of the Danube (sheet Kučevo). The formation is late Badenian and transgressively overlain Paleozoic formations, Permian sandstones and the Lower Miocene Vuković Formation. It is overlain by the Kamenovo Formation. The Golubac Formation in the type locality is mostly composed of sand, siltstone and sandy siltstone, sandstone and limestone, conglomerate and clay (BOJIĆ & TANASKOVIĆ, 2003; BLAGOJEVIĆ, 2020). The Golubac Formation is characterized by a rich fauna of gastropods and bivalves: *Potamides disjunctus* (SOWERBY), *Potamides melanopsiformis* AUINGER, *Naticarius stercusmuscarum* (GMELIN), *Lautoconus ponderosus* (BROCCHI), *Amalda glandiformis* (LAMARCK), *Athleta rarispina* (LAMARCK), *Nassarius dujardini*, *Perrona* sp., *Clavatulla interrupta (*BROCCHI), *Clavatula sophiae* (HOERNES & AUINGER),

Variocorbula gibba (Olivi), *Anadara diluvii* (Lamarck), *Lucina columbella* Lamarck, *Acanthocardia paucicostata* (Sowerby), *Cardites partschi* (Münster), *Venus nux* Gmelin, *Circomphalus subplicatus* (d'Orbigny), *Anadara turonica* (Dujardin), *Corbula carinata* Dujardin, *Paroxystele orientalis* (Cossmann & Peyrot) and also oysters, echinids, corals and others (Bojić & Tanasković, 2003; Blagojević, 2020). Foraminifera include *Ammonia beccarii, Elphidium crispum, Biasterigina planorbis, Borelis melo, B. haueri, Globulina punctata, G. rugosa, G. gibba* and other. A relatively rich and diverse palynological association, characterized by the dominance of conifers, was found in the clayey siltstones of Golubac Formation (Bojić & Tanasković, 2003; Blagojević, 2020). Sedimentation took place in shallow coastal areas (lithoral and sublithoral) of relatively warm seas. The occurrence of limestone facies and fossils of corals and oysters indicates shorter periods of lagoonal-reef character (Bojić & Tanasković, 2003; Blagojević, 2020). Based on this overview of the type locality and the correlation of these data with the previous data from the study area, it was concluded that sedimentary conditions, type of sediments and fossil fauna correspond to Golubac Formation.

The type locality of the Kamenovo Formation is located in the south-eastern region of Požarevac and is recognized on the geological sheets of Kučevo, Veliko Gradište 3 and Požarevac 3. The Kamenovo Formation is Sarmatian age and concordantly overlain the Golubac Formation, and its hanging wall are the Kličevac Formation, the Stig Formation made of marl and deluvial sediments. Based on the lithological and paleontological evaluation of the Kamenovo Formation, it is possible to distinguish clayey-sandy and sandstone-limestone parts. The clayey-sandy part forms the lower parts of the formation and consists of gray and blue sandy clays alternating with silty clays, siltstones, silty sands, sands, marls and sandstones (Bojić & Tanasković, 2003; Blagojević, 2020). The higher parts of the section are composed of sandstones alternating with thinner layers of argillaceous-carbonate sand, sandy clay and limestone. The limestones are organogenic, oolitic, sandy, and biosparitic. In the lower part of the formation, a community of forminifera and ostracods was observed in the sandy siltstones in the village of Trnovče: *Elphidium reginum, Poronosonion granosum, Miocyprideis sarmatica, Hemycitheria hungarica* (Bojić & Tanasković, 2003; Blagojević, 2020) indicating a Sarmatian age. Numerous foraminifera were found in the biosparitic limestones of the village of Kamenovo, represented mostly by elphiids, and *Porosononion granosum*. Apart from foraminifera, ostracod species characteristic of Sarmatian age are also present (Bojić & Tanasković, 2003; Blagojević, 2020). Accordingly, we can conclude from the data shown in this section and the data from the studied area that the same conditions prevailed during sedimentation at the type locality and in the studied area. This is confirmed by the preserved fossil fauna, which is characteristic of the brackish environment in the early Sarmatian.

Conclusions

We recognized these two formations in the Despotovac area based on the correlation of the sediments studied with the sediments from the type localities. In these investigations we have found that the types of sedimentary environments and the corresponding fossil assemblages are characteristic of the Upper Badenian age. The studied Badenian sediments correlate well with the Badenian sediments from the type locality near Golubac and both belong to the Golubac Formation. The micropaleontological assemblages indicate that the paleoenvironment is mainly marginal to shallow marine, with a marine environment of normal salinity.

The studied Sarmatian sediments correspond to the upper part of the Kamenovo Formation or only its higher sequence, which is characterized by a development of sandstone and limestone. Early Sarmatian Sea (Tóthet al., 2010) is characterized by a stable bottom-water temperature (~ 15 °C) and variable salinity (20–32‰). The Fossil assemblage from studied area represents a paleoenvironment that corresponds to Early Sarmatian Sea conditions.

The sedimentary processes and microfossil assemblages of the investigated area match the conditions in the regional province of the Central Paratethys during the Middle Miocene.

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Резиме

Стратиграфске импликације средњег миоцена околине Деспотовца: издвајање две нове формације

У раду су представљени резултати теренских истраживања седимената средњег миоцена, реализованих у оквиру пројекта израде Основне геолошке карте 1:50 000, лист Лапово 4, под покровитељством Геолошког завода Србије. Истраживања миоцена на подручју Деспотовца, имају за циљ да пруже увид у стратиграфске односе на истраживаном подручју, као и да се прикажу и документују новоиздвојене средњомиоценске формације.

У геотектонском погледу истраживани простор захвата источни део моравског рова, који представља део Панонског басена са развијеним неогеним творевинама, различитог литолошког састава и добрим делом тектонски поремећене. Ове просторе карактерише и развој угљоносне продуктивне серије. На основу теренских истраживања и анализе прикупљених узорака, издвојене су две формације: Формација Голубац (баден) и Формација Каменово (сармат).

На истраживаном подручју седименти бадена су проучавани на две локације. Први локалитет се налази у крајњем северозападном делу истраживаног простора,у близини насељеног места Везичево, у потоку Црвенац. Откривени седименти баденске старости представљени су масивним песковитим кречњацима са пратећом богатом фауном у смени са слабовезаним песковима. Издвојена фауна припада типичној морској фауни и указује на плитководну средину литорала до сублиторала. Богату фосилну фауну представљају различити плиткоморски организми као што су ехиниди, корали, бентоске фораминифере, остракоди, шкољке и пужеви. Присуство коралских заједница нам сведочи о топлој, прозрачној воденој средини, богатој кисеоником. На основу услова седиментације, стратиграфског положаја и литолошког састава ове баденске творевине могу се корелисати са Формацијом Голупца која је издвојена ранијим истраживањем на подручју северно од листа Лапово 4, у подручју

насељеног места Голубац (Bojić & Tanasković, 2003; Blagojević, 2020). Проучени профили сарматске старости се налазе уз поток Стара Богава, у близини насељеног места Богава. Профил карактерише смена глиновито алевритичних седимената и слабо везаних пескова различите гранулације. Више делове профила карактеришу жути шупљикави кречњаци, у чијој повлати се уочавају шљунковито песковити седименти. Сарматска старост седимената је потврђена на локалитетима 1280 и 1317 и ове сарматске творевине се могу корелисати са Формацијом Каменова која је издвојена ранијим истраживањима на подручју северно од листа Лапово 4 у подручју насељеног места Каменово (Bojić & Tanasković, 2003; Blagojević, 2020). На основу корелације проучаваних седимената и седимената са типских локалитета издвојили смо две формације на подручју Деспотовца. Током ових истраживања утврдили смо да литолошки чланови и присутна фосилна асоцијација одговарају развоју на типским локалитетима, те приказани баденски седименти одговарају баденским седиментима типског локалитета Голубачке формације. Сарматски седименти анализирани у овом раду одговарају горњем делу формације Каменово, односно пешчарско-кречњачком развићу.

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