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Paleontological and biostratigraphical characteristics of the Badenian deposits on the Srebrenik-Donja Orahovica profile (Bosnia and Herzegovina)

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Abstract

This paper describes the biostratigraphic and paleontological research conducted on the geological section of Srebrenik-Donja Orahovica (Northern Bosnia and Herzegovina). The samples for micropaleontological research were taken from the exploration works (eight wells and nine excavations). Based on the presence of microforaminifera, the stratigraphic level of Lower Badenian was defined. According to micropaleontological and biostratigraphic analyses within this stratigraphic level, one local foraminiferal zone was identified: zone with *Trilobatus trilobus* and *Orbulina suturalis* which represents the upper parts of the Lower Badenian. This zone is characterized by a rich microfossil community with a dominance of planktonic forms over benthic ones, normal salinity, warm sea, and basic character of the environment.

Keywords:

Foraminifera; biostratigraphy; Lower Badenian; Bosnia and Herzegovina

1. Introduction

Marine Miocene sediments in Bosnia and Herzegovina are present only in the area of northern Bosnia, which in the Miocene represented the southern rim of the Central Paratethys (see **Figure 1**). In many parts, these sediments are covered with younger deposits so data on lithofacial and biofacial features are lacking. For these reasons, an insufficient number of paleogeographic analyses of Miocene sediments have been performed. A significant contribution to the knowledge of facial, biostratigraphic, tectonic and other features of marine Miocene sediments in Bosnia and Herzegovina has been made by numerous researchers: **Katzer, 1903; Stevanović and Eremija 1960; Soklić, 1964, 1982, 1988, 2001; Soklić and Vrabac, 1995; Čičić, 1964, 2002; Čičić and Jovanović, 1987; Kranjec, 1969; Eremia, 1970; Atanacković, 1977, 1981; Stojčić et al., 1978; Petrović, 1979/80; Pantić et al., 1988; Petrović et al., 1990; Vrabac, 1986, 1987, 1989, 1991, 1999, 2005, 2007; Vrabac and Mihajlović, 1990; Vrabac and Ferhatbegović, 1997; Vrabac et al., 2000; Vrabac et al., 2005; Vrabac and Ćorić, 2008; Vrabac et al., 2008; Vrabac et al., 2013; Cicha et al., 1998; Pantić et al., 1988; Ferhatbegović, 2001, 2003, 2004, 2006, 2010, 2018; Ferhatbegović and Vrabac, 2006; Ferhatbegović and Jahić, 2013; Ferhatbegović et al., 2013; Ćorić et al., 2007; Rupp and Hohenegger, 2008; Đulović et al., 2010**.

According to the Basic Geological map of former Yugoslavia in scale 1:100 000, sheet Doboj (**Laušević and Jovanović, 1983**) Middle Miocene sediments have a large distribution and are represented by typical marine sediments. In the examined area, Middle Miocene sediments are characterized by significant lithological diversity, which is probably due to the fragmented paleorelief and coastal sedimentation regime (**Vrabac et al., 2007**). Badenian in northern Bosnia is characterized by significant paleogeographic changes (coastal disintegration and bottom relief, mostly normal salinity, favorable gas regime, water temperature identical to tropical to subtropical seas, shallow sea, etc.) (**Pantić et al., 1988; Vrabac et al., 2007**). The fossil faunal association is characterized by numerous microfauna and pteropods. At the lowest level are mostly numerous planktonic foraminifera where globigerinoid and orbitolinoid taxa are the most abundant. They are typical for the Lower Badenian foraminiferal zone *Trilobatus trilobus* and *Orbitolina suturalis*. Benthic forms are represented by buliminas and uvigerinas. In addition to numerous pteropods, there are also mollusks: Pycnodonta cochlear, Chenopus pespelicani, Tellina ottnangensis, Conus sp., and others.

The geological profile Srebrenik - Donja Orahovica (see **Figure 2**) represents an insufficiently known area, especially from a micropaleontological point of view. According to the current information, Badenian and Sar-

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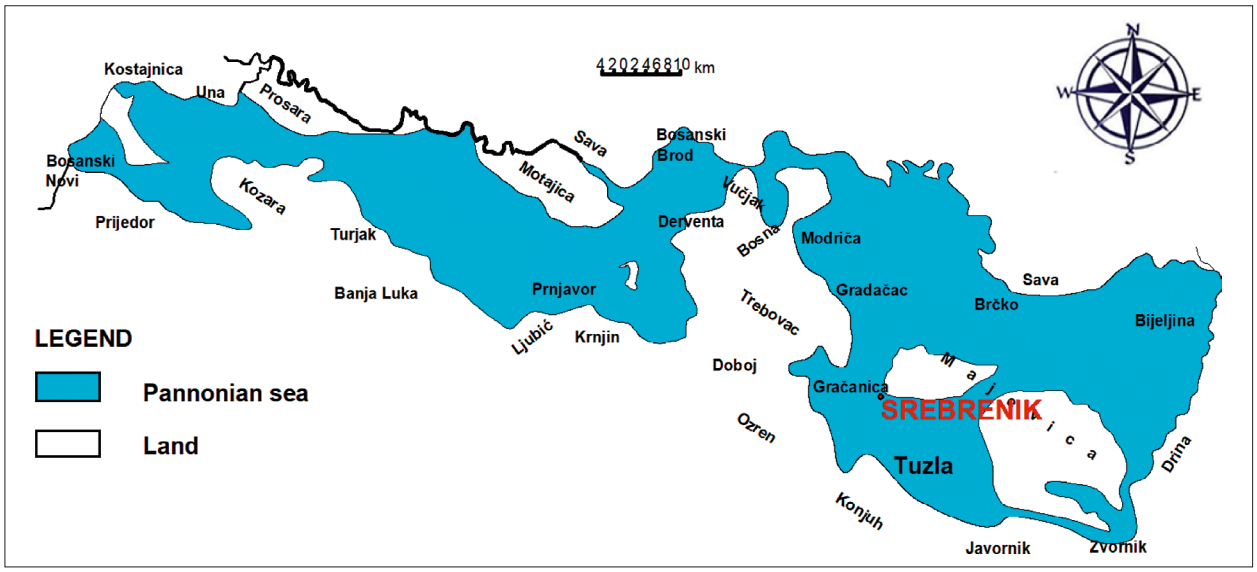

Figure 1: Paleogeographic map of northern Bosnia in the Badenian (**Vrabac et al., 2007**)

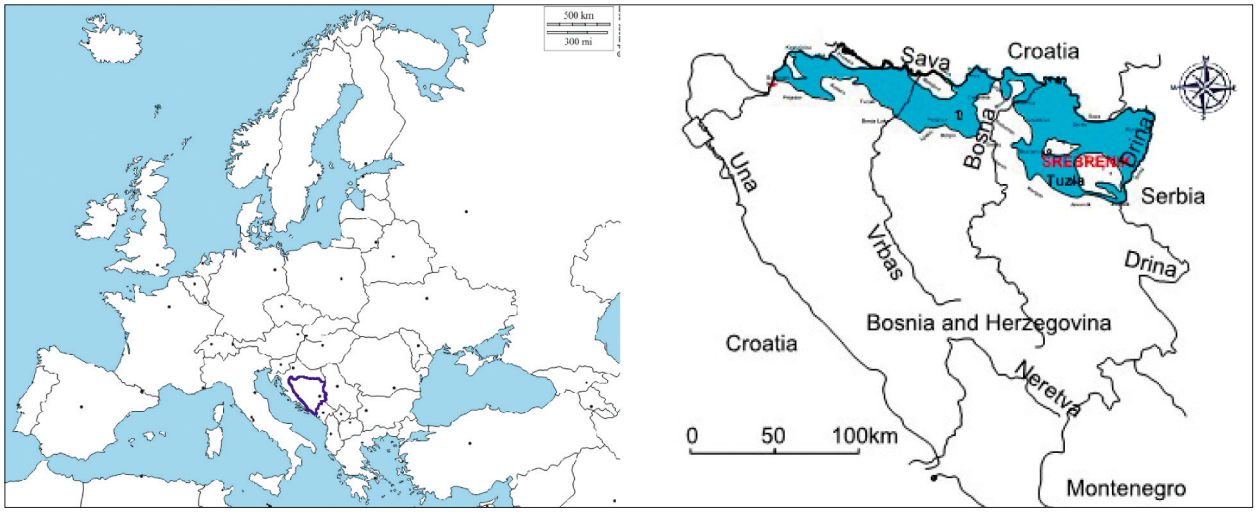

Figure 2: Geographic position of the research area (Srebrenik)

Figure 3: Very rare rock outcrops (a) and geological mapping (b) along the section Srebrenik-Donja Orahovica

matian sediments are present on the Srebrenik - Donja Orahovica exploration profile. The research aims to determine the detailed geological structure of the terrain and paleontological and biostratigraphic characteristics along with the considered profile. The lithological composition, paleontological and biostratigraphic character-

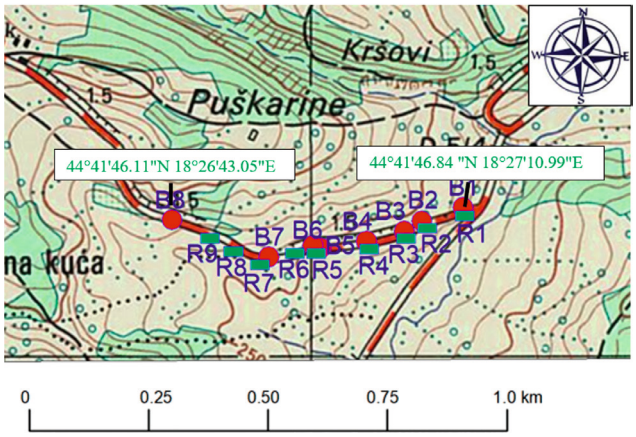

Figure 4: Position of sampling points (topographic map of Sladna sheet 1:25000)
red spots: boreholes, green rectangles: excavations

istics of this area were the main issues to be addressed, based on the data collected during the research. The research was performed using geological mapping, laboratory, and cabinet methods. Micropaleontological analyses were performed to assess the presence of foraminifera in certain stratigraphic levels and more accurately define the boundaries of different biostratigraphic units.

2. Materials and Methods

The research methodology is based on geological mapping (see **Figure 3**) and laboratory and cabinet research. The research aimed to define the biostratigraphic characteristics of sediments on the profile Srebrenik-Donja Orahovica. It is 24.63 km NW of Tuzla city and 3.25 km SW of Srebrenik. Sampling along the road Sre-

Figure 5: Exploration boreholes B-1, B-2 and B-3

Figure 6: Exploration excavations R-2, R-3 and R-4

brenik-Donja Orahovica took place during 2019 and 2020 and was performed between 44°41'46.84 "N 18°27'10.99"E and 44°41'46.11"N 18°26'43.05"E over the length of 900 meters (see **Figure 4**).

The terrain is quite covered with soil and vegetation with very rare rock outcrops along the examined section. The study of microforaminifera was performed on 12 samples (see **Figures 5-11)** that were taken from investigative boreholes and excavations (B-boreholes., R-excavations). The coordinates of sampling points are shown in **Table 1**.

The samples after the collection were packed in special bags and marked. After that, they were wet-sieved at the Faculty of Mining, Geology, and Civil Engineering in Tuzla, using laboratory sieves with a diameter of 0.8, 0.5, 0.25, and 0.15mm (see **Figure 12**). The sieve fraction of 0.15 mm was dried and analyzed using a Leica EZ4D stereomicroscope. For each sample with the association of microforaminifera, a photograph was taken using a digital camera built into the microscope.

2.1. Methods for the micropaleontological examination

Micropaleontology has become especially important in petroleum engineering. During this study, rock particles up to 1 cm in size were caught in a sieve. The same amount of sample was taken from each piece (the weight of the piece is 6 grams). Samples were washed with tap water, dried, labeled, and stored in bags. For micropaleontological research, the method of wet – sieving was applied, whereby the clay rocks were immersed in water with the addition of baking soda or a 15% hydrogen peroxide solution. Glauber's salt was applied to compact marls. After

Figure 7: Exploration excavations R-5, R-6 and R-7

rinsing with a jet of water (see **Figure 13**) on sieves with openings of 0.8, 0.5, 0.25, and 0.15mm, the microfossil material remains, which is then dried and examined under a binocular Leica EZ4D microscope. Foraminifera were determined according to **Cicha et al.** (**1998**).

3. Results

Microscopic determination of foraminifera was performed using a Leica EZ4D microscope with the appropriate software package (see **Figure 14**). Separate samples were carefully analyzed in detail and all fossils were extracted from them. Based on the association of fossils in individual samples, the stratigraphic level was defined. All fossil names were checked by relevant bases (World Register of Marine Species) and revised. **Table 2** shows sampling points and samples and **Table 3** shows the determination of fossils in individual samples. Some species of foraminifera are shown in the **Figure 15.**

Figure 8: Exploration excavations R-8 and R-9

Table 1: Coordinates of sampling points

Marking boreholes and excavations	Gauss-Krieger coordinates		Geographic coordinates	
	x	y	latitude	longitude
B-1	4950309	6536310	44°41’46.84”N	18°27’10.99”E
B-2	4950281	6536226	44°41’45.95”N	18°27’7.17”E
B-3	4950262	6536189	44°41’45.34”N	18°27’5.49”E
B-4	4950241	6536110	44°41’44.68”N	18°27’1.89”E
B-5	4950224	6536044	44°41’44.14”N	18°26’58.89”E
B-6	4950228	6535997	44°41’44.28”N	18°26’56.76”E
B-7	4950206	6535900	44°41’43.58”N	18°26’52.35”E
B-8	4950283	6535695	44°41’46.11”N	18°26’43.05”E
R-1	4950303	6536313	44°41’46.65”N	18°27’11.13”E
R-2	4950270	6536234	44°41’45.59”N	18°27’7.53”E
R-3	4950252	6536193	44°41’45.02”N	18°27’5.67”E
R-4	4950233	6536110	44°41’44.42”N	18°27’1.89”E
R-5	4950222	6536035	44°41’44.07”N	18°26’58.48”E
R-6	4950213	6535973	44°41’43.79”N	18°26’55.66”E
R-7	4950198	6535897	44°41’43.32”N	18°26’52.21”E
R-8	4950223	6535830	44°41’44.14”N	18°26’49.17”E
R-9	4950262	6535784	44°41’45.42”N	18°26’47.09”E

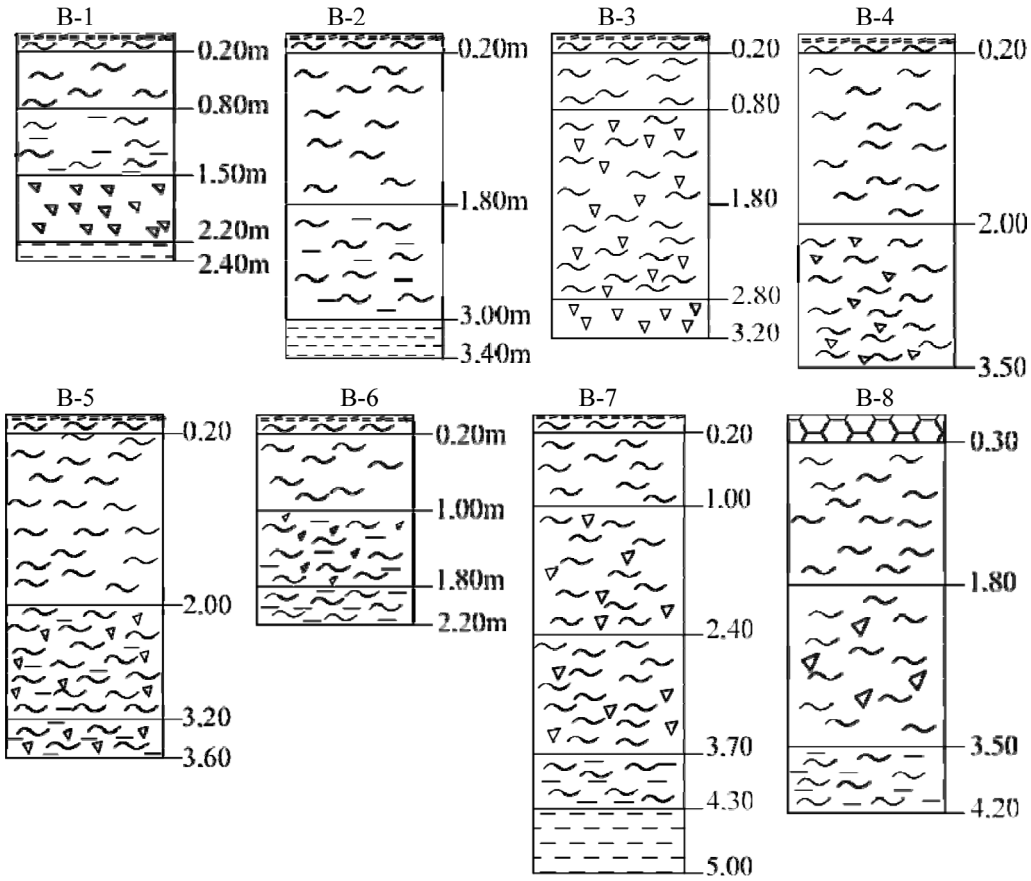

Figure 9: Exploration boreholes profiles in the research area

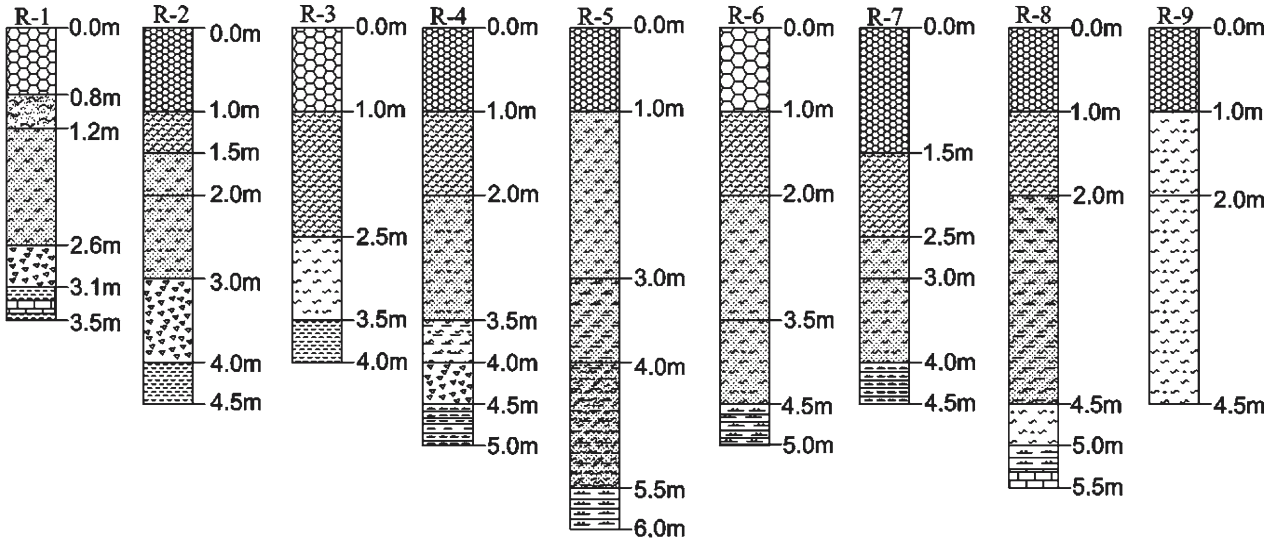

Figure 10: Exploration excavations profiles in the research area

4. Discussion

In Bosnia and Herzegovina, marine Miocene deposits are present in northern Bosnia and are covered with younger deposits, an aggravating circumstance for performing paleogeographic reconstructions. In addition, data on the lithofacial and biofacial characteristics of the Miocene sediments are not available in the parts where these sediments are covered leaving many questions unresolved. Geological characteristics have been studied in detail on numerous outcrops of the Miocene sediments, while a very small number of published papers present paleogeographic reconstructions or sedimentological analyses. A detailed analysis of the sedimentation conditions of the Badenian and Sarmatian facies of northern Bosnia was performed by **Vrabac, S. (1989)**. Geological

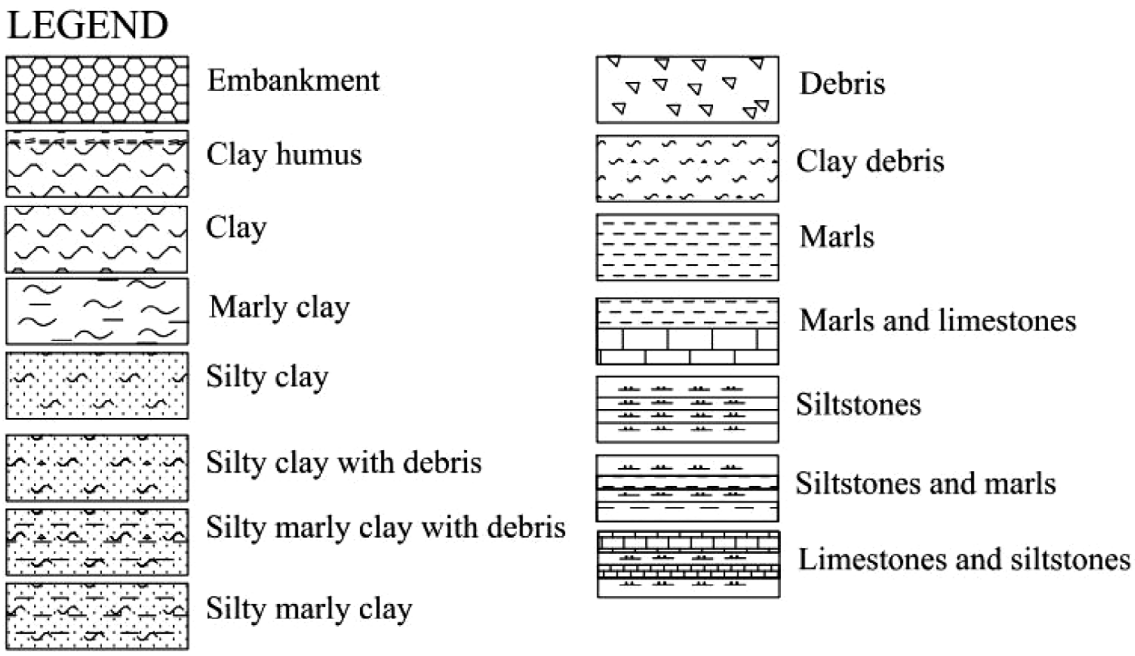

Figure 11: Legend for exploration boreholes and excavations

Figure 12: Laboratory at the Faculty of Mining, Geology, and Civil Engineering in Tuzla, with sample probes (a) and sample drying accessories (b).

mapping of the exploration works determined the sediments that are present on this terrain profile. Lithological members are represented by siltstones, marls, and limestones. Based on the presence of microforaminifera in analyzed samples, the stratigraphic level of Lower Badenian was defined. Within this stratigraphic level, only one zone has been identified: *Trilobatus trilobus* and *Orbulina suturalis* representing the upper part of the Lower Badenian. This zone was previously isolated in the Lower Badenian sediments of the Ugljevik area (**Petrović et al., 1990; Vrabac & Mihajlović, 1990**) and the Tuzla Basin (**Petrović et al., 1990; Vrabac & Ćorić, 2008; Ferhatbegović, 2013**). The site is characterized by a rich microfossil community in which planktonic forms dominate, while benthic forms are present to a lesser extent. *Trilobatus trilobus, Orbulina suturalis*, and *Globigerina bulloides* appear as dominant and leading fossils. The Lower Badenian sediments of this area correspond in age to the Lagenid zone of the Vienna Basin. Based on the rich and diverse microfossil community, it can be concluded *that the gas regime was favorable and that the water temperature was warm*. The warm-loving foraminifera *Trilobatus trilobus*, *Orbulina suturalis*, *Globigerinella*, etc. (**Rupp & Hohenegger,**

Figure 13: Preparation of samples (a), sample rinsing (b) and dried samples (c).

Table 2: Sampling points and samples

B-boreholes, R-excavations	Samples
R1	1
B1	1a
R3	3
B3	3a
R4	4
B4	4a
R5	5
B5	5a
R6	6
B6	6a
R7	7
B7	7a

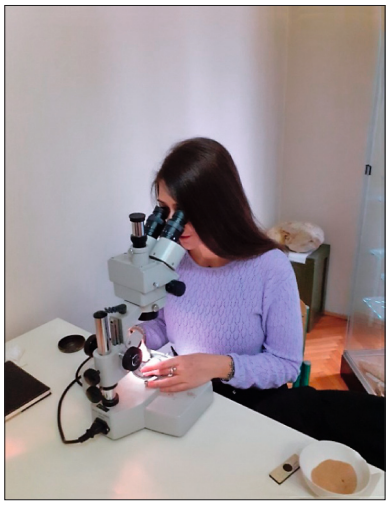

Figure 14: Leica EZ4D microscope

Table 3: Representation of microfossils in samples

Lower Badenian-zone Trilobatus trilobus and Orbulina suturalis												
Microfossils	**Samples**											
	1	1a	3	3a	4	4a	5	5a	6	6a	7	7a
Alfredosilvestris levinsoni Andersen, 1961					+	+						
Asterigerinata planorbis (d`Orbigny, 1846)					+	+					+	+
Bulimina elongata d`Orbigny, 1846			+	+	+	+					+	+
Cibicidoides ungerianus (d`Orbigny, 1846)							+	+			+	+
Dentoglobigerina altispira (Cushman & Jarvis, 1936)	+	+	+						+	+		
Elphidium crispum (Linnaeus, 1758)											+	+
Elphidium flexuosum (d`Orbigny, 1846)			+	+								
Globigerina bulloides d`Orbigny, 1826	+	+	+	+	+				+	+	+	+
Globigerina diplostoma Reuss, 1850					+	+						
Globigerinella regularis d`Orbigny, 1846			+	+	+	+	+	+				
Lobatula lobatula (Walker & Jacob, 1798)									+	+		
Nonion commune (d`Orbigny, 1846)		+							+	+		
Orbulina suturalis Brönimann, 1951			+	+								
Pyramidulina raphanistrum (Linnaeus, 1758)			+	+	+	+						
Trilobatus trilobus (Reuss,1850)	+	+	+	+	+	+	+	+	+	+	+	+

Figure 15: Some species of foraminifera from samples: a) *Trilobatus trilobus* (Reuss,1850); b) *Orbulina suturalis* Brönimann, 1951; c) *Nonion commune* (d` Orbigny, 1846); d) *Bulimina elongata* d`Orbigny, 1846; e) *Elphidium crispum* (Linnaeus, 1758); f) *Elphidium flexuosum* (d`Orbigny, 1846);g) *Pyramidulina raphanistrum* (Linnaeus, 1758); h) *Asterigerinata planorbis* (d`Orbigny, 1846); i) *Globigerinella regularis* d`Orbigny, 1846; j) *Dentoglobigerina altispira* (Cushman & Jarvis, 1936)

2008) and reef limestones indicate that the seawater was warm during the lower Badenian in the investigated area. The presence of a large number of echinoid remains, known as stenohaline organisms, indicates that the sea in this area in the Lower Badenian had normal salinity. Numerous planktonic foraminifera indicates the wide connection of this sedimentary basin with the open sea. Based on the number of planktonic forms with carbonate shells and the richness of oxygen, it can be concluded that the character of the environment was basic, not acidic.

5. Conclusions

Based on the performed geological, micropaleontological, and biostratigraphic analyses, it is proven that the Lower Badenian sediments are present along the whole research area. The Lower Badenian sediments are lithologically represented by grey and layered marls, limestones, and platy siltstones of a yellowish-brown to grey colour. Based on index microfossils, one local foraminiferal zone has been determined: zone with *Trilobatus trilobus* and *Orbulina suturalis,* representing the upper part of the Lower Badenian. *Trilobatus trilobus* (REUSS), *Orbulina suturalis* Brönimann and *Globigerina bulloides* d`Orbigny appear as dominant and leading fossils. Some other planktonic taxa e.g. *Globigerinella regularis* (d'Orbigny), *Globigerina diplostoma* Reuss, *Dentoglobigerina altispira* (Cushman & Jarvis), also occur in the samples. Benthic forms are scarce and are mainly represented by the genera *Bulimina*, *Nonion,* and *Cibicidoides*. Analysis and synthesis of data obtained from this study will be the foundation for preparing detailed geological maps, paleogeographic reconstructions, structural-tectonic analyses, and other specialistic studies.

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SAŽETAK

Paleontološke i biostratigrafske karakteristike badenskih naslaga na profilu Srebrenik – Donja Orahovica (Bosna i Hercegovina)

U radu su opisana biostratigrafska i paleontološka istraživanja provedena na geološkome profilu Srebrenik – Donja Orahovica. Za istraženo područje, koje je geološki detaljno kartirano, napravljeno je osam istražnih bušotina i devet istražnih raskopa. Uzorci za mikropaleontološka istraživanja uzeti su iz spomenutih istraživačkih radova. Geološko kartiranje terena, kartiranje jezgre istražnih bušotina i raskopa te podatci dobiveni laboratorijskim istraživanjima uzoraka (paleontološka istraživanja) poslužili su kao osnova za izradu geoloških profila i geoloških karata. Mikroskopsko određivanje foraminifera izvedeno je s pomoću Leica EZ4D mikroskopa s odgovarajućim programskim paketom. Na temelju prisutnosti mikroforaminifera definiran je stratigrafski nivo donji baden. Prema mikropaleontološkim i biostratigrafskim analizama unutar ovoga stratigrafskog nivoa određena je jedna lokalna foraminiferska *Trilobatus trilobus* i *Orbulina suturalis* zona koja predstavlja gornji dio donjega badena.

Ključne riječi:
foraminifere, biostratigrafija, donji baden, Bosna i Hercegovina

Author`s contribution

Zijad Ferhatbegović (Associate professor) was responsible for the research idea and planning, fieldwork, supervising micropaleontological analyses, interpretations, and presentation of the results. **Amila Avdić** (MA geology) conducted fieldwork, collected samples in the field, prepared and determined microfossils. **Sumeja Durmić** (MA geology) performed geological mapping, collected samples in the field, prepared and determined microfossils.