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PALEOECOLOGICAL SIGNIFICANCE OF BENTHIC FORAMINIFERAL FAUNA FROM THE OVČE POLE BASIN, REPUBLIC OF MACEDONIA

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A b s t r a c t: This paper presents paleoenvironmental interpretation of the Eocene beds in Ovče Pole basin in the NE part of the Republic of Macedonia on the basis of data obtained from research of foraminiferous associations. Foraminifera were obtained from 6 sections (79 samples) comprising the marly-clayey succession of Late Eocene age. We define and illustrate 10 morphological groups. Each group primarily reveals life-style and feeding strategy of foraminifera. The present article aims to expand the paleoenvironmental analysis by combining of the morphological features with inferred life-style and feeding strategy of the foraminifera. Comparison of our morphogroup system to modern and fossil ones is outlined accordingly. Generally, the investigated assemblages are slightly dominated by morphogroups characteristic for shallow (shelf) environment.

Key words: benthic foraminifera; morphogroups; paleoecology; Paleogene; Ovče Pole basin

INTRODUCTION

The history of the Earth in the Eocene has generated considerable interest in the past decade due to global changes in climate, passing from extreme greenhouse conditions during the early Eocene to icehouse cooling in the late Eocene (Zachos, 2001). The most extensively studied Eocene climatic event and its effect on biotic communities is the transient warming at the onset of the epoch known as the Paleocene Eocene Thermal Maximum (PETM) (Kennett and Stott, 1991; Thomas and Shackelton, 1996), and this drastic change in climate is reflected in sea biota, especially in the vulnerable planktonic foraminifera. Foraminiferal assemblages exhibited significant changes in response to the climatic fluctuations in the Eocene (Khanolkar and Saraswati, 2015).

These microfossils have been used as tools for paleoenvironmental analysis since the end of the 19th century when agglutinated foraminifera from the Carpathians were involved in the studies (Grzybowski, 1898), but the real initial steps in the elucidating of the paleoecological significance of foraminiferal test morphology are dated from the 60s, 70s and 80s of the 20th century (Bandy, 1960, 1964; Chamney, 1976; Severin,1983).

A great number of modern genera can be traced back to the Paleogene of the Tethys region. We can thus refer to the principles of taxonomic uniformitarianism to interpret palaeoenvironmental conditions that determined the composition of the ancient foraminiferal assemblage.

There is a relatively small amount of data regarding the paleoecology of fossil organisms from the Ovče Pole basin, on the territory of Macedonia. Only limited amount of paleontological investigations have been performed in this area. Macrofossil groups, such as anthozoa, gastropoda, bivalvia and echinoidea, have been studied and were the basis for several conclusions regarding the paleoecological conditions of the basin (Maksimović et al., 1954; Mitrović-Petrović et al., 1990). The high taxonomic diversity of the foraminiferal fauna in the Paleogene sediments in the Ovče Pole basin allowed us to do some further and more detailed palaeoecological investigations.

The present article thu saims to make paleoecological analysis based on data obtained from the study of taxonomical composition and structure of small benthic foraminiferal assemblages by combining morphological features with inferred lifestyle (epifaunal, shallow infaunal and deep infaunal) and feeding strategy (suspension-feeders, deposit feeders, herbivores, etc.) of the foraminifera.

GEOLOGICAL SETTING

The Ovče Pole Paleogene basin, located in the NE part of the territory of the Republic of Macedonia, structurally belongs to the Vardar zone (Figure 1). Vardar zone is an old structure (Arsovski et al., 1984) which was formed with crushing of the Grenvile Earth's crust in Riphean Cambrian. Until Triassic, Vardar zone is characterized with geosynclinals development, tended to thinning the Earth's crust. With rifting processes in the mediterranean part of Tethys, in Jurassic was formed narrow ocean, and in the Vardar zone was created ocean type of crust.

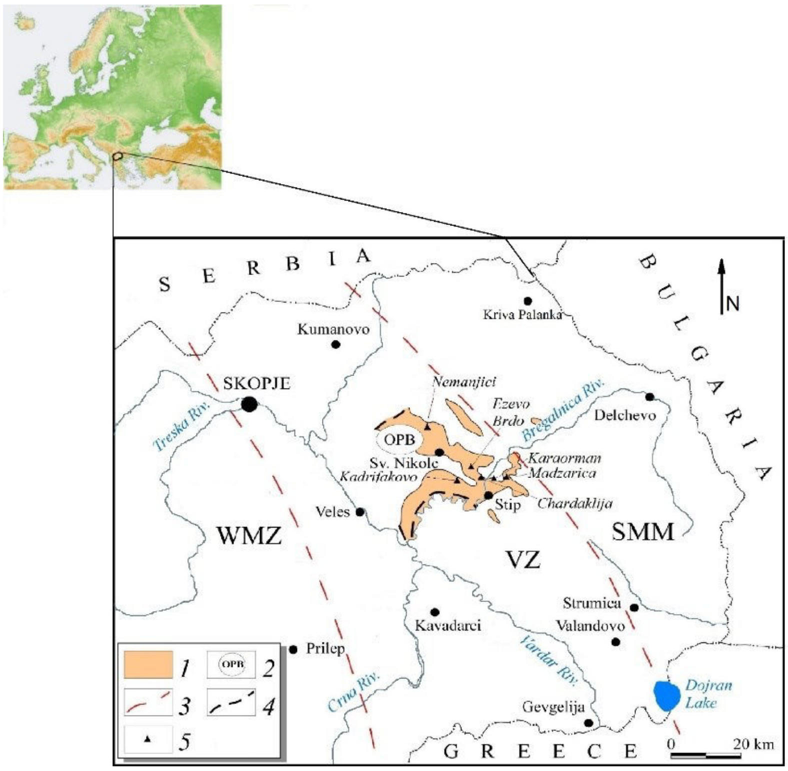

Fig. 1. Sketch of the location of the Ovče Pole basin in the Republic of Macedonia
1. Distribution of Paleogene sediments; 2. Ovče Pole Paleogene Basin (OPB), 3. Tectonic boundary: Serbian–Macedonian massif (SMM), Vardar zone (VZ), Western Macedonian zone (WMZ); 4. Basin boundary; 5. Studied sections

The Ovče Pole basin is a large Paleogene sedimentary mass with NW–SE trend that is superimposed on varied rocks from the eastern part of the Vardar zone in the territory of the Republic of Macedonia. Paleogene in the Ovče Pole basin is developed in flyschoid and flysch facies. It is composed of 3.5 km thick succession, which is subdivided into four units: basal unit, lower flysch unit, unit of yellow sandstones and upper flysch unit. Lithologic composition of basal lithozone is represented by conglomerates, sandstones, clays and carbonate layers (represented by limestones and marls). The lower border of the basal lithozone is transgressive, and the upper border is concordant, and it continuously passes into the lower flysch lithozone. Based on the lithological composition and the super positioning order the age of this lithozone is calculated as being Upper Eocene–Preabonian (Maksimovič et al., 1954). The lower flysch lithozone is represented by rhythmic occurrence and prevalence of sandstones over conglomerates and with rare interlayers of clays, marls and aleurolites. The lower border is concordant and it represents a gradational transition of basal lithozone into lower flysch lithozone. The upper border is concordant and sharp, and it stands out because of the characteristic yellow-brown colour of the sandstones covering the lower flysch lithozone. Lithologic composition of the lithozone of yellow sandstones is represented with sandstones with yellow-brown colour and thin interlayers of clays. The lower and upper border of the yellow sandstones lithozone is continuous and clear, which separates this unit from the lower and upper flysch lithozone. Lithologic composition of the upper flysch lithozone is represented with claymarly layers that rhythmically alternate with sandstones, siltstones, clays with marly clays and oolitic limestones. The lower border of the upper flysch lithozone is continuous, clear, outlined and separated from the yellow sandstone lithozone. The upper border of this lithozone is mostly covered with effusive rocks and younger sediment deposits, parts of which are uncovered and decomposed. The found and determined faunal material from gastropoda, bivalvia, anthozoa, foraminiferas and nanofossils confirms the Upper Eocene–Lower Oligocene age of these sedimentary layers (Maksimovič et al. 1954; Stojanova, 2008; Stojanova et al. 2011, 2012, 2013; Stojanova and Petrov, 2012, 2016).

MATERIALS AND METHODS

The foraminiferal fauna of the upper flysch unit was studied from six Paleogene sections: Čardaklija, Eževo Brdo, Karaorman, Kadrifakovo, Madžarica and Nemanjici (Stojanova, Petrov, 2016). 79 samples were taken and positive results were obtained for foraminiferal fauna. Technical work was carried out by using classical methods for the micropaleontological analysis. Samples are prepared by crushing into roughly five millimeter fragments. The crushed sample is then placed in a glass beaker and water. Next, the material is washed through a 0.10 mm (generally 0.50 mm, 0.25 mm and 0.10 mm) sieve untill the liquid coming through the sieve is clean (i.e. the clay fraction has been removed). The sample then be dried at a temperature of up to 100 °C. Washed, dried fossil samples can be picked from any a fine brush and a reflected light, binocular microscope, and upon which relative abundances of taxa were calculated. The most representative taxa were photographed using a Scanning Electron Microscope (JMS–5510–JEOL). Morphogroups were determined to on the basis of external test morphology (test shape) and the nature of test coiling (i.e. chamber addition), (Valchev and Stojanova, 2014). The paleoenvironmental interpretation is made on the basis of data obtained from the study of taxonomical composition, morphogroups, comparison with modern species belonging to the same genera and lithologic features of sediments.

RESULTS

Upper Eocene foraminiferal fauna is represented by 62 species, belonging to 32 genera and 23 families (Stojanova et al., 2016). Most of them are allready recorded and taxonomically described (Džuranov et al.,1999; Valchev et al., 2013 a, b). The majority of the species, i.e. 57, belong to benthic foraminifera (Džuranov et al., 1999; Stojanova et al., 2013; Valchev et al., 2013), and 5 species are planktonic (Juranov, in: Stojanova et al., 2013).

Morphogroups of benthic foraminifera

A morphogroup is an aggregation of forms with similar test morphology, independent of systematic relationships (Murray, 1973, 2006). On the basis of external test morphology (test shape) and the nature of test coiling (i.e. chamber addition) we have previously defined 11 foraminiferal morphogroups from the Paleogene sediments of the Republic of Macedonia (Valchev, Stojanova, 2016). While in the benthic foraminifers fauna of the Ovče Pole basin are defined 10 morphological groups (see Plates I–II). Additional data about their inferred lifestyle and feeding strategy (based on published data from modern and fossil assemblages, e.g. Jones, Charnock, 1985; Corliss, 1985, 1991; Corliss, Chen, 1988; Nagy et al., 1995; Reolid et al., 2008; Alperin et al., 2011; Murray et al., 2011, etc.) are given here.

1) ***Rounded trochospiral morphogroup (RT)***. It includes species with trochospiral mode of coiling and broadly rounded periphery (Plate I, 1): *Baggina subconica* (Terquem), *Valvulineria jacksonensis* Cushman, *Anomalinoides acutus* (Plummer), *Anomalinoides danicus* (Brotzen), and *Anomalinoides welleri* (Plummer). This morphogroup comprises

epifaunal active herbivores, detrivores, omnivores and bactrivores.

2) ***Plano-convex trochospiral morphogroup (PT)***. It is represented by forms with trochospiral tests, having flat umbilical side and narrowly rounded to sharp periphery (Plate I, 2–7): *Cibicides carinatus* (Terquem), *Cibicides lobatulus* (Walker and Jakobs), *Cibicides tallahatensis* Bandy, *Cibicides ungerianus* (d'Orbigny), *Cibicides* cf. *westi* Howe, *Cibicides* sp., *Gyroidinoides soldanii* (d'Orbigny), *Pararotalia audouini* (d'Orbigny), and *Pararotalia subinermis* Bhatia. The listed taxa are epifaunal grazing herbovores; primary weed fauna.

3) ***Biconvex trochospiral morphogroup (BT)***. It contains species with trochospiral mode of coiling and biconvex morphology, characterized by sharply angled to narrowly rounded periphery (Plate I, 8–10): *Trochammina deformis* Grzybowski, *Eponides minima* Cushman, *Eponides* sp., *Cibicidoides* sp., *Heterolepa dutemplei* (d'Orbigny), and *Heterolepa perlucida* (Nuttall). Epifaunal active herbivores, detrivores and omnivores are included here.

4) ***Milioline morphogroup (M)***. It consists of species with flattened tests, elliptical outline and milioline chamber arrangement (Plate I, 11–14): *Spiroloculina communis communis* Cushman et Todd, *Quinqueloculina juleana* d'Orbigny, *Quinqueloculina* sp., *Triloculina angularis* d'Orbigny, *Triloculina gibba* d'Orbigny, *Hauerina* sp., and *Pyrgo bulloides* (d'Orbigny). The representatives of this morphogroup are epifaunal active deposit-feeders, detrivores and herbivores.

5) ***Rounded planispiral morphogroup (RP)***. It includes compact tests with planispirally arranged chambers and broadly rounded periphery (Plate I, 15–17): *Nonion graniferum* (Terquem), *Nonionella winniana* Howe, *Mellonis affine* (Reuss), and *Pullenia quinqueloba* (Reuss). Shallow infaunal active deposit-feeders and detrivores are included in this morphotype.

6) ***Lenticular morphogroup (L).*** Species from this group display biconvex morphology with sharply angled or keeled periphery (Plate I, 18–19): *Lenticulina* cf. *wilcoxensis* (Cushman and Ponton), *Lenticulina yaguatensis* (Bermudez), and *Lenticulina* sp. This morphogroup is represented by epifaunal to deep infaunal (predominantly the latter), active deposit-feeders and grazing omnivores.

7) ***Tapered and cylindrical morphogroup (T/C).*** It is represented by forms with round, oval or triangular cross section, and parallel or subparallel sides (Plate II, 1–12). Rectilinear and straight uniserial, biserial and triserial tests are included in this morphogroup: *Marssonella indentanta* (Cushman et Jarvis), *Textularia bronniana* (d'Orbigny), *Textularia minuta* Terquem, *Nodosaria ewaldi* Reuss, *Nodosaria* sp., *Glandulina ovula* d'Orbigny, *Bulimina sculptilis* Cushman, *B. trigona* Terquem, *Fursenkoina dibollensis* (Cushman et Applin), *Caucasina eocaenica* Chalilov, *Caucasina tenebricosa* Pishvanova, *Siphonodosaria adolphina* (d'Orbigny), and *Chilostomelloides balkhanensis* (Dain and Chalilov). The morphogroup includes shallow to deep infaunal deposit-feeders, detrivores and bacterial scavengers.

8) ***Spherical morphogroup (S).*** It contains species with unilocular and inflated planispiral or trochospiral multilocular tests (Plate II, 13–15): *Saccammina placenta* (Grzybowski), *Lagena humifera* Bandy, *Lagena striata* (d'Orbigny), *Globulina gibba* d'Orbigny, *Guttulina irregularis* (d'Orbigny), and *Favulina hexagona* (Williamson). The foraminifera included here are shallow infaunal detrivores or deposit-feeders.

9) ***Flattened tapered morphogroup (FT).*** This group includes uniserial, biserial and palmate tests, with ovate to compressed in cross section, and parallel to subparallel sides (Plate II, 16–22). It is represented by *Spiroplectinella carinata* (d'Orbigny), *Spiroplectinella dentata* (Alth), *Bolivina* cf. *antegressa* Subbotina, *B.* cf. *cookei* Cushman, *gracilis* Cushman and Applin, *Bolivina nobilis* Hantken, *B. reticulata* Hantken, and *Bolivina scalprata* Schwager. This morphogroup is characterized by shallow infaunal detrivores and scavengers.

10) ***Heteromorphous morphogroup*** **(H)**. It includes forms showing two or more types of chamber arrangement (Plate II, 23): *Percultazonaria fragaria* (Gümbel). Shallow infaunal active deposit-feeders.

The morphogroups, described above, are not uniformly distributed in the studied area (Figure 2). Only two of them – milioline (M) and tapered and cylindrical (T/C), are presented in all sections, while the heteromorphous (H) (established in Nemanjici section only) group is the rarest ones. The other morphogroups were found in at least six sections. The greatest variety of test morphologies is observed in Nemanjici section, where 10 morphogroups were described. On the other hand, the Karaorman section has the lowest variety of test morphology (two morphogroups). The other studied sections contain between five and seven morphogroups.

Distribution of morphogroups within individual sections is shown in Figures 3–8.

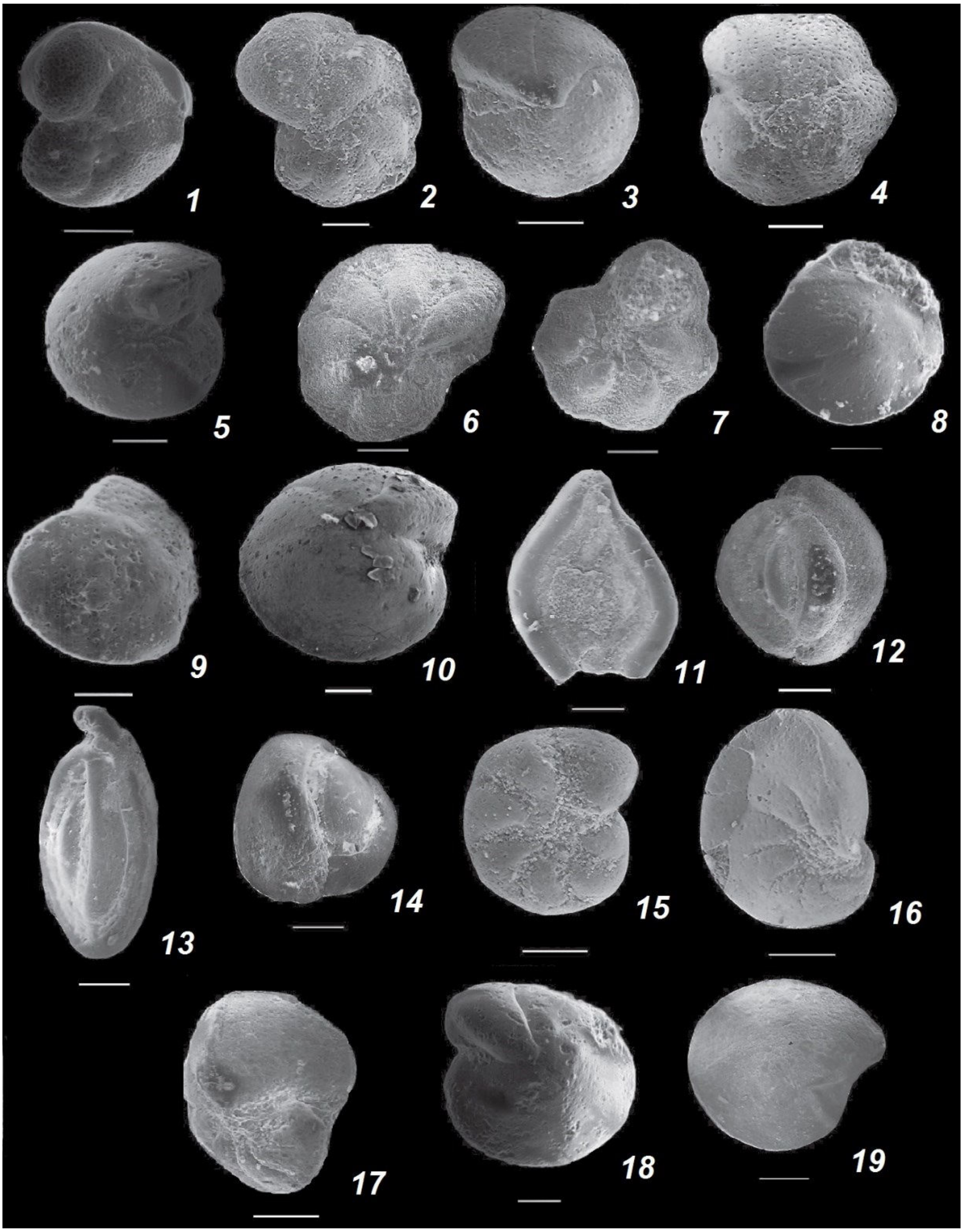

PLATE I: **Rounded trochospiral morphogroup (RT):** 1. *Anomalinoides danicus* (Brotzen): Nemanjici section, SEM×280. **Plano-convex trochospiral morphogroup (PT):** 2. *Cibicides carinatus* (Terquem): Čardaklija section, SEM×126. 3. *Cibicides tallahatensis* Bandy: Čardaklija section, SEM×143. 4. *Cibicides* cf. *westi* Howe: Čardaklija section, SEM×150. 5. *Gyroidinoides soldanii* (d'Orbigny, 1826): Madžarica section, SEM×220. 6. *Pararotalia audouini* (d'Orbigny): Čardaklija section, SEM×143. 7. *Pararotalia subinermis* Bhatia: Čardaklija section, SEM×203. **Biconvex trochospiral morphogroup (BT):** 8. *Eponides* sp.: Nemanjici section, SEM×200. 9, 10. *Cibicidoides* sp.: Nemanjici section, SEM×200. **Milioline morphogroup (M):** 11. *Spiroloculina communis communis* Cushman et Todd: Čardaklija section, SEM×137. 12. *Quinqueloculina* sp.: Čardaklija section, SEM×115. 13. *Quinqueloculina juleana* d'Orbigny: Čardaklija section, SEM×137. 14. *Triloculina gibba* d'Orbigny: Čardaklija section, SEM×150. **Rounded planispiral morphogroup (RP):** 15. *Nonion graniferum* (Terquem): Čardaklija section, SEM×287. 16, 17. *Nonionella winniana* Howe: Čardaklija section, 16, SEM×126; 17, SEM×203. **Lenticular morphogroup (L):** 18. *Lenticulina* cf. *wilcoxensis* (Cushman and Ponton): Kadrifakovo section, SEM×340. 19. *Lenticulina yaguatensis* (Bermudez): Čardaklija section, SEM×170.

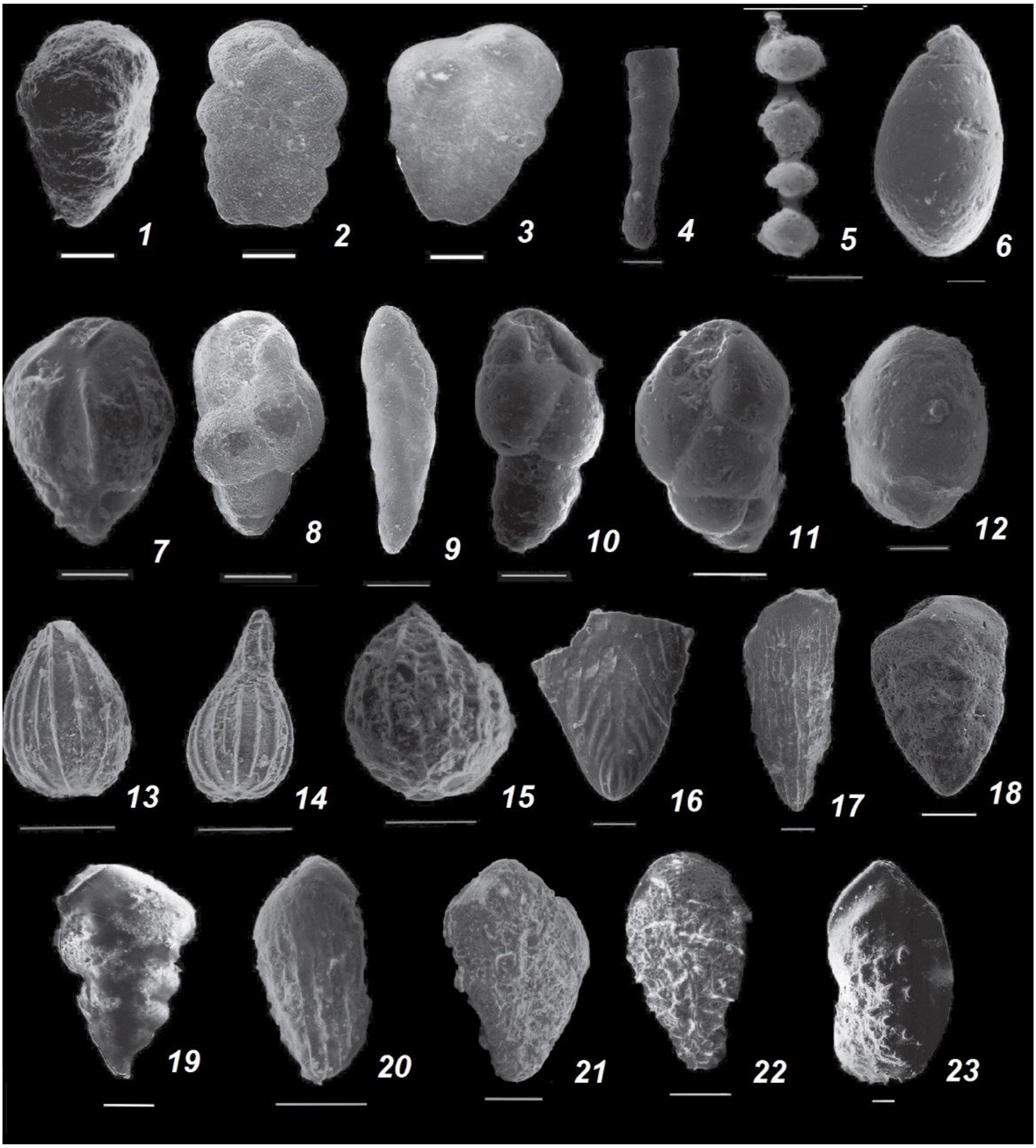

PLATE II: Tapered and cylindrical morphogroup (T/C): 1. *Marssonella indentanta* (Cushman et Jarvis): Nemanjici section, SEM×200. 2. *Textularia bronniana* (d'Orbigny): Čardaklija section, SEM×156. 3. *Textularia minuta* Terquem: Čardaklija section, SEM×178. 4. *Nodosaria* sp.: Nemanjici section, SEM×200. 5. *Siphonodosaria adolphina* (d'Orbigny): Nemanjici section, SEM×110. 6. *Glandulina ovula* d'Orbigny: Nemanjici section, SEM×400. 7. *Bulimina sculptilis* Cushman: Nemanjici section, SEM×300. 8. *Bulimina trigona* Terquem: Čardaklija section, SEM×186. 9. *Fursenkoina dibollensis* (Cushman et Applin): Čardaklija section, SEM×101. 10. *Caucasina eocenica* Chalilov: Nemanjici section, SEM×240. 11. *Caucasina tenebricosa* Pishvanova: Nemanjici section, SEM×300. 12. *Chilostomelloides balkhanensis* (Dain et Chalilov): Nemanjici section, SEM×250. **Spherical morphogroup (S):** 13. *Lagena humifera* Bandy: Čardaklija section, SEM×221. 14. *Lagena striata* (d'Orbigny): Čardaklija section, SEM×221. 15. *Favulina hexagona* (Williamson): Nemanjici section, SEM×340. **Flattened tapered morphogroup (FT):** 16. *Palmula budensis* (Hantken): Nemanjici section, SEM×180. 17. *Bolivina* cf. *antegressa* Subbotina: Nemanjici section, SEM×140. 18. *Bolivina* cf. *cookei* Cushman, 1922: Nemanjici section, SEM×250. 19. *Bolivina gracilis* Cushman and Applin: Nemanjici section, SEM×185. 20. *Bolivina nobilis* Hantken: Nemanjici section, SEM×325. 21. *Bolivina reticulata* Hantken: Nemanjici section, SEM×250. 22. *Bolivina scalprata* Schwager: Nemanjici section, SEM×250. **Heteromorphous morphogroup (H):** 23. *Percultazonaria fragaria* (Gümbel): Nemanjici section, SEM×110.

Morphogroup \ Basin and section	Ovche Pole Paleogene basin: Nemanjici	Ezevo Brdo	Kadrifakovo	Madzarica	Chardaklija	Karaorman
Rounded trochospiral (RT)	●					
Plano-convex trochospiral (PT)	●	●	●	●	●	
Biconvex trochospiral (BT)	●			●	●	
Milioline (M)	●	●	●	●	●	●
Rounded planispiral (RP)	●	●	●		●	
Lenticular (L)	●	●	●		●	
Tapered and cylindrical (T/C)	●	●	●	●	●	●
Spherical (S)	●	●	●	●	●	
Flattened tapered (FT)	●			●		
Heteromorphous (H)	●					

Fig. 2. Distribution of foraminiferal morphogroups in the Ovče Pole basin

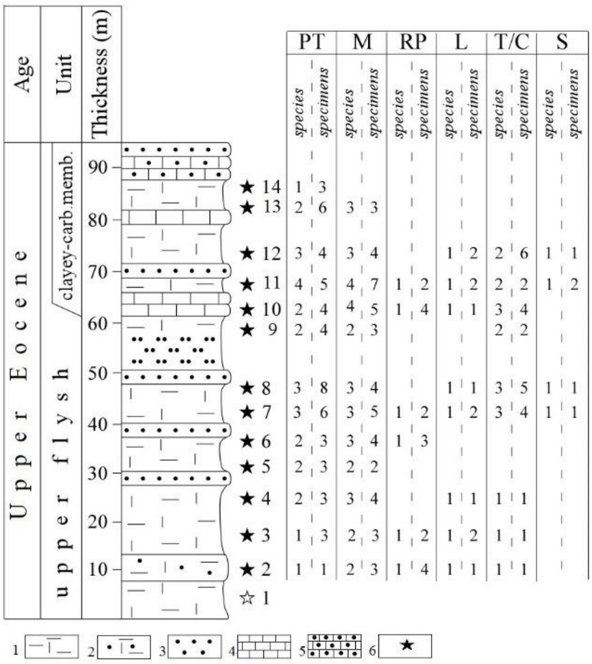

Fig. 4. Distribution of morphogroups in the Eževo Brdo section
1 – clay-carbonate sediments, 2 – clay-carbonate-sandy sediments, 3 – sandstones, 4 – limestones, 5 – sandy limestones, 6 – samples

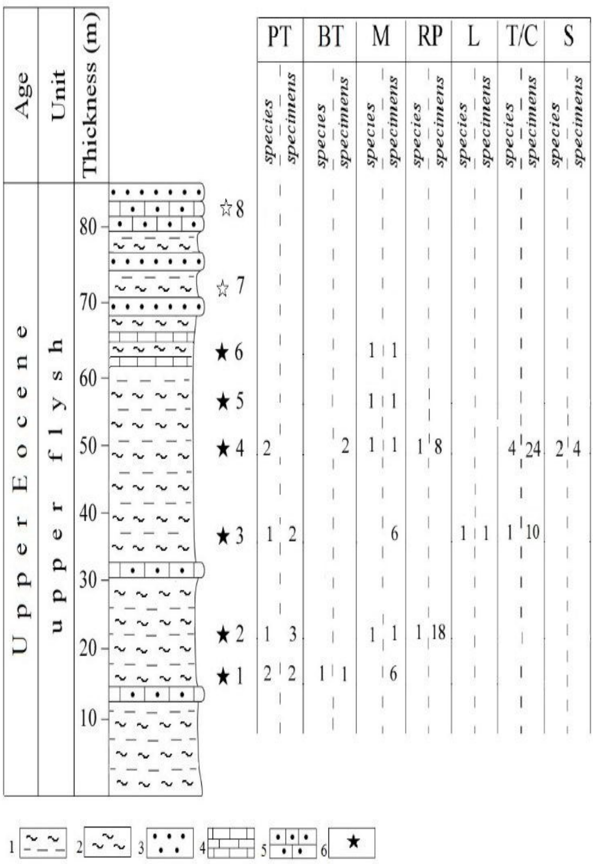

Fig. 3. Distribution of morphogroups in the Čardaklija section
1 – clay-carbonate sediments, 2 – clayey sediments, 3 – sandstones, 4 – limestones, 5 – sandy limestones, 6 – samples

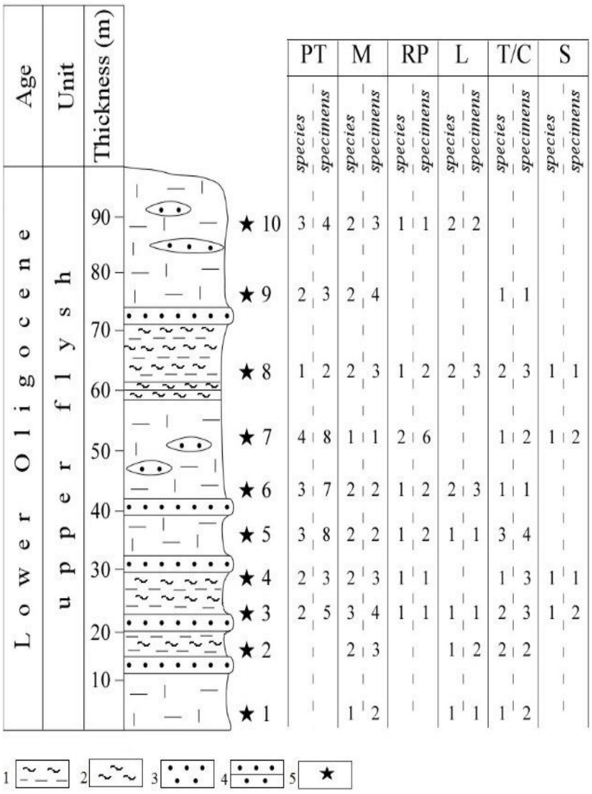

Fig. 5. Distribution of morphogroups in the Kadrifakovo section
1 – clay-carbonate sediments, 2 – clayey sediments, 3 – sandstones, 4 – clayey-carbonate sediments, 5 –samples

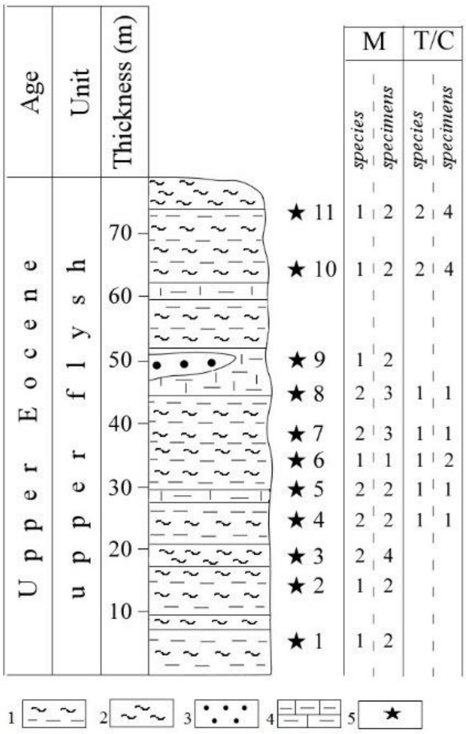

Fig. 6. Distribution of morphogroups
in the Karaorman section
1 – clay-carbonate sediments, 2 – clayey sediments,
3 –sandstones, 4 – clayey-carbonate sediments, 5 – samples

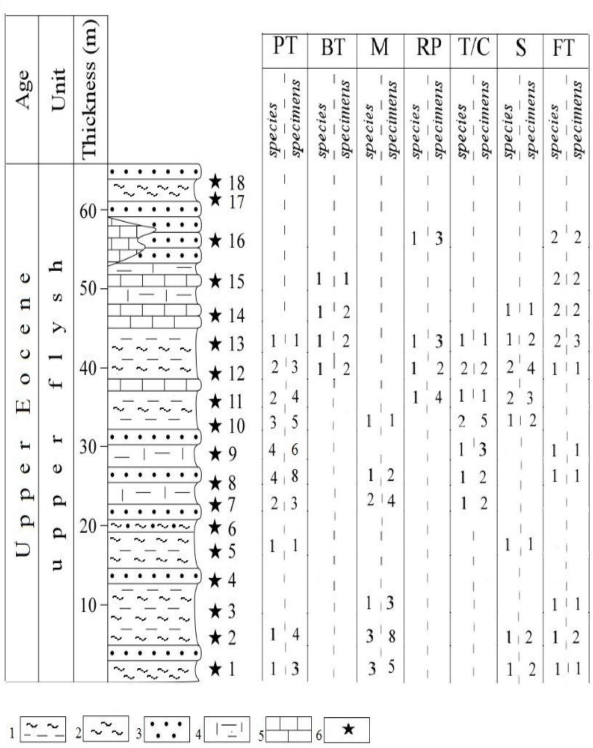

Fig. 7. Distribution of morphogroups in the Madžarica section
1 – clay-carbonate sediments, 2 – clayey sediments,
3 – sandstones, 4 – carbonate-clay sediments, 5 – samples

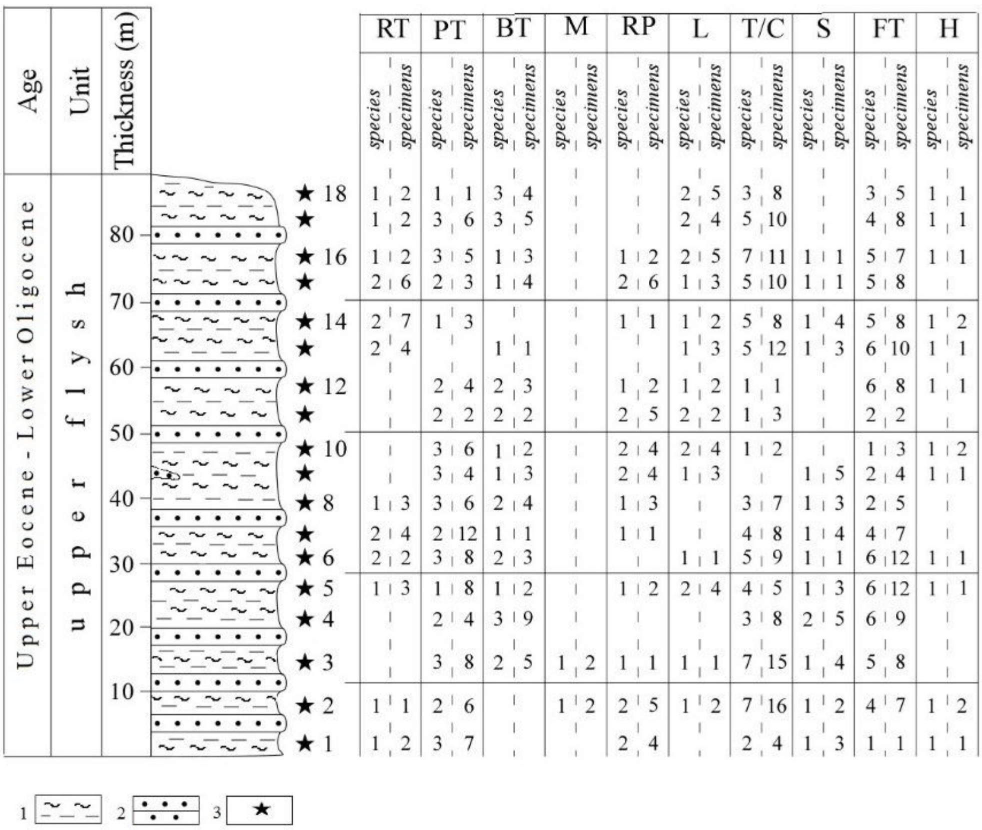

Fig. 8. Distribution of morphogroups in the Nemanjici section
1 – clay-carbonate sediments, 2 – sandstones; 3 – samples

DISCUSSION

As can be seen from the distribution of the morphogroups along the sections, there is no strongly dominating one. For example, the most characteristic morphotypes in Nemanjici section (the most diverse section from test morphology point of view) are tapered and cylindrical (T/C), plano-convex trochospiral (PT) and flattened tapered (FT) foraminifera, which are recorded in all samples. The Eževo Brdo, Madžarica and Kadrifakovo sections are dominated by plano-convex trochospiral (PT), tapered and cylindrical (T/C) and milioline (M) morphogroups, but with low specimen abundance, while in the other studied sections the morphogroups are represented mainly by single specimens and therefore there is no dominating one.

That most (all) of determined genera have recent species, so that we know about their preferences about substrate, feeding matter, salinity, T, depth range, water dynamics etc. These attributes for each genus are given in Table 1.

T a b l e 1

Ecological data for foraminiferal genera in the Ovče Pole Paleogene basin

Places of distribution	Genus	ML	Sb	MF	S ‰	T	D (m)	E
C, E, K_d, N	***Spiroloculina*** d'Orbigny	E	sedim.	herbiv.	30–35	temp. warm	0–40	inner shelf
C, K_r, E, M, K_d	***Quinqueloculina*** d'Orbigny	E	plant sedim.	herbiv.	35–65	cold warm	0–25	marine shelf
C, E	***Triloculina*** d'Orbigny	E	mud. sand	herbiv.	35–55	temp. warm	0–25	inner shelf
K_d, N	***Lenticulina*** Lamark	E	mud.	detritiv	30–35	cold	50–200	shelf bathy
N	***Bolivina*** d'Orbigny	I	mud. sedim.	detritiv	30–35	cold warm	0–40	inner shelf
N	***Bulimina*** d'Orbigny	I	mud, sand	detritiv	30–35	cold warm	0–40	inner shelf
C, M	***Fursenkoina*** Loeblich and Tappan	I	mud.	detritiv	30–35	cold	0–1200	upper bathy
N	***Cancris*** de Montfort	E	sedim.	detritiv	30–35	temp. subtr.	10–150	shelf
C, N	***Eponides*** de Montfort	E	sand	herbiv.	30–35	cold temp.	0–5000	shelf abyss.
N	***Cibicidoides*** Thalmann	E	hard substr.	detritiv	30–35	cold	50–200	shelf bathy
C, E, K_r, M, K_d, N	***Cibicides*** de Montfort	E	hard substr.	detritiv	30–35	cold warm	50–200	shelf bathy
C, M, K_d	***Nonion*** de Montfort	I	mud.	herbiv.	30–35	cold temp.	0–180	shelf
C, E, M, K_d	***Nonionella*** Cushman	I	mud.	herbiv.	30–35	temp. warm	10–1000	upper bathy
N	***Pullenia*** Parker and Jones	I	mud.	detritiv	30–35	cold	50–500	outer shelf
N	***Melonis*** de Montfort	I	mud.	detritiv	30–35	<10º	50–200	shelf-bath.
N	***Chilostomella*** Reuss	I	hard substr.	detritiv	30–35	cold	50–200	shelf-bath.
N	***Heterolepa*** Franzemak	E	hard subsrt.	detritiv	30–35	temp. cold	50–200	shelf bathy
N	***Gyroidina*** d'Orbigny	E	mud.	detritiv	30–35	cold	50–200	shelf-bath.
N	***Hanzawaia*** Asano	E	hard substr.	herbiv.	30–35	temp. warm	0–40	inner shelf
C, E, M, K_d	***Pararotalia*** Le Cavez	E	sand	herbiv.	30–35	warm	0–40	inner shelf

Explanation: C – Čardaklija, E – Eževo Brdo, K_d – Kadrifakovo, M – Madžarica, K_r – Karaorman, N – Nemanjici, ML – mode of life, Sb – substrate, MF – mode of feeding, S – salinity, T – temperature, D – depth, E – environment

Additional data as the presence of macrofauna by some representatives types – anthozoa, gastropoda, bivalvia and echinids (Maksimović et al., 1954; Mitrović-Petrović et al., 1990) were used for better paleoecological interpretation.

In terms of the substrate conditions in the basin, there are some organisms present from the type of epifauna and infauna. The first one includes *Lenticulina* Lamark, *Heterolepa* Franzemak*, Pararotalia* Le Cavez*, Cancris* de Montfort*, Cibicides* de Montfort*, Cibicidoides* Thalmann, *Giroidina* d'Orbigny*, Hanzawaia* Asano, *Quinqueloculina* d'Orbigny*, Spiroloculina* d'Orbigny*, Textularia* Defrance*,* and *Triloculina* d'Orbigny. Representatives of the infauna, such as *Melonis* de Montfort, *Nonion* de Montfort*, Nonionella* Cushman*, Pulenia* Parker and Jones*, Bolivina* d'Orbigny*, Bulimina* d'Orbigny*, Chilostomella* Reuss, and *Fursenkoina* Loeblich and Tappan live in the soupy upper layer of the sediment. The macro-epifauna is represented by genera *Spondylus* and *Ostrea* which belong to sessile benthos. Macrofossil infauna includes *Natica, Cardium* and *Panopea* (Maksimović et al., 1954, Mitrović-Petrović et al., 1990).

In terms of the feeding, the foraminiferal fauna contains herbivores*,* such as *Spiroloculina* d'Orbigny*, Quinqueloculina* d'Orbigny, and detritivores – for example *Lenticulina* Lamark*, Heterolepa* Franzemak*, Melonis* de Montfort*,* and *Nonion* de Montfort*.*

Temperature**:** The temperature of the water directly influences the existence and the spatial distribution of the organisms. Most of the foraminiferal representatives in the basin prefered a moderately warm environment (*Noninella* Cushman, *Pararotalia* Le Cavez*, Hanzawaia* Asano), and only a few exist today in a cold environment (*Giroidina* d'Orbigny, *Cibicidoides* Thalmann). Temperature influences the test size and test morphology (Boltovskoy et al., 1991). The trends are towards an increase of the test size and the test porosity with the increase of temperature (Frerichs et al., 1963, in Ujetz, 1996). Assemblages with high species diversity are typical for basins with constant high temperature (Boggs, 1987, in Ujetz, 1996). Temperature influences also calcium carbonate availability in the water column. It values decrease as the temperature decreases. Such an environment is characterized mainly by calcareous thick-walled foraminifers (Boltovskoy, Wright, 1976, in Ujetz, 1996). The presence of large-sized agglutinants and low species diversity indicates constant temperature and stagnant water conditions (Haynes, 1981). The temperature range is confirmed by the presence of corals. Today, corals thrive at temperatures of 25–29 °C. They rarely survive above 40 °C, and the minimum temperature for their survival is 16–17 °C. The present snails (*Strombus, Conus, Turritella*) and shells in the basin also show tropical trait of the fauna (Stojanović, 1992).

Salinity**:** Salinity represents a one of the main factors gowerning the distribution of recent organisms in the basins. Most of the foraminifersa are adapted to the conditions with a normal degree of salinity – about 35 ‰ (Brasier, 1980). Most of the foraminiferal genera determined, such as *Anomalinoides* Brotzen*, Pararotalia* Le Cavez*, Cibicidoides* Thalmann, *Fursenkoina* Loeblich and Tappan*, Heterolepa* Franzemak*, Lagena* Walkerand Jacob*, Nonion* de Montfort, and *Textularia* Defrance, require salinity between 35 and 37 ‰ (Murray, 1991). The presence of planktonic species in some samples (Nemanjici section) also confirms normal saline waters (Boltovskoy, Wright, 1976, in: Ujetz, 1996). Normal salinity is confirmed by the presence of macrofauna *Natica, Spondylus* and *Pecten*, which survive in the seas with salinity of 34–36 ‰. Echinoids are likewise stenohaline organisms, while the genus *Ostrea* is tolerant to brackish conditions (Stojanović, 1992).

Depth**:** Most of the benthic foraminiferal fauna that is present in Ovče Pole basin exists today in a shelf-batial environment (inner shelf up to 200 m). Planktonic foraminifera live in the upper layers of open marine basins. The dominating morphogroups in the most representative Nemanjici section (T/C, PT, FT) are recorded predominantly in shallow-water environments in modern (Corliss, Chen, 1988; Khare et al., 1995; Alperin et al., 2011) and ancient seas (Szydło, 2005; Reolid et al., 2008; Setoyama et al., 2011).

The epifaunal-infaunal data show that both groups of tests are equally presented in the Paleogene of the Ovče Pole basin. Such a ratio is characteristic for inner to middle shelf conditions. The majority of the foraminiferal tests is badly preserved and deformed, which is typical for littoral to sublittoral conditions or due to turbidity flow. On the other hand, nummulitids, corals, shallow-water molluscs – Crassatella, Pecten, Natica, etc. (Maksimovič et al., 1954) and echinids (Mitrović-Petrović et al., 1990) have been previously found. This fact is another proof for inner shelf environment. With foraminifera analysis in the basin are represented mixed assemblage, consisting of shallow-water derived species, which prefered warm conditions, and deep water species, that lived in colder environment. In all basin sections, the character of marine sedimentation of the open sea prevails, accompained by strong currents and the relative participation of foraminifera, predominantly of a planktonic type). After the formation of these sediments there is an interruption in sedimentation, probably caused by tectonic implosions, which at that time were intense within the Alpine orogenic cycle. This fact is another proof for indicate restless sedimentation and turbidic currents, which also influenced the foraminifera to be moved and presedimentation within sedimentation series.

CONCLUSION

In the Paleogene sedimentary rocks (Upper Eocene–Lower Oligocene) from the upper flysch lithozone of the Ovče Pole basin we defined and illustrated 10 morphogroups by arranging taxa according to morphological features (external test morphology – test shape and the nature of test coiling – chamber addition), combined with microhabitats (epifaunal, shallow infaunal and deep infaunal) and feeding strategies (suspension-feeders, herbivores, bacterivores, omnivores, etc.). Generally, the investigated assemblages are slightly dominated by morphogroups characteristic for shallow or shallow (inner shelf) environment. In terms of the depth, the sea environment is shelf. The more southern parts of the basin have been more shallow (inner shelf), while the northern part of the basin has been deeper, for which as a confirmation are the plankton foraminifera. The part of the basin that is more shallow, i.e. the southern part, is featured with higher water dynamics. Additional data as well as the presence of macrofauna for the paleoenvironmental conditions during the Late Eocene this fact is another proof for inner shelf environment.

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Р е з и м е

ПАЛЕОЕКОЛОШКО ЗНАЧЕЊЕ НА БЕНТОСНАТА ФОРАМИНИФЕРНА ФАУНА ОД ОВЧЕПОЛСКИОТ БАСЕН, РЕПУБЛИКА МАКЕДОНИЈА

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Клучни зборови: бентосна фораминифера; морфогрупи; палеоекологија; палеоген; овчеполски басен

Овчеполскиот палеогенски басен се наоѓа во североисточниот дел на територијата на Република Македонија и тектонски и припаѓа на Вардарската зона. Микрофаунистичкиот материјал е претставен од 62 вида, добиен е од 6 профили (79 примероци) од глиновито лапоровитите седименти на горната флишна литозона на басенот. Врз основа на резултатите од анализата на бентосната фораминиферна асоцијација се дефинирани и илустрирани 10 морфолошки

групи (морфогрупи или морфотипови): заоблена трохоспирална (RT), планконвексна трохоспирална (PT), биконвексна трохоспирална (BT), милиолидна (M), заоблена планиспирална (RP), лентикуларна (L), конусна и цилиндрична (T/C), сферична (S) и хетероморфна (H). Овој труд има за цел да направи палеоеколошка анализа на животната средина врз основа на податоците добиени од проучувањето на таксономскиот состав и структурата на малите бентосни фораминифери, со комбинирање на морфолошките карактеристики и стратегијата за живот, начин на хранење, соленост, температура, динамика и длабочина на водата на фораминиферите.