Foraminiferal successions in the shallow water Sarmatian sediments from the MZ 93 borehole (Vienna Basin, Slovak part)

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Sukcesie dierkavcov v plytkovodných sedimentoch sarmatu z vrtu MZ 93 (slovenská časť viedenskej panvy)

Abstract: The grey, grey-green, grey-brown claystone, silty claystone and silts yield foraminiferal association of Sarmatian (Upper Serravallian 12.7–11.6 Ma). The studied deposits belong to the Holíč Formation. The foraminiferal assemblages suggest a very shallow water depositional environment. In such conditions, the environment can change rapidly in dependence on tidal effects causing the repeated drying and inflow of fresh water. Therefore, it was not possible to rely on stratigraphical value of identified ecozones. The Sarmatian fauna was commonly regarded as a brackish-water community suffering from gradually decreasing salinity. However, our results allowed us to interpret very unstable marginal marine conditions, even hypersaline episodes. The foraminiferal associations document sedimentation in a very shallow water with several episodes of reduced oxygenation at the bottom, changing upward to hypo/hypersaline marshes, vegetated swamps and finally to the Glyptostrobus marsh.

Key words: Vienna Basin, Sarmatian, Foraminifera, palaeoecological interpretations.

1. INTRODUCTION

The Paratethys was an epicontinental sea that developed as a relict of the ancient ocean Tethys. It existed between the Early Oligocene and late Middle Miocene times. During the Middle Miocene, the geodynamic processes of the Dinaride uplift restricted the connections between the Paratethys and the Mediterranean (Rögl, 1999; Steininger & Wessely, 2000; Kováč, 2000), and caused a distinct change in the oceanographic and biotic evolution of the Paratethys. In the Middle Miocene, a regressive phase took place at the end of the Badenian (Central Paratethys) leading to a dramatic change in marine biota (Harzhauser & Piller, 2007). Thus, the complex evolution of the Paratethys is reflected in the distribution and evolution of the foraminiferal fauna, differing in abundance and composition from those in open oceans (e.g. Iaccarino, 1985; Rögl, 1985; Cicha et al., 1998). This separate evolution has caused an establishment of a regional time-scale, different from the standard Mediterranean chronostratigraphic stage system (Fig. 1). The Sarmatian corresponds to the Late Serravallian of the Mediterranean time scale and covers the time span between 12.7 Ma and 11.61 Ma (Kováč et al., 2007; Zuschin et al., 2007). At the Badenian/Sarmatian boundary, the marine planktic foraminiferal group disappeared, except of *Streptochilus* and small microperforate globigerinids (Filipescu & Silye, 2008). Mostly euryhaline benthic foraminiferal forms persisted into the Sarmatian of the Central Paratethys. The Sarmatian fauna was classically regarded as a brackish-water community (e.g. Papp, 1956; Zlínska, 1998; Fordinál et al., 2006) suffering gradually decreasing salinity (Čierna, 1974). However, several authors have recently suggested that the Sarmatian sea was in fact more or less marine, even with hypersaline episodes, and explained the diversity fall by significant changes in water chemistry, especially high alkalinity (e.g. Pisera, 1996; Filipescu, 2004[a]; Harzhauser & Kowalke, 2002; Piller & Harzhauser, 2005; Harzhauser et al., 2007; Kováč et al., 2005). The aim of the present work is to identify foraminiferal associations, their stratigraphical potential and palaeoenvironmental changes that occurred during the Badenian/Sarmatian transition in the studied area. Changes in water salinity in the brackish and marine environments and other environmental parameters (e.g., productivity, oxygen level in bottom waters, water depth) were interpreted using qualitative and quantitative palaeontological analyses (Murray, 2006; Pascual & Rodriguez-Lazaro; 2006; Sen Gupta, 2002).

2. GEOLOGICAL SETTING AND METHODS

The studied borehole MZ 93 (Malacky surroundings) is situated in the Slovakian part of the Vienna Basin, the area covered by dense network of oil-prospecting wells (Fig. 1). The sediments are characterized by the most complex record and contain sufficient amount of foraminiferal shells. Foraminiferal associations were identified in cores no. 5, 4, 3, 2 with a total drilling depth from 875.0 to 623.5 m. In total, 64 samples were taken from 6 cores of the MZ 93 borehole. Samples were detracted every 40 cm and replenished in intervals with lithological or micropalaeontological changes.

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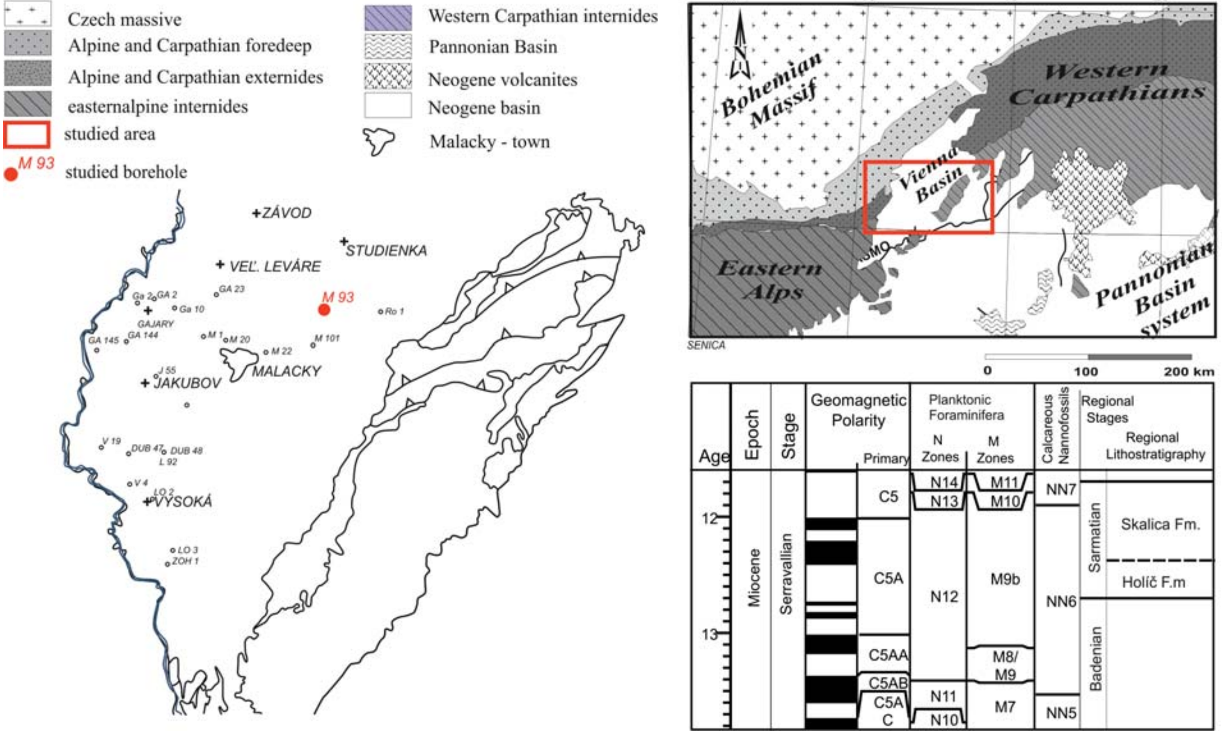


Fig. 1. Geographical and geological situation of the studied borehole.
Obr. 1. Geografická a geologická lokalizácia študovaného vrtu.

The sediments from the core no. 5 (875.0 – 870.0 m, 7 samples in interval of ~40 cm) (Fig. 2) represent the lower Sarmatian fine-grained and mid-grained grey, gray-green and grey-brown clays to siltstones with sandy beds. The residua contain many shells of reworked foraminifers. The ostracod shells, their fragments, fish otolits, framboidal pyrite and limonite crusts prevailed in the lower part of the core.

The core no. 4 (from 870.0 to 861.0 m, 17 samples) consists of fine to mid-grained green, brown and green clay and mudstone with sand laminae and beds. The residua contained limonite crusts, mollusc fragments, ostracod shells and a small number of concretions. The lower part of studied core contained mainly reworked foraminifera and charred flora debris; in the upper part, cyanolithes were common.

The sediments of core no. 3 (from 861.0 to 858 m, 3 samples) contained green sandy clay and sand. The residua comprise a high amount of reworked foraminifera in the bottom part, accompanied by limonite and framboidal pyrite.

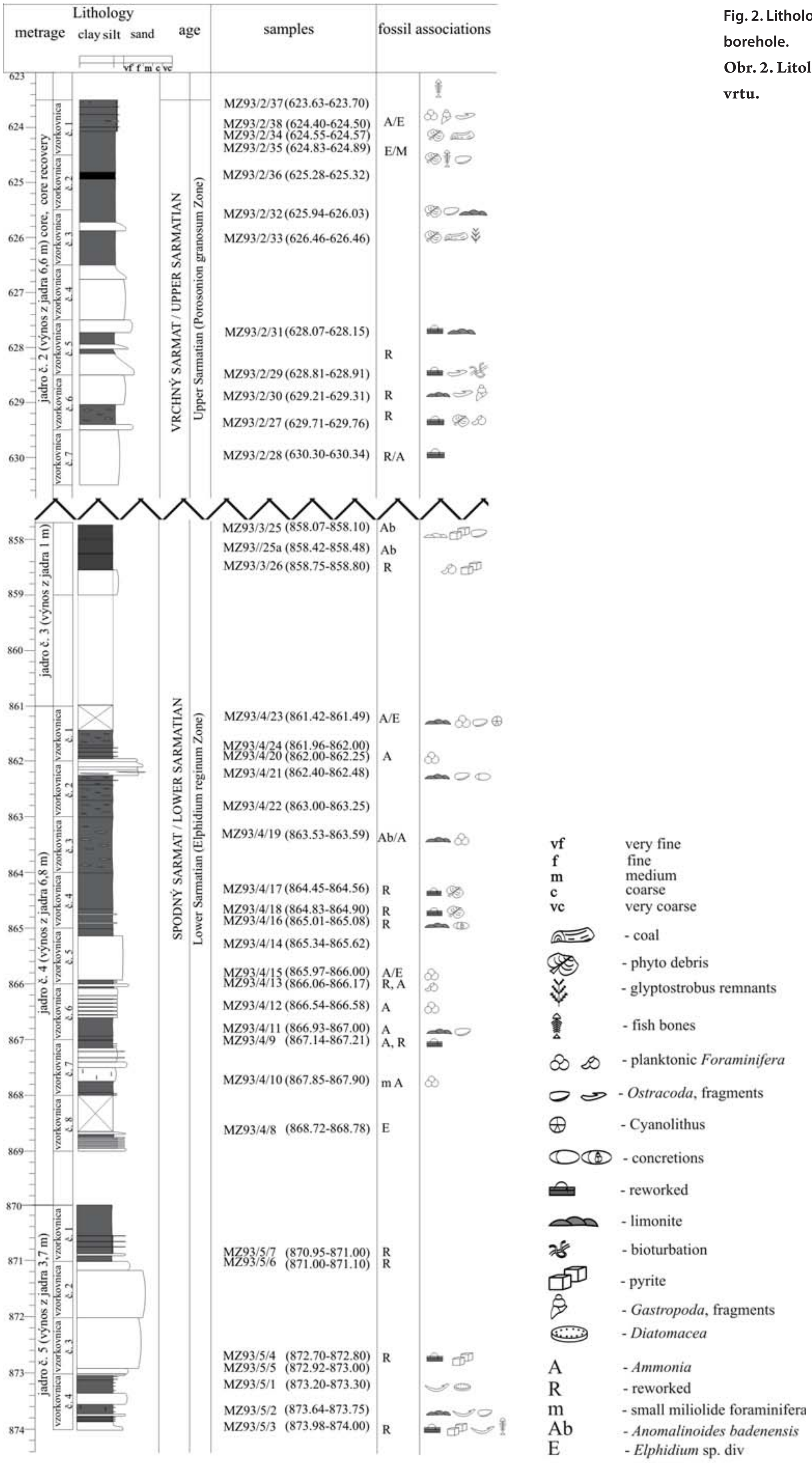
The shallowest core no. 2 (632.0 – 623.5 m, 11 samples from an interval of approximately 60 cm) contain grey, grey and green fine-grained mudstone, grey and green silty mudstone laminated towards the overlying bed with carbonized layers and fine-grained sand. The residua from the lower part of the drill core contain a lot of reworked foraminiferal tests; ostracod shell fragments, gastropods, limonite crusts and the moulds of bioturbations. The overlying bed contains, besides ostracods and their fragments, gastropods and fish bones, a high portion of charred debris, coal and remnants of *Glyptostrobus* cones (Plate 1).

The separation of foraminifers follows standard washing methods. The samples were diluted in water or hydrogen peroxide, washed and sieved through 71 μm mesh. At least 250 individuals of benthic foraminifers were selected per sample. Counting was completed for planktic foraminifers in the samples where they were present. The taxonomic analyses are based on the Loeblich & Tappan (1988) and Cicha et al. (1998) publications. The data set was stored in the database (Hudáčková & Hudáček, 2001) and subsequently processed in Microsoft Office 2000 (Excel, Access) and PAST (Hammer et al., 2001). POLPAL software was used for the visualization of dominance diagrams (Nalepka & Walanus, 2003). The raw data was transformed into percentages over the total abundance and percent abundance curves were plotted (Fig. 3). Species with similar environmental significance were grouped together in order to the most accurate interpretation of their distribution patterns (appendix 1, 2; e.g. Kaiho, 1999; Spezzaferri et al., 2002; Murray, 2006).

The statistical analyses of foraminiferal associations are made as S (species richness, number of species per sample) and diversity indices (Shannon_H and Fisher *α* index Fisher et al., 1943). In order to estimate the palaeobathymetry in the study area we have compiled the bathymetric distribution of recent benthic foraminifera to recognize the appropriate paleodepth indicators (e.g. Spezzaferri et al., 2004; Meric et al., 2004; Hohenegger, 2005). The post-mortem mixing of species caused by transport, reworking and sediment mixing was diminished by the elimination of species living in the water depth-range not consistent with the assemblage (Hohenegger, 2005).

Fig. 2. Lithological section of the studied borehole.

Obr. 2. Litologický nákres študovaného vrtu.



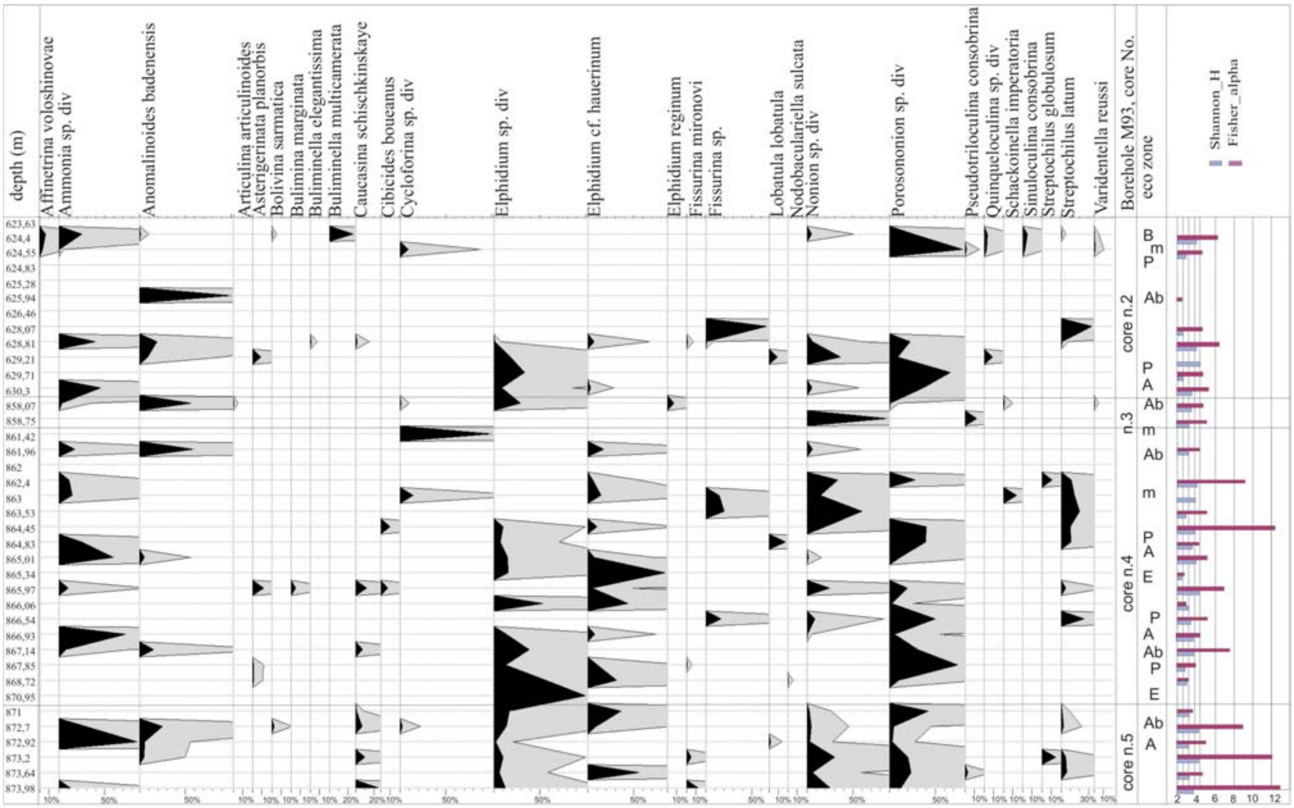
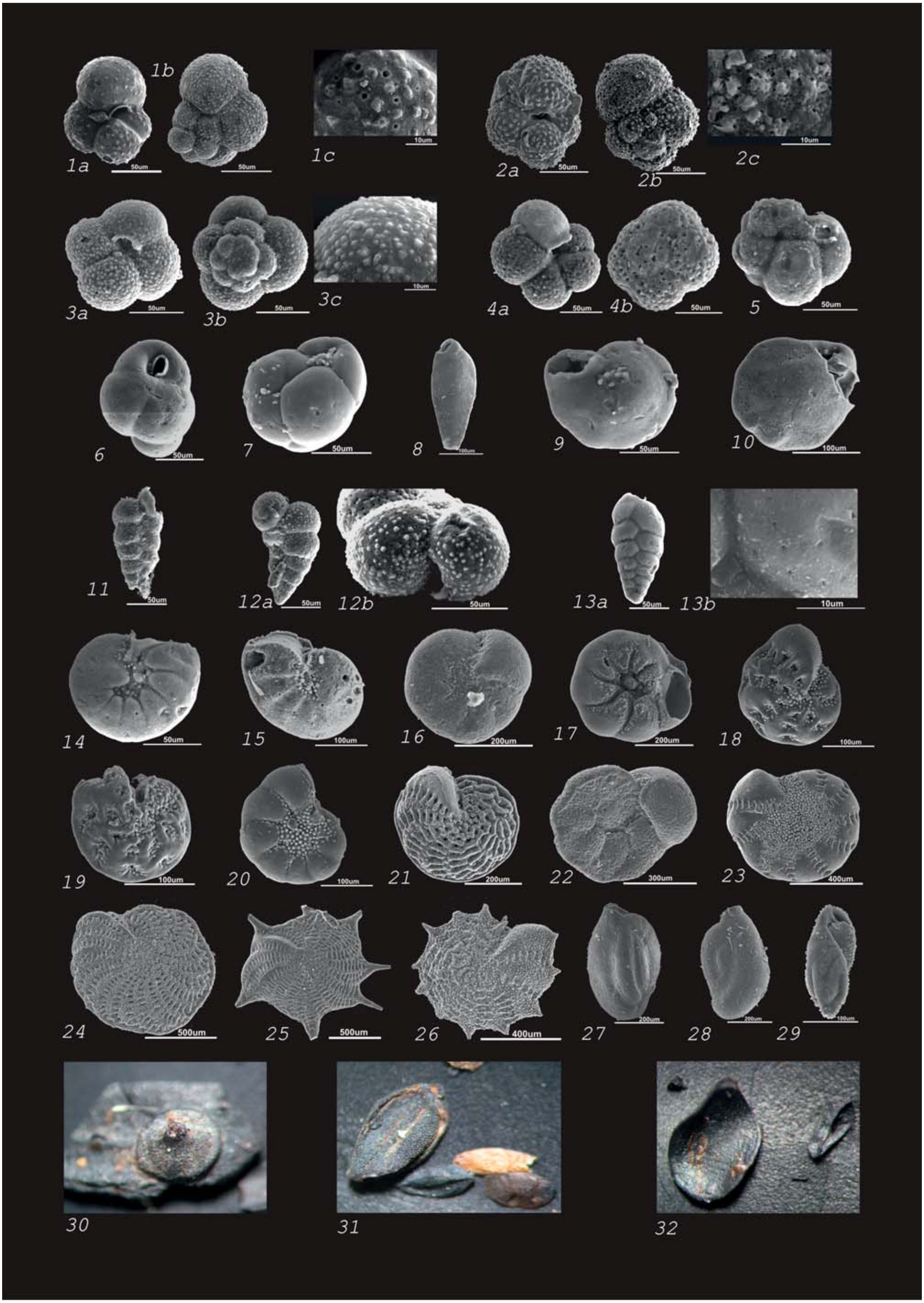


Fig. 3. The dominance of the significant taxa identified in the MZ 93 borehole, association type and diversity.

Obr. 3. Percentuálne zastúpenie dôležitých taxónov dierkavcov a typické asociácie identifikované vo vrte MZ 93, ako aj hodnoty indexov diverzity.

Plate 1: 1. *Tenuitella clemenciae* (Bermúdez), 1a. apertural side, 1b. spiral side, 1c. wall detail (depth 873.20); 2. *Tenuitellinata juvenilis* (Bolli), 2a. apertural side, 2b. spiral side, 2c. wall detail (depth 873.20); 3. *Tenuitellinata uvula* (Ehrenberg), 3a.apertural side, 3b. spiral side, 3c. wall detail (depth 873.20); 4. *Turborotalita quinqueloba* (Natland), 4a. apertural side, 4b. spiral side; 5. *Cassigerinella globulosa* Egger; 6. *Bulimina elongata* (d´Orbigny) (depth 873.20); 7. *Globocassidulina subglobosa* (Brady); 8. *Bolivina dilatata dilatata* Reuss; 9. *Cibicidoides lopjanicus* (Myatlyuk) (depth 873.64); 10. *Cassidulina laevigata* d´Orbigny (depth 873.64); 11. *Streptochilus latum* Brönnimann and Resig; 12a. *Streptochilus globulosum* (Cushman); 12b. apertura and wall (depth 873.20); 13a. *Bolivina molassica* Hofmann; 13b. wall (depth 873.20), 14. *Nonion biporus* Krasheninnikov (depth 862.40); 15. *Nonion commune* (d´Orbigny) (depth 873.64); 16. *Ammonia tepida* (Cushman) (depth 867.85); 17. *Ammonia parkinsoniana* (d´Orbigny), (depth 867.85; 866.93); 18. *Elphidium hauerinum* (d´Orbigny); 19. *Elphidium microelegans* Serova; 20. *Porosononion granosum* (d´Orbigny) (depth 858.07); 21. *Elphidium macellum* (Fichtel & Moll) (depth 865.34); 22. *Anomalinoides badenensis* (d´Orbigny); 23. *Elphidium glabrum* Bystricka (depth 867.85); 24. *Elphidium crispum* (Linne) (depth 867.85); 25. *Elphidium reginum* (d´Orbigny) (depth 867.85); 26. *Elphidium josephinum* (d´Orbigny) (depth 867.85); 27. *Cycloforina badenensis* (d´Orbigny); 28. *Quinqueloculina minakovae* Bogdanowicz; 29. *Buliminella multicamerata* Cushman & Parker (depth 624.55), 30 – 32. rests of the *Glyptostrobus* sp. pine, mag. 25x (depth 623.63);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To estimate the level of oxygenation of the sea floor, we have divided the benthic foraminifera into oxic, suboxic and dysoxic indicators according to Kaiho, (1994). The benthic foraminiferal oxygen index (BFOI, Kaiho, 1999) was used in two modes. First one, consider *Ammonia* gr. as a species tolerating lowered oxygen (less than 0,1ml/l) (Moodley & Hess, 1992) and even facultative anaerobic conditions (Pawlowski et al., 1995), and the second one, considering *Ammonia* gr. as representing of oxic conditions (Murray, 1991).

The stratigraphicaly important specimens were studied in detail and documented by SEM microscope TESCAN and Hitachi (Plate 1).

3. RESULTS

The associations consisted of euryhaline Foraminifera (Fig. 3), which usually correspond to the Sarmatian sediments of the Cetral Paratethys realm. Only presence of one Sarmatian bilateral wounded planktic foraminiferal genera *Streptochilus* Brönnimann & Resig (Plate 1, Fig. 11, 12) was confirmed by SEM study of shell walls, shape and aperture (Smart & Thomas, 2007). Based on the appearance of genus *Streptochilus,* the sediments are assigned to the *Streptochilus* Assemblage Biozone (Filipescu & Silye, 2008). The first appearance of *Elphidium reginum* (d´Orbigny) and *Schackoinella imperatoria* (d´Orbigny) (Cicha et al., 1998) confirm the Sarmatian age of the studied sediments.

The *Ammonia, Anomalinoides dividens, Elphidium reginum* and *Porosononion granosum* biozones (Grill, 1941; *Luczkowska, 1972*) were identified on the base of dominance of the index taxa (Fig. 4). In the studied material, the *Ammonia* Zone is highly dominated by *Ammonia* sp. div. Other genera (*Elphidium, Porosonion*) are very rare in the associations and reach up to 2 – 10%. The *Anomalinoides dividens* Zone is characterized by dominance of *Anomalinoides badenensis* (d´Orbigny) (60 – 95%) accompanied by *Ammonia* sp., *Elphidium* sp. and *Porosonion granosum* (d´Orbigny). The most diversified Zone here is the *Elphidium reginum* Zone (Fig. 3), composed mostly of *Elphidum* sp. div. In this zone, the Sarmatian index species *Elphidium reginum* d´Orbigny is common, and *Porosonion granosum* (d´Orbigny) accompanied by small miliolids are present. The *Porosonion granosum* Zone is defined by strong prevalence of *Porosonion granosum* (d´Orbigny) accompanied by *Elphidium* sp. div., or together with small miliolide taxa in the uppermost part of section. The identified biozonal associations alternated during the deposition and did not prove a direct correlation with stratigraphical age. The alteration of zones follows foraminiferal succession. According to laboratory experiments, *Ammonia* group, *Elphidium* and *Haynesina* are active colonizers of sterile substrate in water depth 6 – 16 m (Schafer & Young, 1977). *Quinqueloculina seminulum* (Linne) is an active colonizer occupying the water depth around 6 m (Schafer & Young, 1977). Three types of successions with dominant benthic foraminiferal genera are identified in studied material. The first type of succession starts with opportunistic *Ammonia* acme, followed by *Elphidium*, *Porosonion*, *Nonion*, and *Bolivina* genera. The second type starts with *Anomalinoides* positively correlated with *Bolivina,* and negatively with *Elphidium* acme, succeeded by *Nonion* sp. div. The third recognized succession starts with *Porosonion* acme, followed by *Nonion* and miliolids.

In general, the identified benthic foraminiferal associations dominated by rotaliide genera (*Elphidium*, *Ammonia*) less abundant were porcellaneous forms (*Sinuloculina, Quinqueloculina*). The taxa with agglutinated type of test were extremely rare (Fig. 3). Diversity of the assemblages varies negatively in compliance with the dominance. The Fisher α diversity (Fig. 3) shows extremely high excursions in the lowermost cores, with general decrease in the uppermost core of the borehole. The lowest (Shannon_H index) diversity showed the samples with the *Porosonion* association. Higher H diversities were recognized in the samples without dominant species. A high portion of reworked Karpatian and Badenian foraminifera mostly consists of microperforated planktic genera in compliance with *Cassigerinella globulosa* Egger, *Orbulina suturalis* Brönnimann and other species as *Bulimina*, *Bolivina*, *Cibicidoides*, *Rosalina* and *Globocassidulina*. Microperforate genera *Tenuitellinata* and *Tenuitella* are accompanied by small *Turborotalita quinqueloba* (Natland) (Plate. 1). Mentioned reworked foraminifers have shown the sizing of the similar shape and shells size (at around 100 μm). Breaking and smoothing of foraminiferal shell surface is visible under SEM (Plate 1). The group of allochtonous species was not included into the palaeoecological interpretation. The specimens considered as reworked are comprised into one group called allochtonous in Fig. 4.

The sum of factors representing palaeodepth during the sedimentation was determined by the presence and dominance of susceptible genera (appendix 1 and 2). The dominance of nearshore taxa is visible in the entire profile (Fig. 4) together with absence of deep water infauna. Information about the paleobathymetry is completed by abundant occurrence of epiphytic species (Fig. 4) representing a zone with sufficient amount of sun light. A limiting depth is also documented by presence of *Ammonia* gr. (depth-range 1 – 60 m) in the lower part of the section, and by *Nonion depressulus* (Walker & Jacob) in the upper part of the section, which, according to Hohenegger et al. (1989), lives in compliance with seagrass, in water depth up to 5 m (Alve & Murray, 1999).

Besides the change in bathymetry, the salinity changes were also analyzed. The salinity fluctuation and a high amount of taxa tolerating euryhaline conditions were observed in all samples: genera *Elphidium*, *Ammonia*, *Nonion*, species *Porosononion martkobi* (Bogdanowicz), *Porosononion* sp. and *P. granosum* (d'Orbigny). The above mentioned taxa form more than 50% of associations in 867.85 – 867.9 m, and 624.55 – 624.57 m levels (Fig. 3). Elphidiids are characterized by two morphologies: some possess the peripheral keel, others have rounded peripheries. Keeled morphotypes are mostly herbivorous, epifaunal dwellers preferring sandy sediment, which occur in the shallow marine environments (inner shelf) with warm to temperate and normal to hypersaline (35 – 70 ‰) waters (Murray, 2006). A relatively high occurrence of epifaunal, free or clinging herbivorous, normal to hypersaline (32 – 65‰) species of *Quinqueloculina* tolerating salinity

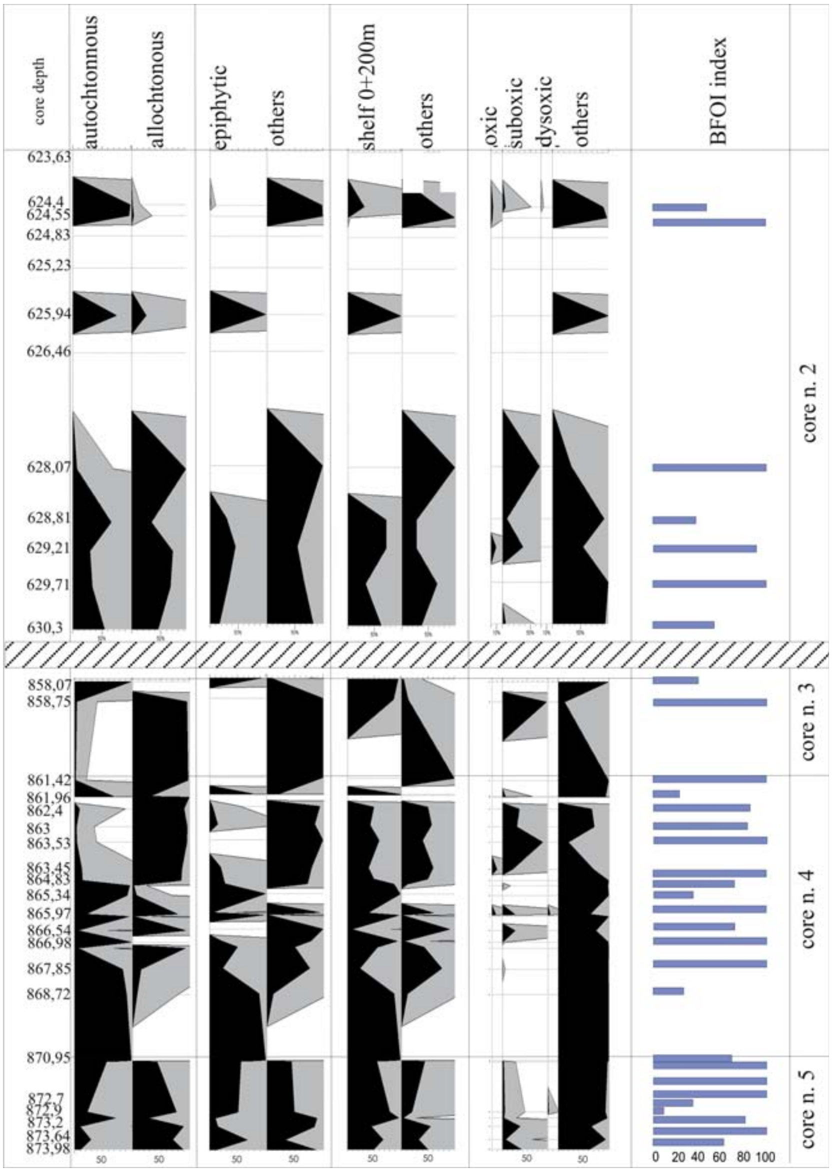

Fig. 4. Percentual proportion of the ecologically significant foraminiferal groups against the BFOI index value (*Ammonia* gr. as suboxic).
Obr. 4: Percentuálne zastúpenie ekologicky významných skupín dierkavcov spolu s hodnotou BFOI indexu (*Ammonia* gr. ako suboxický typ).

(Murray, 2006) was detected in the upper part of core (629.21 – 629.31 m, 624.40 – 624.50 m; 624.55 – 624.57 m) (Fig. 3).

The evaluation of oxygenation with *Ammonia* gr. taken as oxic species shows that all associations fall into well oxygenated conditions (minimum BFOI index reached 72.43 at around 3.0 – 4.5 ml^{-1} in the lowermost sample). Taken *Ammonia* gr. as suboxic species suggested that the depositional area was dominated by well aerated waters. Three significant samples showing low oxic conditions (BFOI index 10 – 30) were recognized in deeper cores (872.92 – 872.7 m; 866.93 m; 861.96 m) and one with BFOI 47.4 in the uppermost core (624.4 m) (Fig. 3).

4. DISCUSSION AND CONCLUSIONS

The Sarmatian age of studied sediments was identified on the basis of foraminiferal association characterized by the presence of benthic index species *Elphidium reginum* d´Orbigny and *Anomalinoides dividens* Luczkowska. Also the Sarmatian biozones as *Ammonia, Anomalinoides dividens, Elphidium reginum* and *Porosononion granosum* are recognized in the studied material (Grill, 1943, Luczkowska, 1967, 1971). Typical associations of mentioned biozones alternated and did not prove a direct correlation with the stratigraphical age. The *Elphidium reginum* Zone corresponds to Lower Sarmatian and *Porosonion granosum* Zone with rare *Affinetrina voloshinovae pectiniformis* (Bogdanowicz) to the Upper Sarmatian. *Ammonia* Biozone, the *Anomalinoides dividens* Zone with small miliolides, *Elphidium hauerinum* Zone and *Porosonion* Zone intervene during the Early-Middle Sarmatian in the presented material. When determining the age, we have used the presence of planktic index fossils also, which presupposes at least a short-time opening of migration ways and communication with surrounding seas. On the basis of precise SEM study, the planktic species *Streptochilus latum* (Brönnimann & Resig) and *S. globulosum* (Cushman) were identified. These species are regarded as index fossils of

Streptochilus Biozone (Filipescu & Silye, 2008), corresponding to Upper Sarmatian. The species of *Streptochilus* genus occurred in positive correlation with reworked species, thus it is not clear whether they are autochtonnous. It is also possible, that this planktic species indicates a short-time reopening of the sea ways which is linked to the increasing number of reworked ones (Goldstein & Wattkins, 1999; Murray, 2006; Patterson et. al., 1999). This can be promoted by a positive correlation of *Streptochilus* with *Anomalinoides* and *Bolivina*, genera with a supposed meroplanktic mode of life (Alve & Goldstein 2002; Filipescu 2004[b]). Benthic foraminiferal associations of the lowermost part of the section suggest shallow sheltered lagoon, environment, changing to associations of salt or brackish marshes (Sen Gupta, 2002). Special character of our benthic association is a very small amount of agglutinated foraminifera which obviously composes the main portion of those from the marsh environments (Phleger, 1970, 1977; Murray, 2006). The identified successions can constitute short term environmental changes caused by the itinerancy of tidal channels. The deepest normal marine environment was identified in the sediments of the lowermost cores, containing keeled *Elphidium*, genus tolerating oligotrophic photic zone conditions of protected lagoons (depths around 20 m). Towards the top of the section, the conditions were changing and the depositional environment was becoming shallower. In the uppermost parts of the profile, the terrestric conditions were suggested (e.g., in 626.46 m), foraminifera barren interval, but consisting of "water pines" cone remains typical for edging parts of water areas. In addition to shallowing trend, the changes in salinity are observed. In the overlying parts of the profile, the abundance of the *Porosononion* increases, showing shallowing and mellowing of the depositional area. In the two depth intervals (861.42 m and 624.55 m), the increasing content of *Quinqueloculina* documents the salinity increase. The oxygen deprived environment in some parts of the profile probably documents the increased eutrophication. The most significant feature of the profile is the cyclical fluctuation of the genus *Ammonia*, usually accompanied by representatives of the genus *Anomalinoides* with a very low portion of reworked species. The *Ammonia* association is probably a pioneering association in the area of initial water flooding, following by appearance of the genus *Anomalinoides* in deeper water (Filipescu 2004). The association of *Anomalinoides* is changed into the association dominated of the *Elphidium* genus, which pass into *Porosonion* association. This succession would suggest a cycle from the flooding to deeper water conditions and the next progressive shallowing and lowering salinity of the depositional environment. Similar oscillations in water level occur in peripheral areas of water bodies (Meric et al., 2004; Hiscott et al., 2006).

We can conclude, that the Sarmatian sediments of Malacky 93 borehole were most probably deposited in the very shallow marginal sea conditions, or in the margin of a protected lagoon, with the edge which migrated time. In the uppermost part, the Glyptostrobus marshes were identified. The eutrophication significantly increased towards the upper part of the section. The main factors limiting the foraminiferal association were the eutrophication, tide height, landscape relief and salinity changes caused by evaporation.

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Resumé: Vo vrte Mz 93 boli vyhodnocované sedimenty zo 4 jadier (5, 4, 3, 2) s celkovým rozsahom hĺbky od 875 m do 623,5 m. Vrt je situovaný v oblasti mesta Malacky, v slovenskej časti Viedenskej panvy. Vrtné jadrá boli tvorené jemno a strednozrnným šedým, šedozeleným a šedohnedým ílom až ílovcom, s polohami piesku, vo vrchných častiach boli sedimenty laminované, s vrstvičkami zuhoľnatenej rastlinnej hmoty. Dierkavce boli separované plavením štandardnými metodikami. Vo výplavoch z najspodnejších sedimentov vrtného jadra boli identifikované okrem rôznych organických zvyškov (schránky lastúrničiek a ich úlomky, úlomky lastúr mäkkýšov, kostičky rýb) redeponované schránky dierkavcov ako aj schránky autochtónnych dierkavcov. Smerom do nadložia pribúdali zvyšky vegetácie, ktoré boli v najvrchnejšom jadre zastúpené zvyškami šišiek glyptostróbov. Sedimenty boli na základe prítomnosti Elphidium reginum d´Orbigny, Affinetrina voloshinovae pectiniformis (Bogdanowicz) zaradené do sarmatu (12,7 – 11,6 Ma). Typické asociácie sarmatu (Ammonia, Anomalinoides badenensis, veľké elfídiá, malé miliolidy a Porosonion) sa v študovaných sedimentoch striedali a teda neumožnili dokázať priamu súvislosť s vekom. Môžeme povedať, že spoločenstvo zóny Elphidium reginum patrí do spodného sarmatu, nakoľko neobsahuje dierkavce charakteristické pre mladšie sedimenty. Iba vo vrchných častiach vrtu, v asociácii zóny Porosonion granosum sa zriedkavo vyskytovali druhy ako Affinetrina voloshinovae pectiniformis (Bogdanowicz), ktoré boli doteraz určené len vo vrchnosarmatských sedimentoch Centrálnej Paratetýdy. Spoločenstvá dierkavcov v študovaných sedimentoch dokumentovali veľmi plytkovodné sedimentačné podmienky. V takýchto sedimentačných podmienkach sa v závislosti od reliéfu, výšky prílivu ako aj vysychania okrajových častí sedimentačného priestoru striedali podmienky morské, brakické a hypersalinné a vyvíjali sa v nich zodpovedajúce spoločenstvá dierkavcov.

Appendix 1. Ecological groups of foraminifera according to SenGupta 2002, Murray 2006 and Seiglie 1966.

Appendix 1. Skupiny dierkavcov s rovnakými paleoekologickými nárokmi, zostavené podľa SenGupta 2002, Murray 2006 Seiglie 1966.

Shallow water	Infauna	Epiphytic	Euryhaline	Hyperhaline
Ammonia sp. div.	Bolivina pseudoplicata	Anomalinoides badenensis	Ammonia sp. div.	Quinqueloculina sp.div.
Anomalinoides badenensis	Bolivina sarmatica	Elphidium sp. div.	Cibicides boueanus	Quinqueloculina minakovae
Elphidium sp.div	Bulimina marginata	Lobatula lobatula	Nonion sp.	Quinqueloculina badenensis
Lobatula lobatula	Buliminella elegantissima	Nonion commune	Porosononion martkobi	Quinqueloculina sp.
Nonion sp. div.	Buliminella multicamerata		Porosononion granosum	
			Porosononion martkobi (Bogdanowicz)	
			Porosononion sp.	

Appendix. 2: Ecological groups of foraminifera toleration to various O2 value, according to Sen Gupta 2002, Kaiho 1994, 1999, Murray 2006, Moodley & Hess, 1992, and Pawlowski et al. 1995.

Appendix. 2: Skupiny dierkavcov rozdelené na základe tolerancie nedostatku kyslíka, podľa Sen Gupta 2002, Kaiho 1994, 1999, Murray 2006, Moodley & Hess, 1992, and Pawlowski et al. 1995.

Oxic	Suboxic	Dysoxic
Cibicides boueanus	Fissurina mironovi	Bolivina pseudoplicata
Quinqueloculina akneriana rotunda	Fissurina sp.	Bolivina sarmatica
Quinqueloculina badenensis	Nonion biporus	Bulimina marginata
Quinqueloculina minakovae	Nonion bogdanowiczi	Buliminella elegantissima
Quinqueloculina sp.	Nonion commune	Buliminella multicamerata
	Nonion depressulum	Ammonia gr.
	Nonion serenus	
	Nonion sp.	
	Nonion tumidulus	

Appendix 3: List of foraminiferal taxa identified in the studied material.

Appendix 3: Zoznam taxónov dierkavcov identifikovaných v študovanom materiále.

Adelosina longiostra (d´Orbigny)
Affinetrina voloshinovae pectiniformis (Bogdanowicz)
Alabamina sp.
Ammonia parkinsoniana (d´Orbigny)
Ammonia sp.
Ammonia tepida (Cushman)
Ammonia vienensis (d´Orbigny)
Angulogerina angulosa (Williamson)
Anomalinoides dividens Luczkowska
Anomalinoides badenensis (d´Orbigny)
Articulina articulinoides Gerke & Issaeva
Asterigerinata planorbis (d´Orbigny)
Baggina sp.
Bolivina antiqua d´Orbigny
Bolivina dilatata brevis Cicha & Zapletalova
Bolivina dilatata dilatata Reuss
Bolivina dilatata maxima Cicha & Zapletalova
Bolivina molassica Hofmann
Bolivina plicatella Cushman
Bolivina pokornyi Cicha & Zapletalova
Bolivina pseudoplicata Heron – Allen & Earland
Bolivina sarmatica Didkovski
Bolivina sp.
Bulimina elongata d´Orbigny
Bulimina marginata d´Orbigny
Bulimina sp.
Bulimina striata d´Orbigny
Buliminella elegantissima (d´Orbigny)
Buliminella multicamerata (Cushman & Parker)
Cassidulina laevigata d´Orbigny
Cassidulina sp.
Cassigerinella globulosa (Egger)
Catapsydrax dissimilis Cushman & Bermudez
Caucasina schischkinskaye Samoilova
Cibicides boueanus (d´Orbigny)
Cibicides sp.
Cibicidoides budayi (Cicha & Zapletalova)
Cibicidoides lopjanicus (Myatlyuk)
Cibicidoides ungerianus ornatus (Cushman)
Cibicidoides sp.
Cycloforina badenensis (d´Orbigny)
Cycloforina contorta (d´Orbigny)
Cycloforina sp.
Elphidium advenum Cushman
Elphidium crispum (Linne)
Elphidium excavatum excavatum (Terquem)
Elphidium flexuosum (d´Orbigny)
Elphidium glabrum Bystrická
Elphidium hauerinum (d´Orbigny)
Elphidium josephinum (d´Orbigny)
Elphidium joukovi Serova
Elphidium macellum (Fichtel & Moll)
Elphidium microelegans Serova
Elphidium midhati (Karrer)
Elphidium reginum (d´Orbigny)
Elphidium rugosum (d´Orbigny)
Elphidium sp.
Eponides repandus (Fichtel & Moll)
Eponides sp.
Fissurina mironovi (Bogdanowicz)
Fissurina sp.
Fursenkoina acuta (d´Orbigny)
Glandulina sp.
Turborotalita quinqueloba (Natland)
Globigerinoides trilobus (Reuss)
Globocassidulina oblonga (Reuss)
Globocassidulina subglobosa (Brady)
Globorotalia (Obandyella) bykovae (Aisenstat)
Globorotalia sp.
Globorotalia (Obandyella) transsylvanica Popescu
Heterolepa dutemplei (d´Orbigny)
Heterolepa sp.
Lobatula lobatula (Walker & Jacob)
Neoeponodes schreibersi (d´Orbigny)
Nodobaculariella sulcata (Reuss)
Nodosaria sp.
Nonion biporus Krashennikov
Nonion bogdanowiczi Voloshinova
Nonion commune (d´Orbigny)
Nonion depressulum (Walker & Jacob)
Nonion serenus Venglinski
Nonion sp.
Nonion tumidulus Pischvanova
Orbulina suturalis Brönnimann
Porosononion granosum (d´Orbigny)
Porosononion martkobi (Bogdanowicz)
Porosononion sp.
Praeglobobulimina pupoides (d´Orbigny)
Praeglobobulimina sp.
Pseudotriloculina consobrina (d´Orbigny)
Pullenia bulloides (d´Orbigny)
Pygmaeoseistron hispidum (Reuss)
Quinqueloculina akneriana rotunda Gerke
Quinqueloculina badenensis d´Orbigny
Quinqueloculina minakovae Bogdanowicz
Quinqueloculina sp.
Reusella spinulosa (Reuss)
Reussella sp.
Rosalina obtuse d´Orbigny
Rosalina sp.
Schackoinella imperatoria (d´Orbigny)
Sinuloculina consobrina sarmatica (Gerke)
Stilostomella adolphina (d´Orbigny)
Stilostomella sp.
Streptochilus globulosum (Cushman)
Streptochilus latum Brönnimann & Reisig
Subbotina cryptomphala (Glaessner)
Subbotina utilisindex (Jenkins & Orr)
Tenuitella clemenciae (Bermudez)
Tenuitellinata juvenilis (Bolli)
Tenuitellinata pseudoedita (Subbotina)
Tenuitellinata uvula (Ehrenberg)
Trifarina sp.
Varidentella reussi (Bogdanowicz)
Varidentella sarmatica (Karrer)
Varidentella sp.