New methods in foraminiferal and calcareous nannoplankton analysis and evolution of Oligocene and Miocene basins of the Southern Slovakia

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Abstract. New methods in the study of foraminiferal and calcareous nannoplankton assemblages enable to distinguish and paleoecologically and paleogeographically interpret nine time intervals in the marine evolution of the South Slovak depressions. Kiscellian represents tectonically inactive period with good correlatin between local and global sea-level changes and widespread occurrence of low-oxic facies. Tectonic activity is evident during the Egerian. Basin morphology gradually changed from the Buda Basin to the Fiľakovo /Pétervásara Basin and communication with the East Slovak Basin was opened. Local sea-level changes cannot be correlated with global ones. Displacement of the Kiscellian and Egerian foraminiferal assemblages around the Plešivec-Rapovce Fault can be observed. Eggenburgian evolution of the basin is characterized by weak influence of tectonic activity and local and global sea-level changes can be correlated. Changes in basin morphology can be observed in the Eggenburgian when communication with Bánovce Depression was opened. During the Ottnangian, rearrangment of basin geometry from the Fiľakovo/Pétervásara Basin to Novohrad/Nógrád Basin was finished. Communication with open sea was realized across the Várpalota area. The Karpatian represented tectonically inactive period with good correlation between local and global sea-level changes. Specific evolution of the South Slovak depressions is observable around the Karpatian / Badenian boundary; it may be connected with the initiation of volvanic activity. Early Badenian transgression occurred later in the South Slovak depressions than in other Central Paratethys basins.

Key words: South Slovak depressions, Tertiary, Foraminifera, calcareous nannoplankton, paleogeography

Introduction

The South Slovak depressions represents an area with very good level of standard biostratigraphic, litostratigraphic and sedimentological analysis summarized by Vass et al. 1979, 1983, 1986, 1989, 1992. The principal results are shown in Fig. 1. Lithostratigraphical units were defined by Vass and Elečko (1982). Correlation with standard nannoplankton zones (Martini, 1971) was done by Lehotayová (1982). Paleogeographical maps were constructed for every stage for the Ipeľ a Rimava Depressions (Vass et al., 1979, 1989). Important tectonic events were distinguished (Vass et al., 1993; Márton et al. 1995; Vass 1995). Local sea-level changes were correlated with global changes (Vass, 1995). In the analysed time interval, radiometric ages were determined for the Lower Miocene only (Vass et al., 1971; Vass and Bagdarasjan, 1978; Vass et al., 1985, 1987; Vass and Balogh, 1986; Repčok, 1987; Kantor et al., 1988 in Vass et al., 1992).

The above mentioned level of knowledges enables to test possible application of new methods of micropaleontological study on precise biostratigraphy, paleoecology, paleogeography and tectonic evolution of the Basin.

The aim of this paper is to show synthesis of results obtained by the use of new micropaleontological methods in deciphering the evolution of marine basins in the Oligocene and Miocene of the South Slovak depressions.

1. Study area

Geomorphological unit called South Slovak depressions consists of 3 partial depressions: Ipeľ, Rimava and Lučenec. It was a part of three marine basins during the Oligocene and Miocene (Vass, 1995):

(1) Buda Basin (Oligocene - Egerian/Eggenburgian boundary); the South Slovak depressions represents northern part of the Buda Basin;

(2) Fiľakovo/Pétervásara Basin (Eggenburgian); the South Slovak depressions was situated in the southern margin of this basin;

(3) Novohrad/Nógrád Basin (Ottnangian-Karpatian), the northern margin of which was represented by the South Slovak depressions.

The Lower Badenian transgression penetrated from the Danube Basin to the area of the South Slovak depressions and the Basin represented eastern margin of this marine basin.

Area of the South Slovak depressions was flooded by the following prominent marine transgresions: the Kiscellian-Egerian, the Eggenburgian, the Ottnangian-Karpatian and the relatively short Lower Badenian transgression. The long-lasting emergence was recorded during the Upper Eggenburgian and Ottnangian, an episodic one during the Upper Karpatian.

Lithostratigraphic units were defined for the Oligocene and Miocene fill of the South Slovak depressions

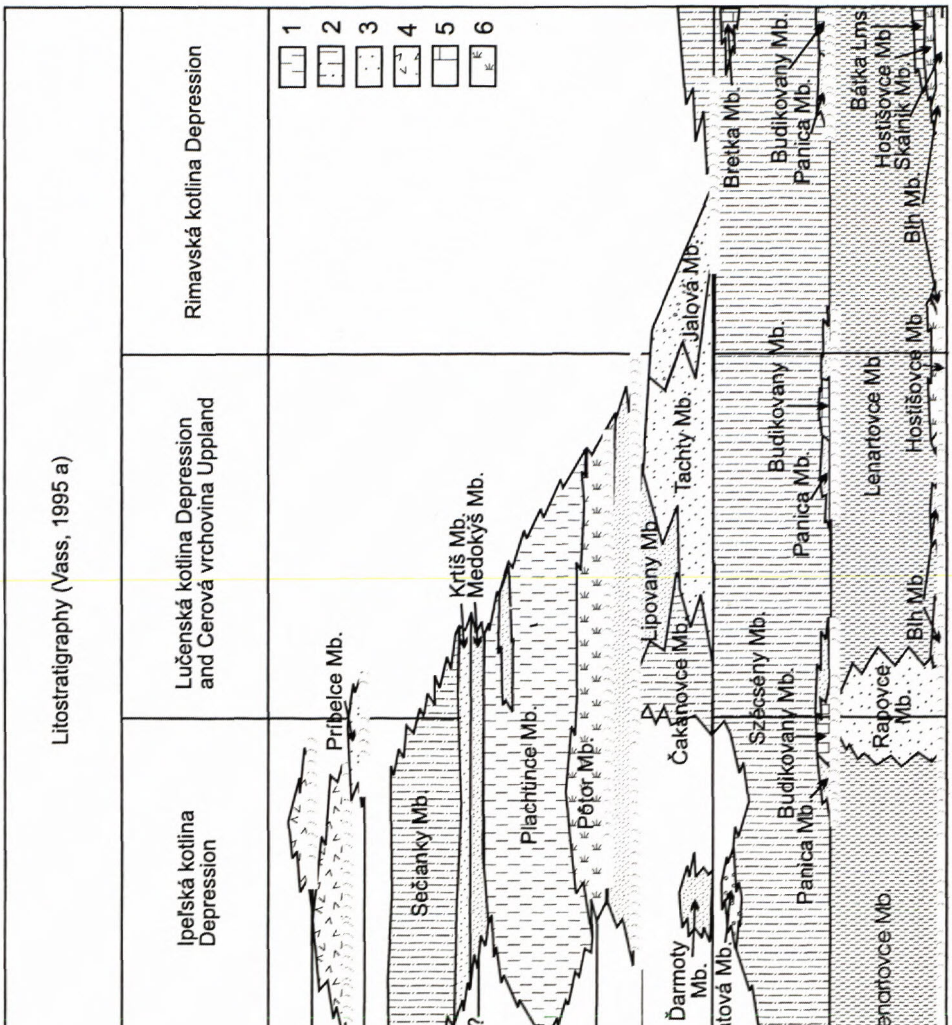

Fig. 1. A synthesis of the hitherto published litostratigraphic, biostratigraphic and radiometric data from the South Slovak depressions, tectonic events and correlation with global sea-level changes. 1 – claystones, 2 – silstones, 3 – sandstones, 4 – volcanoclastics, 5 – limestones, 6 – fluviolacustrine and terrestrial deposits

and correlated with the Central Paratethys stages. Marine units were correlated with standard planktonic foraminiferal and calcareous nannoplankton zonation (Fig. 1 based on data from the Vass et al., 1979, 1983, 1986, 1989, 1992).

Three important tectonic events were distinguished for the South Slovak depressions (Vass et al., 1993; Márton et al., 1995; Vass, 1995):

(1) 19-20 Ma - escape controlled by left-lateral strike-slip along the Plešivec-Rapovce Fault (several tens of kms);

(2) 18-17 Ma - first phase of rotation: CCW rotation by 50°;

(3) 16-15.5 Ma - second phase of rotation: CCW rotation by 30°.

2. Methods

Foraminifers were separated from the washing residuum using standard methods. Fraction > 63 μm was analysed. 200-300 specimens were used for quantitative analysis. Weight of the washed rock sample and of the washed residuum were recorded.

Calcareous nannoplankton was analysed using standard method in light microscope.

The following methods were first applied in the South Slovak depressions:

1. Biostratigraphy based on the correlation of LAD and FAD of biostratigraphically significant species instead of correlation with standard biozones. Planktonic foraminiferal species and calcareous nannoplankton species were discussed. Well recognizable horizons were selected for precise microbiostratigraphic correlation.

2. Taphonomical analysis. Suspension-transported, bedload-transported and indigenous tests were recognized using analysis of size-sorting of tests, their abrasion and

corrosion and coexistence of species with differnet ecological requirements in assemblages (Holcová 1996a). Paleoecology can be precised and interpreted separately for source areas and areas of deposition. (Fig. 2)

3. Analysis of reworked species. Such species can be recognized if their stratigraphical ranges differ from the those of species from autochthonous assemblages. Occurrences of reworked microfossils were used for the interpretation of source material for sediments (Fig. 3).

4. Multivariate statistics was aplied in paleogeography (Šutovská et al., 1993; Holcová and Maslowská, 1999).

5. Paleoecological synthesis as an indicator of tectonic activity. Paleoecological interpretations for isochronous samples were compared. Significant differences in paleoenvironment interpreted for neighbouring samples may indicate horizontal displacement along strike-slip faults.

6. Analysis of cyclicity in foraminiferal and calcareous nannoplankton assemblages can be used in detailed stratigraphy (Holcová, 1999).

Sedimentary history of the South Slovak depressions was reconstrued for the time interval defined by prominent biostratigraphic events (LADs and FADs of calcareous nannoplankton and planktonic foraminiferal species). The lithostratigraphic units were correlated with these time intervals, and a synthesis of paleoecological reconstruction was made for them.

4. Results

4.1. Important biostratigraphic events

4.1.1. LAD of *Paraglobigerina opima opima*

LAD of *Paraglobigerina opima opima* is the first significant event in the South Slovak depressions. Berrgren et al. (1995) dated this event to 27.1 Ma (= approximately Kiscellian/Egerian boundary sensu Rögl, 1998), Cicha et al. (1998) correlated it with the Lower Egerian. In the South Slovak depressions, this event is connected with a change in the character of foraminiferal assemblages: large-size and diversified older assemblages with *Paraglobigerina opima opima* were substituted by small-size, low-diversified assemblages composed mainly of small-sized globigerinas. A decreasing diversity of planktonic foraminifers in this time interval was recorded also in the Pacific Ocean (Srinivasan and Kennett, 1983).

In the analysed material, this event can be corellated with the lithological change from the Lénartovce Mb. to the Szécsény Mb or appears in the lowermost part of the Szécsény Mb.

4.1.2. FAD of *Helicosphaera kamptneri*

This event was recorded in two boreholes as a marked event in the lower part of the Szécsény Mb. Perch-Nielsen (1985) described its FAD around the NN 1, NN 2 zones. Savitska (unpublished data) reported this event at the NN 1/NN 2 boundary from the Ukraine Carpathians. In the South Slovak depressions, this event needs verification using a higher number of sections.

4.1.3. LAD of *Reticulofenestra bisecta*

LO of *Reticulofenestra bisecta* is used to approximate the NP 25/NN 1 boundary (Berrgren et al., 1995; 23.9 Ma, Rio et al., 1990 for the Indian Ocean). In the Mediterranen, this event was recorded in the lower part of NN 1 Zone (Fornaciari and Rio, 1996). In the Central Paratethys, it was reported from younger sediments (NN1/NN2 boundary, Savitska, unpublished data). In the study area, this species was observed continuously up to the level with *Discoaster druggi* and *Globigerinoides trilobus*. As many reworked Oligocene nannoliths occur at this level (*Cyclicargolithus abisectus, Helicosphaera recta, Discolithina latelliptica,* etc.), reworking of *Reticulofenestra bisecta* is also expected at this time level. No criteria were found for the recognition of its reworking. Therefore, the LAD of *Reticulofenestra bisecta* cannot be used as a good biostratigraphic marker.

4.1.4. FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica*

In the study area, FAD of *Reticulofenestra pseudoumbilica* is a very common event, while *Globigerinoides primordius* is rare. These events were mentioned also in the manuscripts of Tuba in Vass et al. (1986) and Báldi in Vass et al. (1986).

Berrgren et al. (1995) dated the FAD of *Globigerinoides primordius* to 26.7 Ma. In the Central Paratethys, the FAD of *Globigerinoides primordius* is placed to the lowermost Egerian (Cicha et al., 1971; Cicha et al.,1975; Horváth, 1983; Kucinsky, 1984; Gruzman, 1983; Cicha et al., 1998) while the FAD of *Reticulofenestra pseudoumbilica* appeared at the NN1/NN2 boundary (Marineatu, 1993). In the Atlantic Ocean near Madeira, Howe and Sblendorio-Levy (1998) described the FAD of *Reticulofenestra pseudoumbilica* (> 7 μm) in the upper part of NN 2 Zone. In the Mediterranean, the FAD of *Reticulofenestra pseudoumbilica* was described only in the Middle Miocene (NN 6 Zone; Fornaciari and Rio, 1996). This discrepancy is caused by different taxonomical concept of authors. Small-sized specimens are also determined as *R. pseudoumbilica* in the Paratethys, but only specimens larger than 11 μm are described as *R. pseudoumbilica* in the Mediterranen.

The isochroneity of the FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* is specific for the South Slovak depressions. In other basin of the Central Paratethys FAD of *Globigerinoides primordius* preceded FAD of *Reticulofenestra pseudoumbilica.*

Also the succession of the LAD of *Paraglobigerina opima opima* and FAD of *Globigerinoides primordius* in the South Slovak depressions differs from the other Central Paratethys basins. The following succesion of significant FAD and LAD of planktonic foraminifers was observed in the same Buda Basin in northern Hungary including stratotype sections Eger and Novay (Sztrákos, 1978; Horváth, 1983): 1. FAD *Globigerinella obesa*, FAD *Globigerinoides* (Egerian/Kiscellian boundary), 2. LAD *Paraglobigerina opima opima* (Lower Egerian).

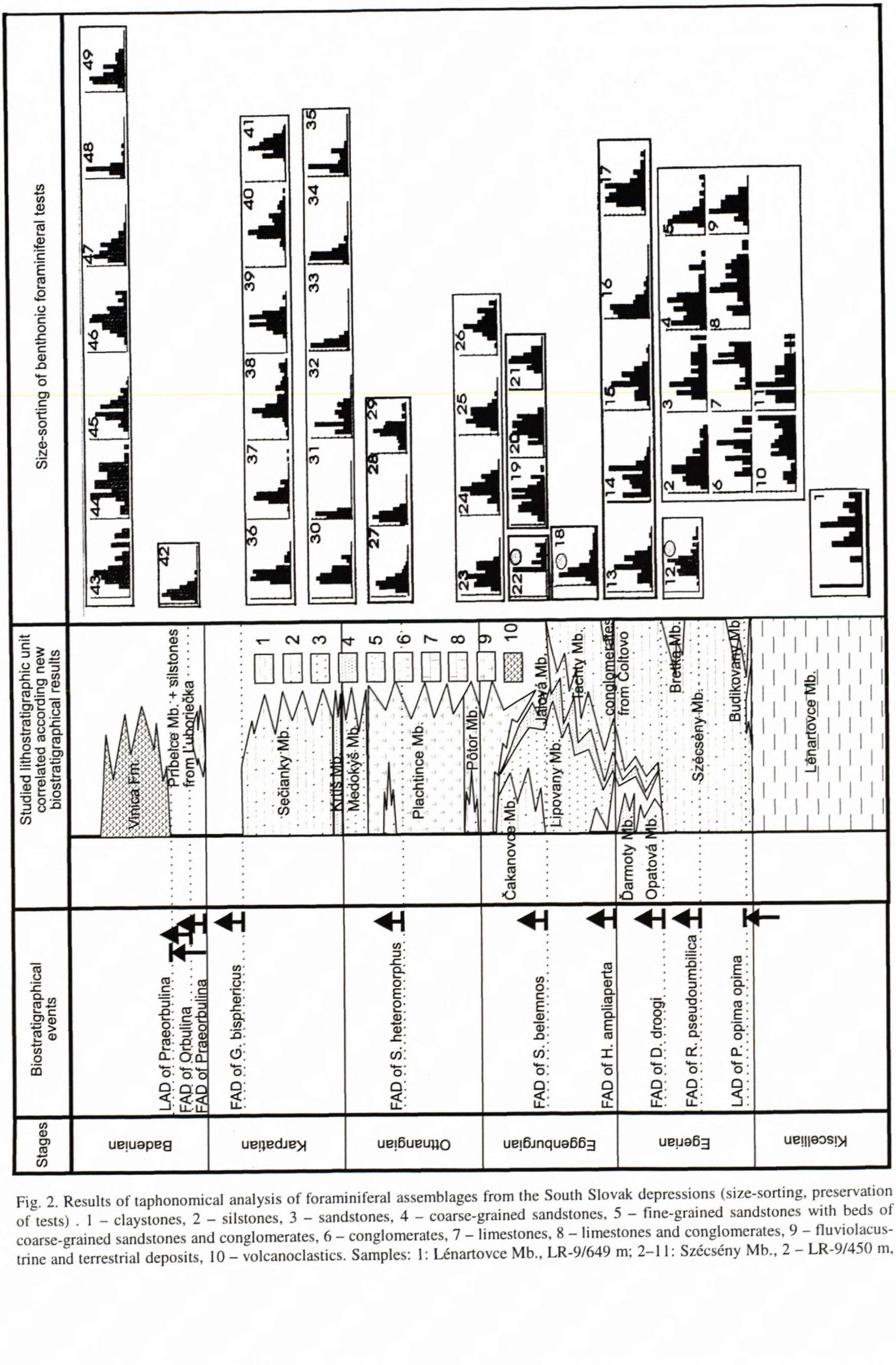

Fig. 2. Results of taphonomical analysis of foraminiferal assemblages from the South Slovak depressions (size-sorting, preservation of tests) . 1 – claystones, 2 – silstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – fluviolacustrine and terrestrial deposits, 10 – volcanoclastics. Samples: 1: Lénartovce Mb., LR-9/649 m; 2–11: Szécsény Mb., 2 – LR-9/450 m,

This observation agrees with the stratigraphical ranges of the species given by Cicha et al. 1998. The same succesion of these species was used in planktonic foraminiferal zonation proposed for the Central Paratethys by Cicha et al., 1975 (zone *Globorotalia opima opima - Globigerinoides*).

In the South Slovak depressions, the interval between the LAD of *Paraglobigerina opima opima* and the FAD of *Globigerinoides primordius* is characterized by low-diversified, small-sized assemblages of planktonic foraminifers. This interval was also found in northern Hungary but is shorter than in the South Slovak depressions (glauconitic sand in the lowermost Egerian). Both biostratigraphic specifics observed in the South Slovak depressions (isochroneity of the FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* and succession of the LAD of *Paraglobigerina opima opima* and FAD of *Globigerinoides primordius*) are caused by the late FAD of *Globigerinoides primordius* in the South Slovak depressions. The late penetration of *Globigerinoides primordius* (together with more diversified planktonic foraminiferal assemblages) into segments of the Buda Basin now situated in the South Slovak depressions probably resulted from tectonic activity in this period, which changed configuration of the basin and isolated this part of the Buda Basin. Precise palynspastic reconstructions of the original location of this isolated bay is impossible because all tectonic displacements have not been explained yet.

4.1.5. FADs of *Discoaster druggi* 23.2 Ma and *Helicosphaera scissura*

The FAD of *Discoaster druggi* was used for the definition of base of the NN 2 Zone and was dated on 23.2 Ma (Berggren et al. 1995). This event is well observed in the Mediterranean (Fornaciari and Rio, 1996). In the Central Paratethys, this event was mentioned from the same level from the Ukraine: NN1/NN 2 boundary.

In the South Slovak depressions, there are two practical problems in distinguishing this event: the species are rare, discoasters are often broken, and these broken specimens cannot be correctly determined.

It is very probable that the FAD of *Discoaster druggi* can be correlated with the FAD of *Helicosphaera scissura*. The latter species is relative by abundant and the events are well observable. The event of the FAD of *Helicosphaera scissura* has not been mentioned from other parts of the Central Paratethys.

4.1.6. FADs of *Helicosphaera ampliaperta* and *Globigerinoides trilobus*

These are local events, important for the Mediterranean and Central Paratethys (FAD of *Helicosphaera ampliaperta*), or only for the Central Paratethys (FAD of *Globigerinoides trilobus*). FAD of *Helicosphaera ampliaperta* was dated to aproximatelly 20 Ma from the Mediterranean (Fornaciari and Rio, 1996). From the Central Paratethys, they are described from Romania and placed within the NN 2 Zone (Marunteanu, 1992). The species appeared in the transsgresive Loiberstdorf Fm. from the Eggenburgian stratotype Loibersdorf (Holcová, in prep.).

The FAD of *Globigerinoides trilobus* was described from different stratigraphical levels in the Central Paratethys: Cicha et al. 1998 dated it to the upper Egerian, and so did Trofimovitsh (unpublished data) from the Ukraine. In Romania, this species is mentioned from the middle Egerian (Popescu, unpublished data).

4.1.7. FAD of *Sphenolithus belemnos*

The FAD of *Sphenolithus belemnos* is dated to 19.2 Ma (Berggren et al., 1995) and defined aproximately the NN 2/NN 3 boundary and strictly the CN 1/CN 2 boundary. Fornaciari and Rio (1996) dated this event to aproximately 19.1 Ma in the Mediterranean area. From the Central Paratethys, this event was described in Romania at the NN 2/NN 3 boundary (Marunteanu, unpublished data). Savitska (unpublished data) described the FAD of *Sphenolithus belemnos* from the interval of the NN 2 + NN 3 zones.

In the South Slovak depressions, the FAD of *Sphenolithus belemnos* was observed in the uppermost part of the Lipovany Mb. The specimens are small-sized but morphologically fully identical with the holotype.

4.1.8. FAD of *Sphenolithus heteromorphus*

The FAD of *Sphenolithus heteromorphus* was dated to 18.2 Ma (Berggren et al., 1995). Fornaciari and Rio (1996) mentioned only FCO of this species from the lower part of NN 4 Zone. In the Central Paratethys, Marunteanu (unpublished data) described this event from the upper part of the NN 3 Zone.

In the South Slovak depressions, this event was reported from the marine ingression in the Plachtince Mb.

3 – LR-9/200 m, 4 – LR-9/12 m, 5 – LR-10/400 m, 6 – LR-10/150 m, 7 – LR-9/75 m, 8 – Španie Pole, 9 – Jesenské, 10 – Tornaľa-Behynce, 11 – Budikovany; 12 – Bretka Mb., Bretka - stratotype of Bretka Mb.; 13–17: Opatová Mb., 13 – ČO-1/96 m, 14 – VV-12/15 m, 15 – VV-12/6 m, 16 – ČO-1/6 m, 17 – ČO-1/74 m; 18: Ďarmoty Mb., Slovenské Ďarmoty, stratotype of Ďarmoty Mb.; 19–21: Tachty Mb., 19 – EH-1/77 m, 20 – Hostice, 21 – EH-2/20 m; 22: Jalová Mb., stratotype of Jalová Mb.; 23 – 26: Lipovany Mb., Lipovany, stratotype of Lipovany Mb.; 27–29: Plachtince Mb., 27 – D-19/561 m, 28 – D-19/588 m, 29 – LKŠ-1/340 m; 30 – 35: Medokýš Mb., 30 – N-65/120 m, 31 – Malý Krtíš, stratotype of Medokýš Mb., 32 – LKŠ-1/238 m, 33 – N-91/360 m, 34 – N-91/340 m, 35 – N-91/310 m; 36–41: Sečianky Mb., 36 – LKŠ-1/187 m, 37 – LKŠ-1/145 m, 38 – LKŠ-1/85 m, 39 – LKŠ-1/26 m, 40 – N-91/230 m, 41 – N-91/215 m; 42: Príbelce Mb., Horné Príbelce, stratotype of Príbelce Mb.; 43–49: tuffs with marine fauna in Vinica Fm., 43 – Trenč, 44 – Hámor, 45 – Plášťovce, 46 – N-83/278 m, 47 – N-83/225 m, 48 – N-95/275 m, 49 – N-95/250 m. Range of test size: 0,09–0,5 mm; lenght of class in histograms: 0,03 mm.

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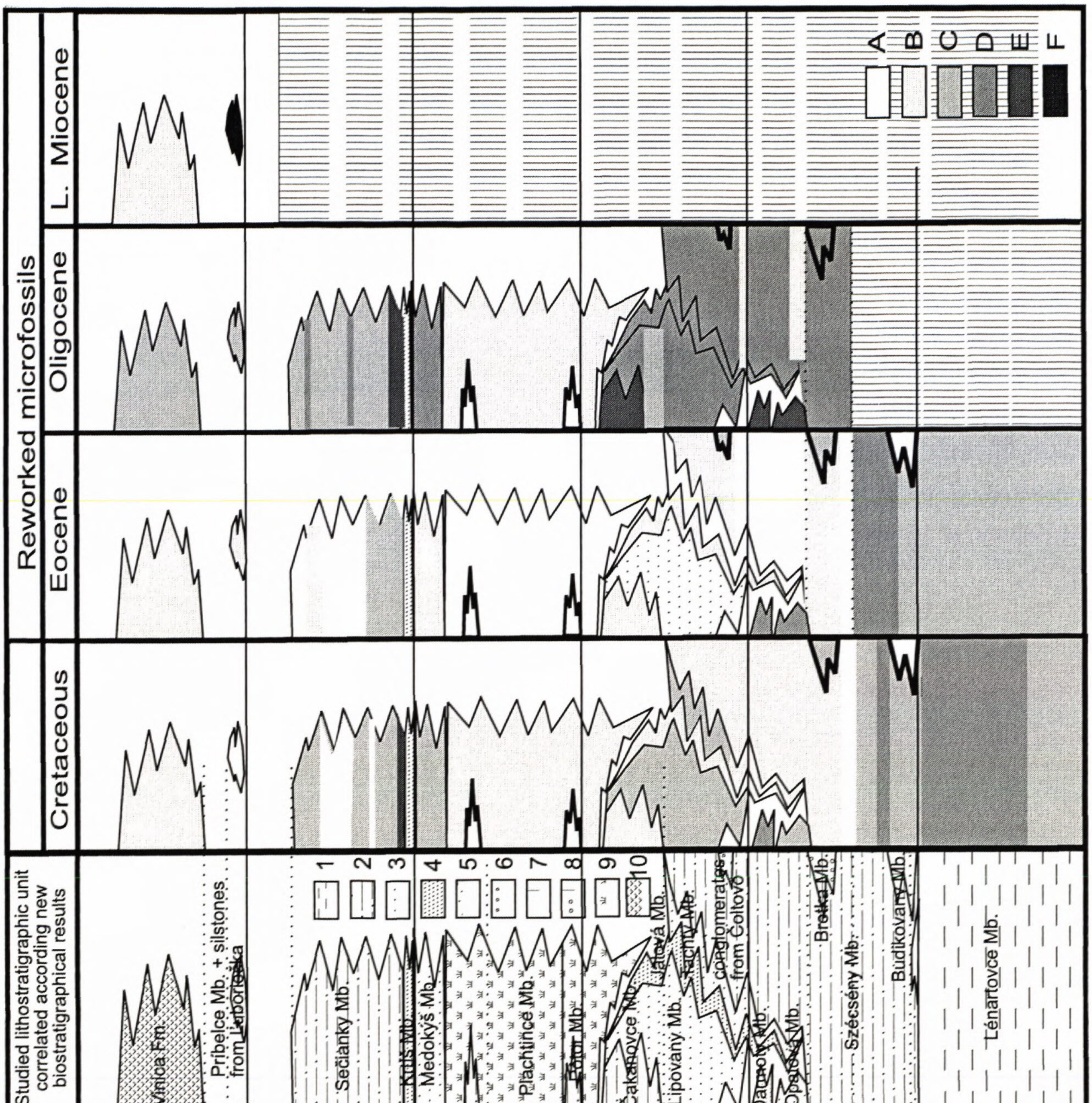

Fig. 3. Abundance and stratigraphical ranges of reworked assemblages in Oligocene and Miocene formations of the South Slovak depressions. 1 – claystones, 2 – silstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – fluviolacustrine and terrestrial deposits, 10 – volcanoclastics. A – F: Relative abundance of reworked species, A – 0 %, B – less than 1 %, C – 1-5 %, D – 5-10 %, E – 10-50 %, F – more than 50 %.

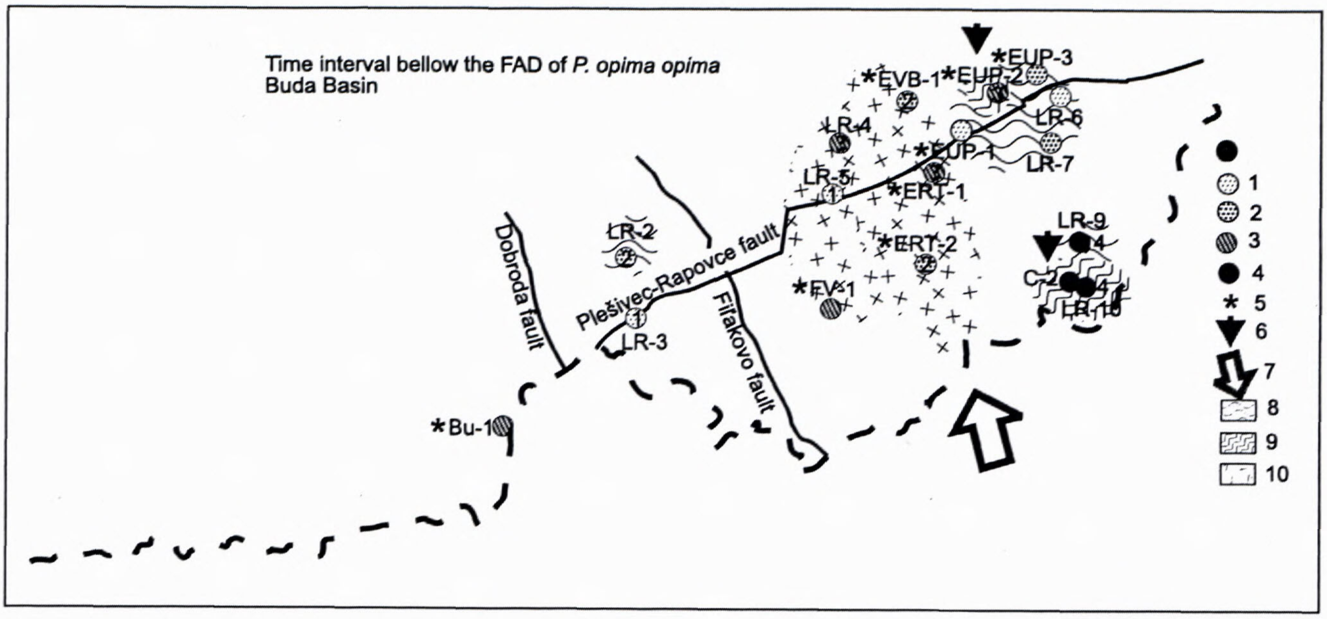

Fig. 4. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval below the FAD of *P. opima opima*. 1 – littoral, 2 – upper neritic, 3 – lower neritic, 4 – low-oxic, lower neritic to upper bathyal, 5 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 6 – local depocentre, 7 – proposed marine connection with other basin, 8 – LAD of *P. opima opima* correlated with layer of coarse-grained sediments, glauconite or limestone, 9 – LAD of *P. opima opima* correlated with lithological change from claystones to silstones, 10 – LAD of *P. opima opima* in the Lučenec Fm. Numbers 1 – 4 represent groups obtained by the Braun-Blanquet's methods.

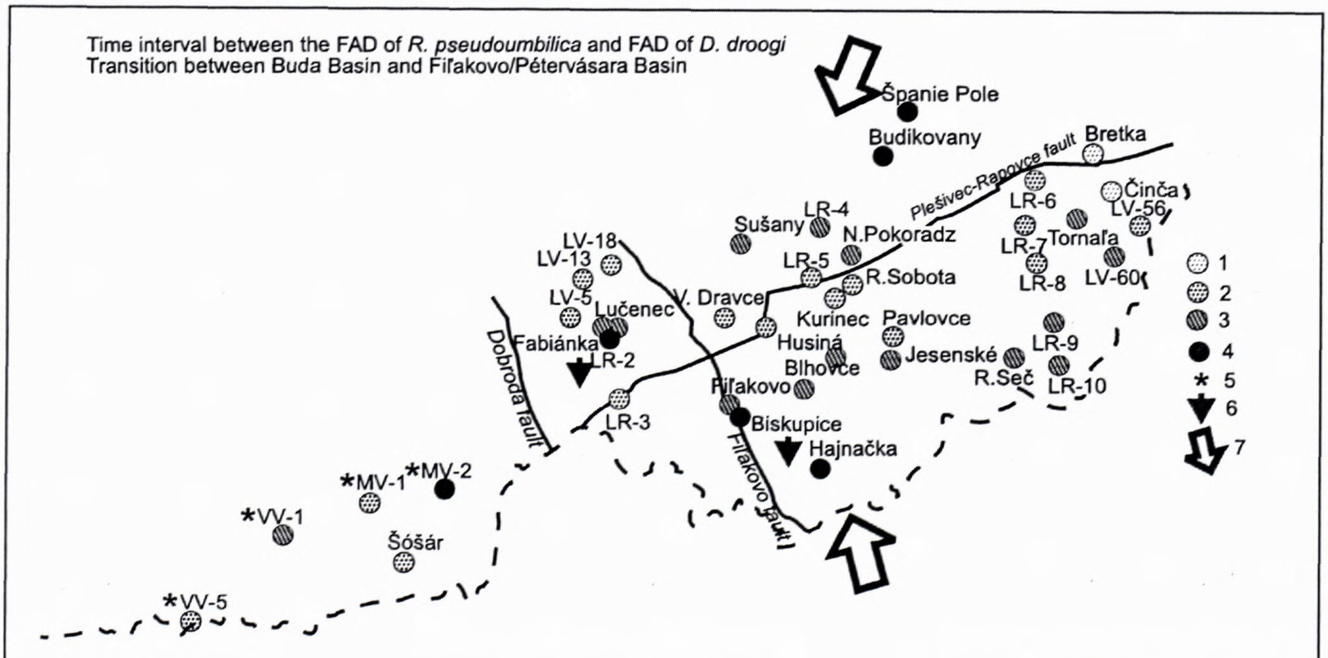

Fig. 5. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between FAD of *Reticulofenestra pseudoumbilica* and FAD of *Discoaster druggi*. 1 – littoral, 2 – upper neritic, 3 – lower neritic with low P/B-ratio, 4 – lower neritic with high P/B-ratio, 5 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 6 – local depocentre, 7 – proposed marine connection with other basin.

From the biostratigraphic point of view, a coexistence of *Sphenolithus belemnos* and *Sphenolithus heteromorphus* is mentioned. This is a short event recorded at one level in marine sediments of the Plachtince Mb. The possible coexistence of these species was discussed for different regions: common occurrence was mentioned from the Atlantic Ocean (Bukry, 1972; Takayama and Sato, 1985) and from the equatorial Pacific (Pujos, 1985). The event was not observed in the equatorial Atlantic (Olafsson, 1989), subtropical Indic Ocean (Fornaciari et al., 1990) and the Mediterranean (Fornaciari and Rio, 1996).

4.1.9. LAD of *Sphenolithus belemnos*

The LAD of *Sphenolithus belemnos* is dated to 18.3 Ma and defined by the NN 3/NN 4 boundary (Berggren et al., 1995). In the Mediterranean realm, this boundary was defined by the LCO of *Sphenolithus belemnos* (Fornaciari and Rio 1996). In the Central Paratethys, the LAD of *Sphenolithus belemnos* is correlated with NN 3/NN 4 in Romania (Marunteanu, unpublished data).

Continous marine sedimentation during the interval around LAD of *Sphenolithus belemnos* did not occur in the South Slovak depressions. The first sediments without *Sphenolithus belemnos* pertain to the Medokýš Mb.

4.1.10. FAD of *Globigerinoides bisphericus*

This event was described from the Medditerranean (Iaccarino, 1985) and dated to about 18.5 Ma in the zone with *Sphenolithus heteromorphus*. This time level can be correlated with Ottnangian in the Paratethys. The FAD of *Globigerinoides bisphericus* is a significant biostratigrafical event in the Central Paratethys but its FAD in the Paratethys is later than in the Mediterranean and correlated with the middle Karpatian (Cicha et al. 1998). FAD of *Globigerinoides bisphericus* is described from the Carpathian Foredeep (Cicha 1995), East Slovak Basin (Kováč and Zlinská 1998) in the upper part of Karpatian. The event was not observed in the South Slovak depressions.

4.1.11. LAD of *Helicosphaera ampliaperta*

This important biostratigraphic event is dated to 15.6 Ma in the world ocean (Berggren et al., 1995) and defined NN 4/NN 5 boundary. LCO (16.1 Ma) and LO (about 15.8 Ma) are distinguished in the Mediterranean (Fornaciari and Rio, 1996). This event is correlated with the NN4/NN5 boundary also in all Central Paratethys basins.

The last reliable occurrence of indigenous *Helicosphaera ampliaperta* was reported from the Karpatian Sečianky Mb. from the South Slovak depressions. The occurrence of *Helicosphaera ampliaperta* in sediments with *Praeorbulina* is questionable because reworked microfossils from the Lower Miocene prevailed in these sediments.

4.1.12. FAD of *Praeorbulina*

The FAD of *Praeorbulina* represents an important bioevent dated to 16.4 Ma in the world ocean (Berggren et al., 1995), and to about 16.2 in the Mediterranean region (Iaccarino, 1985). Cicha et al. (1998) correlated this event in the Central Paratethys with the base of the Badenian. Sporadic occurrences of *Praeorbulina* were described from the Carpathian Foredeep (Cicha, 1995) from the lowstand sediments at the Karpatian/Badenian boundary. Rögl (1998) correlated this level with the beginning of transgression in the entire circum-Mediterranean region and penetration of warm-water elements (including larger foraminifers) into higher latitudes.

Only one specimen of *Praeorbulina* was recorded in the South Slovak depressions in the sediments originally correlated with the Medokýš Mb. with prevailing reworked Lower Miocene microfossils. Mentioned very rare occurrence of *Praeorbulina* may be caused by paleoenvironment insuitable for pennetration of open marine elements (shallow-water, partly hyposaline).

4.1.13. FAD of *Orbulina*

FAD of *Orbulina* in the world ocean is dated to 15.1 Ma. Iaccarino (1985) correlated this FAD with a similar time level in the Mediterranean. Cicha et al. (1998) placed the FAD of Or*bulina* to the middle part of Lower Badenian in the Central Paratethys. Some authors (Popescu, Trofimovitsch, unpublished data) correlated this event with the Karpatian/Badenian boundary in the Central Paratethys basins in Romania and Ukrainian Carpathians.

In the Slovak Slovak Basin, *Orbulina* first appeared in the Vinica Fm.

4.1.14. LAD of *Praeorbulina*

The LAD of *Praeorbulina* is dated to 14.8 Ma in the world ocean (Berggren et al. 1995). Cicha et al. (1998) correlated this LAD with the middle part of Lower Badenian in the Central Paratethys on aproximately the same level as the FAD of *Orbulina.* Overlap of stratigraphical ranges of *Praeorbulina* and *Orbulina* was recorded most Neogene Basin in the Western Carpathians: the East Slovak Basin (Kováč and Zlinská, 1998), the Danube Basin (Zlinská et al.,1997), the Vienna Basin (Kováč and Hudáčková, 1997) and the Carpathian Foredeep.

This overlap was not observed in the South Slovak depressions. This indicates a hiathus representing this time interval.

4.2. Characteristics of time intervals defined by biostratigraphic events

Among all biostratigraphic events, the most appropriate events were choosen for the South Slovak depressions and time intervals between succesive pairs of these events were characterized.

Buda Basin

4.2.1. Time interval between the beginning of Oligocene sedimentation and LAD of *P. opima opima* (Kiscellian and lowermost Egerian)

In the South Slovak depressions, this time interval can be generally correlated with the deposition of the Lénartovce Mb. and with the Kiscellian. The age of the LAD of *P. opima opima* given by Berrgren et al. (1995), 27.1 Ma, can be well correlated with the age determined for the Kiscellian/Egerian boundary (about 27 Ma, Rögl, 1998).

Absence of older Oligocene bioevents indicates the Upper Kiscellian age of Lénartovce Mb.

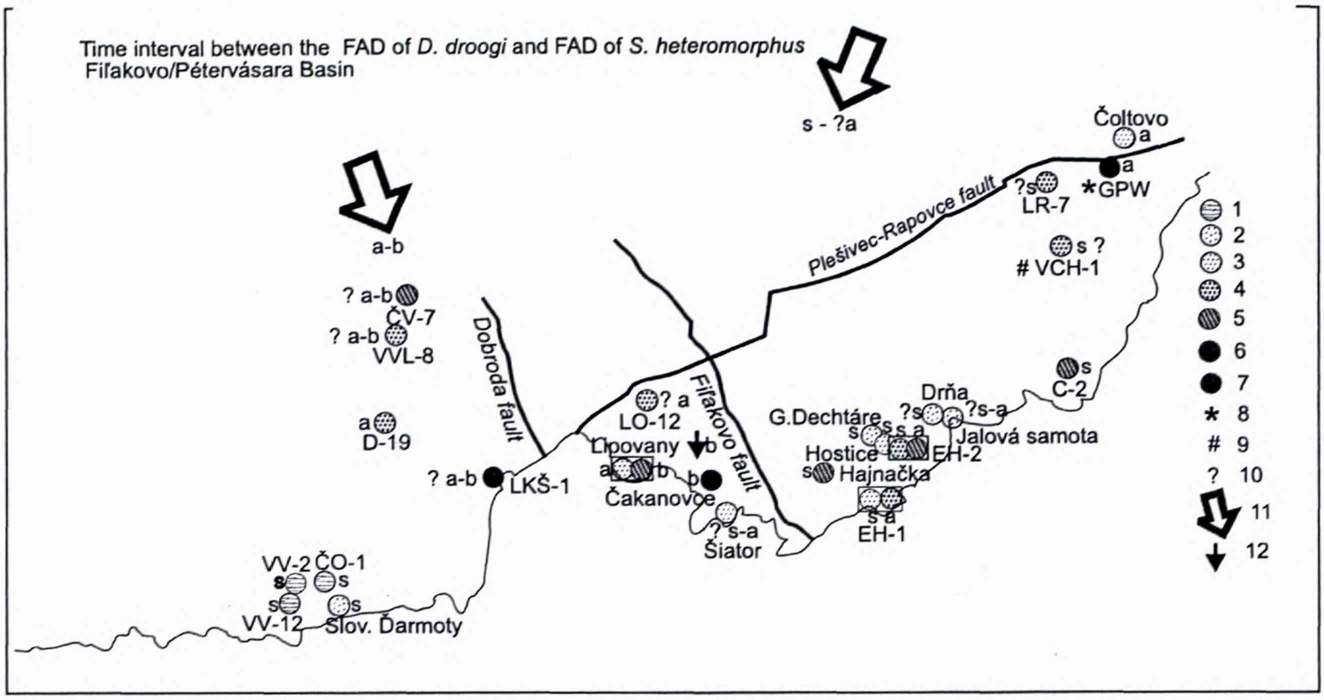

Fig. 6. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Discoaster druggi* and FAD of *Sphenolithus heteromorphus*. 1 – deltaic (alternation of suspension-transported and *Ammonia*-assemblages), 2 – hyposaline, 3 – littoral, normal marine, 4 – upper neritic, 5 – lower neritic with low P/B-ratio, 6 – lower neritic with high P/B-ratio, 7 – low-oxic, 8 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 9 – biostratigraphic data from Ondrejíčková, 10 – imprecise biostratigraphic correlation, 11 – proposed marine connection with other basin, s – time interval between the FAD of *Discoaster druggi* and FAD of *Helicosphaera ampliaperta,* a – interval between the FAD of *Helicopshaera ampliaperta* and FAD of *Sphenolithus belemnos*, b – interval between the FAD of *Sphenolithus belemnos* and FAD of *S. heteromorphus.*

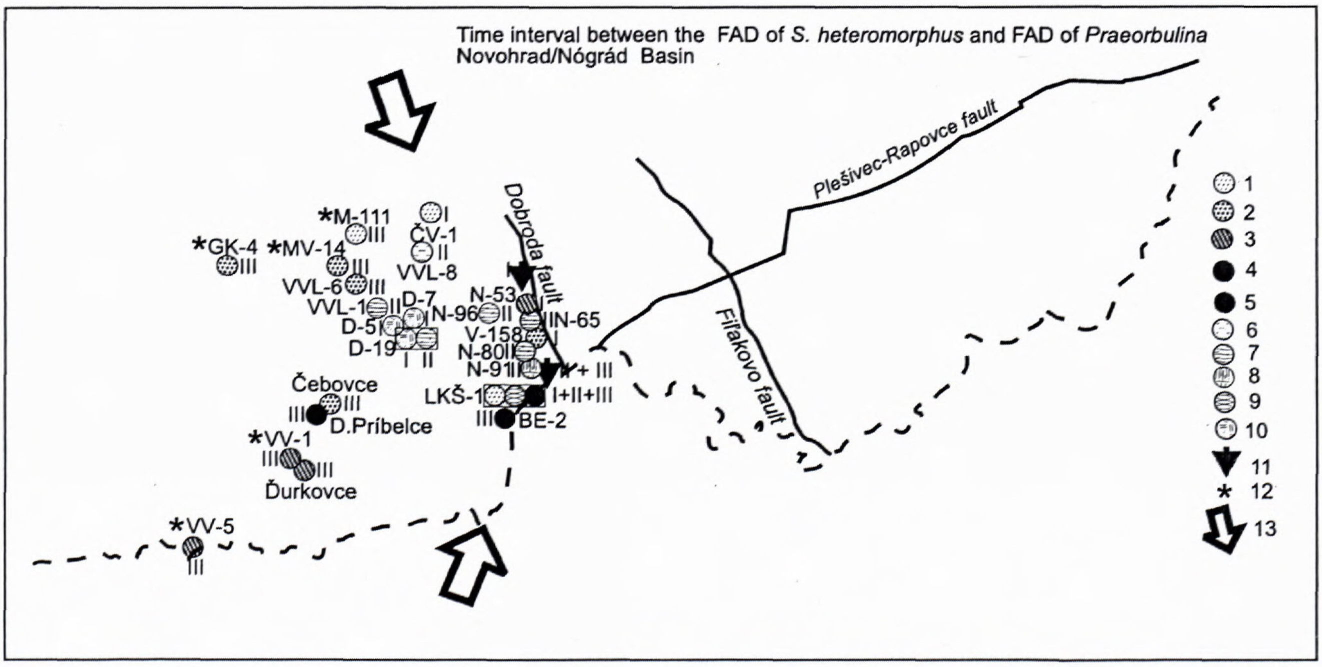

Fig. 7. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina*. 1 – littoral, 2 – upper neritic, 3 – lower neritic, 4 – bathyal, 5 – low-oxic, 6 – only suspension-transported foraminiferal tests in assemblage, 7 – suspension-transported tests + indigenous strongly hyposaline, 8 – suspension-transported tests + indigenous littoral hyposaline to normal marine, 9 – suspension-transported tests + indigenous upper neritic, 10 – upper neritic + suspension-transported planktonic foraminiferal tests, 11 – local depocentre, 12 – revised material deposited in collections of the Slovak Geological Survey, Bratislava, 13 – proposed marine connection with other basin, I – Ottnangian marine ingressions, II – sea-level cycle respresented by the Medokýš Mb. III – sea-level cycle represented by the Sečianky Mb.

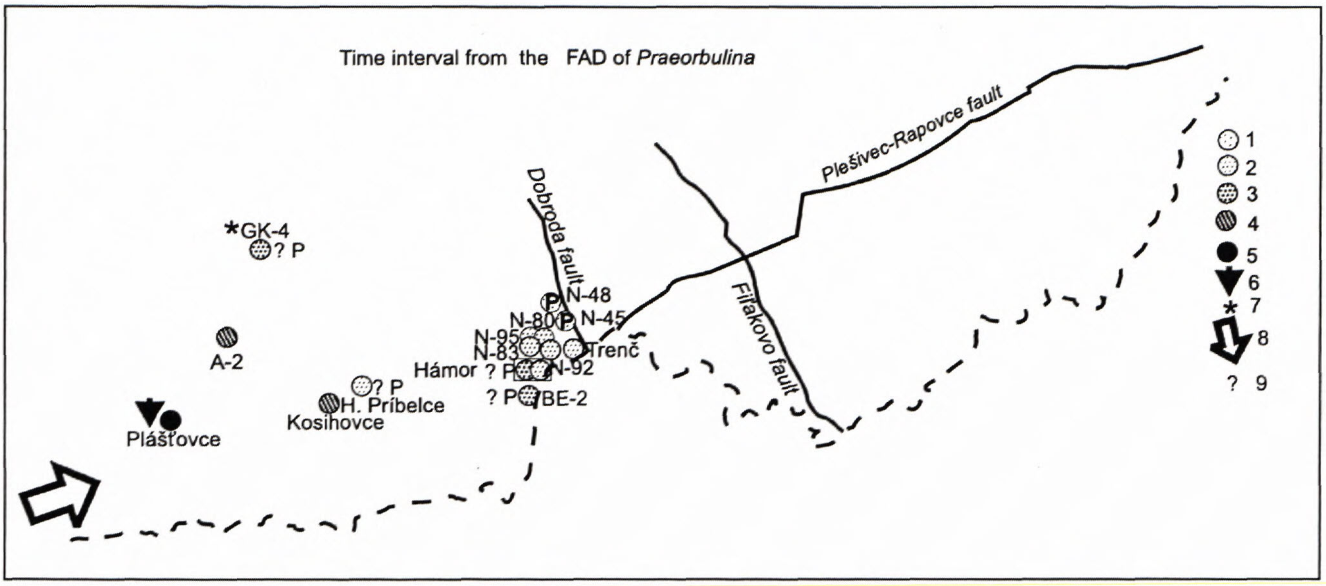

Fig. 8. Distributions of the studied foraminiferal assemblages in the South Slovak depressions in the time interval between the FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina*. 1 – hyposaline, 2 – littoral, normal marine, 3 – upper neritic, 4 – lower neritic with low P/B-ratio, 5 – lower neritic with high P/B-ratio, 6 – local depocentre, 7 – revised material deposited in collections the Slovak Geological Survey, Bratislava, 8 – proposed marine connection with other basin, 9 – imprecise biostratigraphic correlation.

Sediments with *P. opima opima* occur sporadically only in boreholes (nine boreholes with sediments from this time interval were studied). The LAD of *P. opima opima* is connected with a well distinct lithological change from dark claystones of the Lénartovce Mb. to lighter siltstones of the Szécsény Mb. Beds with glauconite, beds of limestones or coarse-grained sediments (conglomerates) appear around the LAD. In other boreholes, a gradual change from the Lénartovce Mb. to the Szécsény Mb. was observed. Kantorová in Vass et al. (1986) described *Paraglobigerina opima opima* also from the lowermost part of the Szécsény Mb. from borehole (FV-1) with a gradual transition from the Lénartovce Mb. to the Szécsény Mb. Spatial distribution of different types of the boundary between the Lénartovce Mb. and the Szécsény Mb. is figured on Fig. 4. Different types of transitions from the Lénartovce Mb. to the Szécsény Mb. connected with the LAD of *Paraglobigerina opima opima* may indicate a more complicated tectonic displacement of the original sedimentary basin.

There are two possibilities to explain the find of *Paraglobigerina opima opima* in the Szécsény Mb.:

(1) lithological change from the Lénartovce Mb. to the Szécsény Mb. is isochronous and *Paraglobigerina opima opima* may locally survive till the lower Egerian.

(2) LAD of *Paraglobigerina opima opima* is isochronous and sections with gradual change from the Lénartovce Mb. to the Szécsény Mb. are complete. An abrupt lithological change may be connected with a short-time hiathus and the absence of the lowermost part of the Szécsény Mb. with *Paraglobigerina opima opima.* This second possibility is more probable.

Benthonic foraminiferal assemblages are characterized by high abundance and high diversity (but not as high as in Hungary) and higher P/B-ratio than in the overlying sediments (20 - 40 % as opposed to 5 - 20 %). Species composition of benthonic foraminiferal assemblages is different from that of the overlying assemblages and can be well distinguished by multivariate statistics (block clustering analysis, Šutovská et al. 1993). Assemblages are indigenous: no size-sorting, no abrasion and corrosion were observed, juveniles and adults are present.

The assemblages can be well paleoecologically interpreted. The maximum paleodepth is estimated at 500 m. Assemblages with euryoxibiont elements were recorded in the central part of the basin. The occurrence of pyrite is characteristic for these washing residua and indicates low-oxic paleoenvironment. This anoxic event is characteristic for the whole Paratethys (Rögl, 1998). In marginal parts of basin, hyposaline assemblages occur with *Elphidiella* div. sp. Hypersaline lagoonal facies was described from the Krupina Depression (Vass et al., 1979). Shallowing was observed in the uppermost part of this time interval.

Based on the character of anoxic events, three categories of Oligocene to Miocene basins in the central Paratethys were distinguished (Šutovská, 1990):

(1) those where low-oxic environment occurred in the central part of basin dominated by deposition of dark claystone. Marginal parts of the basin were characterized by hyposaline facies. This distribution of low-oxic environment required stable development, and tectonically inactive marine basins with flat bottom in the central part and weak circulation of near-bottom waters.

(2) low-oxic environment was distributed locally in different paleodepths. This type of distribution of low-oxic facies was connected with the deposition of "schlier". This is interpreted for periods of depth-diversified bottom, when low-oxic environment persisted

only in partly isolated small parts of basin for limited time periods.

(3) low-oxic environment did not develop. Periods with no low-oxic environment can be connected with period of large transgressions.

The Kiscellian anoxic event represents type (1) of this classification.

Using Brau-Blanquet methods's (Brau-Blanquet, 1964; application in micropaleontology Hilterman and Tuxen, 1974), 4 types of assemblages of benthonic foraminifers were distinguished. Their spatial distributions (as well as spatial distribution of other studied Kiscellian samples) are shown in Fig. 4. This figure gives a rough idea about the paleogeography of the South Slovak depressions during the Kiscellian: southward deepening was generally observed (from the upper neritic to the lower neritic zones, approximatelly from 50 to 500 m). Shallow-water assemblages along the SW-NE belt (Rapovce - Čierna Lúka - Teriakovce) can be parallelized with similar discrepancy in paleodepth interpretation in the Egerian (Fig. 5). The occurrence of a shallow-water assemblage in the middle of the present-day South Slovak depressions probable indicates postsedimentary displacement of NW and SE segments and it can be well paralleled with the post-Egerian escape controled by the left strike-slip along the Plešivec-Rapovce Fault (Vass et al., 1993). Different types of transitions from the Lénartovce Mb. to the Szécsény Mb. in the South Slovak depressions may indicate more complicated tectonic displacement of the original sedimentary basin along smaller ruptures.

In the calcareous nannoplankton assemblages, *Cyclicargolithus floridanus* prevailed over *Coccolithus pelagicus,* which dominated the assemblages of the overlying Szecseny Mb. Cretaceous and Eocene reworked calcareous nannofossils are present, Cretaceous prevailed in the upper part of the sections.

Based on the oscillation of foraminiferal abundance in the Lénartovce Mb. (high in its middle part, lower in the lower and upper part of the cycle), increasing abundance of reworked microfossils in its upper part and shallowing in its uppermost part, one cycle of sea-level changes can be interpreted for this unit. The correlation of local cycles with global sea-level changes during the Kiscellian and the lower Egerian is possible. Based on the ages of LAD of the *P. opima opima* and the Kiscellian/Egerian boundary, the Kiscellian cycle may be correlated with cycle TB 1.2 of global sea-level changes (Haq, 1988, 1991) in agreement with Vass (1995).

4.2.2. Time interval between LAD of *Globorotalia opima opima* and FADs of *Globigerinoides primordius* and *Reticulofenestra pseudoumbilica* (lower part of Egerian)

This interval can be correlated with the lower part of Szécseny Mb. (with the exception of the lowermost part, in some boreholes probably missing). In the studied material, sediments of this time interval occur only in boreholes. Lithological character of the lower boundary was discussed in the previous chapter. In the marginal part of the basin, this time interval probably started with Budikovany Mb. The upper boundary defined by the FADs of *G. primordius* and *R. pseudoumbilica* is not connected with any lithological change.

Planktonic foraminiferal assemblages are low-diversified with small-size, hardly determinable *Globigerina* ex gr. *praebulloides*. These assemblages are substituted by large globigerinas, globorotaliids (*Globorotalia mayeri*) and *Globigerinoides* above the FADs of *G. primordius* and *R. pseudoumbilica*.

Benthonic foraminiferal assemblages are diversified and abundant, values of diversity and abundance are correlable with the Kiscellian ones in the lower part of the interval, decrease in the upper part of the interval. Size sorting of foraminiferal tests is polymodal (Fig. 2) which indicates indigenous tests.

Assemblages are lower neritic (paleodepth can be estimated at 50 - 200 m), stenohaline, predominantly well aerated. Euryoxibiont taxa (bolivinas, uvigerinas, praeglobobuliminas) dominated in assemblages in short time intervals in different depth zones of the basin (type (2) of distribution of euryoxibiont assemblages from the previous chapter). Significant depth changes are not interpretable from the species compositions of assemblages.

Lateral changes of foraminiferal assemblages reflect higher diversification of paleoenvironment at the bottom of the basin in comparison with the Kiscellian. A detailed basin geometry was not reconstructed for this interval because sediments of this interval can be reliably distinguished in only seven boreholes. Similarity of general basin configuration (depocentre, marginal part of basin) with the Kiscellian one is supposed.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. The abundance of nannoplankton is lower than that in the Kiscellian. Reworked Cretaceous and Eocene species are not very abundant (5 - 10 %) and reach peak abundance in the middle part of the interval.

In the marginal part of basin this interval started with sedimentation of bioclastic limestones of the Budikovany Mb. The Member is dated by large foraminifers (*Miogypsina formosensis*) to the uppermost Oligocene (Vaňová in Báldi and Seneš, 1975). Foraminifers are not so abundant and diversified as in the Szécseny Mb. Benthonic foraminiferal assemblages are dominated by cibicidoids. Cibicidoids in this interval are interpreted as shallow-water assemblages (Šutovská, 1991). Size-sorting of tests shows mixed indigenous and bedload-transported assemblages (Fig. 2). Calcareous nannoplankton is rare, the assemblages are dominated by *Coccolithus pelagicus*. Among biostratigraphically important species, *Cyclicargolithus abisectus* and *Reticulofenestra bisecta* are present. No reworked microfossils were found which characterizes transsgressive sediments.

Changes in quantitative characteristics (foraminiferal abundance, relative abundance of reworked species) may indicate cycles of sea-level changes correlable with this time interval. Correlation with global sea-level changes during the Egerian is questionable. For the South Slovak depressions, only two indistinct cycles can be defined during this interval (27.5 - 20. 5 Ma) whereas three global cycles of sea level changes (TB 1.3. - TB 1.5.) are distinguished by Haq (1988, 1991). This discrepancy is probable caused by influence of tectonic activity also reflected in the rebuilding of basin geometry during the Upper Egerian. Three cycles of sea-level changes can be observed in basins where *Globigerinoides primordius* penetrated earlier (for detailed discussion see Chapter 4.1.4.) because the FAD of *Globigerinoides primordius* can be well correlated with the base of TB 1.3. cycle (26.7 Ma versus 26.5 Ma).

Transition between Buda Basin and Fiľakovo/Pétervásara Basin

4.2.3. Interval between FADs of *Reticulofenestra pseudoumbilica* and *Globigerinoides primordius* and FADs of *Discoaster druggi* and *Helicosphaera scissura* (middle part of Egerian)

The middle part of the Szesceny Mb. was deposited predominantly during this time interval. The uppermost part of Szecseny Mb. from most of area of the South Slovak depressions was eroded and sediments of this time interval are preserved only in areas where the overlying sediments are present. No lithological changes were recorded around the FADs of *Reticulofenestrǎ pseudoumbilica* and *Globigerinoides primordius*. Also the changes in benthonic foraminiferal assemblages are small. Assemblages are diversiefied, tests are abundant and assemblages are composed of indigenous tests. Cluster analysis of benthonic foraminiferal assemblages from the eastern part of the basin showed some changes in species composition around these FADs (Šutovská, 1987). This is mainly caused by the disappearance of agglutinated species and increase in the relative abundance of cibicidoids (especially heterolepas). This may be a consequence of shallowing in this part of the basin. Similarly to the older interval, foraminiferal assemblages indicate lower neritic, stenohaline, predominantly well aerated environment. Distribution of euryoxibiont taxa also represents type (2) described in Chapter 4.2.1. Depth changes during this time interval cannot be inferred from species composition of the assemblages.

The most marked changes was observed in the planktonic foraminiferal assemblages above the FADs of *G. primordius* and *R. pseudoumbilica*. Assemblages composed of small-sized globigerinas are substituted by large globigerinas, globorotaliids (*Globorotalia mayeri*) and *Globigerinoides*. This indicates penetration of new faunas caused by opening of a new sea-way. This may indicate together with the increase in abundance of foraminiferal and calcareous nannoplankton and the decrease in the number of reworked nannoliths, transsgressive tract of a new cycle of sea-level changes. This transgression was described by Báldi (1986) from Hungary and is correlated with the Oligocene/Miocene boundary. No reliable biostratigraphic criterion for the correlation of FADs of *G. primordius* and *R. pseudoumbilica* with the Oligocene/Miocene boundary in the South Slovak depressions was found. Penetration of new planktonic foraminifers coincides with the period of broad connection of Indian Ocean and the Paratethys sea accompanied by penetration of numerous warm-water immigrants (Rögl, 1998).

Calcareous nannoplankton assemblages do not change relative to the assemblages from the overlying sediments with the exception of the appearance of *Reticulofenestra pseudoumbilica*. The absence of reworked species in the lower part of this horizon is notable.

During this time interval, configuration of the basin started to change (Fig. 5). This is probably a consequence of tectonic events described around the Egerian/ Eggenburgian boundary (Vass et al., 1993; Márton et al., 1995). Foraminiferal assemblages indicating the deepest paleoenvironment (lower neritic to ?upper bathyal) were described from the present NE margin of the South Slovak depressions (Španie Pole, Budikovany, Sušany). The distribution of these lower neritic assemblages agree aproximately coincides with the distribution of the Budikovany Mb., which represents littoral facies of marine basin in the lower Egerian. This probably indicates opening of a sea-way between the South Slovakia and flysh basin in the East Slovakia.

Similarly to the Kiscellian, shallow-water assemblages (upper neritic) are present in a SW-NE-trending zone (Rapovce - Čierna Lúka - Rimavská Sobota - Rašice) in the central part of the present distribution of the Upper Egerian sediments. This probably indicates postsedimentary displacement of NW and SE segments, which can be well paralleled with the post-Egerian escape controlled by the left-lateral strike-slip along the Plešivec-Rapovce Fault (Vass et al., 1993).

Changes in basin geometry may be recorded also in the shift of depocentres. Depocentres in the SE segments shifted from the eastern part of basin (Chanava) to the west (Fiľakovo, Hajnačka), in the NW segment from the surroundings of Polina and Valice (EUP-2, EUP-3) to the surroundings of Lučenec (LR-2).

This interval probably terminated the sedimentation of the Bretka Mb. distributed in the eastern part of the South Slovak depressions. The Bretka Mb. is well dated by large foraminifers. *Miogypsina gunteri* and *Lepidocyclina morgani* are present here (Váňová in Báldi and Seneš, 1975), indicating Neogene (Aquitane) age of the Bretka Mb. Foraminiferal assemblages are similar to those from the Budikovany Mb.: cibicidoids also prevail here. This is probably caused by similar paleoenvironments during the deposition of both units.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. *Reticulofenestra pseudoumbilica* is common. Many reworked calcareous nannoplankton species indicate regressive character of the Member (contrary to the Budikovany Mb. with no reworked species).

Recording of broken specimens probably pertaining to *Discoaster druggi* may be important for biostratigraphic correlation of Bretka Mb. Confirmation of this find, may change the biostratigraphic correlation of this Member.

Fiľakovo/Pétervására Basin

4.2.4. Interval between FADs of *Discoaster druggi* and *Helicosphaera scissura* and FAD of *Helicosphaera ampliaperta* (upper part of Egerian)

Sediments of this interval were partly correlated with the Eggenburgian because the Egerian/Eggenburgian boundary was correlated with the boundary of NN 1/NN 2 zones (Lehotayová, 1984). They are recorded only in isolated occurrences, and a detailed reconstruction of basin configuration during this interval is impossible (Fig. 6). In spite of this, diversification of sedimentary environment is recorded. A general shallowing of the basin is observed, which may be connected with the diversification of marginal facies characteristic for this interval. Configuration of basin the very probable correspond to the basin geometry in the previous interval. Szecseny Mb. was deposited in the central part of the basin. The interval with *Discoaster druggi* and *Helicosphaera scissura* was found in the southern part of the South Slovak depressions: in the suroundings of Fiľakovo and Hostice, where it is overlain by Eggenburgian sediments and thus being "preserved" against denudation. Sediments of this interval can be well observed in the marginal facies in the western part of the basin: Opatovce Mb. and Ďarmoty Mb. were deposited during this time interval. The time equivalent of this marginal facies in the eastern part of Basin may be Bretka Mb. if finding of *Discoaster druggi* will be confirmed (for detailed characteristics of the Bretka Mb. see previous chapter). The Opatovce Mb. and Ďarmoty Mb. were deposited in the shallow-water and hyposaline paleoenvironment. The abundance of foraminifers is low, which, together with many reworked species and shallow-water character of the assemblages, characterizes low stand deposits. Open marine microfossils occur in both units, which indicates a good comunication with open sea.

Opatovce Mb. is represented by deltaic-facies sediments (Holcová-Šutovská et al., 1993). The assemblages are composed of indigenous and suspension-transported foraminiferal tests, which is typical for deltaic deposits. Indigenous assemblages are dominated by *Ammonia* and *Porosononion*. Open marine benthonic foraminifers are present and planktonic foraminifers are abundant in suspension-transported assemblages.

The Ďarmoty Mb. is characterized by the presence of indigenous shallow-water and hyposaline assemblages of benthonic foraminifers dominated by *Ammonia*. The occurrence of planktonic foraminifers at some levels indicates a good communication with open sea. Benthonic assemblages are more diversified than those from the Opatovce Mb. It can mirror the higher salinity during deposition of the Ďarmoty Mb. Finds of genus *Monspeliensina* are significant for the paleogeographical reconstruction. The genus appeared in the Rhône Basin during the Aquitane (Glaçon and Lys, 1968; Anglada and Magne, 1969) and is also known from the Ottnangian and Karpatian of the Central Paratethys (Holcová, 1996b). Sea-way from the Rhône Basin to the Central Paratethys across the Western Paratetys was closed during the Aquitane and the lower part of the Burdigalian, biostratigraphically defined by NN 2 Zone (Schoepfer and Berger, 1989). The exact time and sea-way penetration of *Monspeliensina* from the Rhône Basin to the Central Paratethys during the lowermost Miocene is therefore unknown. *Monspeliensina* may have come from the Mediterranean through the Slovenian corridor opened during the Early Aquitanian (Rögl and Steininger, 1983). Presence of *Monspeliensina* in the Ďarmoty Mb. in comparison with its absence in Opatovce Mb. may reflect fact that Opatovce Mb. is older than Ďarmoty Mb.

Sedimentation of the Tachty Mb started during this time interval. It represents the southern marginal facies of the basin. Pétervására Sandstone is the Hungarian equivalent of the Fiľakovo Member. Sztanó (1995) dated the beggining of their deposition also to the boundary of NN 1/NN 2 zones. The Tachty Mb. indicates local shallowing in marginal parts of the marine basin, and its base cannot be isochronous. On the basis of a detailed sedimentological analysis, Sztanó (1995) described lower aggradation and upper progradation units of the Pétervására Sandstone. The analysed material from the South Slovak depressions does not allow to distinguish this transgressive-regressive cycle, and sediments of this time interval have the character of low stand deposits (shallow-water, with many reworked species, indigenous microfossils are rare).

3. 2. 6. Time interval between FAD of *Helicosphaera ampliaperta* and FAD of *Sphenolithus belemnos* (lower part of Eggenburgian)

During this time interval, diversification of the facies continued. In spite of this, low-oxic environment was not recorded, which indicates a period of good aeration of whole basin. Changes in basin geometry may be expected. In the eastern part of the South Slovak depressions, where this interval preceded the eventual emergence and, only denudation relicts of sediments of this time interval are preserved. Only one locality from this time interval (Gemerská Panica in the NE part of the Rimavská kotlina Depression) has been reliably described from the Szecseny Mb. (Halásová et al., 1996). In the diversified benthonic foraminiferal assemblages, agglutinated taxa prevail (*Bathysiphon, Cyclammina, Haplophragmoides*). The high P/B-ratio (65 %) shows a trend of increase of this value from the lower Egerian to Eggenburgian in the Szecseny schlier. This may be caused mainly be good communication with open sea. *Globigerinoides trilobus* occurs in the planktonic foraminiferal assemblages. Assemblages are well size-sorted, indigenous.

Conglomerates isochronous with the Bretka Member were described from the Čoltovo area (Vass et al., 1989). Foraminifers do not occur in these conglomerates, but the find of *Helicosphaera ampliaperta* among calcareous nannoplankton is important for the determination of the age of these conglomerates, which can be well paralleled with the Eggenburgian. Therefore, they are younger than the Bretka Mb. but indicate similar distribution of marine marginal facies in the Lower Egerian and Eggenburgian in this part of the South Slovak depressions. Many Cretaceous to Oligocene reworked species occur in the calcareous nannoplankton assemblages. Communication of the South Slovak depressions with the East Slovak Basin is questionable during this time interval. *Helicosphaera ampliaperta* hase not been found in the East Slovak Basin (Prešov Mb.), but in the East Slovak Basin, the stratigraphical level with *Helicosphaera ampliaperta* may be preserved only in rare denudational relicts, or completly eroded during the long-lasting emergence.

Another lithofacies is represented by the Tachty Mb. which gradually developed from the Szecseny Mb. Foraminiferal assemblages are rare in the Tachty Mb. They contain predominantly shallow-water, hyposaline species (ammonias dominate) with cibicidoids in deeper parts (suroundings of Hostice). Size-sorting of tests (Fig. 2) and abrasion of larger tests indicate mixing of indigenous tests with tests transported in bedload. Calcareous nannoplankton assemblages are generally very rare and low-diversified with dominance of *Coccolithus pelagicus* with the exception of the assemblages from the Tachty Mb. near the village of Hostice. Reticulofenestras prevail and biostratigraphically significant species *Helicosphaera ampliaperta, Discoaster druggi* occur in the diversified assemblages. The occurrence of morphotype of *Helicosphaera ampliaperta* with large terminal flange may be significant for the paleogeographical reconstruction. This morphotype was first figured by Lehotayová (1984, Tab. 49, Fig. 3). Large terminal flange is similar to that of specimens of *Helicospheara granulata* (with broken central area) described from the NN 2 Zone in the Atlantic Ocean by Perch-Nielsen (1977) and contradicts the description of the species *Helicosphaera ampliaperta* given e.g. by Haq (1973). Aubry (1990) similar morphotype determined like *Helicosphaera ampliaperta* figured.. While typical *Helicosphaera ampliaperta* is very rare, the above mentioned morphotype with large terminal flange is common (5-10 % of assemblages). The FAD of this morphotype may precede the FAD of *Helicosphaera ampliaperta*. The nearest occurrence of this morphotype was recorded in the Flysh Belt (upper part of the Hustopeče Mb.) (Molčíková and Straník, 1987). This morphotype may have penetrated to the South Slovak depressions from the residual flysch basin through the East Slovak Basin - South Slovak depressions sea-way but no indicators of this hypothesis exist. The area with deposition of the Tachty Mb. represents shallow part of the Lower Eggenburgian basin. To the east, the basin was deeper, the Szecseny Mb. was deposited in this deeper part of basin.

Extremely shallow-water environment is represented by the Jalová Mb. Its biostratigraphic correlation with other lithostratigraphic members of the Fiľakovo Formation (Tachty Mb., Jalová Mb., Lipovany Mb., Čakanovce Mb.) is problematic because no index microfossils were recorded. It was described as a lateral facies of the Tachty, Lipovany and Čakanovce Mbs. (Vass et al., 1992). The Jalová Mb. contains rare shallow-water and hyposaline foraminiferal fauna (*Ammonia, Elphidium, Porosononion*). The tests are large, size-sorted, corroded and abraded, which indicates transport in bedload. The Jalová Mb. may represent a heterochronous but isopic facies. Based on sedimentological analysis, this unit is interpreted as filling of the tidal channels (Vass et al., 1992).

A new basin was formed in the western part of the South Slovak Basin (Fiľakovo Fault may form its eastern boundary). This interval is represented by sedimentation of the lower part of the Lipovany Mb. It contains shallow-water benthonic foraminiferal assemblages dominated by *Ammonia parkinsonia-tepida* group. Planktonic foraminifers are rare, represented by small-sized globigerinas. Foraminiferal assemblages are indigenous, reworked species were not recorded. Calcareous nannoplankton is common to abundant. The assemblages are dominated by *Coccolithus pelagicus*. If compared with the Szecseny and Tachty Mb., typical morphotype of *Helicosphaera ampliaperta* is relatively abundant and morphotype with large flange was not recorded. Reworked species are present, being dominated by Oligocene species. Diatoms appear in some horizons. Radiometric age of tuffs from this Member is 20.5+/-0.5 Ma (Repčok in Vass et al., 1992), which is in agreement with the FAD of *Helicosphaera ampliaperta*.

This basin was connected with the Bánovce depression (Halásová et al., 1996); however, the time of opening of this connection cannot be precisely determined.

Deepening of the eastern part of basin (Szesceny Mb.), transgression of the Lipovany Mb. and transgressive character of sediments of this time interval (no low-oxic facies, very few reworked microfossils) may be correlated with the begining of TB 2.1. cycle of global sea-level changes. The possibility of correlation of local and global sea-level cycles shows a decrease in tectonic activity during this time interval. On the other hand, the influence of Upper Egerian/Eggenburgian tectonic events on local sea-level changes continued, because Eggenburgian transgression is a very significant event in other Central Paratethys basins, unlike the South Slovak depressions.

Transition between Fiľakovo/Pétervásara Basin and Novohrad/Nógrád Basin

4. 2. 7. Time interval between FAD of *Sphenolithus belemnos* and FAD of *Sphenolithus heteromorphus* (upper part of Eggenburgian, lower part of Ottnangian)

This interval is characterized by sedimentation of the upper part of the Lipovany Mb. and Čakanovce Mb. The emergence of the South Slovak depressions was associated with sedimentation of fluviolacustrine Bukovinka and Salgotarián Fms. Marine ingressions were distinguished in the Pôtor Mb. (Bukovinka Fm.) and Plachtince Mb. (upper part of Salgotarián Fm.). The time interval discussed can be correlated with the earlier ingression. *Sphenolithus belemnos* was not recorded in the eastern part of the South Slovak depressions (aproximately correlated with the area east of the Fiľakovo Fault) where the Tachty Mb. and Szecseny Mb. were deposited. This may be caused by the earlier emergence of this part of the

South Slovak depressions and/or denudation of these sediments.

Rebuilding of basin morphology from the Fiľakovo/Pétervásara Basin to Novohrad/Nógrád Basin was gradualy finished during this interval. The distribution of shallow-water and deeper-water foraminiferal assemblages from younger Ottnangian and Karpatian marine transgressions is comparable with the distribution of assemblages correlated with the first Ottnangian marine ingression (Fig. 7).

No lithological changes are observed at the level of the FAD of *Sphenolithus belemnos*. Gradual deepening of the depositional environment in the area of the Lipovany Mb. sedimentation can be observed. Stenohaline upper neritic assemblages appear among benthonic foraminiferal assemblages (cibicidoids dominated). Euryoxibiont foraminiferal assemblages with *Cassidulina* and *Bulimina* were locally recorded in the deepest part of the basin. The appearence of low-oxic environment in the deepest part of the basin indicates stabilization of marine environment. Foraminiferal assemblages are indigenous with no reworked specimens, generally small-sized but size-sorted. Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus.* The abundance of reworked specimens slightly increases, with Oligocene redeposits prevailing.

Foraminiferal assemblages from the Čakanovce Mb. show deepening of sedimentary environment.They are the most abundant and diversified assemblages with the highest P/B-ratio in the Eggenburgian of the South Slovak depressions. Calcareous nannoplankton assemblages are similar to those from the Lipovany Mb. Horizons with diatoms in the Lipovany and Čakanovce Mbs. can be correlated with horizons containing tuffaceous material.

Isolated occurrences of Eggenburgian marine sediments from the Ipeľ Basin and from the sediments underlying the volcanics of the Krupina Plateau indicate communication between the South Slovak depressions and the Bánovce Depression (Halásová et al., 1996). The deepest, lower neritic assemblages are described from the Strháre-Trenč Graben. *Sphenolithus belemnos* was not recorded in these sediments, therefore opening of this seaway may be expected during the previous interval. On the other hand, *Sphenolithus belemnos* was reported from the whole interval of Eggenburgian sediments in the Bánovce Depression. This sea-way survived probably during the Ottnangian and Karpatian (Šutovská et al., 1993).

The maximum paleodepths and the highest abundances of indigenous foraminiferal tests in the Eggenburgian, the presence of low-oxic environment and higher abundances of reworked foraminiferal species relative to those in the overlying sediments characterize this time interval. Marine sedimentation in this basin was interrupted by the emergence in the Upper Eggenburgian/Lower Ottnangian. This emergence may be diachronous. Terrestrial Bukovinka Fm. is correlated with the upper part of the Eggenburgian. Radiometric ages determined in this formation (20.1 +/-0.3 Ma: Repčok, 1987; 19.7+/-0.2 Ma: Kantor et al., 1988 in Vass et al., 1992) enable to correlate it with the lower part of the Eggenburgian. They are older than the FADs of *Sphenolithus belemnos* occuring in the marine Eggenburgian sediments. If these radiometric ages are correct, they may indicate diachronous emergence of the South Slovak depressions. The marine ingressions were described from this formation (Pôtor Mb.; Škvarka et aol., 1991). The Bukovinka Fm. is covered by the coal-bearing Salgotarjan Fm. Cretaceous redeposited nannofloras occur rarely in these fluviolacustrine sediments. Other ingression can be correlated with this time interval (Plachtince Mb.). For more details on those ingressions, see below.

Novohrad/Nógrád Basin

4. 2. 8. Time interval between FAD of *Sphenolithus heteromorphus* and FAD of *Praeorbulina* (upper part of Ottnangian, Karpatian)

This interval is characterized by thick sequences of marine sediments which cannot be divided by biostratigraphically significant bioevents. In the upper part of this interval, the FAD of *Globigerinoides bisphericus* represents a significant bioevent in the Paratethys basins (Cicha et al., 1998). This event was not recorded in the South Slovak depressions which can be explained by: (1) the emergence of the area during this time interval, (2) denudation of sediments of this time interval, (3) isolation of the basin during the upper part of the Karpatian; *Globigerinoides bisphericus* could not penetrate to the South Slovak depressions. The second possibility is the most probable because the study of smectite from the underlying Plachtince Mb. (Vass and Šucha, 1994) showed that the original thickness of the Modrý Kameň Fm. (Upper Ottnangian, Karpatian) was 1000 m in contrast with the present-day maximum thickness of about 400 m.

The following cycles of sea-level changes can be distinguished in the South Slovak depressions:

(1) Ottnangian marine ingression in the Pôtor and Plachtince Mb. These ingressions were mentioned by Kúšiková in Klubert (1984), Vass et al. (1987) and Škvarka et al. (1991). These finds motivated a revision of marine Ottnangian sediments (Šutovská, 1993). Two marine ingressions can be distinguished: the older in the Pôtor Mb. and the younger one in the Plachtince Mb. Foraminiferal assemblages are similar in both ingressions. Cibicidoids prevailed, assemblages in marginal parts of the basin (western part) also contained ammonias. In the deepest part of the basin (eastern part), lenticulinas are dominant and uvigerinas are present. Planktonic foraminifers are abundant in some samples, their tests are size-sorted and probably suspension-transported.

Calcareous nannoplankton assemblages are also similar in both ingressions, dominated by *Coccolithus pelagicus.* Rare specimens of *Sphenolithus belemnos* occurr in both ingressions. An assemblage with common *Sphenolithus belemnos* and small-sized *Sphenolithus heteromorphus* was observed at one locality (D-19 borehole) correlated with the upper ingression. Reworked species were recognized in assemblages, which agrees with the transgressive character of these strata.

Basin configuration equals to the configuration during the upper Eggenburgian transgresion (Fig. 6): the deepest part of the basin was situated at the southeastern margin of the present-day distribution of marine Ottnangian sediments. It reflects influence of structure of the Dačov Lom graben (Vass et al., 1979) during the Eggenburgian and Ottnangian. The eastern continuation of the marine basin was probable transected by the Dobroda fault (Vass et al., 1992). In the South Slovak depressions, Ottnangian marine ingression penetrated more westward in comparison with the area of Eggenburgian marine basins.

It is supposed that the marine ingression penetreted to the South Slovak depressions from the SW (Várpalota area, Kókay 1991) via the newly opened "Trans-Tethyan Trench Corridor" (Rögl, 1998 dated the opening of this corridor to the Karpatian). Communication with the Bánovce depression is questionable. Also communication with hyposaline Ottnangian sediments from the Bórsód basin in Hungary (Bohn-Havas, 1983) cannot be clearly documented. This interval can be correlated with the lowstand of global sea-level cycle TB 2.1. as is evident from the lowstand character of the Ottnangian deposits in the Bánovce Depression (low-oxic facies, decrease in salinity). It is probable that the sea-ways between the South Slovak depressions and the Bánovce Depression were closed during this low-stand.

(2) Sedimentation of Medokýš Mb. which was paralelled with the "*Rzehakia* (*Oncophora*) Beds".

The Medokýš Mb. is characterized by high abundances of foraminiferal tests of stenohaline open marine species. In this, the Medokýš Mb. differs from the "*Rzehakia* (*Oncophora*) Beds" in other areas. They were first described by Kantorová et al. (1968) and recently by Holcová (1996a, 1999, in print) and Holcová and Maslowská (1999). Kantorová et al. (1968) assumed the transport of foraminiferal tests of stenohaline foraminiferal species to a hyposaline basin (with hyposaline molluscs *Rzehakia)* by storm waves from an unknown open sea to a brackish basin in the area of the present-day South Slovak depressions. A detailed taphonomical study (Holcová, 1996a) confirmed and specified the previous interpretation. The study also enabled to distinguish indigenous foraminiferal tests. For the interpretation of paleodepth, three types of assemblages are significant: (1) assemblages with stenohaline, upper neritic indigenous species, (2) assemblages with indigenous hyposaline, littoral species, (3) assemblages without indigenous species. According to their distribution, the depocentre can be interpreted at the SE margin of the present-day distribution of sediments, similarly to the Eggenburgian and Ottnangian. Calcareous nannoplankton assemblages are also present. Nannoliths are common in the deepest part of basin and occur in all analysed samples. *Coccolithus pelagicus* prevailed in the assemblages. Cretaceous, Eocene and Oligocene reworked species were recorded.

Opinions on the age of the Medokýš Mb. are controversial. Correlation of the "*Rzehakia* (*Oncophora*) Beds" with the Upper Ottnangian prevails in most Paratethys basins where the „Beds" represent a regressive phase of the Eggenburgian-Ottnangian cycle. In the Pannonian Basin, the *"Rzehakia (Oncophora)* Beds" seem to be in a transgressive position, overlying the continental Ottnangian sediments. Therefore, the "Beds" are considered younger (Karpatian) than the *"Rzehakia (Oncophora)* Beds" in other basins. Occurrences of *Uvigerina graciliformis* Papp et Turnovski and *Sphenolithus heteromorphus* are mentioned as a biostratigraphic criterion for the correlation of the Medokýš Mb. as well as isochronous units from Hungary (Kazár Member) with the Lower Karpatian (Vass, 1995; Horváth and Nagymarosi, 1979; Hámor, 1985). The FAD of *Sphenolithus heteromorphus* does not indicate the Karpatian age of the "*Rzehakia* (*Oncophora*) Beds", because 18.2 Ma is given for its FAD (Berggren et al., 1995). This age falls with in the middle part of the Ottnangian (range of Ottnangian 18.8-17.3 Ma, Rögl, 1998). The FAD of *Uvigerina graciliformis* was defined at the Ottnangian/Karpatian boundary (Cicha et al., 1983; Cicha et al., 1998) but the recent studies shift FAD of the small-sized *Uvigerina graciliformis* to the Upper Ottnangian (Cicha, pers. comm.; Salaj, 1997). Therefore, this biostratigraphic marker cannot solve the Upper Ottnangian vs. Karpatian age of the "*Rzehakia* (*Oncophora*) Beds". The isochroneity of the „*Rzehakia (Oncophora)* Beds" in the Central Paratethys can be interpreted on the basis of a climatostratigraphic event supposed for the sedimentation of the „Beds" . Cooling was suggested by Čtyroký (1987, 1991), a short humid episode by Krhovský et al. (1995). Planderová 1990 interpreted cooling for the Plachtince Mb. New palynological study from the South Slovak depressions (Doláková and Holcová, in prep.) indicated humid but warm climate. A climatic event can be also interpreted from the abundant occurrence of suspension-transported foraminifers. Storm waves are necessary for the widespread occurrence of tests transported this way. Such widespread occurrences of suspension-transported tests are unknow from other stratigraphical levels in the Central Paratethys. In agreement with the occurrences of suspension-transported tests, tempestites were described from the "*Rzehakia (Oncophora)* Beds" in the Nógrád Basin (Hámor, 1985; Vass and Beláček, 1998). Hummocky cross-stratification and laminae of shell detritus were observed also in the Upper Austrian Molasse. Tempestites were described also from other Upper Ottnangian Central Paratethys sediments: e.g., Řehánek and Salaj in Salaj (1997) described tempestites from the Upper Ottnangian of the Carpathian Foredeep. Based on the previous discussion, the Upper Ottnangian age is interpreted for the Medokýš Mb.

The discrepancy in the transgressive vs. regressive character of the "Beds" in the Central Paratethys may be caused by tectonic events at the Ottnangian/Karpatian boundary. This event is dated approximately to 17 - 18 Ma, when transpressional and/or transtensional regime was replaced by a tensional regime (Márton et al., 1995). The event induced paleogeographic changes, which are connected with the penetration of sea in to the South Slovak depressions and therefore caused the transgressive character of the Medokýš Mb. Shallow-water and euryhaline foraminiferal assemblages and many reworked species of calcareous nannoplankton indicate the low-stand character of this cycle of the 4st order. It may be correlated with global sea-level fall between global sea-level cycles TB 2.1 and TB 2.2. (Haq, 1991).

The "*Rzehakia (Oncophora)* Beds"-cycle can be correlated with the "*Ammonia*-Beds" described from the northern part of the Vienna Basin (Dobrá Voda Depression; Kováč et al., 1991) and the northern part of the Danube Basin (Bánovce Depression; Brestenská, 1977). These strata overlie the low-oxic and, in the upper part, hyposaline Eggenburgian-Ottnangian sediments, and also have a transgressive character. This may indicate re-opening of sea-ways between the South Slovak depressions and the Bánovce Depression, as confirmed finds of endemic foraminifer *Monspeliensina* in both basins.

Similarly to the older Ottnangian ingression, two marine sea-ways connecting the Nógrad/Novohrad basin with other central Paratethys basins are interpreted for the "*Oncophora* Beds" time interval:

(i) "old" way connecting the Alpine Foredeep and Central Paratethys. This way was euryhaline in the "*Rzehakia (Oncophora)* Beds" time interval and did not bring biostratigraphically new elements to the Upper Austrian Molasse. It is supposed that this is how euryhaline genus *Monspeliensina* penetrated from the Upper Austrian Molasse to the Nógrád Basin.

(ii) "new" way through the "Trans-Tethyan Trench Corridor", which enabled the penetration of biostratigraphically new elements such as *Uvigerina graciliformis* and *Sphenolithus heteromorphus* from the Mediterranean. This way was opened during the younger marine ingressions. This marine basin is interpreted as a source area of suspension-transported lower neritic to upper bathyal foraminifers.

Diversified and abundant foraminiferal assemblages in the "*Rzehakia (Oncophora)* Beds" from the South Slovak Basin may confirm the hypothesis that the South Slovak depressions was located at the "crossing" of these two ways.

Interpretation of the Medokýš Mb. as a diachronous facies representing marginal parts of the basin, which can be correlated with the whole Modrý Kameň Fm., appeared in Vass et al. (1979). A detailed study of foraminiferal assemblages from this marginal facies (e.g., VVL-6 borehole) showed that they can be distinguished from the foraminifers from the Medokýš Mb.: they contain more diversified foraminiferal assemblages, which are relatively small-sized but not size-sorted, and represent marginal facies of the Sečianky Mb.

Krtíš Mb. was defined, between the Sečianky Mb. and Medokýš Mb. This member is represented by littoral sandstones (Vass et al., 1992) and contains practically no foraminifers and calcareous nannoplankton with the exception of very rare assemblages of cibicidoids, which may be reworked. The Member was paleoecologically interpreted from the rare assemblages of Molusca.

(3) Karpatian sea-level cycle represented by deposition of Sečianky Mb.

Sečianky Mb. represents sediments with rich diversified marine microfauna, which can be used for detailed analysis.

Foraminiferal assemblages are typical indigenous assemblages without size-sorting and breaking of tests. In the South Slovak depressions, indigenous foraminiferal assemblages dominate. Reworked tests appear rarely in the lowemost part of sections. Suspension-transported tests were found in boreholes from marginal parts of the basin. In the central part of the basin (LKŠ-1 borehole), foraminiferal assemblages are diversified, lower neritic to bathyal (a list of species was published by Zlinská and Šutovská, 1990). Sedimentation started with a thin horizon with hyposaline assemblages (small-sized ammonias dominated). This horizon is overlain by normal marine sedimentation. The assemblages indicate good aeration in the basal horizon. Then euryoxibiont taxa (bolivinas, uvigerinas, globocassidulinas) dominated in assemblages at different depth zones of the basin (type (2) of distribution of euryoxibiont assemblages from the previous chapter). Paleodepths changed from the lower neritic to bathyal. Bathyal assemblages described in the LKŠ-1 borehole (Zlinská and Šutovská, 1990) represent the deepest assemblages in the whole history of the South Slovak depressions. Cibicidoids (mainly *Cibicidoides pseudoungerianus*) dominate in assemblages from the marginal part of the basin (GK-4, MV-14, VVL-6). *Ammonia parkinsonia* significantly prevails in nearshore assemblages (M-111 borehole) comprising 50-100 % of the assemblages.

A detailed quantitative analysis of foraminiferal assemblages enabled to distinguish 3 cycles (Holcová, 1999). The upper part of the 3rd cycle is missing. As cyclical changes of quantitative characteristics are well correlated with changes in paleodepth, cycles are very probably caused by sea-level changes of the 4th order. From other Paratethys regions, three cycles of sea-level oscillation were distinguished in the northern part of the Danube Basin (Holcová, 1999). Data for the interpretation of cyclical changes in the Karpatian sediments were published by Hámor (1985) from the time-equivalent of Sečianky Mb. named "Garáb schlier" and Brzobohatý (1993) from the Carpathian Foredeep in Moravia. In both areas, three cycles of sea-level changes were distinguished, which is in agreement with the observations described in the South Slovak depressions.

Foraminiferal tests are not influenced by diagenetic changes. Therefore, isotope analyses of tests cane be done (Šutovská and Kantor, 1991). Changes in oxygen isotope composition may be caused by temperature fluctuations as well as salinity fluctuations. The more probable interpretation for an abrupt change in oxygen isotope composition is the fluctuation in salinity and input of open-marine water to the Central Paratethys basins well correlable with horizons between cycles of sea-level changes of the 4th order. The gradual, moderate changes of oxygen isotope composition may be correlated with changes in paleotemperature: a moderate rise in temperature can be interpreted for the lower part of the Sečianky Mb., moderate cooling for its upper part. This is in agreement with the palynological study of Planderová (e.g. Planderová and Konzalová, 1989). Paleoproductivity can be evaluated on the basis of changes in carbon isotope composition. The good correlation between the abundances of calcareous nannoplankton and planktonic foraminifers and changes in carbon isotope compositions allow to interpret low productictivity in the lower part of the profile and a higher productivity in the upper part.

Calcareous nannoplankton assemblages are dominated by *Coccolithus pelagicus*. *Helicosphaera ampliaperta* and *Sphenolithus heteromorphus* occur among biostratigraphically significant species. Reworked species (mainly Oligocene and Cretaceous, rarely Eocene) occur in the lower part of the member and around boundaries between cycles of sea-level changes of the 4th order. Abundances of diatoms can be well correlated with the amounts of volcanic material.

Paleogeographical changes described from the Central Paratethys between the sedimentation of the "*Rzehakia (Oncophora)* Beds" and the Karpatian Schlier (Rögl 1998) were not recorded in the detailed morphology of the Nógrád Basin. The deepest parts of basin are situated at the SE margin of the area of Karpatian sediments (Fig. 7) similarly to the upper part of the Eggenburgian and Ottnangian and this paleogeography reflects existence of structure of the Dačov Lom graben (Vass et al., 1979) to the Karpatian.. Eastern marginal part of the basin was transected by the Dobroda Fault also similarly to the Ottnangian basin. Karpatian marine flooding was more extensive than the Ottnangian ones, reaching farther west. Re-opening of communication paths between the South Slovak depressions and the Bánovce depression during the uppermost Ottnangian can be interpreted from the statistical analysis of foraminiferal assemblages (Šutovská et al., 1993). Penetration of new fauna was not observed. All biostratigraphically new species appear below the Ottnangian/Karpatian boundary in the Plachtince and Medokýš Mbs., which is caused by opening of the "Trans-Tethyan trench corridor". Differences in species composition between the Sečianky and Medokýš Mbs. are defined by differences in paleoecological conditions.

The Sečianky Mb. represents transgressive and highstand parts the cycle of sea-level changes, which can be correlated with global sea-level cycle TB 2.2. The upper part of the cycle (probably with *Globigerinoides bisphericus)* was eroded as confirmed by the study of smectite from the underlying Plachtince Mb. (Vass and Šucha 1994). This study shows that the original thickness of the Modrý Kameň Fm. (Upper Ottnangian, Karpatian) was 1000 m, as opposed to the present-day maximum thickness of about 400 m.

The Lower Badenian basin

4. 2. 9. Time interval between FAD of *Praeorbulina* and FAD of *Orbulina* (lower part of Early Badenian)

In the South Slovak depressions, only one specimen of *Praeorbulina* was recorded. Therefore, interpretation of this time interval in the South Slovak depressions is not fully reliable. This specimens were recorded in the strata described as the Medokýš Mb. from the surroundings of Ľuboriečka (Holcová et al., 1996). These strata contain suspension-transported foraminifers generally identical with the assemblages from the Medokýš Mb. The occurrence of *Praeorbulina* indicates redeposition of these tests into younger sediments correlated with the lowermost Badenian. A detailed statistical analysis showed that reworking of tests changed species composition of the assemblages, and the reworked assemblages are not fully identical with the assemblages from the Sečianky Mb. (Holcová and Maslowská, 1999). Character of microfauna showed that paleoenvironment was not suitable for appaerence of full marine fauna and therefore praeorbulinas are rare.

The character of sediments with *Praeorbulina* from the South Slovak depressions is comparable with that of sediments described by Cicha (1995) from the Alpine-Carpathian Foredeep. Cicha (1995) described lowstand sediments from the Karpatian - Badenian boundary with rare *Praeorbulina* overlain by transgressive sediments with *Orbulina*. The lowstand character of sediments with *Praeorbulina* in the South Slovak depressions is confirmed by predominance of reworked species. On the second hand, the sediments are in transgressive position: they overlie Ottnangian sediments and seem to represent basal transgressive sediments of the Badenian transgression. Hiatus is interpreted between them and the members with marine fauna from the Vinica Fm. (missing of interval with coexistence of *Orbulina* and *Praeorbulina*). The sediments with *Praeorbulina* may represent a whole cycle of sea-level changes of the 4th order with low amplitude corresponding to global sea-level fall between the TB 2.2. and TB 2.3. cycles.

These sediments may be correlated with the Príbelce Mb. which does not contain stratigraphically significant species. The Príbelce Member was sedimentologically described by Vass (1977). Reworked Oligocene and Miocene poorly preserved nannoliths prevailed in this member (Zlinská and Šutovská, 1991). Correlation with transitional Karpatian/Badenian sediments described by Kantorová (1965) from GK-4 borehole and Kučerová (1980) from BE-2 borehole is still questionable. Their stratigraphical interpretations lack biostratigraphic evidence.

Paleogeographical interpretation for this time interval is impossible because only fragmentary data exist about this interval.

4. 2. 9. Time interval between FAD of *Orbulina* and emergence of the area (upper part of Early Badenian)

Interval with co-existence of *Praeorbulina* and *Orbulina* described in most Central Paratethys basins was not recorded in the South Slovak depressions. Therefore, the Early Badenian transgression, significant for the whole Central Paratethys (Rögl, 1998) is younger in the South Slovak depressions is later than in other Central Paratethys basins. It may be caused by the uplift of area which is reflected in extensive erosion of the Karpatian sediment.

The FAD of *Orbulina* is correlated with the penetration of new diversified and abundant foraminiferal assemblages to the South Slovak depressions. Assemblages are well preserved and well size-sorted, indigenous. Lower neritic assemblages are composed of diversiefied benthonic foraminifers and abundant large planktonic foraminifers with *Orbulina*. The upper neritic assemblages contain mainly epiphytic species (*Rosalina, Asterigerinata, Lobatula*). *Amphistegina* appers in these assemblages. All assemblages indicate good aeration of the whole basin. Calcareous nannoplankton assemblages are diversified and abundant, with commonly occurring *Helicosphaera kamptneri*. Cretaceous, Eocene and Oligocene redepositions are rare.

Morphology of the marine basin was significantly influenced by volcanic activity. The depocentre of the basin was shifted from the area of the Strháre-Trenč Graben to the western part of the basin when the basin continued to the Danube Basin. Gradual eastward shallowing of the basin can be interpreted. Direction of marine transgression was different than in the Karpatian: transgression came from the Danube Basin. Communication with the Bánovce Basin was closed.

The Badenian transgression is correlated with cycle TB 2.3. of global sea-level changes (Vass, 1995; Rögl, 1998; Kováč et al., in print). The base of the cycle in the South Slovak depressions is younger than other Central Paratethys basins, which may be caused by uplift of area in the upper part of Karpatian.

Conclusion

(1) The following new methods were used for a detailed reconstruction of Oligocene and Miocene marine basins preserved in the area of present-day South Slovak depressions,:

(i) biostratigraphic correlation based on the LADs and FADs of biostratigraphically significant planktonic foraminiferal and calcareous nannoplankton species;

(ii) taphonomical analysis of foraminiferal assemblages;

(iii) analysis of abundance of reworked species (foraminifers, calcareous nannoplankton);

(iv) multivariate statistics;

(v) paleoecological synthesis as an indicator of tectonic activity.

(2) Among 14 LADs and FADs significant for the studied time interval, eight were chosen for the definition of nine time intervals. Based on foraminiferal and calcareous nannoplankton assemblages, these intervals were characterized paleoecologically and paleogeographically (Fig. 9).

(3) New biostratigraphic division permitted to define changes in basin geometry between the Buda Basin, Fiľakovo/Pétervásara Basin and Novohrad/Nógrád Basin as continuous, relatively long-lasting processes. The existence of short-lived Fiľakovo/Pétervásara Basin can be correlated with a tectonic event dated to 19-20 Ma.

(4) Shift of depocentres, generally from the east to the west (in present-day coordinates) was observed in the interval from the Kiscellian to the Early Badenian.

(5) Existence of the following tectonic lines can be demonstrated on the basis of detailed paleoecological study:

(i) Plešivec-Rapovce Fault in the Kiscellian and Egerian;

(ii) Dobroda Fault in the Ottnangian and Karpatian.

Fiľakovo Fault may have played some role in the Eggenburgian.

From the Eggenburgian to the Karpatian, location of depocentres reflected influence of structure of the Dačov Lom graben on paleogeography.

(6) Study of reworked species, abundance of foraminifers and paleodepth changes were used for a detailed analysis of sea-level cycles in monotonous sediments.

(7) Local sea-level changes can be well correlated with global changes in the Kiscellian and Karpatian. They may indicate periods of low tectonic activity. Limited correlations can be done for the Eggenburgian, upper part of the Ottnangian and for the Early Badenian. Short-time tectonic events can be expected during this time interval. Correlation with global sea-level changes is questionable during the Egerian. This period can be characterized by significant tectonic activity.

(8) Communication with East Slovakia, Bánovce Depression and Várpalota area can be confirmed by the following micropaleontological data:

(i) occurrence of the deepest foraminiferal assemblages in the NE margin of the South Slovak depressions during the upper part of the Egerian (communication with the Flysh Basin in the East Slovakia);

(ii) isolated occurrences of Eggenburgian foraminiferal assemblages in sediments underlie the volcanics of the Krupina Plateau (communication with the Bánovce Depression);

(iii) penetration of foraminiferal genus *Monspeliensina* to the South Slovak depressions in the uppermost Ottnangian (communication with the Bánovce Depression);

(iv) penetration of small-sized *Uvigerina graciliformis* to the South Slovak depressions in the uppermost Ottnangian (communication with Várpalota area);

(v) similarity of benthonic foraminiferal assemblages revealed by multivariate statistical methods in the Karpatian (communication with the Bánovce Depression).

(9) Distribution of low-oxic foraminiferal assemblages can be used as an indicator of the development of marine basins: Kiscellian is characterized by widespread occurrence of low-oxic assemblages, which indicates a period of long-lasting unchanged environment, tectonically inactive with low circulation of bottom waters.

The Egerian, upper part of the Eggenburgian and partly Karpatian are characterized by episodical and local occurrence of low-oxic assemblages, which can be interpreted as periods with depth-diversified bottom, tectonically active when low-oxic environment persisted only for short time in partly isolated small parts of the basin. Other time intervals (lower part of the Eggenburgian, Ottnan-

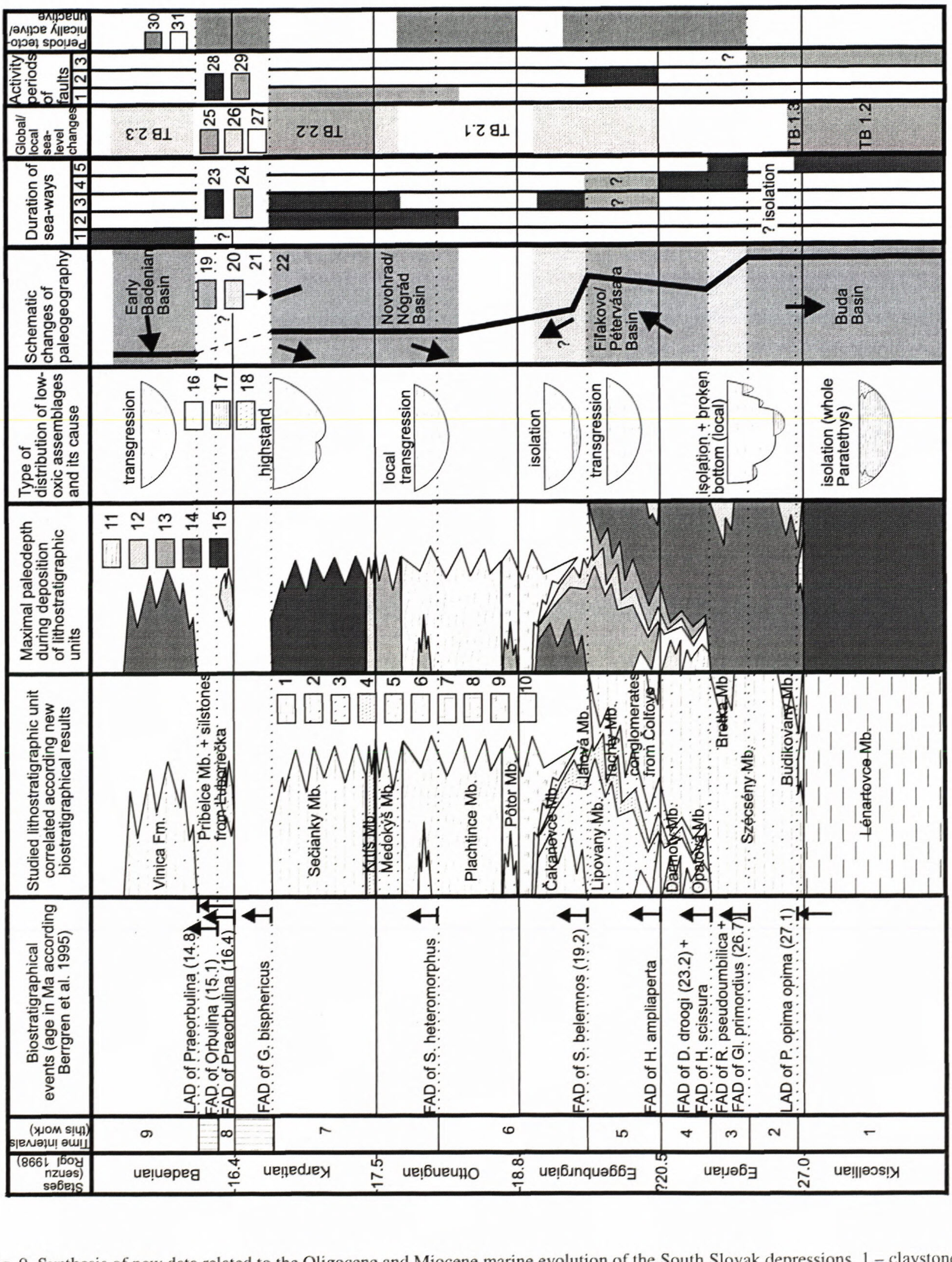

Fig. 9. Synthesis of new data related to the Oligocene and Miocene marine evolution of the South Slovak depressions. 1 – claystones, 2 – siltstones, 3 – sandstones, 4 – coarse-grained sandstones, 5 – fine-grained sandstones with beds of coarse-grained sandstones and conglomerates, 6 – conglomerates, 7 – limestones, 8 – limestones and conglomerates, 9 – terrestrial deposits, 10 – fluviolacustrine deposits; 11 – deltaic deposits, 12 – shallow-water, +/- hyposaline environment, 13 – upper neritic, 14 – lower neritic, 15 – bathyal; 16 – normal marine, well-aerated environment, 17 – low-oxic, 18 – hyposaline; 19 – period with typical paleogeography of the basin, 20 – transitional period, 21 – general direction of deepening of basin; 22 – changes in locations of depocentres approximately from E to W, 23 – period with the existence of a sea-way, 24 – period with a questionable existence of a sea-way (1 – communication with

gian, Early Badenian) are characterized by good aeration of the whole basin indicating a good communication of the South Slovak depressions with the surrounding basins.

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References

Anglada, R. & Magne, J., 1969: Taxyella, a new genus of foraminifer from the Miocene of southeast France. Micropaleontology, 15, 3, 367-372.

Aubry, M.-P., 1990: Handbook of Cenozoic calcareous nannoplankton. Book 4: Heliolithae. Micropaleontology Press, The American Museum of Natural History, New York.

Báldi, T., 1986: Mid-tertiary stratigraphy and paleogeographic evolution of Hungary. Akademiai Kiado, Budapest, 201 p.

Báldi, T.& Seneš, J. 1975: Chronostratigraphie und Neostratotypen Miozän der Zentralen Paratethys. OM Egerien. Veda, Bratislava, 557 p.

Berggren, W.A., Kent, D.V., Swisher III., C.C. & Aubry, M.-P., 1995: A revised cenozoic geochronology and chronostratigraphy. In: Berggren, W.A., Kent, D.V. & Hardenbol, J. (eds.): Geochronology, time scale and global stratigraphic correlations: A unified temporal framework for an historical geology. Society of Economic Paleontologists and Mineralogists, Special Publication No.54, 129-212.

Brau-Blanquet, J., 1964: Pflanzensociologie. Biol. Studien bucher 7, Wien, 865 p.

Brestenská, E. 1977: Mikrobiostratigrafia miocénu bánovskej kotliny. Manuscript. Geofond Bratislava. (In Slovak).

Brzobohatý, R., 1993: Paleoecological and biostratigraphical evaluation of h Karpatian in the Nosislav-3 Borehole (Foraminifera, Otoliths). Knih.Zem.Plyn Nafta, 15, 125-129.

Bukry, D., 1972: Coccoliths stratigraphy - Leg 14, Deep Sea Drilling Project. In: Hayes, D.E., Pimm, A.C. et al. (eds.): Initial reports of the Deep Sea Drilling Project, 14. U.S. Govt. Printing Office, Washington, 487-494.

Cicha, I., 1995: Nové poznatky k vývoji neogénu centrální Paratethydy. Knih.Zem.Plyn Nafta, 16, 67-72. (In Czech).

Cicha, I., Čtyroká, J., Jiříček, R. & Zapletalová, I., 1975: Principal biozones of the Late Tertiary in the East Alps and West Carpathians. Proc.6th Congress RCMNS Bratislava, 19-33.

Cicha, I., Hagn, H. & Martini, E., 1971: Das Oligozän und Miozän der Alpen und der Karpaten. Ein Vergleich mit Hilfe planktonischer Organismen. Mitt. Bayer. St.-Samml. Palaont. hist. Geol., 11, 279-293.

Cicha, I., Rögl, F., Rupp, Ch. & Čtyroká, J., 1998: Oligocene-Miocene foraminifera of the Central Paratethys. Abh.senckenberg. naturforsch. Ges., 549, 1-325.

Cicha, I., Zapletalová, I., Molčíková, V. & Brzobohatý, R., 1983: Stratigraphical range of Eggenburgian-Badenian Foraminifera in West Carpathian Basins. Knih.Zem.Plyn Nafta, 4, 99-144.

Čtyroký, P., 1987: Evolution of the family Rzehakiidae (Mollusca, Bivalvia) in the Tertiary of Eurasia. In: Pokorný, V. (ed.): Contribution of Czechoslovak Palaeontology to Evolutionary Science 1945-1985, Univerzita Karlova Praha, 73-79.

Čtyroký, P., 1991: Division and correlation of the Eggenburgian and Ottnangian in the southern Carpathian Foredeep in southern Moravia. Záp.Karpaty, sér. Geol., 15, 67-109.

Fornaciari, E., Di Stefano, A., Rio, D. & Negri, A., 1996: Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. Micropaleontology, 42(1), 37-63.

Fornaciari, E. & Rio, D., 1996: Latest Oligocene to early middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. Micropaleontology, 42(1), 1-36.

Glacon, G. & Lys, M., 1968: Note prelliminaire a une revision des especes de Monspeliensina, nouveau genre de Foraminifere accompagnant la transgression miocene dans le Languedoc. C. R. Acad. Sc.Paris, 267, 2302-2305.

Gruzman, A.D, 1983: Granica oligocena i miocena v skibovoj zone Ukrajinskych Karpat. In: Iskopajemaja fauna i flora Ukrajiny, Nedra, Moskva, 32-38. (In Polish).

Halásová, E., Hudáčková, N., Holcová, K., Vass, D., Elečko, M. & Pereszlenyi, M., 1996: Sea ways connecting the Fiľakovo/ Petervasara Basin with the Eggenburgian/Burdigalian open sea. Slovak Geol. Mag., 1(2), 125-136.

Hámor, G., 1985: Geology of the Nógrád-Cserhát area. Geologica Hungarica, 22, 1-307.

Haq, U.B., 1973: Evolutionary trends in the Cenozoic coccolitophore genus Helicopontosphaera. Micropaleontology, 19, 1, 32-52.

Haq, B.U., 1991: Sequence stratigraphy, sea-level change, and significance for the deep sea. Spec. Publs. int. Ass. Sediment., 12, 3-39.

Haq, B.U., Hardenbol, J. & Vail, P.R., 1988: Mesozoic and cainozoic chronostratigraphy and cycles of sea level change. In: Wilgus, C.K., Hastings, B.S., Kendal, C.G., Posamentier, H.W., Ross, C.A. & van Wagoner, J.C. (eds.): Sea level changes. Econ. Paleont. Miner., Spec. Publ., 42, 125-154.

Hiltermann, H. & Tuxen, J.J., 1974: Biosociology of recent benthonic Foraminifera after the Brau-Blanquet method. Rev. Esp. micropaleont., 4(1), 75-84.

Holcová, K., 1996a: Determination of transport of foraminiferal tests in the fossil record (South Slovakia Basin, Middle Miocene). N. Jb. Geol. Palaont. Mh., 4, 193-217.

Holcová, K., 1996b: Monspeliensina and Spiroloxostoma, paleogeographically significant foraminiferal genera from the "Rzehakia (Oncophora)Beds" (Upper Ottnangian, Miocene) in the South Slovak depressions (Central Paratethys). Acta Mus.Nat. Pragae, Ser.B, Hist. Nat., 50 (1-4), 101-110.

Holcová, K., Doláková, N., Vass, D., Zágoršek, K. & Zelenka, J., 1996: Morský vývoj v spodnom bádene v strhársko-trenčskej prepadline z pohľadu foraminiferových, machovkových a ostrakodových spoločenstiev a palynológie. Mineralia slovaca, 28, 99-119. (In Slovak).

Holcová, K., 1999: Postmortem transport and resedimentation of foraminiferal tests: relations to cyclical changes of foraminiferal assemblages. Palaeogeography, Palaeoclimatology, Palaeoecology, 145 (1999), 157-182.

Holcová, K., Maslowská, H., 1999: The use of multivariate statistical methods in analysis of postmortem transport and resedimentation of foraminiferal tests in relation to species composition of oryctocenoses. South Slovak depressions (Central Paratethys), Miocene. Revista espan. Micropaleont., .

Holcová-Šutovská, K., Vass, D. & Kvaček Z., 1993: Opatovské vrstvy: vrchnoegerské sedimenty delty v Ipeľskej kotline. Mineralia slovaca, 25, 428-436. (In Slovak, Engl. summary).

Horváth, M., 1983: The foraminifera of the type sections of Novaj and Eger. Ann.Univ.Sci.budapest.Rolando Eotvos, Sect.geol., 25, 9-32.

Horváth, M. & Nagymarosi, A., 1979: A rzehakias retegek és a Garabi slir koráról nannoplankton és foraminifera vizsgálatok alapján. Földt. Közl., 109 (2), 211-229.

the Danube Basin, 2 – communication with Várpalota area, 3 – communication with the Bánovce Depression, 4 – communication with the East Slovakia, 5 – communication with the Buda Basin in Hungary); 25 – period of good correlation between local and global sea-level changes, 26– period with limited correlation between global and local sea-level changes, 27 – period with no correlation between local and global sea-level changes; 28 – deposits deformed by faulting, 29 – proposed synsedimentary activity of faults (1 – Dobroda Fault, 2 – Fiľakovo Fault, 3 – Plešivec–Rapovce Fault); 30 – tectonically active periods, 31 – tectonically inactive periods.

Howe, R.W. & Sblendorio-Levy, J., 1998: Calcareous nannofossil biostratigraphy and sediment accumulation of turbidite sequences on the Madeira abyssal plain, sites 950-952. In: Weaver, P.P.E., Schmincke, H.-U. & Firth, J.V. (eds.): Proceedeng of the Ocean Drilling Program., Scientific Results, Vol. 157, College Station TX (Ocean Drilling Program), 501-520.

Iaccarino, S., 1985: Mediterranean Miocene and Pliocene planktic foraminifera. In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds.): Plankton Stratigraphy, Cambridge University Press, Cambridge, 283-314.

Kantorová, V., 1965: Mikrofauna okrajových fácií z podložia tortónskych vulkanitov Krupinskej vrchoviny. Správy o geologických výskumoch v roku 1964, 2, 97-99. (In Slovak).

Kantorová, V., Ondrejíčková, A. & Vass, D., 1968: A new view of the origin and the age of the Rzehakia (Oncophora) beds in southern Slovakia. G. Geol. (Bologna), 35 (2), 407-415.

Kennnett, J.P.& Srinivasan, M.S., 1983: Neogene planktonic foraminifera. A phylogenetic atlas. Hutchingon Ross Publishing Company, Stroudsburg, 263 p.

Klubert, J.& et al., 1984: Záverečná správa a výpočet zásob Modrý kameň - Horné Strháre, hnedé uhlie. Manuscript. Geofond. Bratislava. (In Slovak).

Kókay, J., 1991: Stratigraphische Revision der unter und mittelmiozan Bildungen des beckens von Várpalota (Bakony Gebirge). In: Lotitzer, H. & Császár, G. (eds.): Jubilaumschift 20 jahre geol. zusammenarbeit Österreich-Ungarn, Wien, 101-108.

Kováč, M. & Hudáčková, N., 1997: Changes paleoenvironment as a result of interaction of tectonic events with sea level changes in the northeastern margin of the Vienna Basin. Zbl. Geol. Palaont. Teil I, 5/6, 457-469.

Kováč, M. & Zlinská, A., 1998: Changes of paleoenvironment as a result of interaction of tectonic events with sea-level oscillation in the East Slovakian Basin.Przegl. Geol., 46, 5, 403-409.

Kováč, M., Nagymarosy, A., Holcová, K., Hudáčková N. & Zlinská, A, in press: Paleogeography, paleoecology and eustasy: Miocene 3rd order cycles of relativ sea-level changes in the Western Carpathian - North Pannonian basins. Acta geol. hungarica.

Krhovský, J., Bubík, M., Hamršmíd, B. & Šťastný, M., 1995: Lower Miocene of the Pouzdřany Unit, the West Carpathian Flysch belt, Southern Moravia. Knih. Zem. Plyn Nafta, 16, 73-83.

Kučerová, E. 1980: Mikrobiostratigrafické a paleoekologická zhodnotenie vrtu BE-2 Muľa. Manuscript. Geofond. Bratislava.

Kucinski, T.M., 1984: Rozwoj badan stratygraficznych neogenu Paratetydy w zakriesie mikrofauny a nannoflory (szczegolnie na granicy miedzy oligocenem i miocenem). Biul.Inst.geol., Z badan geol.w Karpatach, 24, 169-186.

Lehotayová, R., 1982: Miocene nannoplankton zones in west Carpathians. Zap.Karpaty, sér.paleont., 8, 91-110.

Lehotayová, R., 1984: Lower Miocene calcareous nannoflora of the West Carpathians. Záp. Karpaty, sér. paleont., 9, 99-110.

Martini, E., 1971: Standard Tertiary and Quaternary calcareous nanoplankton zonation. In: Proceeding of 2nd planktonic conference, Roma 1970, Roma, 739-785.

Marunteanu, M., 1992: Distribution of the Miocene calcareous nannofossils in the Intra- and Extra- Carpathian areas of Rumania. Knih.Zem.Plyn Nafta, 14b, 2, 247-262.

Márton, E., Vass, D. & Túnyi, I., 1995: Mladoterciérne rotácie megajednotky Pelso a priľahlých Centrálnych Západných Karpát. Knih.Zem.Plyn Nafta, 16, 97-108.

Molčíková, V. & Straník, Z., 1987: Vápnitý nanoplankton ze ždánicko-hustopečského souvrství a jeho vztah k nadloží. Knih. Zem. Plyn Nafta, 6b, 59-76. (In Czech).

Olafsson, G., 1989: Quantitative calcareous nannofossil biostratigraphy of upper Oligocene to middle Miocene sediment from ODP Hole 667A and Middle Miocene sediment from DSDP Site 574. In: Ruddiman, W., Sarnthein, M. et al. (eds.): Proceeding of the Ocean Drilling Program, scientific Results, 108, College Station, TX: Ocean Drilling Program, 9-22.

Perch-Nielsen, K., 1977: Albian to Pleistocene calcareous nannofossils from the western South Atlantic Deep Sea drilling Project, Leg 39. In: Supko, P.R., Perch-Nielsen, K. et al. (eds.): Initial reports DSDP, 39,: U.S. Govt. Printing Office, Washington, 699-823.

Perch-Nielsen, K., 1985: Cenozoic calcareous nannofossils. In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds.): Plankton stratigraphy. Cambridge University Press, Cambridge, 27-553.

Planderová, E. 1990: Miocene microflora of Slovak Central Paratethys and its biostratigraphical significance. Geol. Úst. D. Štúra, Bratislava, 144 p.

Planderová, E. & Konzalová, M., 1989: Correlation of paleoecological condition in the time of the Upper Eggenburgian-Karpatian on the basis of microfloristic study. Geol.Zbor.Geol.carpath., 40, 63-74.

Pujos, A.,1985: Cenozoic nannofossils, central equatorial Pacific, deep sea Drilling Project Leg 85. In: Mayer, L., Theyer, F. et al. (eds.): Initial Reports of the Deep Sea Drilling Project, 85, U.S. Govt. Printing Office, Washington, 581-608.

Repčok, I., 1987: Vek niektorých vulkanitov Krupinskej planiny, Burdy a Cerovej vrchoviny metódov stôp po štiepení uránu. Geol. Práce, Spr., 86, 173-177. (In Slovak, Engl. summary).

Rio, D., Fornaciari, E. & Raffi, I. 1990: Late Oligocene through early Pleistocene calcareous nannofossils from western equatorial Indian Ocean (Leg 115). In: Duncan, R. A., Backman, J., Peterson, L. C. et al. (eds.): Proceedings of the Ocean Drilling Program, Scientific Results, 115, College Station TX: Ocean drilling Program, 175-221.

Rögl, F., 1998: Paleogeographic considerations for Mediterranean and Paratehys seaways (Oligocene to Miocene). Ann. Naturhist. Mus. Wien, 99A, 279-310.

Rögl, F. & Steininger, F.F., 1983: Vom Zerfall der Tethys zu Mediterran und Paratethys.-Die neogene Palaegeographie and Palinspastik des zirkummediterranen Raumes. Ann. Naturhist. Mus. Wien, 85/A, 135-164.

Salaj, J., 1997: Výsledky biostratigrafické studie miocénu z vrtů v rašoviské depresi (oblast Ždánického lesa). Zem. Plyn Nafta, 41 (3), 127-159. (In Czech, Engl. summary).

Schoepfer, P. & Berger, J.-P., 1989: Burdigalian and Helvetian in Western Switzerland. Geol. Zbor. Geol. carpath., 40, 17-22.

Šutovská, K., 1987: Foraminifery a nanoplanktón vrtov LR-9 a LR-10 (kišcel a eger Rimavskej kotliny, južné Slovensko) so zameraním na štatistické spracovanie tanatocenóz. Manuscript, Thesis, PřFUK Praha. (In Slovak).

Šutovská, K. 1991: Shallow-water assemblages of Neogene Foraminifers of the western part of the Western Carpathians. Acta geol. geograph. Univ. Comenianae, Geologica 47/1, 95-113.

Šutovská, K., 1991: Oligocene and Miocene anoxic facies from inner Western Carpathians. Abstracts IXth Congres R.C.M.N.S. November 1990. Barcelona.

Šutovská, K., 1993: Morský otnang v Ipeľskej a Lučeneckej kotline. Sbor.VII.uhel.konf.prirodov.fak. Praha, 201-202.

Šutovská, K. & Kantor, J., 1992: Oxygen and carbon isotopic analysis of Karpatian foraminifera from LKŠ-1 borehole (Southern Slovakian Basin). Mineralia slovaca, 24, 209-218.

Šutovská, K., Maslowská, H. & Bezvoda, V., 1993: Analysis of foraminiferal assemblages from the Western Carpathian Lower Miocene using special statistical methods. Geol.Carpath., 44(3), 189-200.

Sztanó, O., 1995: Paleogeographic significance of tidal deposits: an example from an early Miocene Paratethys embayment, Northern Hungary. Palaeogeogr., Palaeoclimatol., Palaeoecol., 113, 173-187.

Sztrákos, K., 1978:Stratigraphie et Foraminiferes de l'Oligocene du nordest de la Hongrie. These, Univ. P. et M. Curie, Paris, 133 p.

Takayama, T. & Sato, T., 1985: Coccolith Biostratigraphy of the North Atlantic Ocean, Deep Sea Drilling Project Leg 94. In: Ruddiman, W.F., Kidd, R.B., Thomas, E. et al. (eds.): Initial reports of the Deep Sea Drilling Project, 94, U.S. Govt. Printing Office, Washington, 651-702.

Vass, D., 1977: Príbelské vrstvy, ich sedimentárne textúry a genéza. Záp.Karpaty, sér.geol., 2, 145-198. (In Slovak).

Vass, D., 1995:Global sea level changes reflected on Northern margin of the Hungarian Paleogene the Filakovo and Novohrad (Nograd) Lower Miocene Basin (South Slovakia). Mineralia slov., 27, 193-206.

Vass, D., 1996: The origin and disappearance of Hungarian Paleogene Basins and short-term Lower Miocene Basin in Northern Hungary and Southern Slovakia. Slovak Geol. Mag., 1, 81-95.

Vass, D., Edit., 1986: Vysvetlivky ku geologickej mape Rimavskej kotliny a priľahlej časti Slovenského rudohoria, 1 : 50 000. Geol. Úst. D. Štúra, Bratislava, 177 p. (In Slovak).

Vass, D. & Bagdasarian, G.P., 1978: A radiometric time scale for the Neogene of the Paratethys region. Studies in Geology, 6, 179-203.

Vass, D., Bagdasarian, G.P. & Konečný, V., 1971: Determination of the absolute age of the West Carpathian Miocene. Földt. Közl., 101, 2-3.

Vass, D. & Balogh, K., 1986: Radiometryczna skala wiekowa neogenu Paratetydy. Ann. Soc. Geol. Polon., 56, 375-384. (In Polish).

Vass, D. & Beláček, B., 1998: Konvolutné deformácie v medokýšnych vrstvách Ipeľskej kotliny. Mineralia slovaca, 29, 391-400. (In Slovak)

Vass, D. & Elečko, M., 1982: Litostratigrafické jednotky kiščelu až egenburgu Rimavskej kotliny a Cerovej vrchoviny. Geol. Práce, Spr., 77, 111-124. (In Slovak, Engl. summary).

Vass, D., Elečko, M. et al., 1989: Geológia Rimavskej kotliny. Geol. Úst. D. Štúra, Bratislava, 160 p. (In Slovak, Engl. summary).

Vass, D., Elečko, M., Kantorová, V., Lehotayová, R. & Klubert, J., 1987: Prvý nález morského otnangu v juhoslovenskej panve. Mineralia slovaca, 19(5), 417-422.

Vass, D., Edit., 1983: Vysvetlivky ku geologickej mape Ipeľskej kotliny a Krupinskej planiny 1:50 000. Geol. Úst. D. Štúra, Bratislava, 126 p. (In Slovak, Engl. summary).

Vass, D., Edit., 1992: Vysvetlivky ku geologickej mape Lučeneckej kotliny a Cerovej vrchoviny 1:50 000. Geol. Úst. D. Štúra, Bratislava, 196 p. (In Slovak, Engl. summary).

Vass, D., Hók, J., Kováč, P. & Elečko, M., 1993: Sled paleogénnych a neogénnych tektonických udalostí vo svetle napäťových analýz. Mineralia slovaca, 25 (2), 79-82. (In Slovak, Engl. summary).

Vass, D., Konečný, V. & Šefara, J. 1979: Geologická stavba Ipeľskej kotliny a Krupinskej planiny. Geol. Úst. D. Štúra, Bratislava, 227 p. (In Slovak).

Vass, D., Repčok, I., Balogh, K. & Halmai, J., 1987: Revised Radiometric time-scale for the Central Paratethys Neogene. Magy. áll. földt. Intéz. Évk., 70, 423-434.

Vass, D., Repčok, I., Halmai, J. & Baloh, K., 1985: Contributions to the improvement of numerical time scale for the Central Paratethys Neogene. Abstracts. 8th Congress of RCMNS. Budapest., 595-596.

Vass, D. & Šucha, V., 1984: Rekonštrukcia geologického vývoja sedimentov Lučeneckej kotliny: Štúdium ílových minerálov. Geol. Práce, Spr., 99, 39-46.

Zlinská, A., Halásová, E. & Antolíková, S., 1997: Zhodnotenie foraminiferových a nanoplanktónových asociácií z vrtu VTB-1 (Bruty, JV časť podunajskej panvy). Zem. Plyn Nafta, 42 (2), 157-167. (In Slovak).

Zlinská, A. & Šutovská, K., 1990: Biostratigrafické a paleoekologické zhodnotenie vrtu LKŠ-1 na základe foraminifer (Lučenecká kotlina). Mineralia slovaca, 22, 335-343. (In Slovak, Engl. summary).

Zlinská, A. & Šutovská, K., 1991: Biostratigrafia príbelských vrstiev. Mineralia slovaca, 23, 245-250. (In Slovak, Engl. summary).