Quantitative calcareous nannoplankton biostratigraphy of the Oligocene/Miocene boundary interval in the northern part of the Buda Basin (Central Paratethys)

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Relative abundances of seventeen calcareous nannoplankton species were analysed from around the Oligocene/Miocene boundary interval (NP 25–NN 2 Zones) in the northern part of the Buda Basin (Central Paratethys). A succession of four bioevents can be observed in all sections: FAD of Helicosphaera carteri, FAD of Reticulofenestra cf. pseudoumbilica, and FADs of Discoaster druggii and Helicosphaera scissura. The Oligocene/Miocene boundary lies between the FAD of Reticulofenestra cf. pseudoumbilica and FADs of Discoaster druggii and Helicosphaera scissura; events known to approximate it are not recognized.

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INTRODUCTION

Oligocene and Miocene marine basins in the Western Carpathians (Fig. 1) were a part of the Paratethys seas. Paratethys formed a chain of isolated episodically communicating basins. Accurate biostratigraphic correlation within and between such basins, based on biostratigraphic events (LAD, FAD, FCO, LCO) may be problematic because the incoming of new faunas may reflect with opening of local seaways. Good results can be obtained in time intervals characterized by good communication of the basins with the open ocean, when palaeoenvironmental conditions were favourable for index taxa. Good communication of basins depends on both global sea-level changes (Haq et al., 1988) and on local tectonic activity as it influences local sea-level changes (Kováč et al., 2001). If basins developed in separate tectonic domains (which is the case for the Central Paratethys basins), the correlation of bioevents may be not consistent.

These circumstances probably contributed to the uncertainty regarding the exact position of the Paleogene/Neogene boundary in the Central Paratethys (Báldi, 1986; Rögl, 1998; Cicha et al., 1998). This uncertainty is reflected also in the fact that the boundary lies within the local Central Paratethys stage Egerian (Báldi and Seneš, 1975; Steininger et al., 1976). Good index taxa upon which to determine the boundary cannot, with the exception of large foraminifers (Papp, 1975; Váňová, 1975).

The aim of this research is a detailed quantitative analysis of calcareous nannoplankton bioevents around the broader Oligocene/Miocene boundary interval (Zones NP 25–NN 2) in the northern part of the Buda Basin and an assessment of their utility in determining this boundary.

THE OLIGOCENE/MIOCENE BOUNDARY INTERVAL IN THE CENTRAL PARATETHYS

The Oligocene/Miocene boundary (Fig. 2) has been placed in the upper part of the Egerian (Báldi and Seneš, 1975; Steininger et al., 1976; Rögl, 1998), close to the base of the NN 1 Zone of Martini (1971). The Egerian/Eggenburgian boundary was correlated with the NN 1/NN 2 zonal boundary of Martini (1971; Lehotayová and Molčíková, 1975), and is now correlated with the upper part of the NN 2 Zone of Martini (1971; Steininger et al., 1990; Rögl, 1998). The entire interval
studied can be correlated with the upper part of Chattian, the Aquitanian and the lower part of Burdigalian (Rögl, 1998).

The palaeogeography during the late Kiscellian (early Chattian) was characterized by the isolation of the Paratethys. A seaway opened between the Paratethys and the Indian Ocean, enabled penetration of warm-water faunas around the Oligocene/Miocene boundary. The seaway along the Alpine Foredeep was closed for a short time (Rögl and Steininger, 1983; Rögl, 1998, 1999). At the beginning of the Eggenburgian a broad connection between the Indian Ocean and both the Mediterranean and the Paratethys was accompanied by migration of faunas and floras. Seaways along the Alpine Foredeep were reopened (Rögl, 1998, 1999).

Continuous sedimentation across the Oligocene/Miocene boundary interval has been reported from the flysch zone of the Central Paratethys, the Lower Austrian Molasse, the South and East Slovakian basins and the Transcarpathian Basin in Romania (Steininger et al., 1985).

BIOSTRATIGRAPHIC EVENTS IN THE OLIGOCENE/MIOCENE BOUNDARY INTERVAL

Before collecting quantitative biostratigraphic data, the principal calcareous nannoplankton bioevents were summarized for the broader Oligocene/Miocene boundary interval and compared with foraminiferal bioevents. For this synthesis, we use biostratigraphic data from the world oceans (Berggren et al., 1995), generalized data from the Mediterranean (Fornaciari and Rio, 1996) and the data from the Carrosio-Lemme section.
These data were correlated with those from the Central Paratethys basins: data of the present author from the northern part of the Buda Basin (Horváth and Nagymarosy, 1979; Horváth, 1983), the Bavarian and Austrian Molasse (Báldi and Seneč, 1975; Rögl in Cicha et al., 1998), the Pouzdřany Unit (Krňovský et al., 1995), the Ždanice Unit (Molčáková and Straník, 1987), from the flysch zone in Poland (Olszewska in Cicha et al., 1998; Oszczypko-Clowes, 2001), and Ukraine (Andreyeva-Grigorovich et al., 1979; Trofinovics and Savitska, unpubl. data), and synthetic data for Romania (Popescu in Cicha et al., 1998; Marunteanu, 1992). The following calcareous nanoplankton bioevents can be distinguished:

1. LAD of *Helicosphaera recta*

   This event defines the NP 25/NN 1 boundary according to Martini (1971). Because the taxon is rare, the event was replaced by the LAD of *Reticulofenestra bisecta* (Berggren et al., 1995). In the Mediterranean region (synthesis of data by Fornaciari and Rio, 1996), this event is not isochronous and hence not reliable for biostratigraphic correlation. Marunteanu (1992) described this event from Romania.

2. LAD of *Reticulofenestra bisecta*

   This event is used to approximate the NP 25/NN 1 boundary (Berggren et al., 1995; 23.9 Ma; Rio et al., 1990, for the Indian Ocean). In the Mediterranean, this event has been recorded in the lower part of the NN 1 Zone (Fornaciari and Rio, 1996) and considered to be the best approximation for the Oligocene/Miocene boundary. In the Central Paratethys, it has been reported from younger deposits (NN1/NN2 boundary, Savitska, unpubl. data).

3. LAD of *Reticulofenestra abisecta*

   The problematic reliability of this bioevent is connected with the controversial taxonomic status of this species. It is difficult to distinguish smaller specimens from *Cyclicargolithus floridanus* (Rio et al., 1990; Bubík, 1992; author’s own unpubl. observation). Okada and Bukry (1980) used the LCO of *Reticulofenestra abisecta* for the definition of the CN1a/CN1b boundary in low-latitude zonation. This event was used also in Mediterranean stratigraphy (Theodoridis, 1984) but its reliability was questioned by other authors (Martini and Muller, 1986; Fornaciari and Rio, 1996).

   In spite of these problems, this bioevent has frequently been used as a biostratigraphic indicator in the Central Paratethys: it can be correlated with the NP 25/NN 1 boundary according to Báldi-Béke (1984), Bystrická (1979). In Ukraine, the event has been recorded from the NN 1/NN 2 boundary (Savitska, unpubl. data).

4. LAD of *Discolithina latelliptica*

   This endemic Paratethys species is considered to be stratigraphically important. According to Báldi-Béke (1984), Bystrická (1979), etc. it indicates the Oligocene.

5. LADs of *Sphenolithus conicus* and *S. capricornutus*

   These events have been described from the Carrosio-Lemme section: the LAD of *Sphenolithus capricornutus* from the Oligocene/Miocene boundary and the LAD of *Sphenolithus conicus* from the NN 1/NN 2 zonal boundary. The events were dated at 23.6 Ma (LAD of *Sphenolithus conicus*) and 23.8 Ma (LAD of *Sphenolithus capricornutus*; Aubry and Villa, 1996). The occurrence of these calcareous nanoplankton species in the Central Paratethys has been reported from Hungary (Horváth and Nagymarosy, 1979) and Poland (Oszczypko-Clowes, 2001).

6. FADs of *Reticulofenestra pseudoumbilica* and *R. excavata*

   These are approximately isochronous events in the Central Paratethys. Molčáková and Straník (1987) described the FAD of *R. pseudoumbilica* as somewhat earlier than the FAD of *R. excavata*. Outside this area, the FAD of *R. pseudoumbilica* has been described from different stratigraphic levels. This discrepancy is caused by different taxonomic concepts among different authors: specimens smaller than 11 μm were placed within *R. pseudoumbilica* by some authors but were excluded by others. In the Mediterranean, the FAD of *R. pseudoumbilica* has been described only from the middle Miocene (NN 6 Zone; Fornaciari and Rio, 1996). In the Atlantic Ocean near Madeira, Howe and Sblendorio-Levy (1998) described the FAD of *R. pseudoumbilica* (> 7 μm) from the upper part of the NN 2 Zone. This event is correlated with the NN1/NN 2 boundary in the Central Paratethys in Romania (Marunteanu, 1992).

   *Reticulofenestra excavata* is an endemic species described from the Central Paratethys (Lehotayová, 1975). Its FAD is correlated with the NN 2 Zone (Lehotayová, 1975).

7. FAD of *Discoaster druggi*

   The FAD of *D. druggi* was used for the definition of the base of the NN 2 Zone and was dated at 23.2 Ma for the world ocean (Berggren et al., 1995). This event is observed in the Mediterranean but it is rare and unsuitable for routine work (Fornaciari and Rio, 1996). In the Central Paratethys, this event has been mentioned from the same level (NN1/NN 2 boundary) from many basins (Horváth and Nagymarosy, 1979; Lehotayová, 1982, 1984; Marunteanu, 1992).

8. FAD of *Helicosphaera mediterranea*

   In the Mediterranean region, this event is correlated with the middle part of the NN 2 Zone after the FAD of *H. ampliaperta* (Fornaciari and Rio, 1996). Marunteanu correlated the event with the uppermost part of the NP 25 Zone.

9. FAD of *Helicosphaera carteri*

   Perch-Nielsen (1985) described this event from around the NN 1, NN 2 Zones. From the Mediterranean, the FCO of the species has been reported from the NN 2 Zone (Fornaciari and Rio, 1996). The FAD of the species was dated at 22.6 Ma in the NN 2 Zone in the Carrosio/Lemme section (Aubry and Villa, 1996).

10. LCO of *Helicosphaera euphratis*

    In the Mediterranean region, the LCO has been correlated with the FCO of *Helicosphaera euphratis* in the NN 2 Zone (Coccioni et al., 1997).

11. FAD of *Helicosphaera ampliaperta*

    The FAD of *H. ampliaperta* was dated at approximately 20 Ma in the Mediterranean (Fornaciari and Rio, 1996). From the Central Paratethys, this was described from Romania and placed within the NN 2 Zone (Marunteanu, 1992). This event marks approximately the Egerian/Eggenburgian boundary.

   The calcareous nanoplankton bioevents have been correlated with the following foraminiferal events:

1. LAD of *Paraglobigerina opima opima*

   Berggren et al. (1995) dated this event at 27.1 Ma (= approximately Kiscellian/Egerian boundary sensu Rögl, 1998) in the World Ocean. In the Paratethys, Cicha et al. (1998) corre-
lated it with the lower Egerian. Approximately at the same level, the large-sized and diverse older planktonic foraminiferal assemblages with *Paragloborgerina opima opima* were replaced by low-diversity assemblages composed mainly of small-sized globigerinas. A decreasing diversity of planktonic foraminifers in this time interval was recorded also in the Pacific Ocean (Kennett and Srinivasan, 1983).

2. **LAD of *Uvigerina hantkeni***

The local Central Paratethys event was dated to the Egerian/Eggenburgian boundary (Cicha et al., 1986), and subsequently to the middle part of the Egerian (Cicha et al., 1998).

3. **FAD of *Globigerinoides primordius***

This event has been dated at 26.7 Ma for the World Ocean (Berggren et al., 1995) and to the lowermost Egerian in the Central Paratethys (Cicha et al., 1998).

4. **FAD of *Globigerinoides trilobus***

This event coincides with the LAD of *Paragloborotalia kugleri* in the Carrosio-Lemme section (laccarino et al., 1996) which was dated at 21.5 Ma according to Berggren et al. (1995). Cicha et al. (1998) correlated this event with the uppermost Egerian in the Central Paratethys.

5. **FAD of *Uvigerina posthantkeni***

The FAD of this endemic Central Paratethys species was described from the uppermost Egerian (Cicha et al., 1986) or to the Egerian/Eggenburgian boundary (Cicha et al., 1998).

**MATERIAL AND METHODS**

The material analysed comes from the South Slovak depressions (Fig. 2). In this area, standard biostratigraphic, lithostratigraphic and sedimental analyses are well summarized by Vass (1996) and Vass et al. (1979, 1983, 1985, 1989, 1992). Lithostratigraphic units were defined by Vass and Elečko (1982). Correlation with standard nannoplankton zones (Martini, 1971) was made by Lehotayová (1982). Palaeogeographical maps were constructed for every stage for the Ipeľa Rimava Depressions (Vass et al., 1979, 1989). Important tectonic events were distinguished (Vass et al., 1993; Mártan et al., 1995; Vass, 1995). Local sea-level changes (Vass, 1995) were correlated with the global ones of Haq et al., (1988).

The geomorphological unit termed the South Slovak depressions formed a part of two marine basins during the Oligocene/Miocene boundary interval (Vass, 1995):

1. the Buda Basin (Oligocene-Egerian/Eggenburgian boundary); the South Slovak depressions represent the northern part of the Buda Basin;
2. the Fiľakovo/Petervásara Basin (Eggenburgian); the South Slovak depressions were situated on the southern margin of this basin.

The area of the South Slovak depressions was flooded during this time interval by the prominent Kiscellian-Egerian transgression and a smaller Eggenburgian transgression. A long-lasting emergence followed, during the Upper Eggenburgian and Ottnangian (Vass, 1995).

Based on important tectonic events distinguished for the Oligocene and Miocene of the South Slovak depressions (Vass et al., 1993; Mártan et al., 1995; Vass, 1995), the left-lateral strike-slip along the Plešivec–Rapovce fault (several tens of km) has been dated at 19–20 Ma. It may have been an influence across the broader Oligocene/Miocene boundary interval.

The time interval studied is represented by three formations (Vass et al., 1989; Fig. 2):

1. the Čič Formation is composed predominantly of dark claystones and siltslones of the Lémartovce Member containing a typical Kiscellian marine fauna (Mollusca: *Nuculana deshayesiana*, *Propeamussium bronzi zimanyii*, *Thyasira nysti*, *Ondrejčíková*, 1978; Foraminifera: *Tritaxia szaboi*, *Lenticulina kubinyi*, Kantorová, 1978). Lehotayová (1978) correlated this lithostratigraphical unit with the NP 24 Zone. This member was described only from the bases of boreholes LR-9 and FV-1. Marginal facies of the Čič Formation are represented by the Blh and Hostišovce members.

2. the Lučenec Formation is represented mainly by calcareous siltslones (“schlier”) of the Szécsény Member. This member yielded most of the samples analysed (Fig. 2). *Paragloborgerina opima opima* was recorded in the lower part of the member (Kantorová, 1978) and *Globigerinoides primordius* in the upper part (Holcová, 2001). Lehotayová (1978) correlated this member with the upper part of the NP 24, NP 25 and NN 1 zones. The pollen spectra were determined as typical Oligo-Miocene (Planderová, 1990).

Marginal facies are represented by the Budikovany and Bretka members. These members are lithologically similar, and comprise organodetrital limestones and conglomerates. Both members were dated on the basis of larger foraminifer (Vaňová, 1975). *Miogypsina formosensis* from the Budikovany Member indicates the upper Oligocene age for the Budikovany Member while *Miogypsina gunteri* and *M. tani* indicate a lower Miocene age for the Bretka Member. Nannoplankton from these members was studied from the type sections of Budikovany and Bretka (Báldi and Senèš, 1975).

3. the Fiľakovo Formation: the Tachtý Member consisting of sandstones was analysed from this formation. The sandstones contain *Uvigerina primiformis* (Kantorová in Vass et al., 1980) the FAD of which is correlated with the base of the Eggenburgian (Cicha et al., 1998). Lehotayová (1982) correlated the member with the NN 2 Zone. Other members of the Fiľakovo Formation represent a marginal facies, do not contain calcareous nannoplankton and were not studied.

The calcareous nannoplankton was studied by the standard method using a polarizing light microscope. Quantitative data were obtained counting, when possible, about 500 specimens. 200–300 specimens were used for samples where calcareous nannoplankton was rare (marginal facies of the Egerian in the Budikovany and Bretka sections).

**RESULTS AND DISCUSSION**

**RECOGNIZED BIOEVENTS**

The relative abundances of seventeen species were recorded and compared in total (Figs. 3–10). Besides biostratigraphically significant species, relative abundances of the most common species (*Coccolithus pelagicus*, *plexus* of small *Reticulofenestra*, *Cyclicargolithus floridanus*) were also analysed. Helicoliths (six species) and placoliths (seven species) dominate the assemblage.
Fig. 3. A — Coccolithus pelagicus (Wallich) Schiller, borehole C-2, 550 m; B — small Reticulofenestra sp., borehole FV-1, 60 m; C — small Reticulofenestra sp., borehole FV-1, 140 m; D — Reticulofenestra cf. pseudoumbilica (Gartner) Gartner (first small specimen), borehole FV-1, 120 m; E — Reticulofenestra cf. pseudoumbilica (Gartner) Gartner, borehole FV-1, 550 m; G — Cyclicargolithus abisectus (Müller) Wise, borehole C-2, 350 m; H — Reticulofenestra bisecta Hay, Mohler and Wade, borehole FV-1, 140 m; I — Reticulofenestra bisecta Hay, Mohler and Wade, borehole C-2, 350 m; J — Helicosphaera recta Haq, borehole C-2, 550 m; K — Helicosphaera euphratis Haq, borehole C-2, 400 m; L — Helicosphaera carteri (Wallich) Kamptner (form with larger opening), borehole FV-1, 60 m; M — Helicosphaera carteri (Wallich) Kamptner (form with narrow opening), borehole C-2, 300 m; N — Helicosphaera scissura Miller, borehole FV-1, 140 m; O — Helicosphaera mediterranea Müller, borehole FV-1, 60 m; P1 — Sphenolithus conicus Bukry, crossed nicols 45°; P2 — Sphenolithus conicus Bukry, crossed nicols 0°, borehole LR-9, 400 m; Q — Sphenolithus capricornatus Bukry and Percival, borehole FV-1, 140 m; R — Discoaster druggii Bramlette and Wilcoxon, borehole EH-2, 20 m; S — Helicosphaera ampliaperta Bramlette and Wilcoxon, borehole EH-2, 15 m; T — Helicosphaera ampliaperta Bramlette and Wilcoxon, borehole EH-1, 38 m; U — Discolithina latelliptica Báldi-Beke, borehole C-2, 400 m.
Small *Reticulofenestra* (determined as *R. minuta* by, e.g. Haq, 1980; Spezzaferi and Coric, 2001, etc.; Fig. 3B, C) represent very probably two or more species which cannot be distinguished under the light microscope (Haq, 1980). Within the *Reticulofenestra* group, large *Reticulofenestra* (4.5–8 μm in diameter) started to appear. The variety characterized by a large central opening (representing 0.2–0.4 placolith diameter) was here determined as *Reticulofenestra cf. pseudoumbilica* (Fig. 3D, E). It can be compared with *Reticulofenestra pseudoumbilica* described from the lower Miocene in other Central Paratethys basins (Molèíková and Straník, 1987; Marunteanu, 1992).

The following bioevents can be recognized in the sections analysed:

— borehole LR-9 (Fig. 4): the FAD of *Helicosphaera carteri* and LAD of *Helicosphaera recta* were recorded at the base of the borehole; their reliability is therefore questionable. These events are overlain by the FCO of *H. carteri* and LCO of *Discolithina latelliptica*. The FAD of *Helicosphaera mediterranea* was described from the uppermost part of the borehole.

— borehole LR-10 (Fig. 5): the FAD of *Helicosphaera carteri* was observed in the lower part of the borehole. In the middle part, two problematic LADs of *Helicosphaera recta* and *Sphenolithus conicus* were recorded based on isolated occurrences of these species. The acme of small *Reticulofenestra* as well as the FAD of *Reticulofenestra cf. pseudoumbilica* were observed in the upper part of the borehole.

— Budikovany section (Fig. 6): calcareous nannoplankton is very rare; the FAD of *Reticulofenestra cf. pseudoumbilica* was observed only in the uppermost part of the section.

— borehole LR-2 (Fig. 7): an isolated occurrence of *Helicosphaera recta* in one sample was recorded in the lower part of the borehole. The acme of small *Reticulofenestra* as well as the FAD of *Helicosphaera carteri* were observed in the middle part of the borehole. FADs of *Reticulofenestra cf. pseudoumbilica*, *Discoaster druggii*, *Reticulofenestra excavata*, *Helicosphaera mediterranea* and *H. scissura* were recorded in the upper part of the borehole near the same level.

— borehole C-2 (Fig. 8): two isolated occurrences of *Helicosphaera recta* were observed in the middle part of the borehole. *Reticulofenestra excavata*, *R. cf. pseudoumbilica*, *Discoaster druggii*, *Helicosphaera mediterranea* and *H. ampliaperta* successively appear from the middle to the upper part of the borehole. In this borehole, the LAD of *Reticulofenestra bisecta* can be observed at the level of the FAD of *Discoaster druggii*.

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**Fig. 4.** Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in borehole LR-9.

*Other explanations as on Figure 2.*

**Fig. 5.** Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in borehole LR-10.

*Other explanations as on Figures 2 and 4.*
— borehole FV-1 (Fig. 9) yielded a section of prime importance and was sampled in detail. LADs of Helicosphaera recta, Sphenolithus conicus as well as FADs of Reticulofenestra cf. pseudoumbilica, R. excavata, Helicosphaera scissura and H. mediterranea are connected with rare and discontinuous occurrences of these taxa. In this borehole, the LAD of H. euphratis can be observed. Clear, practically isochronous FCOs of Reticulofenestra cf. pseudoumbilica

Fig. 6. Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in the Budikovany section

Other explanations as on Figures 2 and 4

Fig. 7. Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in borehole LR-2

Other explanations as on Figures 2 and 4

Fig. 8. Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in borehole C-2

Egg. — Eggenburgian; other explanations as on Figures 2 and 4

Fig. 9. Relative abundances of the most common and stratigraphically significant taxa of calcareous nannoplankton in borehole FV-1

Other explanations as on Figures 2 and 4
and *R. excavata* were recorded above the FCO of small *Reticulofenestra*.

— borehole EH-2 (Fig. 10): intervals with no calcareous nannoplankton were recorded in this borehole, which may influence the recognition of the calcareous nannoplankton events. Only the FAD of *Helicosphaera ampliaperta* is well defined.

— borehole EH-1 (Fig. 11): a well-defined FAD of *Helicosphaera ampliaperta* lies only slightly above the FAD of *Discoaster druggi*. This species occurred only discontinuously.

The comparison of the succession and character of bioevents described in the individual boreholes enabled classification of the bioevents to the following groups:

1. Well-established biostratigraphic events were recorded in all sections at the corresponding stratigraphical level. Distinct FADs (or LADs) are characterized by continuous occurrences of taxa in all or most of the samples above (or below) the level of the event. The following events can be classified as well-established ones: the FAD of *Reticulofenestra* cf. *pseudoumbilica* (recorded in boreholes LR-10, FV-1, LR-2, C-2, Budikovany section), the FAD of *Reticulofenestra excavata* (recorded in boreholes FV-1, LR-2, C-2), the FAD of *Helicosphaera ampliaperta* (boreholes C-2, EH-1, EH-2), the FAD of *Helicosphaera carteri*: the event was recorded in the lowermost part of sections LR-9, LR-10 where it cannot be well evaluated, but is well documented in borehole LR-2.

2. Less perfectly established events: two types of events were included in this category:

   — the species does not occur continuously over its FAD and the events were not recorded in all sections: the FAD of *Helicosphaera scissura* (boreholes FV-1, LR-2, EH-1, EH-2), the FAD of *Discoaster druggii* (boreholes C-2, LR-2, EH-1), the FAD of *Helicosphaera mediterranea* (boreholes C-2, LR-2, LR-9);

   — FCOs which cannot be clearly recognized in all sections: the FCO of small *Reticulofenestra* (clearly recognizable in boreholes LR-10, FV-1, unclear in boreholes LR-2 and C-2).

3. Problematic events. Biostratigraphically significant taxa are very rare, occurring in only as a few specimens in the sections. For this reason, the level of the event may be random. The LADs of *Helicosphaera recta*, *Sphenolithus conicus* and the LAD of *Sphenolithus capricornutus* were assigned to this category.

Based on data from the literature (see chapter Biostratigraphic events in the Oligocene/Miocene boundary interval), the following LADs were expected: LADs of *Reticulofenestra abisecta*, *R. bisecta* and *Discolithina latelliptica*. The LADs of *Reticulofenestra abisecta* and *R. bisecta* were determined only in borehole C-2 around the FAD of *Discoaster druggii*. The LAD of *Discolithina latelliptica* was not recorded. The absence of these events in boreholes may be caused by reworking of the taxa. Therefore, some quantitative criteria were sought to distinguish between reworked and autochthonous occurrences of *Reticulofenestra abisecta*, *R. bisecta* and *Discolithina latelliptica*. Discontinuous occurrences and lower relative abundances of the taxa were expected above their LADs where only reworked specimens can be recorded.

This can be observed only for *Reticulofenestra bisecta* which occurs continuously in boreholes LR-9, LR-10 which can be correlated with Zones NP 25 and NN 1: *Discoaster druggii* was not recorded in these boreholes. Discontinuous occurrences were observed in boreholes EH-2 and EH-1 which can be correlated with the NN 2 Zone based on the occurrence...
of Discoaster druggii. In borehole FV-1, analysed in great detail, the relative abundance of R. bisecta decreases in the uppermost part where Helicosphaera scissura appears. The LAD of Reticulofenestra bisecta cannot be recognized in borehole LR-2 where the clearly recognizable FADs of Discoaster druggii and Reticulofenestra scissura were recorded.

This change was not observed in Reticulofenestra abisecta. The expected discontinuous occurrences were observed in borehole EH-1. At a certain stratigraphical level, in the upper part of borehole EH-2, R. abisecta occurs continuously and is relatively abundant. On the contrary, this species occurs sporadically in borehole LR-2 where its autochthonous occurrence was expected.

SUCCESSION OF BIOEVENTS

Successions of calcareous nannoplankton bioevents were compared for the boreholes studied. The following succession can be observed for 17 bioevents analysed (Fig. 12): (1) the FAD of Helicosphaera carteri; (2) the LAD of Sphenolithus conicus and the FCO of small Reticulofenestra; these events were not recorded in all sections; (3) the FAD of Reticulofenestra cf. pseudombilica (with a diameter exceeding 4.5 μm); the FAD of Reticulofenestra excavata is coeval or slightly younger; (4) the FADs of Discoaster druggii and Helicosphaera scissura always lie above the FAD of Reticulofenestra cf. pseudombilica and are usually of the same age. The events were not recorded in all sections analysed; (5) the LAD of Reticulofenestra bisecta can be approximately correlated with the FADs of Discoaster druggii and Helicosphaera scissura and is expressed by discontinuous occurrences of the taxa in the sections; (6) the FAD of Helicosphaera ampliaperta.

Two events showed a random position in the sections: the LAD of Helicosphaera recta (from the uppermost level studied below the FAD of Helicosphaera carteri to the FAD of Helicosphaera scissura), the FAD of Helicosphaera mediterranea (from the FAD of Helicosphaera carteri to the FAD of Helicosphaera ampliaperta).

Biostratigraphically significant events observed only once were recorded at the following levels: the LAD of Sphenolithus capricornutus between the FADs of Helicosphaera carteri and Reticulofenestra cf. pseudombilica near the FAD of Sphenolithus conicus; the LADs of Cyclicargolithus abisectus and Cyclicargolithus bisectus at the level of the FAD of Discoaster druggii.

<table>
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<tr>
<th>World Ocean</th>
<th>Mediterranean</th>
<th>Stratigraphical correlation after Rögl (1998)</th>
<th>Central Paratethys</th>
<th>Northern part of Buda Basin (Central Paratethys; this work)</th>
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<tr>
<td>Oligocene</td>
<td>Chattian</td>
<td>NP 25</td>
<td>FAD Helicosphaera mediterranea 5</td>
<td>LAD Reticulofenestra excavata 8, 10, 11</td>
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<td>Rupelian</td>
<td>Keuperian</td>
<td>NP 24</td>
<td>FAD Helicosphaera aequata 8</td>
<td>FAD Discoaster druggii</td>
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<td></td>
<td>LAD Helicosphaera recta 7</td>
<td>FAD Reticulofenestra excavata 8</td>
<td>FAD Reticulofenestra bisecta 9</td>
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Fig. 12. Correlation of the most significant calcareous nannoplankton bioevents in the studied boreholes and sections studied.
CONCLUSIONS

Six of the calcareous nannoplankton events observed can be clearly recognized in the South Slovak depressions. These events were compared with the distribution of planktonic and large foraminifers in the sections analysed, and the following correlation with standard biostratigraphic data can be made:

The FAD of *Helicosphaera carteri* is the oldest event in the studied sections. It was recorded closely above the LAD of *Paraglobigerina opima opima* in borehole LR-9 and can be correlated with the Oligocene. In other areas it was recorded in the younger Miocene NN 1, NN 2 Zones (Perch-Nielsen, 1985; Marunteanu, 1992, *Helicosphaera kamptneri*; Krhovský et al., 1995; Aubry and Villa, 1996, etc.). Also, its replacement by *H. euphratis* described from the Mediterranean was not observed, and the two taxa occur together.

The interval with abundant occurrence of small *Reticulofenestra* represents an ecosratigraphical event which is also repeated at other stratigraphical levels in the Central Paratethys (Karpian: Spezzaferri and Coric, 2001; lower Badenian: Švábenická, 2002; Zágoršek and Holcová, in press). Gartner (Karpatian: Spezzaferri and Coric, 2001; lower Badenian: Marunteanu, 1992) and *Paraglobigerina opima opima* studied sections. It was recorded closely above the LAD of this species in the Budikovany section.

These results showed that the Oligocene/Miocene boundary approximation based on calcareous nannoplankton cannot be recognized in the area studied. The boundary falls between the FAD of *Reticulofenestra bisecta* and *Helicosphaera scissura*. These results showed that the Oligocene/Miocene boundary

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