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Oligocene–Early Miocene planktonic microbiostratigraphy and paleoenvironments of the South Slovakian Basin (Lučenec Depression)

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Abstract: Oligocene and Lower Miocene sediments of the Lučenec Depression were studied to demonstrate the planktonic bioevents and climatic proxies from the Číž Formation (Rupelian) and Lučenec Formation (Chattian–Aquitanian) on the basis of quantitative analyses of foraminifers and calcareous nannofossils. The oldest nannofossil assemblages of the Číž Formation belonged to the NP23 Zone and were dominated by *Reticulofenestra ornata* known for preference of temperate eutrophic water conditions. An increase in bioproductivity was documented by abundant large-sized planktonic foraminifers (e.g. *Turborotalia ampliapertura, Paragloborotalia nana, Subbotina gortanii*) and epifaunal to shallow-infaunal benthic species. The middle part of the Číž Formation reveals a lowstand progradation of deltaic sediments of the Rapovce Member. There, the planktonic foraminifers are impoverished in both size and diversity, containing mostly tenuitellid and cassigerinellid species, probably as a result of decreased salinity and increased anoxia in the Tard Clay. Contrary of this, the benthic foraminifers are rich, mainly the infaunal forms of uvigerinid species. They probably proliferated due to a high organic flux from riverine input. Open marine conditions were restored in the upper part of the Číž Formation above the lowest occurrence (LO) of *Cyclicargolithus abisectus* on the NP23–NP24 zone boundary. The transitional interval between the Číž and Lučenec formations (O5/O6 — NP24/25) was approximated by the HOs of *Paragloborotalia opima* and *Sphenolithus distentus* and the LOs of *Globigerinoides primordius* and *Pontosphaera enormis*. Benthic foraminifera of the Lučenec Formation indicate a high productivity and oxygen-deplected environments. The Oligocene–Miocene boundary in the Lučenec Formation was appointed by the HOs of *Helicospahera recta* and *Dictyococcites bisectus*. Foraminiferal markers of this boundary were established from the HO of *Globigerina ciperoensis* and the LO of *G. ottnangiensis*. The highest nannofossil dating in the Lučenec Formation is recorded by the LOs of *Helicosphaera mediterranea* (NN1 Zone) and *Discoaster druggi* (NN2 Zone). The uppermost part of the Lučenec Formation contained many Paratethys benthic foraminifera, such as *Uvigerina posthantkeni*.

Key words: Oligocene–Lower Miocene, calcareous nannofossils, planktonic foraminifers, biozonation, climatic proxies, paleoecology.

Introduction

The Paleogene formations of the Intra-Carpathian area belong to two different basins — the Hungarian Paleogene Basin and Central-Carpathian Paleogene Basin. These basins overlay the Mesozoic basement nappe units, which were emerged during the post-Gosau time and differ in type of sedimentation. Shallow-water epicontinental deposits fill the Hungarian Paleogene Basin, while deep-water flysch is characteristic of the Central-Carpathian Paleogene Basin (Nagymarosy 1990). The two basins also differ in their geotectonic position. The Hungarian Paleogene Basin was probably formed as a retro-arc foredeep basin (Tari et al. 1993), but the Central-Carpathian Paleogene Basin is interpreted as a fore-arc basin (Soták et al. 2001).

The Hungarian Paleogene Basin extends northward into the South Slovakian Basin (Fig. 1). Its north-western margin occurs on the Šahy Antiform, which represents a strike-slip elevation bordering the Buda Line (Vass 2003). Sediments of the Hungarian Paleogene Basin occur in the Štúrovo area and in the Ipeľ, Lučenec and Rimava depressions. The Paleogene formations were drilled by a series of boreholes such as Mužľa-4 (Seneš 1960; Brestenská & Lehotayová 1960), Chanava LR-9 (Šutovská 1987), Lučenec LC-2 (Vass et al. 2004), Rapovce LR-3 (Vass & Elečko 1992), Číž C-2 (Vass & Elečko 1982), Mužľa LKŠ-1 (Zlinská & Šutovská 1990), Ivanice FGRK-1 (Zlinská 2009), Bátka RKZ-1 (Vass 1995a), Gemerská Párnica (Halásová et al. 1996), Gemerček RAO-5 (Nagy et al. 2004) and others (see Vass et al. 2007).

The core of the Rapovce GTL-2 borehole drilled for the geothermal survey by Geospectrum Ltd. Bratislava in 2007 provided a new opportunity to study the Oligocene and Lower Miocene formations of the Lučenec Depression. The GTL-2 core provided the reference section for study and understanding of the high-resolution stratigraphy and paleoenvironmental proxies of the Oligocene and Lower Miocene deposits in the Lučenec Depression.

Geological setting

The Hungarian Paleogene Basin began to develop after a long-term uplift, lateritic weathering and karst bauxite depo-

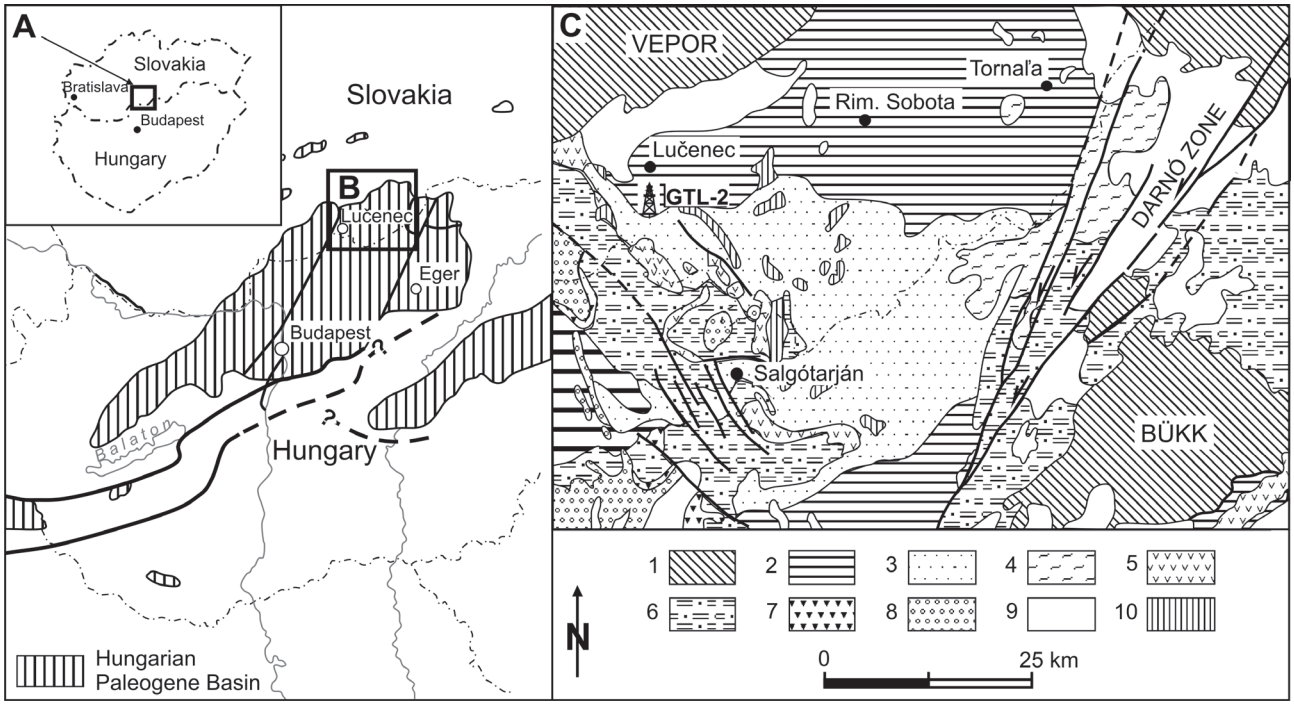


Fig. 1. Regional geological context of area studied (**A**) within the Hungarian Paleogene Basin (**B** — scheme after Nagymarosy 1990), South Slovakian North Hungarian units (**C** — sketch map after Vass 1995b) and location of the Rapovce GTL-2 borehole. **Legend to sketch map:** 1 — pre-Teriary units; 2 — Hungarian Paleogene Basin; 3, 4 — Fiľakovo-Pétervására Basin: 3 — Fiľakovo Formation and Pétervására Sandstone, 4 — Upper Szécsény and Putnok Schliers; 5 — Eggenburgian rhyodacide tuffs in Gyulakeszi and Bukovina Formations; 6 — Nógrad-Novohrad Basin, Ottnangian and Karpatian sediments; 7 — Upper Karpatian–Lower Badenian ryolite formation (Tarr Tuff); 8 — Middle to Upper Miocene volcanics; 9 — Middle to Upper Miocene sediments; 10 — Upper Miocene to Pleistocene basalts.

sition in Bakony and the Transdanubian area (Báldi 1986). The Lutetian transgression gradually flooded lagoons, where coal-bearing layers were accumulated (Dorog Coal, Obid Member). Progradation of a shallow-water carbonate platform is documented by the Szöc and Szépvölgy limestones. Their outer shelf equivalent is represented by the Padrag and Buda Marls (Báldi-Beke & Báldi 1985; Kázmér et al. 2003). Late Eocene depocenters were shifted to the Buda Basin, which rapidly subsided during the Oligocene, until bathyal conditions were reached. Basin differentiation led to initial isolation recorded by euxinic facies of the Tard Clay (Báldi 1986). The Rupelian-Chattian sequences of the North Buda Basin are formed by the Kiscell Clay, Szécény Schlier and Eger Sandstone (Báldi 1986). The Oligocene transgression is also expressed by the initial flooding of the basinal area in Southern Slovakia (Vass 1995a).

The Oligocene sequence of the Lučenec Depression (Fig. 2) started by the continental fluvial deposits of the Skálnik Member, followed by transgressive sediments of the Číž Formation represented by conglomerates, breccias, sandstones and siltstones with marine fauna. The lower members of the Číž Formation consist of lagoonal sediments of the Blh Member, nearshore sediments of the Hostišovce Member and offshore and carbonate peri-platform facies named the Bátka Limestone. The major part of the Číž Formation belongs to the Lenártovce Member, which is characterized by deep-water facies of grey claystones, siltstones and sandstones known as Kiscell Clay. The regressive sequence of the Číž Formation is developed in deltaic sediments of the Rapovce Member, represented by grey sandstones and siltstones with plant remnants, coal laminae and shallow water fauna (Vass 1995a).

The Egerian cycle of deposition in the South Slovakian Basin is represented by the Lučenec Formation, reaching thicknesses of more than 1000 m in some places. The sediments of the Lučenec Formation superposed the deep-water sediments of the Číž Formation or covered the pre-Tertiary basement. These transgressive deposits are formed by breccias, conglomerates and sandstones of the Panica Member, bioclastic limestones and calcareous sandstones with *Miogypsina* and *Lepidocyclina* of the Budikovany Member and clastic limestones, breccias and conglomerates with large pectinids of the Bretka Member. The Lučenec Formation is mostly composed of grey calcareous siltstones of the Szecsény Schlier, which documents the outer shelf up to upper bathyal environment. Upper Eggerian sediments of the Lučenec Formation belong to the Opatová Member (Šutovská-Holcová et al. 1993), representing delta-type sediments, such as channel gravels, prodelta claystones, delta-front sandstones and coal seams, developed in a great thickness (150 m). These deltaic deposits represent the terminal sediments of the North Buda Basin, which evolved into the Fiľakovo/Pétervására Basin from the beginning of the Early Miocene and then from the Ottnangian into the Nógrád/Novohrad Basin.

Transgressive sediments of the Fiľakovo/Pétervására Basin are represented by the Fiľakovo Formation. They are shallow-

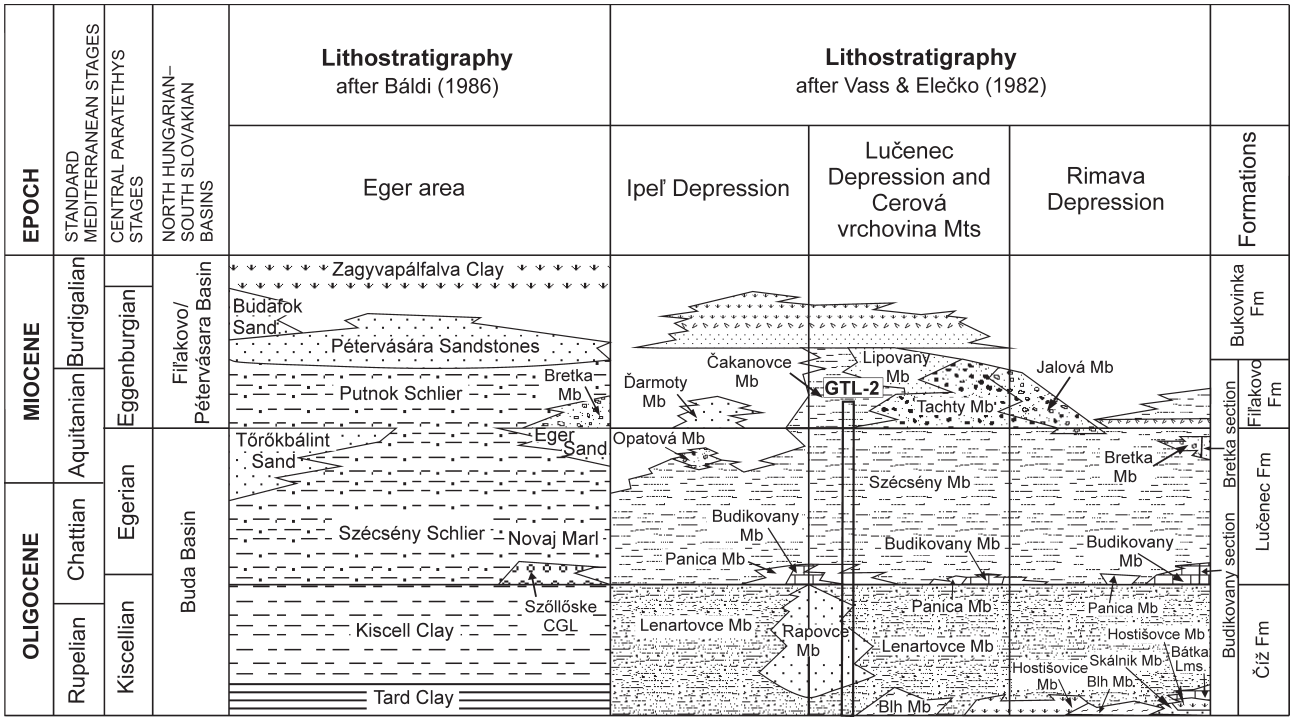


Fig. 2. Lithostratigraphic scheme of the North Hungarian–South Slovakian basins, providing the correlation of the Oligocene–Lower Miocene formations in the Lučenec, Ipeľ and Rimava Depressions (Vass & Elečko 1982 adapted by Holcová 2005) and Eger area (Báldi 1986). **Abbreviations:** Mb — member, CGL — conglomerates, Lms. — limestones.

water sediments deposited in high-energy shoreface and shallow-marine environments described as the Čakanovce Beds, Lipovany Sandstone, Tachty Sandstone, Jalová Sandstone and Pétervására Sandstone (e.g. Vass & Elečko 1982; Sztanó & Tari 1993). The Late Eggenburgian regression resulted in terrestrial clay and sandy-gravel deposition of the Zagyvapálfa and Bukovinka Formations, which include numerous bird and mammal footprints covered by thick tuff deposits of the Gyulakeszi Rhyolite Tuff Formation (Márton et al. 1996).

The new subsidence is related to accommodation of the Nógrád/Novohrad basin in the Early Ottnangian time. Marine transgression was preceded by fluvial, swampy and lacustrine sedimentation of the Salgótarján Formation, which contains coal bearing deposits of the Pôtor Member (Vass et al. 1983). The upper Ottnangian–Karpatian formations of marine deposits are represented by the Plachtince/Mátra Beds and Modrý Kameň/Egyházasgerge Formations. The main part of the Modrý Kameň Formation belongs to the Sečianky Member also named the Garáb Schlier, consisting of calcareous claystones with full-marine fauna such as benthic and planktonic foraminifers, mollusks, gastropods (e.g. Holcová 1996; Ondrejíčková 1972; Vass 2002). The Modrý Kameň Formation is superposed by the Tarr Tuff Formation, which marks the beginning of volcanic activity at the Karpatian-Badenian boundary. Badenian basin-fill formations are formed by shoreface sands of the Príbelce Member, volcanoclastic sediments and volcanic intrusive complexes named the Vinica Formation, Halič and Šiator Andesites and Pokoradza Formation. The Nógrád/Novohrad Basin came to an end due to domal uplift of the South Slovakian volcanic area, which resulted in marine regression and basin inversion from the Middle Badenian time (Vass & Šucha 1994; Vass 1995b; Kováč et al. 2001). Upper Miocene deposits of the Lučenec and Rimava depressions are represented by fluvial gravels and variegated clays of the Poltár Formation and basalts of the Podrečany Formation.

Material and methods

The Rapovce GTL-2 core was drilled at a site located 4.36 km south of Lučenec near Rapovce village (N 48°16′ 39.52″, E 19°40′ 43.47″ — Fig. 1). The borehole reached a depth of up to 1501.5 m and caught the following lithostratigraphic formations (Vass et al. 2008 — Fig. 2): Fiľakovo Formation (5.00–45.00 m), Lučenec Formation (45.00–606.00 m), Číž Formation (606.00–775.00 m) and Mesozoic basement complex represented by the Middle- and Upper Triassic carbonates (775.00–1501.50 m). The sands and sandstones of the Fiľakovo Formation in the upper part of the GTL-2 borehole belong to the Lipovany Member. The Lučenec Formation consists of grey calcareous siltstones of the Széczény Schlier (45.00–595.00 m) with intercalations of 1m thick beds of fine-grained sandstones. Sediments below the Széczény Schlier belong to the Panica Member, consisting of coarse- to medium grained conglomerates and sandstones (595.00–606.00 m). The Číž Formation reaches a thickness of up to 169 m (606.00–775.00 m) and its main part is formed by deltaic sands of the Rapovce Member (606.00–745.00 m), outer shelf siltstones and claystones of the Lenártovce Mem-

ber (745.00–65.00 m), lagoon coal-bearing sandstones of the Hostišovce Member (795.00–770.00 m) and transgressive sandstones and pebbly sandstones of the Blh Member (770.00–775.00 m).

Both the standard Mediterranean and regional Central Paratethys stages to the Oligocene and Early Miocene stratigraphic interpretation. The Paleogene Time Scale for the standard Mediterranean stages followed Gradstein et al. (2012) and the Paratethyan stages were applied in accordance with their definition for the Kiscellian (Báldi 1969, emend. Báldi et al. 1984), Egerian (Báldi & Seneš 1975, emend. Báldi et al. 1999) and Eggenburgian (Steininger & Seneš 1971). The Paratethyan nomenclature was also used in an informal sense, as for designation of Kiscell-type fossil assemblages, sedimentary facies, transgressive events (e.g. initial flooding of the Kiscellian Sea into the South Slovakian Basin — cf. Vass 2003).

The borehole section was sampled every 5 meters and provided 78 samples for foraminiferal and calcareous nannoplankton study. The samples were taken mainly from the calcareous-rich claystones and siltstones. Nannofossil samples were prepared by the decantation method (Haq & Lohmann 1976; Perch-Nielsen 1985). The smear slides were inspected under the light microscope Zeiss at 1.500× magnification and nannofossils documented by digital camera. For quantitative analysis, at least 300 specimens per sample were counted in randomly selected fields.

The foraminiferal microfauna was washed, dried and sieved, obtaining the size fractions >250 μm, >150 μm and >38 μm. The residues were examined under a stereomicroscope Olympus and picked for study using the JEOL Scanning Electron microscope.

Nannoplankton age determination was carried out according to the zonation by Martini (1971), completed by Perch-Nielsen (1985), Young (1998) and Wise et al. (2002). Planktonic foraminiferal biostratigraphy was applied on the basis of the Oligocene–Early Miocene zonal schemes (Berggren & Miller 1988; Spezzaferri 1994; Berggren et al. 1995) and Paratethyan foraminiferal data (Sztrákos 1979; Rögl 1985; Cicha et al. 1998; etc.). Bioevents of nannoplankton and foraminiferal biostratigraphy were denoted by the acronyms *sensu* Berggren & Pearson (2005), "LO" for the lowest occurrence and "HO" for the highest occurrence of the index species.

Nannofossil assemblages were evaluated on the basis of specimen preservation and abundance, nannofossil temperature preferences and their trophic strategy. Statistical methods (percentage analyses) were performed by counting of 300 specimens on each sample, providing paleoecological data for evaluation of autochthonous nannofossil species. Percentage share of each nannoplankton group is expressed in diagrams.

Preservation of calcareous nannofossils was determined according to Roth & Thierstein (1972) as follows: VP (very poor) — etching and mechanical damage to specimens is very intensive, P (poor) — fragmentation and/or overgrowth of the specimens makes it difficult to identify them, M (moderate) — mechanical damage and etching of the specimens are visible in the minority of the nannoassemblage, specimens are easily determinable, G (good) — the species are very easily identifiable, etching and overgrowth is slight.

The samples were evaluated by using the following abundance scale: VH (very high) — more than 20 specimens in the 1 field of view, H (high) — 10–20 specimens in the 1 field of view, M (moderate) — 5–10 specimens in the 1 field of view, L (low) — 1–5 specimens in the 1 field of view and VL (very low) — less than 5 specimens in the 5 field of view.

Climatic proxies and trophic conditions were inferred from the temperature preferences and life strategy of calcareous nannofossils (Wei et al. 1992; Bralower 2002; Persico & Villa 2004; Bartol et al. 2008) and planktonic foraminifera (Boersma & Premoli Silva 1983, 1991; Spezzaferi 1995; Wade et al. 2007).

Results

Calcareous nannofossils

Preservation of calcareous nannofossils was moderate, because the specimens are slightly mechanically damaged, but most of them can still be identified easily. Abundance of calcareous nannofossils was low, considering <5 specimens occur in one field of view of the microscope.

Species diversity

Nannoplankton assemblages are moderately diversified, involving a total number of 37 nannofossil taxa with 30 (85 %) autochthonous and 7 (15 %) reworked species. Their proportion is rather equal, showing a slight downwar increase of reworked species in the Číž Formation (18 %) and upward increase of autochthonous species in the Lučenec Formation (86 %) — Fig. 3. The ratio of the reworked species could have increased due to nannofosil resedimentation in prodeltaic/deltaic sediments of the Číž Formation, whereas the indigenous species dominated during the stabilization of full-marine environments in the Lučenec Formation (Széczény Schlier — cf. Vass 1995a).

Nannofossils of the Číž Formation from the depth 775–595 m are rich in species *Coccolithus pelagicus*, *Cycli-*

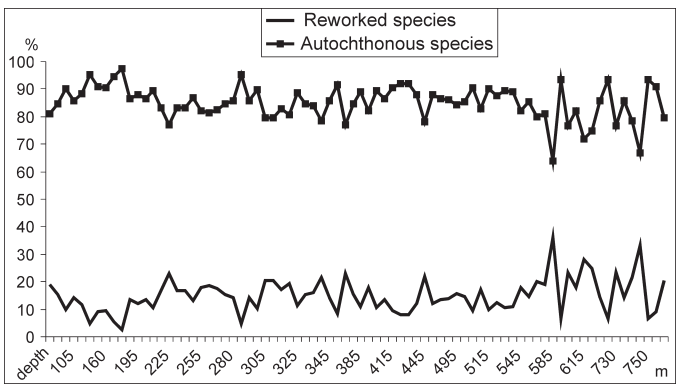


Fig. 3. Nannofossil variations in the ratio of autochthonous versus reworked species across the Rapovce GTL-2 section.

cargolithus floridanus, *Dictyococcites bisectus* and *Zygrhablithus bijugatus*. The common species of this nannoplankton association are *Helicosphaera compacta, Helicosphaera euphratis*, *Reticulofenestra lockeri* and *Reticulofenestra scrippsae*. There is also a low abundance of the species *Isthmolithus recurvus* and *Reticulofenestra ornata*, which disappear at the 595 m interval.

The most abundant nannofossils in the Lučenec Formation comprise the species *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus* and *Zygrhablithus bijugatus*. They are commonly associated with *Helicosphaera compacta*, *Helicosphaera euphratis* and *Reticulofenestra lockeri*. The nannofossil association with *Cyclicargolithus abisectus*, *Helicosphaera recta* and *Pontosphaera desueta* appeared from the depth of 470–595 m. The association changed at the depth of 470 m by disappearance of *Helicosphaera compacta* and *Sphenolithus distentus* and appearance of *Pontosphaera enormis*. Rare occurrences of *Discoaster* cf. *adamanteus, Triquetrorhabdulus* cf. *carinatus* and *Sphenolithus conicus* were recorded from the depth of 345–300 m. Some important species of the association, such as *Cyclicargolithus abisectus*, *Helicosphaera recta* and *Dictyococcites bisectus*, vanished at the depth of 210 m. New specimens of nannofossils *Helicosphaera carteri*, *Helicosphaera mediterranea* and *Discoaster druggii* appeared from the depth of 160 m.

Nannoplankton biostratigraphic interpretations

Nannofossil assemblages of the Číž and Lučenec formations consist of several stratigraphically important taxa, which enable us to distinguish the following nannoplankton zones (Figs. 4, 5):

The NP23 Zone was determined in the interval 775–595 m based on the species *Reticulofenestra ornata*, *R. lockeri* and *Isthmolithus recurvus*, which have their lowest common occurrence reported from this zone.

The appearance of *Reticulofenestra lockeri* is the typical nannofossil datum of the NP23 Zone (Nagymarosy & Voronina 1992). This interval represents a peak of anoxic conditions and stagnant regime in Paratethyan basins (Báldi 1984). The isolation of Paratethys and the decline of salinity within the NP23 Zone caused the extinction of cosmopolitan nannoflora and expansion of the endemic species *Reticulofenestra lockeri* that tolerated hyposaline waters (Nagymarosy 2000; Melinte-Dobrinescu & Brustur 2008). The NP23/NP24 zone boundary was stated on the basis of the first occurrence of *Cyclicargolithus abisectus* (Perch-Nielsen 1985; Young 1998). Some authors reported this species already from the upper part of the NP23 Zone (Fornaciari & Rio 1996; Kaenel & Villa 1996; Maiorano & Monechi 2006; Melinte-Dobrinescu & Brustur 2008). In the borehole, the LO of *C. abisectus* was found at 595 m close to the boundary of the Číž and Lučenec formations (Fig. 5).

The NP24 Zone was delimited by the overlapping ranges of stratigrafically important species *Cyclicargolithus abisectus*, *Helicosphaera recta*, *Pontosphaera desueta* and *Reticulofenestra lockeri*. The appearance of cosmopolitan species reflects restored marine environments and sea-level rise (Krhovský & Djurasinovič 1992; Švábenická & Stráník 2004). However, the nannoplankton diversity of the NP24 Zone is not markedly higher than that of the NP23 Zone.

The NP24–NP25 boundary is inferred from the HO of *Sphenolithus distentus* (Berggren et al. 1995) and was recorded at 470 m. *Pontosphaera enormis*, which has its LO within NP24–25, can be used as a marker species (Young 1998). In the Rapovce section it has a depth of 470 m. This boundary was also outlined by the species of *Helicosphaera compacta*, which has occurrences at 470 m that imply their HO in the NP24 Zone (Maiorano & Monechi 2006; Melinte-Dobrinescu & Brustur 2008). The nannofossil associations of the NP24 and NP25 zones should also be different in size from *Cyclicargolithus abisectus* (Śliwińska et al. 2012), whereby the abundance of *Cyclicargolithus abisectus* >10 μm corresponds to the lower part of the NP24 and NP23 zones and large-sized nannofossils of *Cyclicargolithus abisectus* >13 μm correspond to the uppermost part of the NP24 and lower part of NP25 zones. Significant increase in the size of these nannofossils was not observed. The upper part of the NP 25 Zone is marked by the LOs of *Triquetrorhabdulus* cf. *carinatus* and *Sphenolithus conicus* in the interval between 345–300 m.

The Oligocene-Miocene boundary is unclear since there is no agreement on the definition of the base of the NN1 Zone (LO of *Helicosphaera recta* sensu Martini, 1971) and CN1 Zone (LO *Sphenolithus ciperoensis* sensu Okada & Bukry, 1980). Later, this boundary was redefined by the LO of *Dictyococcites bisectus* at the base of the NN1 Zone (Berggren et al. 1995; Fornaciari & Rio 1996) or by the FOs of *Sphenolithus belemnos* and *Helicosphaera carteri* in the upper part of the NN1 Zone (Young 1998). These nannofossil datums from the Mediterranean were completed by some additional bioevents from the Paratethyan basins, where the Oligocene-Miocene boundary can be marked by the HO of *Dictyococcites bisectus* and FADs of *Helicosphaera kampteri* and *Helicosphaera scissura* (Holcová 2001; Garecka 2012), *Reticulofenestra pseudoumbilica* (Holcová 2005), *Sphenolithus delphix* (Rögl & Nagymarosy 2004), *Helicosphaera mediterranea* (Marunteanu 1999; Chira 2004) and *Sphenolithus capricornutus* (Holcová 2005; Melinte-Dobrinescu & Brustur 2008).

The Oligocene-Miocene boundary of the Rapovce section was identified by the HOs of *Helicosphaera recta* and *Dictyococcites bisectus* at the depth of 210 m. This datum is followed by the appearance of Helicosphaeraceae from the NN1 and NN2 zones. The LOs of *Helicosphaera carteri* and *Helicosphaera mediterranea* were recorded at the depth of 135 m. The NN1–NN2 zone boundary is constrained by the LO of *Discoaster druggii* dated to 23.2 Ma chronostratigraphic scale (Berggren et al. 1995), and in Paratethyan stages corresponds to the Egerian-Eggerburgian boundary (Lehotayová 1982; Marunteanu 1999; Holcová 2002). The LO of *Discoaster druggii* was recorded in the depth of 155 m. These bioevents are too scattered to provide consistent indications of the Oligocene-Miocene boundary (*sensu* Young 1998).

Nannofossil paleoecology

Temperature proxies: The average proportion of the warm-water species, discoasterids, helicosphaerids and sphe-

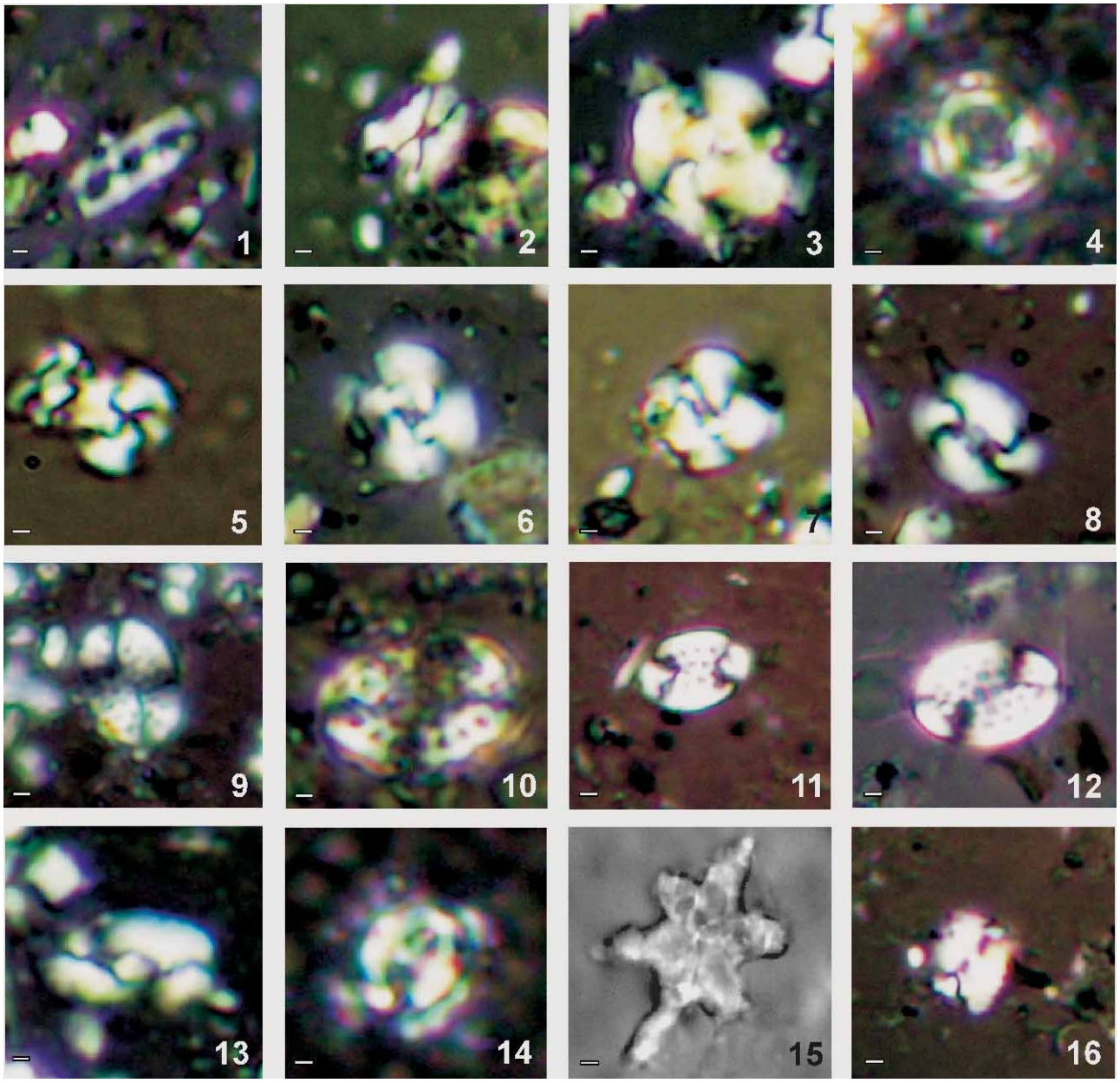


Fig. 4. Calcareous nannoplankton species from the Číž and Lučenec formations in the Rapovce GTL-2 section. **1** — *Isthmolithus recurvus*, 760 m, NP23 Zone, Číž Formation; **2** — *Lanternithus minutus*, 760 m, NP23 Zone, Číž Formation; **3** — *Dictyococcites bisectus*, 745 m, NP23 Zone, Číž Formation; **4** — *Reticulofenestra ornata*, 745 m, NP23 Zone, Číž Formation; **5** — *Cyclicargolithus floridanus*, 725 m, NP23 Zone, Číž Formation; **6, 7** — *Cyclicargolithus abisectus*, 6–560 m, 7–515 m, NP24–25 Zone, Lučenec Formation; **8** — *Reticulofenestra lockeri*, 560 m, NP24–25 Zone, Lučenec Formation; **9** — *Pontosphaera multipora*, 515 m, NP24–25 Zone, Lučenec Formation; **10** — *Pontosphaera desueta*, 495 m, NP25 Zone, Lučenec Formation; **11, 12** — *Pontosphaera enormis*: 11 — 495 m, 12 — 375 m, NP24–25 Zone, Lučenec Formation; **13** — *Helicosphaera euphratis*, 545 m, NP24–25 Zone, Lučenec Formation; **14** — *Helicosphaera mediterranea*, 135 m, NN1–NN2 Zone, Lučenec Formation; **15** — *Discoaster druggii*, 155 m, NN2 Zone, Lučenec Formation, **16** — *Helicosphaera carteri*, 135 m, NN1–NN2 Zone, Lučenec Formation. Scale bars 1 μm.

noliths forms 15 % with increased quantity in the interval of 775–595 m (21 %), corresponding to the NP23 Zone, Mid-Rupelian. The next increase of the warm-water species (17 %) was recorded in the interval 50–150 m, which is correlated with the NN2 Zone, Eggenburgian. The group of species preferring temperate-water conditions such as *Cyclicargolithus floridanus*, *Cyclicargolithus abisectus*, *Coccolithus* sp. and *Dictyococcites bisectus* reaches 54 % of the assemblage (Fig. 6).

The percentage of the cold-water species, above other reticulofenestrids is approximately 16 % of the nannofossil assemblage. The proportion of these species varied by rhythmical decreasing and inceasing with temperature fluctuation. A slight decrease of the cold-water species to 13 % was observed above 175 m.

The nannofossil distribution in the GTL-2 section suggests water temperature differences between the Číž Formation

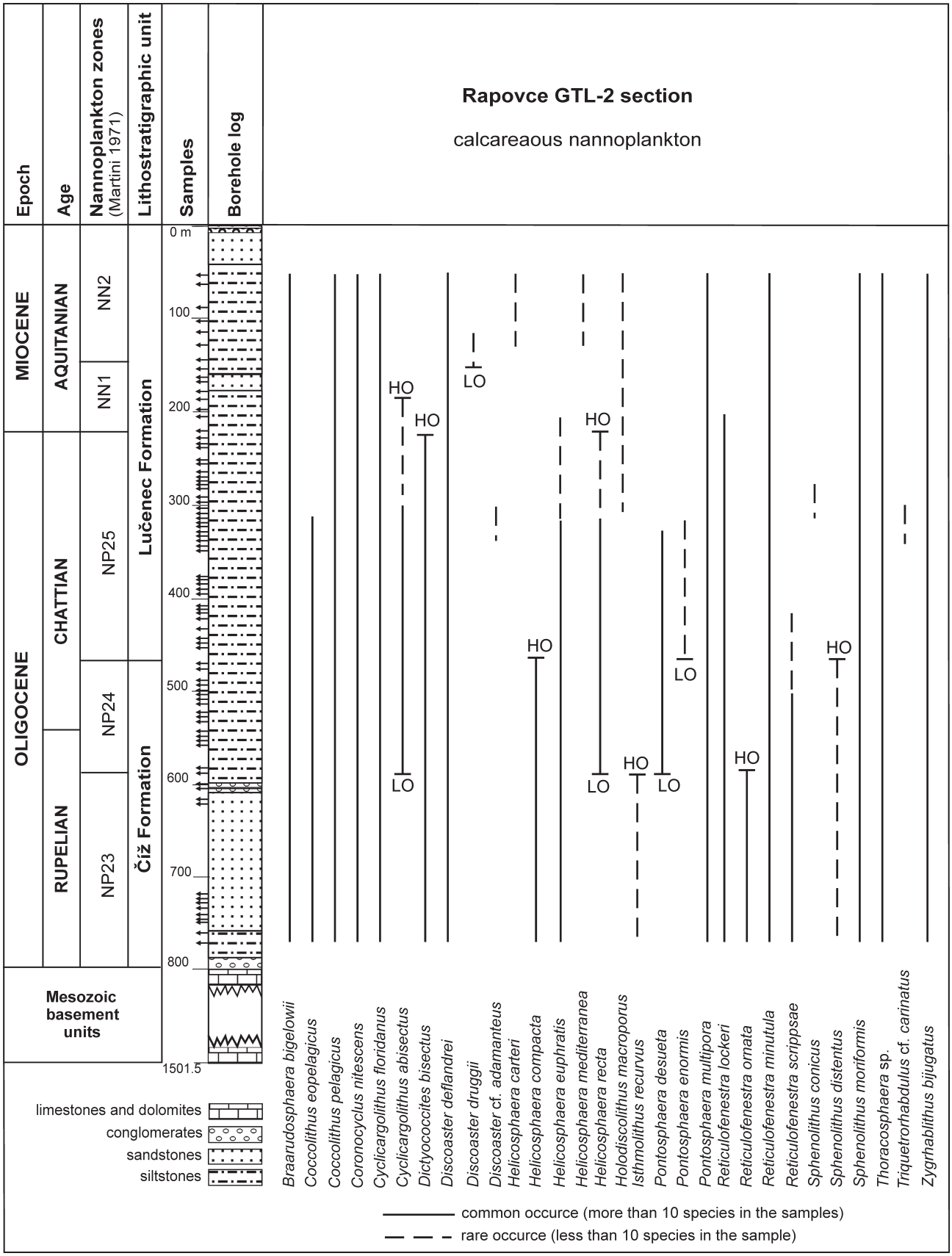


Fig. 5. Distribution of nannofossils in the Rapovce GTL-2 section with indications of important index species for biostratigraphic classification of the Oligocene–Early Miocene formations.

(Rupelian) and Lučenec Formation (Chattian). In the Číž Formation, the highest share of nannofossils belongs to the temperate-water species (54 %), complemented by relatively common warm-water taxa (22 %) and a small number of cold-water taxa (13 %). The assemblages of the Lučenec Formation were also formed mostly by temperate-water species (54 %), but they were complemented by few specimens of warm-water taxa (13 %) and an increased number of cold-water species (17 %). Considering the above mentioned data, the sediments of the Číž Formation were deposited in warmer water conditions than the sediments of the Lučenec Formation.

The balanced composition of the nannofossil assemblages in the interval from 535–770 m of the Lučenec Depression indicates an increase of warm water conditions during the Early Oligocene. That is related to the onset of the Kiscellian transgression (Soták et al. 2002; Soták 2010). This period corresponds to the NP23 and NP24 zones. Similar conditions were reported from the Novaj section (Báldi-Beke 1980, 1984), the Harshegy Sandstone Formation and the Kiscell Clay Formation (Báldi-Beke 1980). Early to Middle Oligocene temperature variations were also recorded by nannofossil proxies in the Krynica Zone of the Magura Nappe (Oszczypko-Clowes & Żydek 2012).

Samples from the interval between 50–150 m show an increase of warm-water species related to Early Miocene climate warming in the NN2 Zone (Soták et al. 2002; Chira 2004; Švábenická et al. 2007).

Trophic resources: Calcareous nannofossils of the Rapovce section imply different trophic-preference conditions. The first group consists of

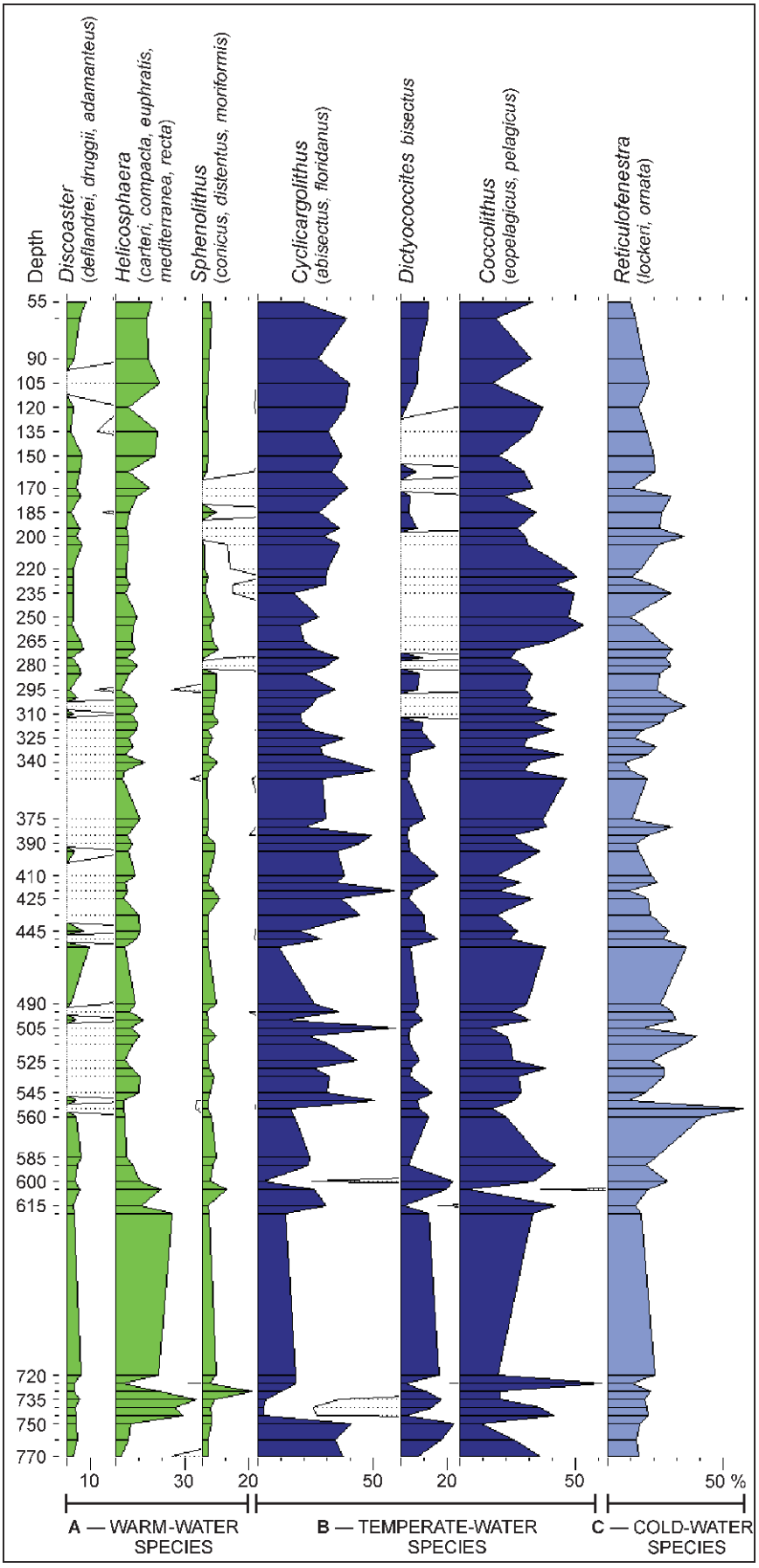


Fig. 6. Quantitative diagram of nannofossils expressed as percentage of species with warm-water preferences (**A**), temperate-water preferences (**B**) and cold-water preferences (**C**) plotted against the depth in the Rapovce GTL-2 borehole section (nannoplankton temperature preferences according to Wei et al. 1992; Bralower 2002; Persico & Villa 2004; Bartol et al. 2008).

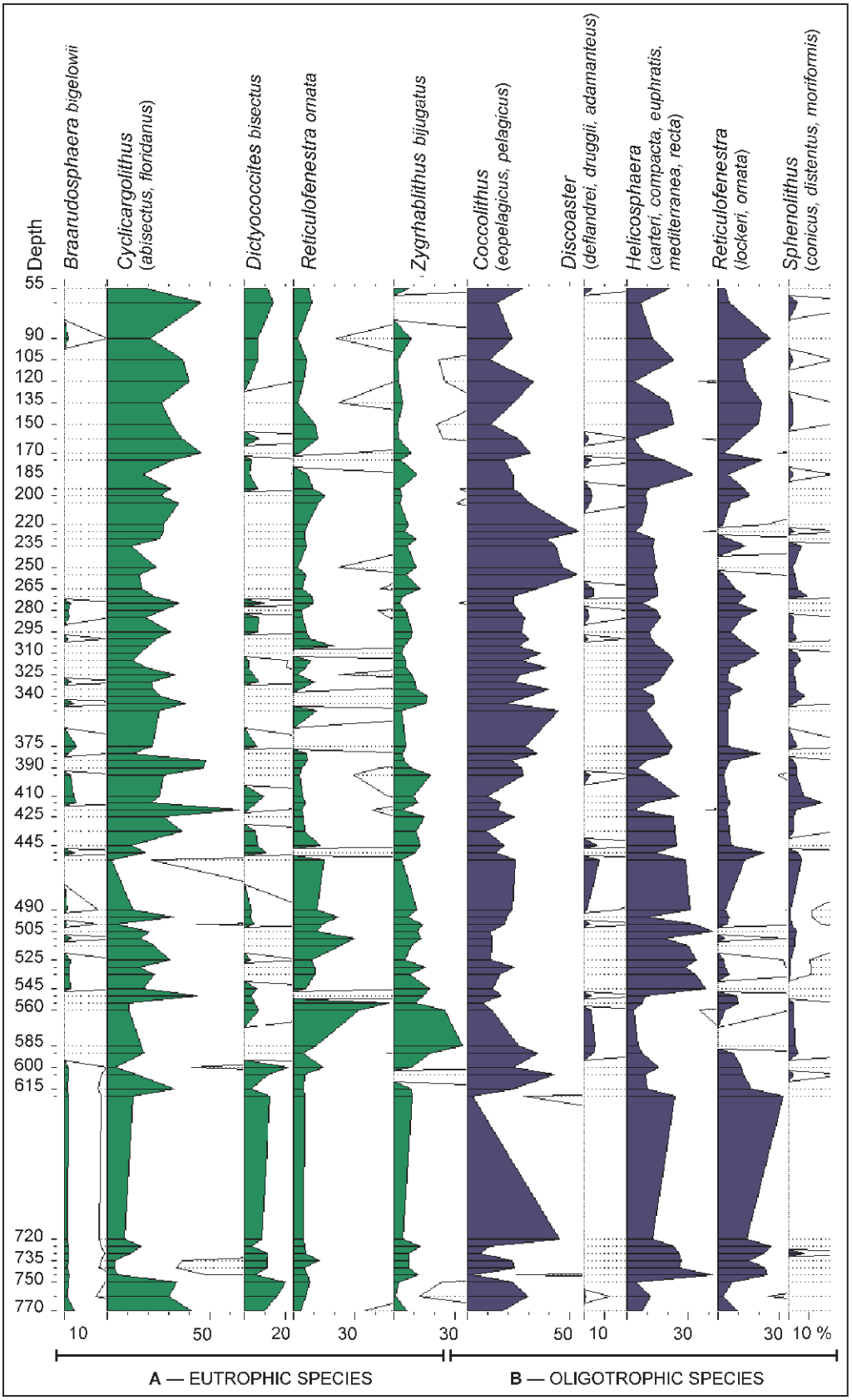


Fig. 7. Quantitative diagram of nannofossils expressed as percentage of eutrophic species (**A**) and oligotrophic species (**B**) and plotted against the depth in the Rapovce GTL-2 borehole section (nannoplankton trophic preferences according to Wei et al. 1992; Bralower 2002; Persico & Villa 2004; Bartol et al. 2008).

eutrophic species such as *Braarudosphaera bigelowii*, *Cyclicargolithus floridanus*, *Cyclicargolithus abisectus*, *Dictyococcites bisectus*, *Reticulofenestra ornata* and *Zyghrablithus bijugatus* (Aubry 1992; Krhovský et al. 1992; Villa et al. 2008).

The second group consists of oligotrophic species that are able to survive even in the areas poorer in nutrients. Oligotrophic species are represented by autochthonous forms such as *Coccolithus*, *Discoaster*, *Helicosphaera*, *Reticulofenestra*, *Sphenolithus*, *Thoracosphaera*, *Triquetrorhabdulus* (Haq & Lohman 1976; Wei & Wise 1990a,b; Aubry 1992; Bralower 2002).

The third group consists of species for which trophic strategy is not exactly specified. Their quantity forms the missing percentage in calculation of high- and low-nutrient taxa in nannofossil assemblages.

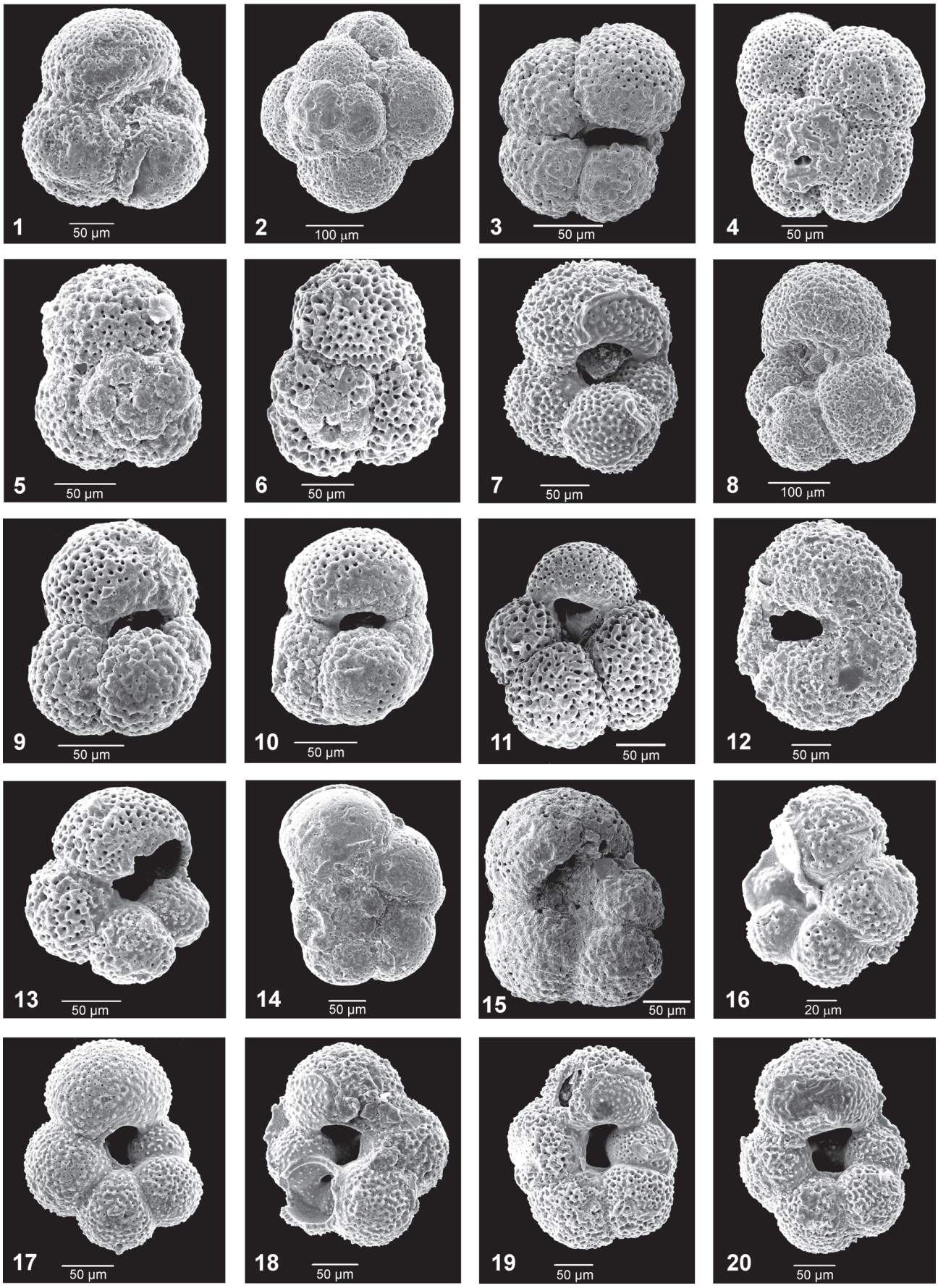
Trophic preferences of calcareous nannofossils (Fig. 7) show a slightly higher percentage of oligotrophic species (44 %) over the high-nutrient taxa (42 %). Eutrophic species are more present in the lower part of the section (48 %), where they prevail over oligotrophic species (38 %). This interval corresponds to the NP23 Zone. Contrary to this, the eutrophic species are less frequent in the higher part of the borehole (39 %), where the oligotrophic species become dominant (49 %). Considering that, the nannofossils of the Číž Formation indicate more eutrophic conditions (48 %) than their mostly oligotrophic assemblages in the Lučenec Formation (39 %). The proliferation of eutrophic species could have been caused by increased resources of nutrients in the basins during the Kiscellian transgression (cf. Báldi-Beke 1980, 1984; Švábenická et al. 2007). Similar eutrophic conditions have also been identified in the Lower Oligocene formations of the Magura basin (Oszczypko-Clowes & Żydek 2012).

Foraminifera: biostratigraphy and paleoenvironments

Planktonic foraminifera of the borehole section show a wide species diversity and distinctive changes in frequency and distribution (Figs. 8, 9). Their succession reaches a great abundance already at the base of the Číž Formation (770/750 m), comprising large-sized forms of globigerinids, turborotaliids and paragloborotaliids. Planktonic associations are diversified to include the following species: *Turborotalia ampliapertura*, *Paragloborotalia nana*, *Subbotina gortanii*, *Globigerina praebulloides*, *Globigerina officinalis* and *Globigerina leroi*. These foraminiferal species enable us to determine the Middle Rupelian age (O2 Zone *sensu* Berggren & Pearson 2005). Planktonic bioproductivity increased probably simultaneously with the sea-level rise during the Kiscellian transgression. Transgressive conditions of the Číž Formation are also indicated by well-aerated shelf environments of benthic foraminifera, represented by the epifaunal species *Eponides umbonatus*, *Heterolepa dutemplei*, *Anomalina cryptomphala*, *Lenticulina budensis*, *Percultazonaria fragaria.* Microfaunistic assemblages of the Číž Formation changed in deltaic sediments of the Rapovce Member in 620–750 m, where planktonic foraminifers provide a distinct reduction in test-size, abundance and diversity. Their association consists of minute forms of tenuitellids, cassigerinellids, globorotaloids and catapsydracids. A similar horizon of small-sized forms of planktonic foraminifers was observed by Horváth (1998) in the Hungarian Paleogene Basin. The taxonomic diversity of planktonic foraminifers in the Rapovce Member decreases to several species: *Tenuitella gemma*, *Cassigerinella globulosa*, *Globorotaloides hexagonus* and *Catapsydrax martini*. Dwarfing of planktonic foraminfers implies stress-induced conditions, such as the influence of hyposaline waters on the morphogenesis of *Cassigerinella chipolensis* (Martinotti, 1989) or cool-water preferences of tunuitellids (Pipperr & Reichenbacher, 2010). Stress conditions of surface-water productivity, which were also indicated by the appearance of pyritized frustules of diatoms and tests of pteropods, were caused probably by eutrophication, shallowing and brackishing of sea-water (Šutovská 1987). The decreased planktonic productivity is replaced by increased benthic productivity, which was manifested by the abundance of uvigerinid foraminifers. The population density of the Rapovce Member was increased in some horizons by monospecific associations of *Uvigerina hantkeni* corresponding to "the *Uvigerina* bloom" in the Kiscell Clay at the base of the NP24 Zone (Horváth 1998).

The transitional beds between the Číž and Lučenec Formations from 600–460 m contain the Kiscellian-Egerian associations of foraminiferal microfauna. The character of the microfauna implies the restoration of full-marine conditions, which is manifested by blooming of the planktonic foraminifers and recolonization of the benthic biota. The abundance of planktonic foraminifera increased abruptly at the beginning of the transgressive cycle above the Rapovce Member in 600–605 m, by the appearance of the Egerian species like *Globoturborotalita ouachitaensis*, *G. angulisuturalis*, *G. woodi* and *G. labiacrassata* (Holcová in Vass et al. 2004). Those foraminifers are associated with *Paragloborotalia opima*, *P. bella*, *Globigerina praebulloides* and *Globigeri-*

Fig. 8. Foraminiferal species from the Číž and Lučenec Formations in the Rapovce GTL-2 section. **1** — *Turborotalia ampliapertura*, 770 m, O2 Zone, Číž Formation; **2** — *Subbotina gortanii*, 770 m, O2 Zone, Číž Formation; **3, 4** — *Paragloborotalia opima*, 515 m, O4–O5 Zone, Číž Formation; **5, 6** — *Globigerinoides primordius*, 455 m, transitional beds of the Číž and Lučenec Formations, O5 Zone; **7, 8** — *Globigerina praebulloides*: 7 — 55 m, M1 Zone, Lučenec Formation, 8 — 770 m, O2 Zone, Číž Formation; **9, 10** — *Glogoturborotalita ouachitaensis*, 605 m, O4 Zone, Číž Formation; **11** — *Globoturborotalita woodi*, 605 m, O4 Zone, Číž Formation; **12** — *Globoturborotalita connecta*, 455 m, O5 Zone, transitional beds of the Číž and Lučenec Formations; **13** — *Paragloborotalia bella*, 605 m, O4 Zone, Číž Formation; **14** — *Paragloborotalia pseudokugleri*, 455 m, O5 Zone, transitional beds of the Číž and Lučenec Formations; **15** — *Globigerina wagneri*, 455 m, O5 Zone, transitional beds of the Číž and Lučenec Formations; **16** — *Globigerina angulioffícinalis*, 225 m, O6 Zone, Lučenec Formation; **17, 18** — *Globigerina ciperoensis*, 135 m, O6 Zone, Lučenec Formation — upper part; **19, 20** — *Globigerina ottnangiensis*, 55 m, M1 Zone, Lučenec Formation — uppermost part.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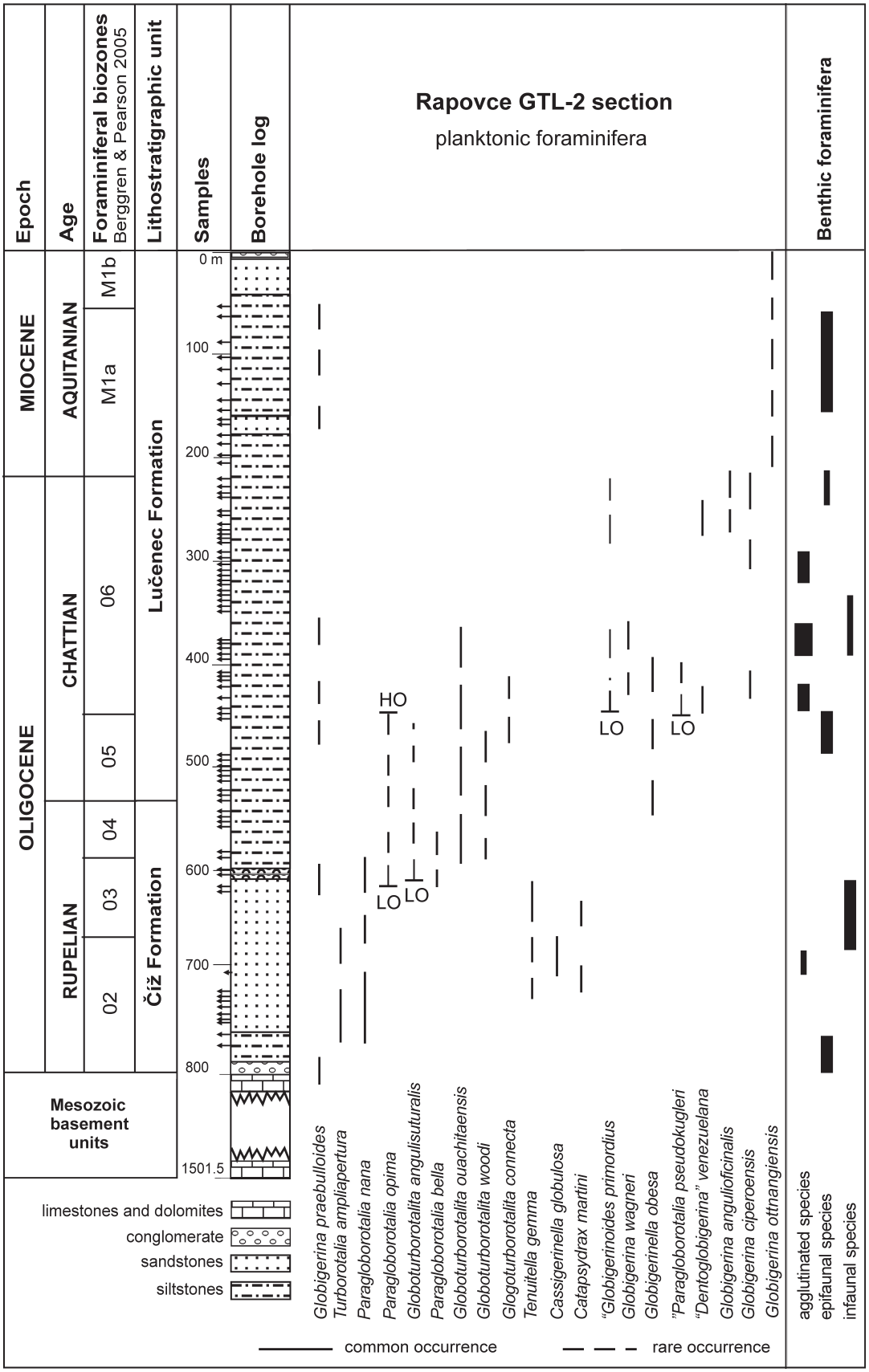

Fig. 9. Distribution of foraminifers in the Rapovce GTL-2 section with indications of important index species for biostratigraphic classification of the Oligocene–Early Miocene formations.

nella obesa. Common occurrence of species from the *Globoturborotalita* — group with *G. angulisuturalis* (LO in O4 Zone according to Berggren & Pearson 2005) and *P. opima* indicates the Early Chattian biozones (P20–21/O3–O4 Zones *sensu* Berggren & Miller 1988; Berggren & Pearson 2005). Benthic foraminifers are represented by euryoxibiont and low-oxygen tolerant species like *Sphaeroidina bulloides*, *Pulenia bulloides*, *Eggerella bradyi*, *Uvigerina vickburgensis*, *Bulimina* cf. *altasica*, *Bulimina schischkinskayae*, *Cassidulinoides tenuis*, *Kareriella quadrinoides*, *Stilostomella consobrina* and *Stilostomella adolphina*.

The base of the Szécsény Schlier of the Lučenec Formation at 455 m is marked by the HO of *Paragloborotalia opima*. Similarly, the presence of this species in the Lučenec Formation was also noted by Holcová (2001, 2005). The extinction of *P. opima* provided an important datum for the early Chattian biozone (O5 Zone *sensu* Berggren & Pearson 2005). At the same horizon, the LO of *Globigerinoides primordius* was recorded. This species appeared together with other primitive specimens of the genus *Globigerinoides* such as transitional forms to *G. altiaperturus* and *G. immaturus* (Keller 1981; Ouda 1998). Change to the new globigerinid forms with secondary appertures on the spiral side appeared in response to Late Oligocene warming (Jenkins 1973). The planktonic foraminifers of the Lučenec Formation also include *Globoturborotalita ouachitaensis*, *G. connecta*, *Globigerina wagneri*, *Paragloborotalia pseudokugleri* (LO in O6 Zone with estimated age 25.9 Ma — Berggren et al. 1995), "*Dentoglobigerina*" cf. *venezuelana* and *Globigerinella obesa*. The benthic foraminiferal microfauna of the Lučenec Formation is enriched in epifaunal habitats with plano-convex trochospiral, biconvex trochospiral, rounded planispiral, spherical and uniserial morphotypes (*sensu* Corliss & Chen 1988). They belong to the following species *Cibicidoides ungerianus*, *C. lopjanicus*, *Gyroidenoides soldani*, *Eponides umbonatus*, *Fontbothia wuellerstorfi*, *Sphaeroidina ciperana*, *Lenticulina cultrata*, *Percultazonaria fragaria*, *Vaginulinopsis pseudodecorata*, *Anomalina affinis*, *Ceratocancris haueri*, *Pullenia bulloides* and *Stilostomella pauperata*. The predominance of epifaunal and shallow infaunal benthic foraminifers implies improved conditions of bottom water oxygenation in the the Lučenec Formation.

The foraminiferal microfauna changes in the upper part of the Lučenec Formation from 330–320 m, with calcareous species diminishing and agglutinated species becoming dominant. Associations involve species like *Trochammina squamata*, *T. inflata*, *T. globigeriniformis* and *Haplophragmoides* sp. This assemblage suggests the deep-water association of agglutinated foraminifera with a reduced amount of dissolved oxygen. Deep-water conditions of the middle bathyal zone are also indicated by infaunal benthic species like *Bulimina coprolithoides*, *Pullenia bulloides* and *Globocassidulina depressa* (cf. Kaiho & Nishimura 1992). These species also provide evidence of dysoxic and highly productive conditions (Corliss & Chen 1988). The occurrence of trochamminid species and bathyal benthic foraminifers in the upper part of the Lučenec Formation indicates a deepening-upward basin during the Egerian time. This is also evident from a high concentration of siliceous sponge rhaxes in schlier sediments. Sea-level rise in the Lučenec Formation coincides with the global eustatic cycle TB1.4, which culminated in the topmost part of the Széczeny Schlier with the appearance of late Oligocene to early Miocene microfauna (Šutovská-Holcová et al. 1993; Vass 1995a).

Late Oligocene planktonic foraminifera were recovered with the appearance of *Paragloborotalia pseudokugleri* at 225 m. It extended to the topmost part of the P22/O6 Zone (Spezzaferri 1991). This species is associated with *Globigerina ciperoensis*, *G. angulioficinalis*, *Globigerinoides primordius* and *G. praealtiaperturus*, their common occurrences are known from the O6 Zone. This evidence appears to establish the Late Chattian age of the Lučenec Formation at 225 m.

The globigerinid foraminifers in the uppermost part of the Lučenec Formation (above 225 m) are developed mostly as five-chambered species belonging to *Globigerina ottnangiensis*. The appearance of this species can be used as a biostratigraphic marker of the Oligocene-Miocene boundary (Rögl 1994; Cicha et al. 1998). The abundance maximum of *G. ottnangiensis* occurs at 55 m. Early Miocene associations of planktonic foraminifera are completed by *Cassigerinella globulosa*, *Paragloborotalia semivera*, "*Dentoglobigerina*" *venezuelana* and *Globigerina praebulloides*. Benthic associations are formed mostly by epifaunal forms with rounded planispiral, plano-convex and biconvex trochospiral, and spherical morphotypes. They belong to the species: *Angulogerina angulosa*, *Lenticulina arcuatostriata*, *L. cultrata*, *Cibicidoides ungerianus*, *C. lopjanicus*, *Almaena osnabrugensis*, *Hanzawia boueana*, *Melonis affinis*, and *Pullenia bulloides*. Infaunal species are less frequent, for example *Praeglobobulimina pupoides* and *Globocassidulina oblonga*, but some of them already belong to the Early Miocene foraminifera. The Eggenburgian index species *Uvigerina posthantkeni* (cf. Cicha et al. 1998; Rupp & Haunold-Jenke 2003; Grunert et al. 2013) appeared in the uppermost part of the Lučenec Formation at 55 m.

Conclusions

The Oligocene and Early Miocene deposits of the Číž and Lučenec Formations provide important data for recognition of the planktonic bioevents and paleoenvironments of the South Slovakian Basin (Fig. 10). The data from the Rapovce GTL-2 section lead to the following conclusions:

1. The Kiscellian transgression at the beginning of the NP23 Zone is marked by extinction and speciation of nannofossils (e.g. LO *R. lockeri* and *R. ornata* and HO *I. recurvus*), and diversification and high-rate bioproductivity of planktonic foraminifera (paragloborotaliids, turborotaliids, globigerinids). The transgressive cycle corresponds to the TB1.2 event of global eustasy (Vass 1995a), which is documented by well-aerated shelf environments with epifaunal benthic foraminifers and nannofossil proxies of warm- to temperate-water and oligotrophic conditions.

2. A regressive phase in the Late Rupelian is documented by the lowstand deposition of prodeltaic sediments of the Rapovce Member. These sediments reveal stress-induced conditions due to eutrophication and brackishing of sea-wa-

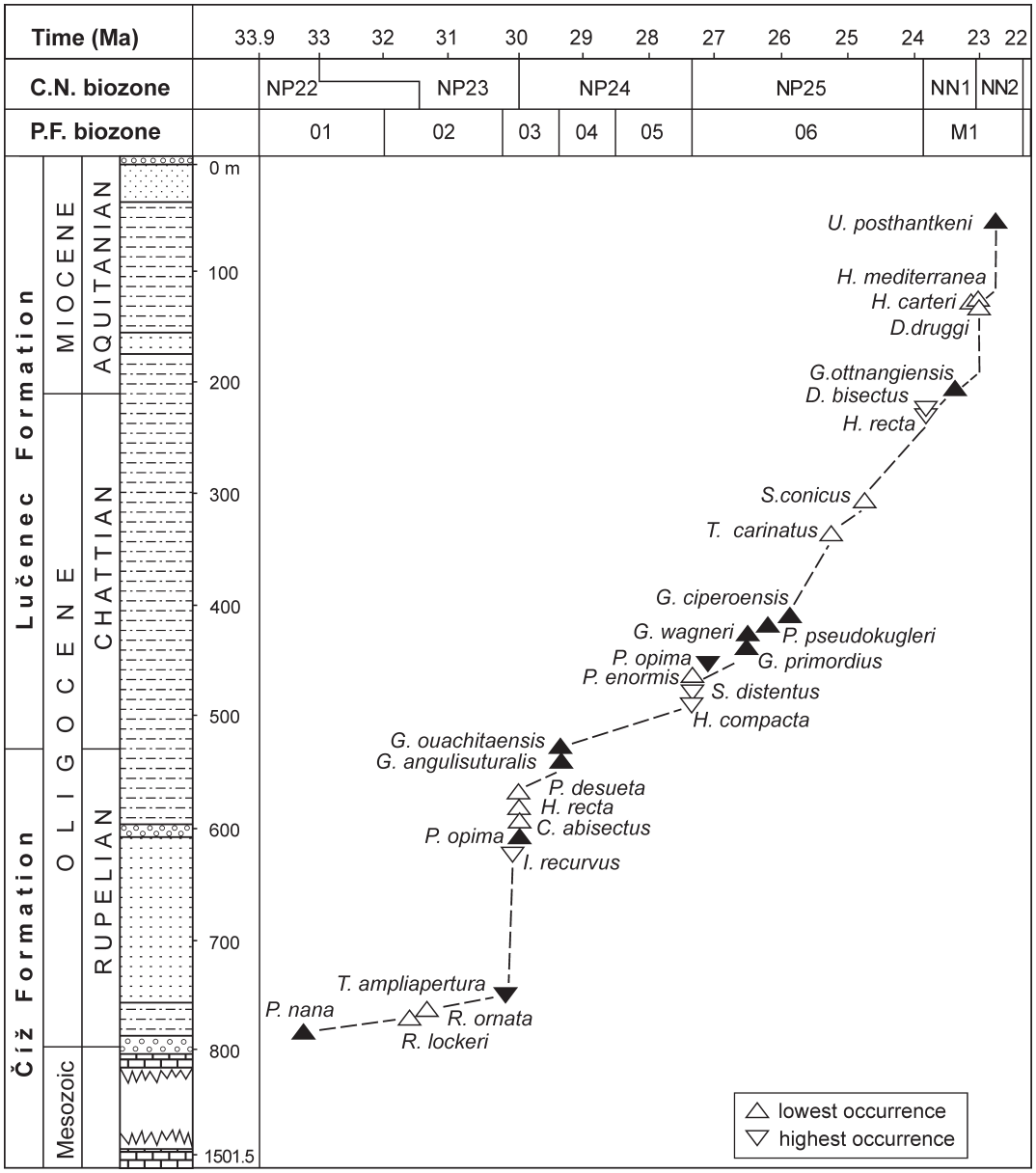

Fig. 10. Integrated biostratigraphy of the Rapovce section with datum events of planktonic foraminifers (black triangles) and nannofossils (white triangles). Biostratigraphic data are indicated by the highest occurrences (HO) and lowest occurrences (LO) of the index taxa.

ter, which resulted in diversity fall and blooming of endemic nannoflora, especially *Reticulofenestra ornata*, and dwarfing of planktonic foraminifera such as tenuitellids and catapsydracids. Infaunal biota, mainly uvigerinid foraminifers, proliferated from increased nutrients and bottom-water dysoxia. Improvement of the open-marine conditions occurred within the NP23–24 boundary, which is approximated by the appearance of nannofossil species *Cyclicargolithus abisectus*.

3. Restoration of full-marine conditions was controlled by the sea-level rise of the TB1.3 cycle in the transitional sequences of the Číž and Lučenec formations. Transgressive sediments are enriched with reworked nannofossils (Fig. 3). The autochthonous species of the NP24 Zone include cosmopolitan nannofossils such as *Cyclicargolithus*, *Helicosphaera*, *Dictyococcites* and *Pontosphaera* (Fig. 6). The climatic proxies of nannofossils indicate eutrophic and temperate-water conditions. Planktonic foraminiferal assemblages with *Paragloborotalia opima* and *Globigerina ciperoensis* define the O5 Zone. The abundance of globoturborotaliid and paragloborotaliid species, which belong to mixed-layered or upper thermocline habitats (Pearson & Wade 2009), implies warm- to temperate-water water conditions. Oxygen depleted conditions are indicated by deep-infaunal benthic species like *Bulimina*, *Chilostomella* and *Stilostomella*.

4. The Rupelian-Chattian boundary was identified by the HO of *Paragloborotalia opima* and the HO of *Sphenolithus distentus* at the base of the Lučenec Formation (O5 Zone, NP24–25 Zone) (Fig. 10). New taxa of planktonic foraminifer are represented by globigerinid forms with secondary apertures (the LO of *Globigerinoides primordius*), which are asso-

ciated with five-chambered species (*Globigerina ciperoensis*) and the first paragloborotaliid forms with arched sutures (*P. pseudokugleri*). Both the appearance of primitive *Globigerinoides* and the nannofossil *Sphenolithus distentus* provide evidence of the Late Oligocene climatic warming. Nannofossil assemblages of the Lučenec Formation are also enriched in content of oligotrophic and temperate-water species compared to those in the Late Rupelian sediments of the Číž Formation. The benthic microfauna of the Lučenec Formation consists of mostly epifaunal and in the upper part also agglutinated forms, which provide evidence of better oxygenation and deepening-upward conditions during the sea-level rising of the TB1.4 cycle.

5. The Oligocene-Miocene boundary was identified in the uppermost part of the Lučenec Formation at 210 m, by several nannofossil bioevents such as the HOs of *Helicosphaera recta* and *Dictyococcites bisectus* and LOs of *Helicosphaera carteri*, *H. mediterranea* and *Discoaster druggii* in the NN1 and NN2 zones (Fig. 10). Early Miocene planktonic foraminifera are represented mostly by five-chambered species belonging to *Globigerina ottnangiensis*. Benthic microfauna strongly increased in abundance with large-sized tests of *Lenticulina* species, associated with numerous specimens of *Angulogerina angulosa* and *Uvigerina posthantkeni*. Benthic life could proliferate with opening of the Eggenburgian seaway connection into the Lučenec Depression. This became evident mainly in the Fiľakovo/Pétervására Basin (Sztanó 1995; Kováč et al. 2001).

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Checklist of taxa mentioned in the text in alphabetic order:

Appendix 1
Nannoplankton species

Arkhangelskiella cymbiformis Vekshina, 1959
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Coccolithus eopelagicus (Bramlette & Riedel, 1954) Bramlette & Sullivan, 1961
Coccolithus formosus (Kamptner, 1963) Wise, 1973
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Coronocyclus nitescens (Kamptner, 1963) Bramlette & Wilcoxon, 1967
Cyclicargolithus abisectus (Müller, 1970) Wise, 1973
Cyclicargolithus floridanus (Hay et al., 1967) Bukry, 1971
Dictyococcites bisectus (Hay, Mohler & Wade, 1966) Bukry & Percival, 1971
Discoaster adamanteus Bramlette & Wilcoxon, 1967
Discoaster deflandrei Bramlette & Riedel, 1954
Discoaster druggii Bramlette & Wilcoxon, 1967
Helicosphaera ampliaperta Bramlette & Wilcoxon, 1967
Helicosphaera bramlettei (Müller, 1970) Jafar & Martini, 1975
Helicosphaera carteri (Wallich, 1877) Kamptner, 1954
Helicosphaera compacta Bramlette & Wilcoxon, 1967
Helicosphaera euphratis Haq, 1966
Helicosphaera kampteri (Hay & Mohler in Hay et al., 1967), Locker, 1970
Helicosphaera mediterranea Müller, 1981
Helicosphaera recta (Haq, 1966) Jafar & Martini, 1975
Helicosphaera scissura Miller, 1981
Holodiscolithus macroporus (Deflandre in Deflandre & Fert, 1954) Roth, 1970
Isthmolithus recurvus Deflandre in Deflandre & Fert, 1954
Pontosphaera desueta (Müller, 1970) Perch-Nielsen, 1984
Pontosphaera enormis (Locker, 1967) Perch-Nielsen, 1984
Pontosphaera multipora (Kamptner, 1948) Roth, 1970 emend. Burns, 1973
Reticulofenestra bisecta (Hay, Mohler & Wade, 1966) Roth, 1970
Reticulofenestra lockeri Müller, 1970
Reticulofenestra minutula (Gartner, 1967) Haq & Berggren, 1978
Reticulofenestra ornata Müller, 1970
Reticulofenestra pseudoumbilica (Gartner, 1967) Gartner, 1969
Reticulofenestra scrippsae (Bukry & Percival, 1971) Roth, 1973
Reticulofenestra umbilica (Levin, 1965) Martini & Ritzkowski, 1968
Sphenolithus belemnos Bramlette & Wilcoxon, 1967
Sphenolithus capricornutus Bukry & Percival, 1971
Sphenolithus ciperoensis Bramlette & Wilcoxon, 1967
Sphenolithus conicus Bukry, 1971
Sphenolithus delphix Bukry, 1973
Sphenolithus distentus (Martini, 1965) Bramlette & Wilcoxon, 1967
Sphenolithus moriformis (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967
Transversopontis pygmaea (Locker, 1967) Perch-Nielsen, 1984
Zygrhablithus bijugatus (Deflandre in Deflandre & Fert, 1954) Deflandre, 1959

Appendix 2
Foraminiferal species

Almaena osnabrugensis (Roemer, 1838)
Angulogerina angulosa (Willimson, 1858)
Anomalina affinis (Hantken, 1948)
Anomalina cryptomphala (Reuss, 1850)
Bulimina cf. *Altasica* Cushman & Parker, 1937
Bulimina coprolithoides Andreae, 1884
Bulimina schischkinskayae Samoylova, 1947
Cassidulinoides tenuis Phleger & Parker, 1951
Cassigerinella globulosa (Egger, 1857)
Cassigerinella chipolensis (Cushman & Ponton, 1932)
Catapsydrax martini (Blow & Banner, 1962)
Ceratocancris haueri (d'Orbigny, 1839)
Cibicidoides lopjanicus (Myatlyuk, 1950)
Cibicidoides ungerianus (d'Orbigny, 1846)
"Dentoglobigerina" venezuelana (Hedberg, 1937)
Eggerella bradyi (Cushman, 1911)
Eponides umbonatus (Reuss, 1860)
Fontbothia wuellerstorfi (Schwager, 1866)
Globigerina angulofficinalis (Blow, 1969)
Globigerina ciperoensis Bolli, 1954
Globigerinella obesa (Bolli, 1957)
Globigerina ottnangiensis Rögl, 1969
Globigerina officinalis Subbotina, 1953
Globigerina praebulloides Blow, 1959
Globigerina praebulloides leroi Blow & Banner, 1962
Globigerina wagneri Rögl, 1994
Globigerinoides altiaperturus Bolli, 1957
Globigerinoides immaturus Le Roy, 1939
Globigerinoides primordius Blow & Banner, 1962
Globocassidulina depressa (Asano & Nakamura, 1937)
Globocassidulina oblonga (Reuss, 1850)
Globorotaloides hexagonus Natland, 1938
Globoturborotalita angulisuturalis (Bolli, 1957)
Globoturborotalita brazieri (Jenkins, 1966)
Globoturborotalita connecta (Jenkins, 1964)
Globoturborotalita labiacrassata (Jenkins, 1966)
Globoturborotalita ouachitaensis (Howe & Wallace, 1932)

Globoturborotalita woodi Jenkins, 1960
Gyroidenoides soldani d'Orbigny, 1982
Hanzawia boueana (d'Orbigny, 1846)
Heterolepa dutemplei (d'Orbigny, 1846)
Kareriella guadryinoides (Fornasini, 1885)
Lenticulina arcuatostriata (Hantken, 1875)
Lenticulina budensis (Hantken, 1875)
Lenticulina cultrata (Montfort, 1808)
Melonis affinis (Reuss, 1851)
Paragloborotalia bella (Jenkins, 1967)
Paragloborotalia nana (Bolli, 1957)
Paragloborotalia opima (Bolli, 1957)
Paragloborotalia pseudocontinuosa (Blow, 1959)
Paragloborotalia pseudokugleri (Blow, 1969)
Percultazonaria fragaria (Gümbel, 1868)
Praeglobobulimina pupoides (d'Orbigny, 1846)
Pulenia bulloides(d'Orbigny, 1826)
Sphaeroidina bulloides (d'Orbigny, 1846)
Sphaeroidina ciperana Cushman & Todd, 1949
Stilostomella adolphina (d'Orbigny, 1846)
Stilostomella consobrina (d'Orbigny, 1839)
Stilostomella pauperata (d'Orbigny, 1839)
Subbotina gortanii (Borsetti, 1959)
Tenuitella gemma Jenkins, 1966
Trochammina globigeriniformis (Parker & Jones, 1865)
Trochammina inflata (Montagu, 1808)
Trochammina squamata (Jones & Parker, 1860)
Turborotalia ampliapertura Bolli, 1957
Uvigerina hantkeni (Cushman & Edwards, 1937)
Uvigerina posthantkeni Papp, 1971
Uvigerina vickburgensis (Cushman & Ellisor, 1931)
Vaginulinopsis pseudodecorata Hagn & Holzl, 1952