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An Early Miocene biserial foraminiferal event in the Transylvanian Basin (Romania)

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Abstract: Investigations of the Lower Miocene of the Transylvanian Basin reveal particularly high abundances (>90 % of total foraminifera) of small sized biserial foraminifera (*Bolivina/Streptochilus*). This biotic event has not been noticed in the Transylvanian Basin so far probably owing to the facies misinterpretation and the small size of the specimens. SEM investigations allow more precise identification of biserial planktonic taxa and more accurate taxonomic interpretations. The high abundance of *Bolivina/Streptochilus* assemblages provide evidence for paleogeographic connections to the Indo-Pacific area and support new paleoenvironmental interpretations at the transition from the Early to Middle Miocene in relation to the paleoceanographic events. Both planktonic foraminifera and calcareous nannoplankton suggest a late Burdigalian age. A new *Bolivina/Streptochilus* Abundance Biozone is proposed just below the Early/Middle Miocene boundary.

Key words: Lower Miocene, Paratethys, Transylvanian Basin, biostratigraphy, *Bolivina*, *Streptochilus*.

Introduction

High abundances of small biserial foraminifera assigned initially to the benthic genus *Bolivina* have been recorded in Lower Miocene sediments in the eastern Atlantic and northwestern Indian Oceans (Thomas 1987; Smart & Ramsay 1995). The Early Miocene 'High Abundance of Bolivinid (HAB) event', as it was called, was considered as a synchronous biotic event having paleoceanographic significance (Smart & Murray 1994). Based on morphologic and isotopic evidence, Smart & Thomas (2006, 2007) reassigned these Early Miocene *Bolivina* to the planktonic genus *Streptochilus*.

High abundance (>90 % of total foraminifera) of small biserial foraminifera have recently been observed in the uppermost Lower Miocene sediments of the Transylvanian Basin (top of the Hida Formation). In this study, we present new data on the biostratigraphic, biogeographic and paleoenvironmental significance of these peculiar assemblages.

Material and methods

Small biserial foraminifera were recovered from several sections at the top of the Lower Miocene Hida Formation. The representative sections are located in the northwestern part of the Transylvanian Basin (Romania), at Ciceu-Giurgeşti (N47.24549; E24.03438), Zagra (N47.26599; E24.28779), and Şoimeni (N46.95658; E23.53370) (Fig. 1).

Fourteen samples were analysed for foraminifera and nannofossils, collected from several small outcrops in distal epiclastic turbidites and hemipelagites (targeted fine-grained intervals), with a sampling resolution of 0.5 meters. Sediment samples were processed using standard micropaleontological methods and the foraminifera were recovered from the >63 μm fraction. Due to their small size, after a preliminary observation under the stereomicroscope, the species were examined and their taxonomic identification confirmed by SEM examination (JSM-JEOL 5510 LV scanning electron microscope). Calcareous nannofossils were processed by the standard smear slide technique and examined under the light microscope (Axiolab Zeiss).

Results

Biserial foraminiferal assemblages

The samples collected from Ciceu-Giurgeşti and Zagra contain almost exclusively small biserial planktonic foraminifera belonging to *Streptochilus pristinum* (Fig. 2), a species described from the Indo-Pacific region by Brönnimann & Resig (1971). This kind of assemblage is documented for the first time in the Lower Miocene of the Transylvanian Basin and, to our knowledge, in the Paratethyan area.

At Şoimeni, the biserial foraminiferal assemblage is dominated by specimens of *Bolivina* (*B. dilatata dilatata* Reuss, *B. dilatata brevis* Cicha & Zapletalova, *B. molassica* Hofmann) (Fig. 3), which have been traditionally considered to be a part of benthic communities. There are no typical *Streptochilus* specimens in the studied assemblages in this section.

According to Brönnimann & Resig (1971) and Smart & Thomas (2007), the genus *Streptochilus* has particular morphological features compared to *Bolivina*: a loop-shaped aperture bordered by a high, collar-like projection, except for an inturned portion at the inner margin. The internal plate that connects succeeding apertural borders does not project freely into the aperture as a tooth plate (as in the case of Bolivinitidae). Recent genetic work has shown that the

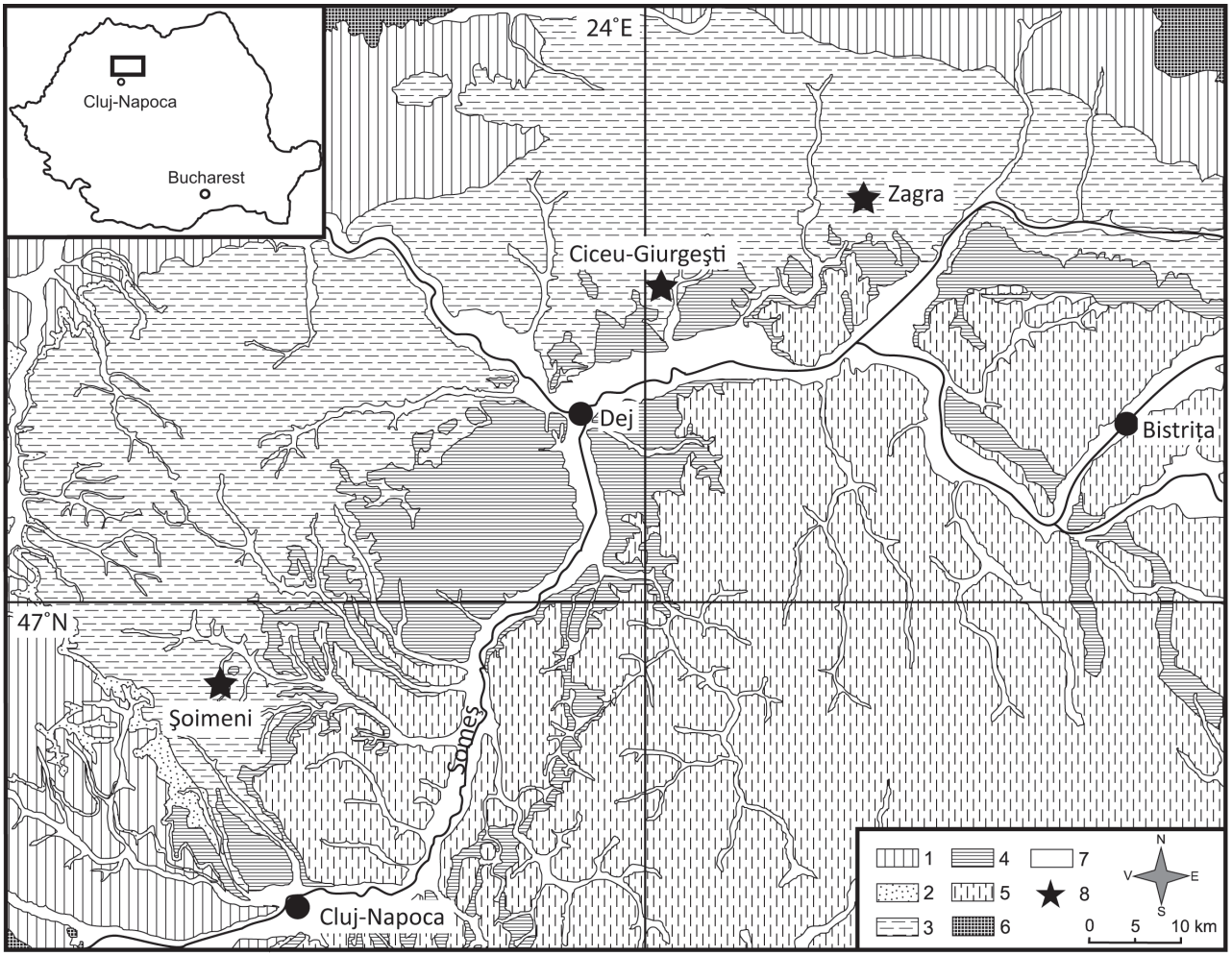

Fig. 1. Location of investigated sections on the simplified geological map (1:200,000). **1** — Paleogene, **2** — Lower Miocene shallow marine formations, **3** — Hida Formation, **4** — Badenian, **5** — Sarmatian, **6** — metamorphics, **7** — Quaternary, **8** — investigated sections.

planktonic *S. globigerus* and the benthic *B. variabilis* are the same biological species (Darling et al. 2009). Regardless of the taxonomic problem (*Streptochilus* or *Bolivina*), the presence of abundant biserial taxa gives a new approach to the paleogeographic and biostratigraphic interpretations.

Biostratigraphy

In the Hida Formation, the planktonic foraminiferal assemblages contain common globigerinids including: *Globigerina ottnangiensis* Rögl, *Globigerina dubia* Egger, *Globigerina pseudociperoensis* Blow, *Globigerina tarchanensis* Subbotina & Chutzieva, *Tenuitellinata selleyi* Li, Radford & Banner. Rögl (1994) and Rögl et al. (2002) have mentioned these as common in the Lower Miocene (Karpatian) of the Central Paratethys. The high abundance biserial foraminifera event is biostratigraphically "sandwiched" between these assemblages and the first Middle Miocene (Badenian) *Praeorbulina* assemblages (M5a Zone in the classification of Berggren et al. 1995 — see Fig. 4).

The biserials seem to be associated with a newly observed transgressive event, considered here as belonging to the TB2.2 cycle of Haq et al. (1988) or Bur4 sequence of Hardenbol et al. (1998). This event produced a change in the sedimentation pattern, from lowstand coarse turbidites and channel fills of the upper Hida Formation to hemipelagic sediments marking the transition to the Middle Miocene Dej Formation.

Calcareous nannofossils (Fig. 5) have low abundance and diversity, moderate to poor preservation, and there are frequent reworked Cretaceous and Paleogene taxa in all sections. The common species indicate the NN4 Zone with *Helicosphaera ampliaperta* (defined from the LO of *Sphenolithus belemnos* and LO of *H. ampliaperta*) positioned in the latest Burdigalian (Martini 1971). At Şoimeni, *H. ampliaperta* (Bramlette & Wilcoxon) was identified only in one sample, but in Ciceu-Giurgeşti and Zagra, this taxon is common and well preserved. The assemblages consist of several other common species: *Reticulofenestra minuta* (Roth), *R. pseudoumbilicus* (Gartner), *Coccolithus pelagicus* (Wallich), and *Cyclicargolithus floridanus* (Roth & Hay). *Calcidiscus* spp. and *Sphenolithus heteromorphus* Deflandre have not been identified in the assemblage, although they are common in the Central Paratethys (Austria, Slovenia, Czech Re-

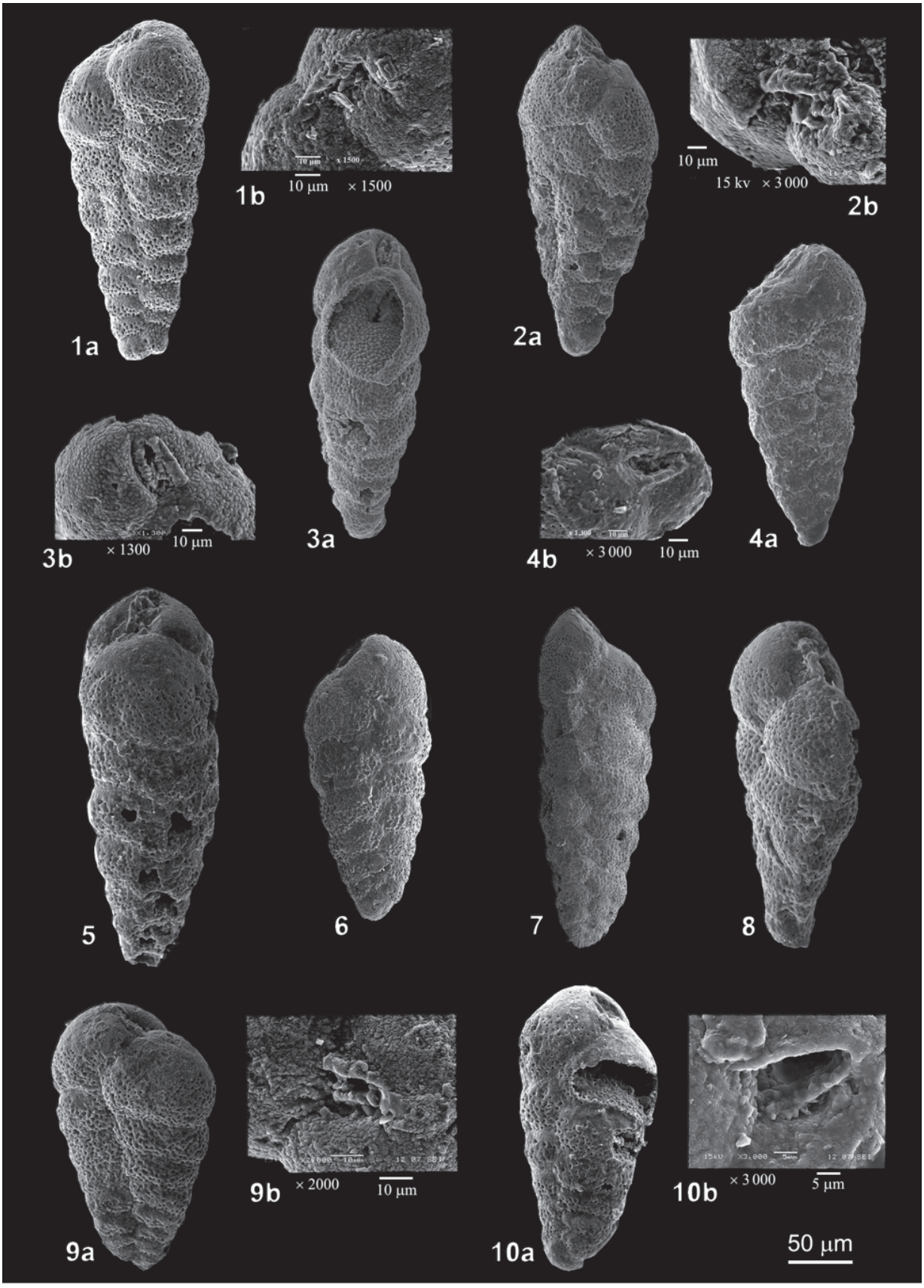

Fig. 2. *Streptochilus pristinum* Brönnimann & Resig from Ciceu-Giurgești and Zagra. **1, 3, 6, 7, 9** — from Ciceu-Giurgești; **2, 4, 5, 8** — from Zagra.

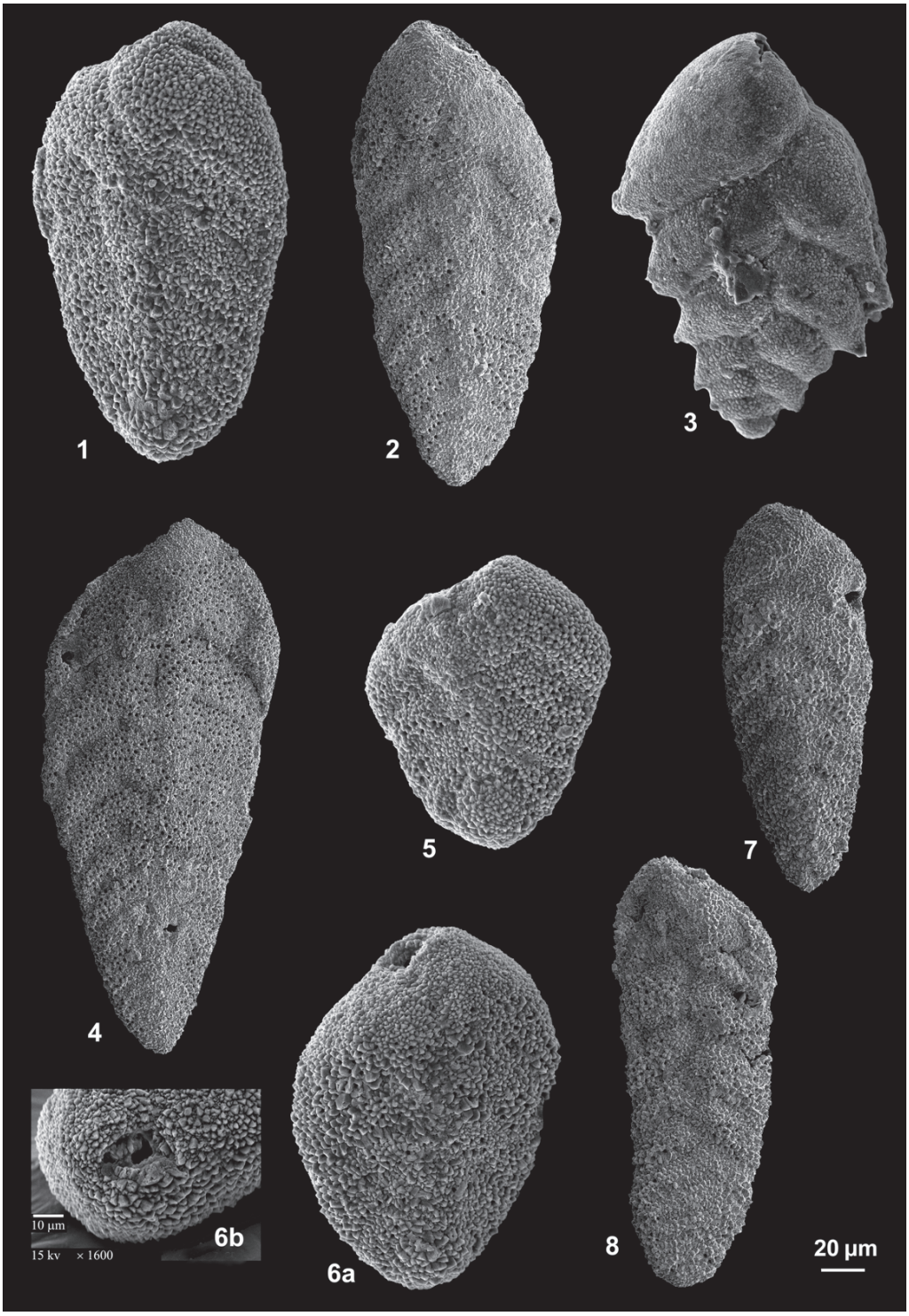

Fig. 3. Bolivinid assemblages from Şoimeni. **1, 2, 4** —*Bolivina dilatata dilatata* Reuss; **3** — *Brizalina alata* Seguenza; **5, 6** — *Bolivina dilatata brevis* Cicha & Zapletalova; **7, 8** — *Bolivina molassica* Hofmann.

public — as mentioned by Martini & Muller 1975; Spezzaferri & Ćoric 2001; Švábenická et al. 2003).

Our abundant biserial assemblages seem to have a clear biogeographic and biostratigraphic importance, owing to the fact that Thomas (1987) correlated the HAB event in the Atlantic Ocean with the calcareous nannofossil Zone NN4 and paleomagnetic Chrons C5C–C5E (Fig. 4). Smart & Murray (1994) consider that the equivalent event in the Atlantic happened 20–17 Ma. Smart & Ramsay (1995) dated the HAB event in the Indian and Atlantic Oceans at 19.5–16.5 Ma, while Smart & Thomas (2006, 2007) gave for the same areas ages of 19–17 Ma.

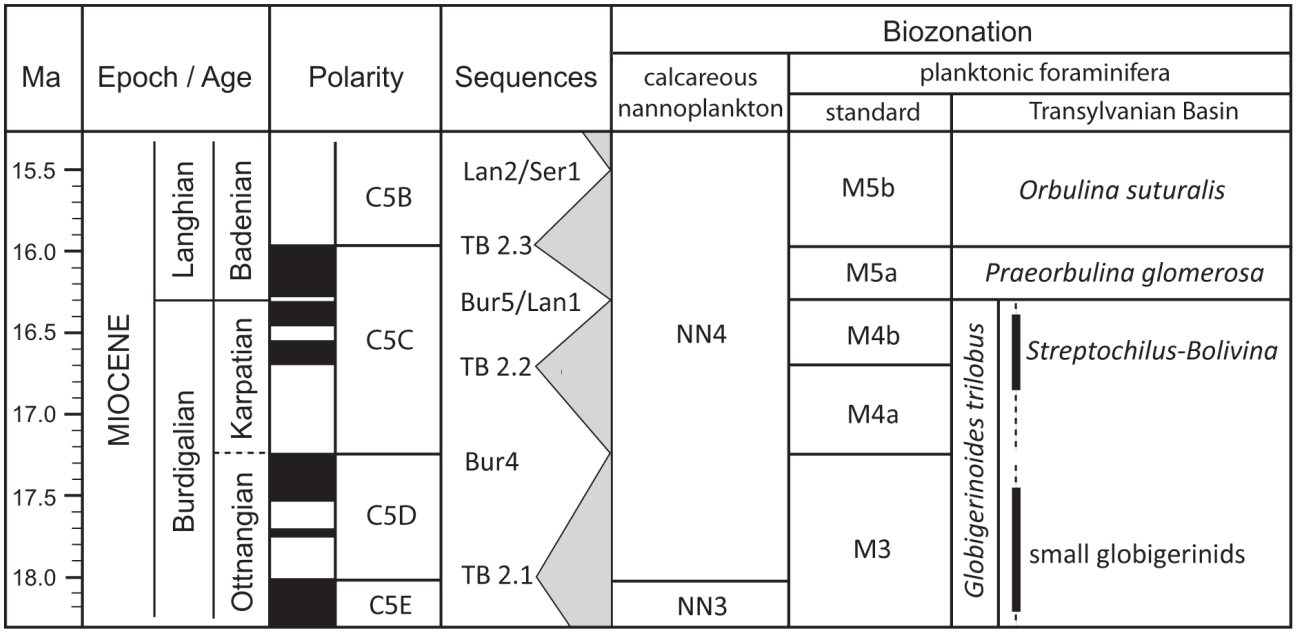

Fig. 4. Position of the *Streptochilus-Bolivina* Abundance Biozone within the stratigraphic zonations in use (zones based on Popescu 1975; Haq et al. 1988; Berggren 1995; Hardenbol et al. 1998; Rögl et al. 2008).

The distinctive occurrence of high abundance biserial foraminifera in relation to a transgressive event gives the assemblage good correlation potential. We therefore define a new biozone:

Streptochilus-Bolivina Abundance Biozone

Definition: The body of strata belonging to the transgressive and highstand interval from the top of the Burdigalian (Fig. 4), with a high abundance of small biserial foraminifera assigned to the genera *Streptochilus* (*S. pristinum* Brönnimann & Resig) and *Bolivina* (*B. dilatata dilatata* Reuss, *B. dilatata brevis* Cicha & Zapletalova, *B. molassica* Hofmann).

Age: Latest Burdigalian (?Ottnangian–Karpatian), above the Early Miocene assemblage with small trochospiral globigerinids (*Globigerina* spp., *Tenuitellinata* spp.) and below the first occurrence of Middle Miocene *Praeorbulina*. Probably the optimum abundance interval was between 16.8 and 16.4 Ma in the classification of Rögl et al. (2008) — see Fig. 4.

Representative sections: Ciceu-Giurgești, Zagra, Șoimeni.

Discussion and interpretation

According to Brönnimann & Resig (1971), the foraminiferal assemblages in the eastern Atlantic, northwestern Indian and western Pacific Oceans record a change just before the Middle Miocene. Small, smooth-walled species of the genus "*Bolivina*" (called *Streptochilus* by Smart & Thomas 2006, 2007) reached extremely high relative abundances in the open-ocean (Thomas 1987; Smart & Ramsay 1995; Smart & Thomas 2007).

The high abundance of biserial foraminifera is difficult to explain. In the modern oceans, such high abundances of bolivinids occur only where an oxygen minimum zone impinges on the sea floor, under upwelling regions along continental margins and in silled basins (Bernhard 1986; Bernhard & Sen Gupta 1999; Nigam et al. 2007). It can be easily observed that the high abundance biserial foraminifera event in the northwestern Transylvanian Basin was not associated with other typical benthic foraminifera. Smart & Thomas (2006) suggested that benthic foraminiferal accumulation rates are low when biserials are abundant. Low export productivity occurs where the thermocline is deep and regeneration rates of organic matter are high (Fischer et al. 2003). This could also be correlated to low oxygenation on the deep-sea floor during the transgressive events due to the poor vertical circulation.

Bolivinids are common for bathyal and shallower water low-oxygen environments (Sen Gupta 2002). Assemblages are typically of low species diversity (2–3 species making up around 80 % of the assemblage) and are associated with a combination of low oxygenation and high organic-matter supply along the continental margin. The dominant species are small, with thin tests, usually belonging to *Bolivina* (Sen Gupta & Machian-Castilio 1993).

Smart & Thomas (2006, 2007) used the information provided by the apertural morphology, accumulation rates and isotopic composition of the tests to show that the abundant Early Miocene biserial foraminifera are in fact planktonic foraminifera and should be assigned to the genus *Streptochilus*. Assigning a planktonic mode of life to these foraminifera could explain their large distribution, while their abundance can be correlated to a high productivity event in surface waters.

Elongated bi- and triserial planktonic foraminifera were common during the Late Cretaceous, some of them as rare survivors of the end Cretaceous mass extinction (Kroon & Nederbragt 1990; Olsson et al. 1999). Biserial forms, usually

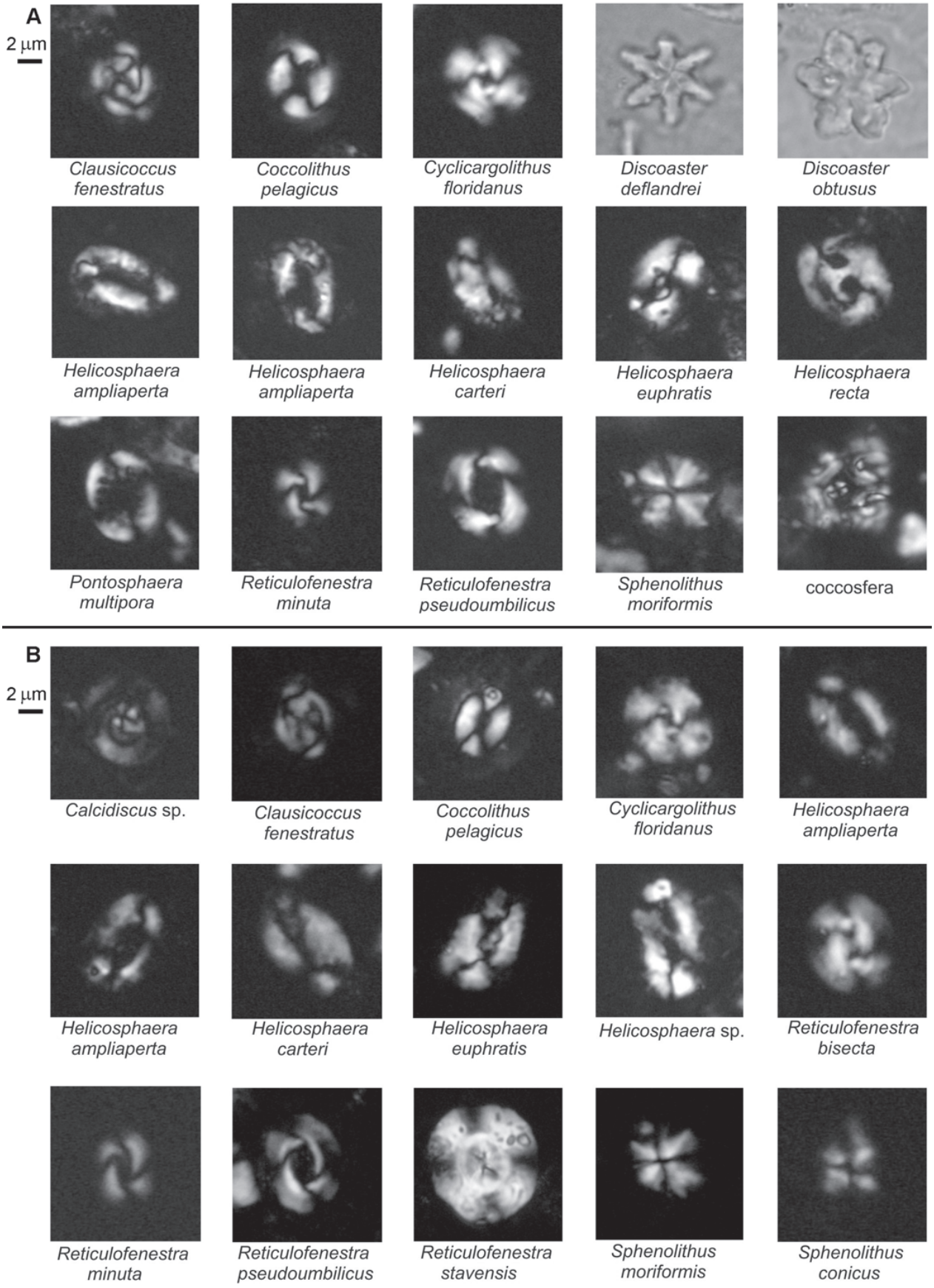

Fig. 5. Calcareous nannoplankton assemblages from Șoimeni (assemblage A) and Ciceu-Giurgești (assemblage B).

assigned to the genus *Chiloguembelina*, were common to abundant in the Paleogene (Olsson et al. 1999; Huber et al. 2006), their abundance reflecting relatively high productivity (Hallock et al. 1991). The genus *Chiloguembelina* was generally considered to have become extinct during the Oligocene, while the genus *Streptochilus* was considered as its descendant (Kennett & Srinivasan 1983).

Miocene *Streptochilus* spp. have been described as tropical to warm-subtropical forms (Brönnimann & Resig 1971; Kennett & Srinivasan 1983; Resig 1989), but they have been reported from the northernmost Atlantic Ocean (Flower 1999) through the Bahama Bank (Kroon et al. 2000), the equatorial western Pacific (Premoli-Silva & Violanti 1981; Resig 1989) and the eastern Indian Ocean (Resig 1989). High abundances of biserial planktonic foraminifera are indicative of eutrophic waters in the Paleogene (Hallock et al. 1991), while high abundances of Miocene–Pliocene *Streptochilus* species were correlated with high accumulation rates of plankton (Resig 1989). In our case, the hypothesis of eutrophic waters seems to fit better, because an important planktonic bloom was recorded only subsequently, related to the advancing Middle Miocene transgression.

Darling et al. (2009) used the term "tychopelagic" to describe organisms that usually live as benthos but can survive and grow in fairly large numbers as plankton and may be advected well offshore into open ocean assemblages. They revealed that tychopelagic *Bolivina* may well evolve into true pelagic forms and consequently biserials can become abundant in the planktonic assemblage at some time intervals (isotopic and distributional evidence suggest their truly pelagic life).

In the Transylvanian Basin, the Early Miocene *Streptochilus*/*Bolivina* may have bloomed opportunistically in response to highly fluctuating nutrient conditions caused by rapid transgression or could have been a part of the planktonic invasions from the Indian Ocean stimulated by the pattern of the surface circulation. Assemblages with biserial planktonics have been also reported from the upper Middle Miocene of the Transylvanian Basin (Filipescu & Silye 2008). The Transylvanian Early Miocene abundant biserial foraminifera assemblage, together with other regionally distributed planktonics, and the obvious differences with the Mediterranean assemblages provide clear evidence for paleogeographic connections to the Indo-Pacific area.

Conclusions

The high abundance biserial foraminifera event identified in the northwestern Transylvanian Basin seems to be related to the last Early Miocene transgressive event (TB2.2 cycle of Haq et al. 1988 or Bur4 sequence of Hardenbol et al. 1998). These particular assemblages were produced by high organic supply, which induced low sea-floor oxygenation and suppressed benthic life. The occurrence of biserial planktonics in relation to a transgressive event suggests open-sea connections of the Paratethys to the east.

The high abundance of biserial foraminifera are biostratigraphically and biogeographically important, making possible the separation of a distinct biozone just below the Lower/Middle Miocene boundary. Although the assemblage is only reported from a small number of localities so far, we suspect that the assemblage has a wider distribution in the Paratethys.

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