

New Paratethyan biozones of planktonic foraminifera described from the Middle Miocene of the Transylvanian Basin (Romania)

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Abstract: Recent investigations of the Upper Badenian and Sarmatian of the Transylvanian Basin revealed particular, small sized planktonic foraminiferal assemblages. SEM investigation permitted more precise taxonomic interpretations of the planktonic species. The Late Badenian assemblage — with trochospiral, microperforate, and pustulose Tenuitellinae — occurring in relation to a transgressive event close to the end of the Badenian, makes possible an increased biostratigraphic resolution. The Sarmatian assemblage with *Streptochilus* (biserial Chiloguembelinidae) provide evidence for the paleogeographic connections to the Indo-Pacific area, and support new paleoenvironmental and biostratigraphic interpretations.

Key words: Badenian, Sarmatian, Paratethys, Transylvanian Basin, biostratigraphy, small planktonic foraminifera.

Introduction

The Middle to Late Miocene tectonic and sedimentary evolution of the Transylvanian Basin was markedly different if compared to other intra-Carpathian basins. The active Carpathian subduction generated a high rate of subsidence and deep-sea settings starting from the Late Badenian, as shown by the sedimentary record (locally over 2000 m of sediments) and the microfossil content (Krézsek & Filipescu 2005; Krézsek & Bally 2006). A stratified water column, with brackish surface circulation and poorly oxygenated bottom waters, affected the distribution of the marine biota.

The Late Badenian to Sarmatian foraminiferal assemblages of the Transylvanian Basin were the subject of several studies during the last decades (e.g. Popescu 1979, 1995; Krézsek & Filipescu 2005). However, the evolution and paleogeographic significance of the small sized planktonic foraminifera occurring around the Badenian-Sarmatian boundary and within the Sarmatian are still poorly studied. Their relationship with the sedimentary environment has been the subject of recent studies revealing new possible applications to sequence stratigraphy and biostratigraphy (Krézsek & Filipescu 2005; Filipescu et al. 2006).

Material and methods

We focused on the planktonic assemblages recovered from the deep-sea intervals of the Middle Miocene in the Transylvanian Basin, which were ignored or incorrectly regarded as reworked. The small microperforated planktonic foraminifera recovered from several outcrops and wells were studied and interpreted in order to clarify their biostratigraphic potential and the relationship with the sedimentary environment.

The representative sections are located in the south-eastern part of the Transylvanian Basin at Rupea, Racoşu de Sus, Făgăraş, Vărd, Grânari, Toarcia, and Nicoleşti (Fig. 1).

The micropaleontological samples were processed and recovered from the >63 µm fraction by standard micropaleontological methods.

Due to the small size of the planktonic foraminifera, species were determined through light microscopy and confirmed by SEM photographs (JSM-JEOL 5510 LV scanning electron microscope).

New potential for planktonic assemblages

The particular biozonation schemes for the Paratethys (Grill 1941; Cicha et al. 1998) can hardly be used for all the particular settings in the Paratethyan basins. Different paleogeographic and paleoenvironmental settings promoted biostratigraphic schemes for the individual Paratethyan basins or sometimes at a national scale (e.g. Papp et al. 1974; Papp et al. 1978; Kováč et al. 2007).

The biostratigraphic zonations of the Middle Miocene in Romania (Fig. 2) experience the same problems (see biozonations in Popescu 1975, 1995; Nicorici et al. 1994). The biozones were usually separated in shallow-marine environments, where the assemblages were abundant and well preserved, but often based on benthic taxa; therefore these could not always be entirely used for the deep-sea sediments in the Transylvanian Basin and the Carpathian area.

The regional planktonic foraminiferal biozonation for the Upper Badenian includes the single *Velapertina* Biozone (Łuczkowska 1971). Recent attempts to increase the biostratigraphic resolution of this thick sedimentary interval only appealed to benthic taxa (Filipescu 2004). Fortunately we managed to discover the biostratigraphic potential of a new

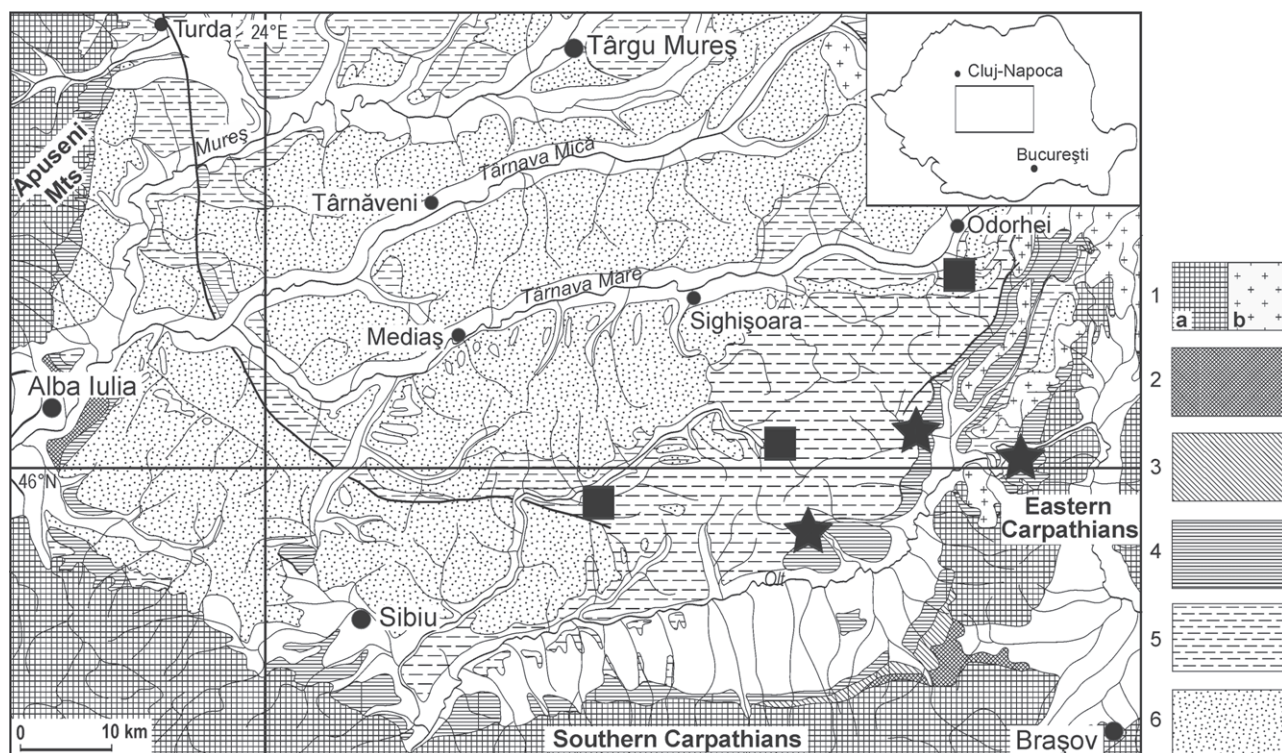


Fig. 1. Location of the investigated sections on the simplified geological map of the southern Transylvanian Basin: **1** — Carpathian units (a — Mesozoic formations; b — Neogene volcanic and volcano-sedimentary formations); **2** — Paleogene; **3** — Lower Miocene; **4** — Badenian; **5** — Sarmatian; **6** — Pannonian (based on the Geological Map of Romania 1 : 1,000,000). The Badenian tenuitellid sections are shown with stars and the Sarmatian *Streptochilus* localities with squares.

	Standard ages	Paratethyan ages	Foraminiferal biozones and ecozones		Position of proposed biozones
			Paratethys	Romania	
11.6 Ma	Tortonian	Pannonian			
	Serravallian	Sarmatian	<i>Porosononion granosum</i> Zone	<i>Porosononion aragviensis</i> Zone	<i>Streptochilus</i> Zone
			<i>Elphidium hauerinum</i> Zone	<i>Dogielina sarmatica</i> Zone	
			<i>Elphidium reginum</i> Zone	<i>Elphidium reginum</i> Zone	
12.7 Ma			<i>Anomalinoidea dividens</i> Zone	<i>Varidentella reussi</i> Zone	
				<i>Anomalinoidea dividens</i> Zone	
				<i>Bogdanowiczia</i> Subzone	<i>Tenuitellinata</i> Zone
13.8 Ma		Badenian	<i>Bulimina-Bolivina</i> Zone	<i>Velapertina</i> Zone	
	Langhian				

Fig. 2. Foraminiferal biozonation in the Paratethys (based on Harzhauser & Piller 2004; Piller et al. 2007) and Romania (based on Popescu 1995; Filipescu 2004) and the position of the newly proposed biozones (ages based on the time scale chart of the International Commission on Stratigraphy: www.stratigraphy.org).

and distinctive planktonic assemblage. These small sized, microperforate characteristic specimens display an acme in the uppermost Badenian and rare occurrences in the Sarmatian (mainly in the lowermost Sarmatian).

Most of the literature on the Sarmatian presented the very limited connections to the open seas and brackish environments (see Papp et al. 1974). Some recent studies (e.g. Filipescu et al. 2000; Piller & Harzhauser 2005) have suggested that the myth

of the brackish Sarmatian Sea is not very solid anymore. Even more, our observations in the Transylvanian Basin could clearly demonstrate that the Sarmatian still preserved typical marine conditions and the connections to the open-seas were still large. The presence of Sarmatian planktonic assemblages, consisting of small microperforate trochospiral and biserial forms, give a new correlation potential for the Sarmatian, and reveals new possibilities for paleogeographic interpretations.

The Late Badenian assemblage with small microporiferate planktonics

The transgression at the end of the Badenian (MLM5 sequence — Krézsek & Filipescu 2005) can be clearly identified in several sections in the south-eastern part of the Transylvanian Basin. A clearly marked package of hemipelagic sediments occurring above the lowstand coarse-grained sediments (e.g. Rupea and Făgăraş) preserves the proof of a planktonic invasion. Our SEM investigations revealed that most of the specimens are microporiferate Globigerinitidae belonging to the genera *Tenuitella* (Subfamily Tenuitellinae Banner, 1982) and *Tenuitellinata* (Subfamily Globigerinitinae Bermúdez, 1961) (Fig. 3).

Tenuitella (Fleisher 1974) include a closely related group of small Cenozoic forms usually assigned to either *Globorotalia* or *Turborotalia*. The common diagnostic features of all species placed in *Tenuitella* are the microporiferate surface of the wall; small pustules or crystallites are common on the wall surface and may obscure the microporifications. Species have a small test, with chambers arranged in a low trochospiral coil, an umbilical to extraumbilical or peripheral low arched aperture bordered by a narrow rim or lip, and a rounded, non carinated periphery.

Tenuitellinata (Li 1987) has a very similar surface to *Tenuitella*, but the aperture is intraumbilical.

The distinctive occurrence of this assemblage over the different sections in south-eastern Transylvania, in a relation with a very clear transgressive event, thus having a good correlation potential, makes possible the separation of a new biozone:

Tenuitellinata Acme Biozone

Definition: The body of strata belonging to the distinct transgressive interval from the top of the Badenian, with a very high abundance of small microporiferate planktonic foraminifera assigned to genera *Tenuitellinata* [*T. juvenilis* (Bolli), *T. pseudoedita* (Subbotina), *T. selleyi* Li, Radford & Banner, *T. uvula* (Ehrenberg)], *Tenuitella* [*T. jamesi* Li, Radford & Banner, *T. minutissima* (Bolli), *T. clemenciae* (Bermúdez)]. Other small species of *Globigerina* are also present, but the size and taxonomic composition of the assemblage is different from the older Miocene assemblages.

Age: Latest Badenian, above *Velapertina* Zone and below the *Anomalinoides dividens* Zone (Fig. 2), in the distinctive, widely (probably regionally) distributed, transgressive interval of the MLM5 sequence (Krézsek & Filipescu 2005).

Representative sections: Racoşu de Jos (N46°00' 44"; E25°19' 09"), Rupea (N46°02' 34"; E25°12' 04"), Făgăraş (N45°51' 11"; E24°57' 00").

The deep-sea circulation in the Paratethyan basins was controlled by the new climatic and tectonic conditions close to the end of the Badenian. This made possible only the life of new assemblages, different from the previously flourishing *Orbulina* and *Velapertina*. As small, thin walled microporiferate, pustulose taxa, *Tenuitella* and *Tenuitellinata* have been considered as shallow to intermediate planktonic spe-

cies (Majewski 2003). Their life in Paratethys was possible only in the upper oxic waters, where the deeper earlier species, larger and with a more complex surface texture, could not survive.

Although the characteristic species have longer stratigraphic ranges, their importance resides in the abundant assemblages, showing a very good correlation potential due to their wide geographic distribution in relation to the Indo-Pacific transgression. It has to be noticed that small microporiferate planktonic species, sometimes assigned to different genera, were mentioned or figured from other Paratethyan basins (e.g. Szczechura 1982, 2000; Rögl 1985; Cicha et al. 1998; Olszewska 1999; Bicchi et al. 2003).

Rare specimens of *Tenuitella* and *Tenuitellinata* (mainly *T. juvenilis* and *T. uvula*) have also been identified in the Sarmatian deep-sea sediments from many sections around the Transylvanian Basin, and also in the wells drilled by Romgaz in the Carpathian Foredeep and at the margin of the Moldavian Platform. By tradition the small planktonics were considered to be reworked (e.g. Popescu 1995). If we consider that they usually occur in relation to the transgressive intervals, clearly proven in our case by the sedimentological characters in outcrops, wells and seismic sections, their presence in situ can be considered normal. Even if the hostile conditions in the surface Sarmatian waters (low salinity and offshore-directed flow), reduced the number of small planktonics, their certain presence suggests open marine connections to the Indo-Pacific area, at least until mid Sarmatian.

The Late Sarmatian assemblage with biserial planktonics

Major changes in the diversity and composition of microfauna occurred in the Sarmatian due to the paleogeographic restrictions and climate alteration. Newly emerged continental areas produced a higher fresh-water input and initiated dominant unidirectional surface currents. The surface basinwards-flowing currents probably stopped most of the possible planktonic invasions. Another effect was the separation of the oxic surface layer from the anoxic bottom waters, and therefore the inhibition of the benthic life (most of the deep-sea sediments consist of allochthonous juveniles and reworked taxa only).

The low abundance and diversity of the Sarmatian foraminifera makes biostratigraphy a very difficult task in the deep-sea sediments of the Transylvanian Basin. Due to the generally accepted absence of planktonic foraminifera, biozonations according to benthics (e.g. Popescu 1995) have been applied with poor results.

Recent investigations of the Upper Sarmatian deposits in the south-eastern Transylvanian Basin revealed several assemblages with very small biserial foraminifera, mainly belonging to *Bolivina* or reworked planktonic taxa (*Chiloguembelina*, *Heterohelix*). More careful SEM observations permitted the identification of rare specimens of the biserial planktonic genus *Streptochilus* (Family Chiloguembelinidae Reiss, 1963) (Fig. 4), a taxon of Indo-Pacific origin.

According to Brönnimann & Resig (1971), the genus *Streptochilus* has a loop-shaped aperture bordered by a high, collar-like projection, except for an intumed portion at the

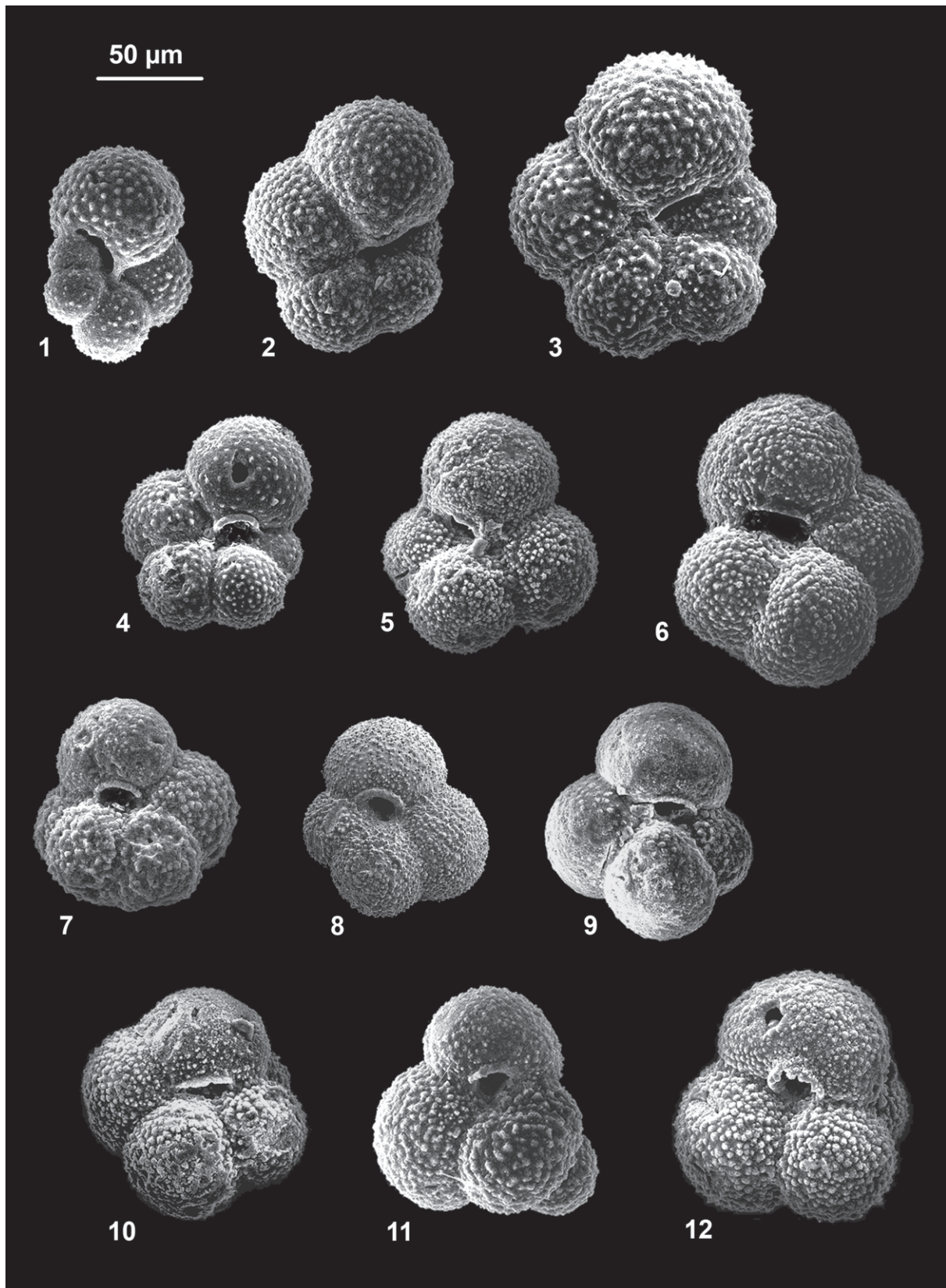


Fig. 3. Small microperforated planktonic foraminifera from the Late Badenian and Sarmatian of the Transylvanian Basin: 1–3 — *Tenuitellinata pseudoedita* (Subbotina); 4, 7 — *Tenuitellinata selleyi* Li, Radford & Banner; 5, 6 — *Tenuitella clemenciae* (Bermúdez); 8, 9 — *Tenuitellinata juvenilis* (Bolli); 10, 11 — *Tenuitellinata uvula* (Ehrenberg); 12 — *Tenuitellinata* sp. (1, 2, 11 — Sarmatian specimens from Toarcia; 3, 4, 6 — Late Badenian, Făgăraş; 5, 9, 10, 12 — Late Badenian, Rupea; 7 — Late Badenian, Racoşu de Jos; 8 — Sarmatian, Mărtiniş.)

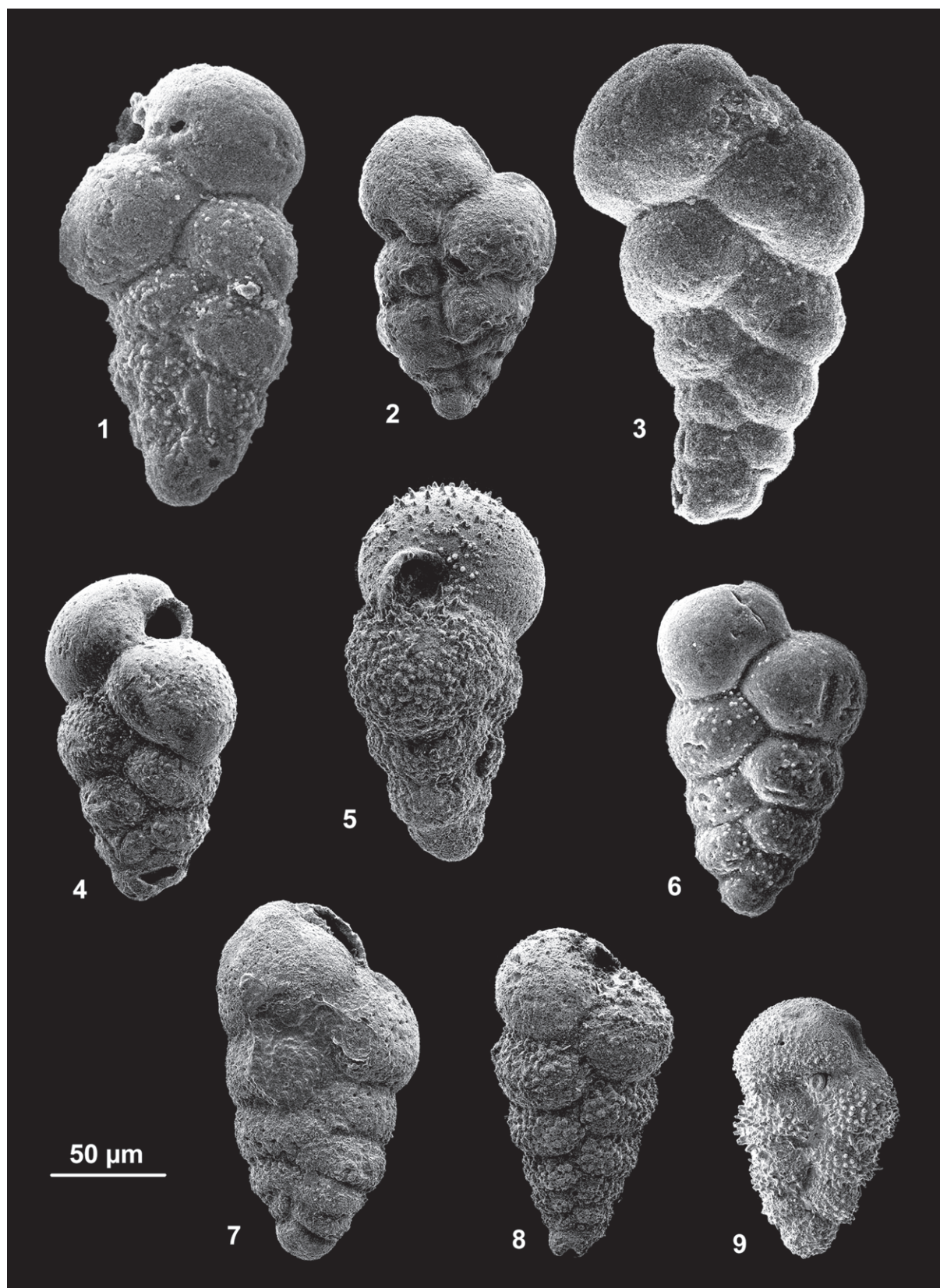


Fig. 4. Small biserial planktonic foraminifera from the Sarmatian of the Transylvanian Basin: 1–4 — *Streptochilus globulosum* (Cushman); 5 — *Streptochilus* aff. *globulosum* (Cushman); 6, 7 — *Streptochilus latum* Brönnimann & Resig; 8 — *Streptochilus* aff. *latum* Brönnimann & Resig; 9 — *Streptochilus* sp. (1, 6 — from Vărd; 2, 7 — Nicolești; 3 — Toarcia; 4, 8 — Șoroștin; 5 — Șoarș; 9 — Grânari.)

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*).

The occurrence of *Streptochilus* in the Upper Sarmatian supports the separation of a new biozone:

Streptochilus Assemblage Biozone

Definition: The strata containing *Streptochilus* [*S. globulosum* (Cushman), *S. latum* Brönnimann & Resig, *S. subglobigerum* (Schwager)], the “small *Bolivina* assemblage” (see the assemblages figured by Didkovski & Satanowskaja 1970; Vengliński 1975), and very rare microperforated trochospiral small planktonic foraminifera.

Age: Late Sarmatian (Fig. 2), equivalent to the *Porosonion aragviensis* Zone of benthic foraminifera (transgressive interval of the MLM7 sequence — Krézsek & Filipescu 2005).

Representative sections: Grânari (N46°01'46"; E24°58'21"), Nicoleşti (N46°14'37"; E25°15'19"), Toarcă (N45°53'12"; E24°44'36"), Vărd (45°56'22"; E24°36'06").

The assemblage with *Streptochilus* gives new elements for paleogeographic interpretations and reveals a new biostratigraphic potential for the Sarmatian.

First of all, the presence of cosmopolitan planktonic taxa demonstrates open marine connections to the east until the Late Sarmatian.

In the modern oceans, *Streptochilus* occupies the oxygen minimum zone and its highest frequencies occur in combination with the reduced water circulation and development of the oxygen minimum zone during high sea level (Resig & Kroopnick 1983; Resig 1993). During the Miocene, *Streptochilus* could have been a part of the planktonic invasions stimulated by periodic upwelling at the eastern border of the Paratethys due to a seasonal pattern of the surface circulation.

Several species of *Streptochilus* were recognized in the Middle Miocene to Early Pleistocene, concentrated in the tropical Indo-Pacific, with only a few reported occurrences in the Caribbean, the Gulf of Mexico, and the Atlantic oceans (Brönnimann & Resig 1971; Boltovskoy 1978; Resig & Kroopnick 1983; Thomas 1987; Boersma & Premoli Silva 1989; Resig 1989, 1993; Flower 1999; Smart & Thomas 2007). In the Paratethys, Bicchi et al. (2003) mentioned *S. globigerum* from the Badenian in Poland.

On the basis of the known stratigraphic ranges (de Klasz et al. 1989; Resig 1993), the studied deposits with *Streptochilus* could be correlated to the interval around the boundary between the Middle and Upper Miocene.

Discussion of stratigraphic boundaries

It is important to observe that one of the peaks of microperforate planktonics (*Tenuitellinata angustumbilicata*, *T. pseudoedita*, *T. juvenilis*) has been mentioned in the Late Serravallian N13 Zone (McGowran & Li 1997). The equivalent of this event could be correlated to the tenuitellid acme presented here.

The identified species of *Streptochilus* have first occurrences (FO) placed in a higher stratigraphic position than we expected. *S. subglobigerum* first occurs in the early Tortonian, FO of *S. latum* is rarely mentioned before Tortonian, and *S. globulosum* occurs sporadically from the Tortonian (de Klasz et al. 1989). On the basis of the first occurrences of *Streptochilus* species and the fact that no planktonic events have been used so far to define the Sarmatian-Pannonian boundary, a revision of the definition and probably shifting the boundary into the Tortonian would be options to consider.

Conclusions

Two new planktonic assemblages have been described from the Miocene of the Transylvanian Basin. The occurrence of these planktonic events within transgressive contexts gives them a very good correlation potential.

The tenuitellid assemblage refines the biozonation of the marine Middle Miocene by introducing the second planktonic biozone in the Late Badenian and creating a new anchor point for the global stratigraphic calibration.

The presence of the biserial *Streptochilus* gives a new image both on the occurrence of planktonics in Paratethys and on the paleogeographic evolution of the region. Therefore, new biostratigraphic opportunities have been opened at the boundary between the Middle and Late Miocene.

The particular Sarmatian brackish assemblages, widely described from all over the Paratethyan areas, lived mainly in the shallow-marine marginal environments, influenced by the continental freshwater input. Deep water assemblages usually lack benthics (due to very poor oxygenation derived from the water-column stratification), but rare planktonics are present. The number of planktonics was reduced and restricted to the transgressive intervals, due to the basinward-dominant flow of the surface brackish waters.

The large Indo-Pacific connections persisted in the Paratethys until the Late Sarmatian (Tortonian).

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