

# New Middle Miocene Bryozoa from Gârbova de Sus (Romania) and their relationship to the sedimentary environment

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**Abstract:** The section of Gârbova de Sus contains diverse fossil groups and rich bryozoan assemblages, with 77 species altogether. Several taxa have been recognized as very important in the assemblage and two new taxa are described in detail: *Poricella garbovensis* sp. nov. and *Therenia transylvanica* sp. nov. Foraminifera and calcareous nannofossil assemblages were used for biostratigraphic and paleoenvironmental interpretations. On the basis of sedimentological features and micropaleontological data, the sequence of paleoenvironments can be subdivided into two intervals indicating slightly different climatic conditions.

**Key words:** Middle Miocene, Transylvanian Basin, nannoplankton, Bryozoa, Foraminifera.

## Introduction

Middle Miocene (Badenian) shallow marine siliciclastic to carbonatic deposits from Gârbova de Sus were accumulated on the eastern border of the Mesozoic structures of the Apuseni Mountains (see location map — Fig. 1). Different groups of fossils from Gârbova de Sus have been studied since the late 19<sup>th</sup> century (Herepey 1888; Koch 1900; Vadász 1915; Gábos & Ghiurcă 1969, Ghiurcă 1974; Nicorici 1975; Filipescu 1996; Filipescu & Gîrbacea 1997). The formation was placed into the upper part of the Lower Badenian and displays two distinct sequences (Filipescu & Gîrbacea 1997): the lower mostly siliciclastic, displaying coastal onlap, and the second mainly carbonatic, with a regressive character. This paper describes a recently discovered bryozoan fauna from Gârbova de Sus. Considering the biomass this fauna is dominated by small nodular cheilostomes belonging to the group of the celloporids, a group of bryozoans usually very poorly preserved. For this reason, precise determination is difficult and therefore the specimens have been listed in Table 1 under the name ‘Celloporids’ only.

## Material and methods

Two main outcrops exist at Gârbova de Sus. The first (GY-1) is located on the left side of Pârâu Pietrii (Stone’s creek) (GPS position: 46° 17.828’ N, 023° 37.233’ E, 424 m above sea level) from where 9 samples were collected. From the second outcrop (GY-2), located on a slightly higher position on Pârâu Bobii (Bobii’s creek) (GPS location 46° 17.972’ N, 023° 37.527’ E, 468 m above sea level) only two samples were taken (Fig. 1).

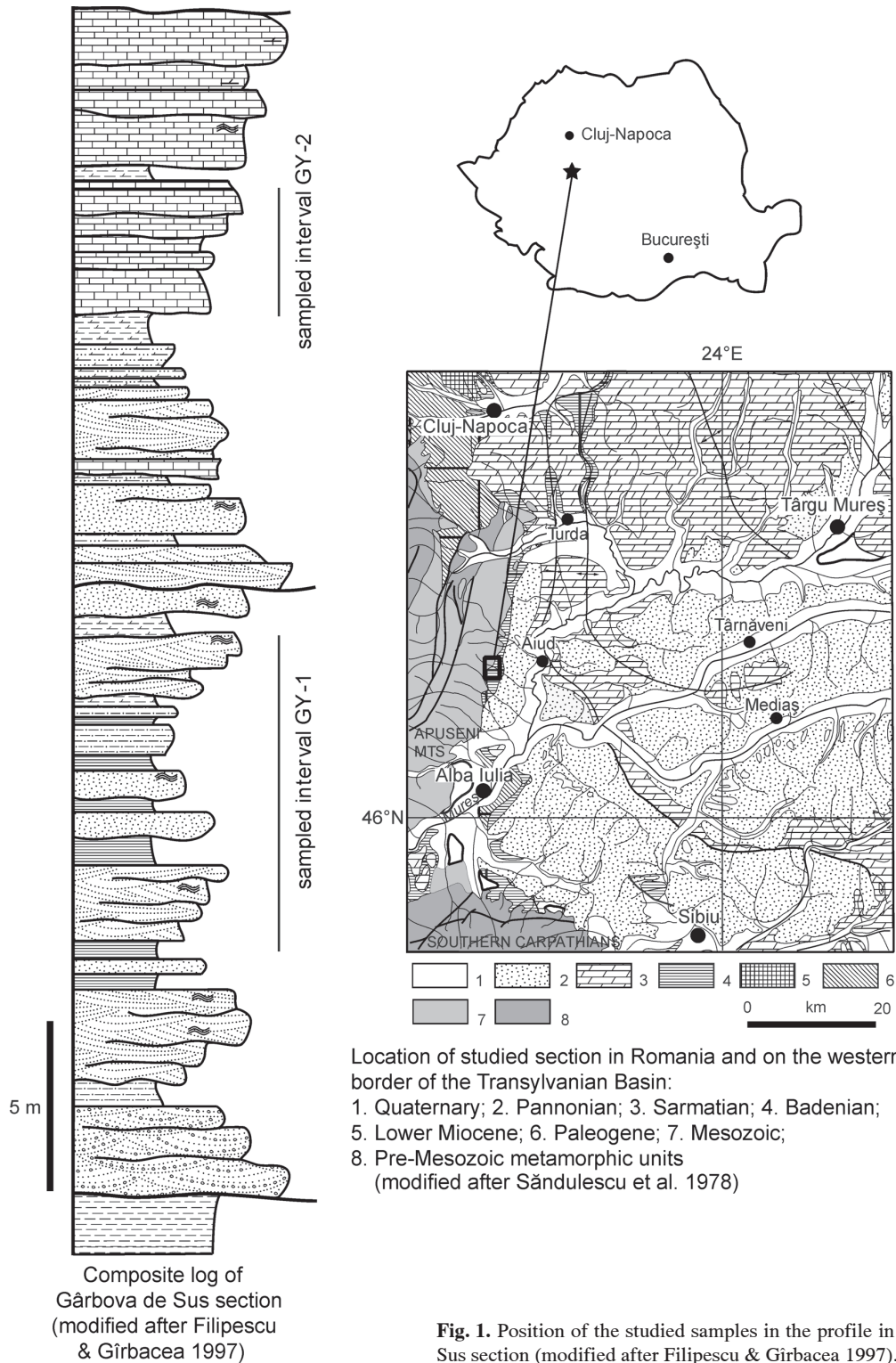
All of the studied material is deposited in the collections of the National Museum Prague, designated as NM-PM2.

Specimens were cleaned by means of ultrasound before sorting under a binocular microscope. Well-preserved and/or fertile specimens of each species were selected for study using a low-vacuum scanning electron microscope LV Hitachi S-3700N at the National Museum Prague. This instrument allowed backscattered electron images to be obtained of uncoated specimens temporarily mounted to stubs using adhesive carbon tabs, or affixed to stage mounts with Carbon plastic.

In order to get information on biostratigraphy and paleoenvironmental settings, foraminifera and calcareous nannoplankton were also studied. Foraminifera were studied from 63–2000 µm fractions after washing of disaggregated rock samples in water. About 200 specimens of benthic foraminifera and 100 specimens of planktonic foraminifera from each sample were determined and relative abundances of taxa were calculated. Evidence of changes caused by taphonomical processes was based on sorting of tests according to size, damaged tests and correspondence of paleoecological requirements of species from the individual assemblages (Murray 1991). Size distribution of tests was evaluated for rounded tests. The largest diameter of the tests was measured using a VIA video measuring system and data were summarized in histograms.

Accumulation of small, usually thin-walled tests (rounded forms <200 µm) indicates suspended load transport; accumulation of large, thick-walled tests (>300 µm) and absence of smaller tests characterizes tests which have been transported as bed load (Murray 1965; Wang & Murray 1983). Breakages and abrasion of tests were studied using the SEM.

Relative abundances of cibicidoids, large foraminifera, infaunal, epiphytic and euryhaline species were used for interpretation of paleoenvironment. For classification of individual species to the above mentioned groups, the data of Murray (1991, 2006), Kaiho (1994, 1999), de Stigner et al. (1998), den Dulk et al. (1998), den Dulk et al. (2000), Spezzaferri et al. (2002) and Báldi (2006) were used.



Estimation of paleotemperature changes in the upper layer of water column was based on the ratio between cool- and warm-water species of planktonic foraminifera (Spezzaferri & Ćorić 2001; Spezzaferri et al. 2002; Bicchi et al. 2003; Rupp & Hohenegger 2008).

Paleodepth was estimated using the relationship between bathymetry and relative abundance of planktonic forami-

nifera as determined by van der Zwaan et al. (1990). This depth relationship between abundance of planktonic and benthic foraminifera is based on the fact that availability of nutrients on the sea floor depends on depth.

Depth [m] =  $e^{3.58718 + (0.03534 \times Pc)}$  where D is estimated depth in meters, Pc is the corrected ratio of planktonic/benthic foraminifera:

**Table 1:** List of all determined Bryozoa with revision of old material.

TAXA - present designation	GY- 1/1	GY- 1/2	GY- 1/3	GY- 1/4	GY- 1/5	GY- 1/6	GY- 1/7	GY- 1/8	GY- 1/9	GY- 2/1	GY- 2/2	Museum material	Ghiurca, 1974	original name of taxa given by Ghiurca (1974), if different as present designation
<i>Adeonella polystomella</i> (Reuss, 1848)		1			1			1				1	1	
<i>Adeonellopsis coscinophora</i> (Reuss, 1848)								1						
<i>Amphiblestrum appendiculatum</i> (Reuss, 1848)								1				1	1	as <i>Ramphonotus</i>
<i>Biflustra</i> sp.								1						
<i>Bobiesipora fasciculata</i> (Reuss, 1848)								1	1					
<i>Buffonellaria kuklinskii</i> Zăgoršek, 2010								1				1	1	as <i>Buffonellodes</i>
<i>Calloporina decorata</i> (Reuss, 1848)												1	1	as <i>Membranipora clathrata</i>
<i>Calpensia gracilis</i> (Münster, 1826)								1					1	as <i>Calpensia calpensis</i> & <i>Calpensia</i>
<i>Cellaria</i> cf. <i>fistulosa</i> (Linnaeus, 1758)		1						1	1			1	1	
<i>Celleporaria palmata</i> (Michelin, 1847)								1	1	1			1	as <i>Holoporella globularis</i>
Celleporids		1						1		1	1	1	1	
<i>Celleporina cerioporoides</i>												1	1	as <i>Costazzia crassa</i>
<i>Ceriopora</i> indet.													1	as <i>Ceriopora globulus</i>
<i>Ceriopora tumulifera</i> Canu & Lecointre, 1934												1	1	as <i>C. cylindrica</i>
<i>Coronopora</i> cf. <i>disticha</i> (Hagenow, 1851)								1	1			1		
<i>Crisia haueri</i> Reuss, 1848								1				1		
<i>Crisia hoernesii</i> Reuss, 1848		1						1	1	1		1	1	as <i>Crisia eburnea</i>
<i>Diplosolen obelium</i> (Johnston, 1838)													1	
<i>Disporella</i> cf. <i>hispida</i> (Fleming, 1828)									1			1	1	as <i>Lichenopora</i>
<i>Disporella</i> cf. <i>radiata</i> (Savigny-Audouin, 1826)												1	1	as <i>Lichenopora coronula</i> , <i>L. multifascigera</i>
<i>Disporella goldfussi</i> (Reuss, 1864)												1	1	as <i>Lichenopora deformis</i>
<i>Emballotheca seriata</i> (Reuss, 1874)									1					as <i>Hippoporina rarepunctata</i>
<i>Eokotosokum? bobiesi</i> (David & Pouyet, 1974)									1				1	as <i>Conopeum lacroixii</i>
<i>Escharella tenera</i> (Reuss, 1874)									1					
<i>Escharoides coccinea</i> (Abildgaard, 1806)								1				1	1	
<i>Exidmonea atlantica</i> David, Mongereau & Pouyet, 1972								1	1	1			1	
<i>Exochoecia compressa</i> (Reuss, 1848)												1		
<i>Flustrellaria fenestrata</i> (Reuss, 1848)									1				1	as <i>Membranipora ogivalina</i>
<i>Hippopleurifera sedgwicki</i> (Milne-Edwards, 1836)													1	as <i>H. elongata</i>
<i>Hornera</i> cf. <i>frondiculata</i> Lamourox, 1821		1						1	1	1		1	1	as <i>H. striata</i>
<i>Hornera verrucosa</i> Reuss, 1866		1						1				1	1	
<i>Christinella pulchra</i>													1	??
<i>Idmidronea coronopus</i> (Defrance, 1822)		1							1				1	
<i>Iodictyum rubeschii</i> (Reuss, 1848)													1	
<i>Margaretta cereoides</i> (Ellis & Solander, 1786)								1	1	1		1	1	
<i>Mecynoechia proboscidea</i> (Milne-Edwards, 1838)		1							1	1		1	1	as <i>Entalophora anomala</i> , <i>Pustulopora proboscidea</i>
<i>Mesenteripora flabellum</i> (Reuss, 1848)												1	1	as <i>Diaperoecia flabellum</i> , <i>D. rugulosa</i>
<i>Metrarabdotos maleckii</i> Cheetham, 1968								1				1	1	as <i>Trigonopora moniliferum</i>
<i>Micropora parvicella</i> Canu & Lecointre, 1927													1	& <i>M. minuta</i>
<i>Microporella berningi</i> Zăgoršek, 2010												1		
<i>Myriapora truncata</i> (Pallas, 1766)												1		
<i>Oncousoecia? biloba</i> (Reuss, 1848)								1	1			1	1	as <i>O. varians</i>
<i>Onychoecia angulosa</i> (Reuss, 1848)												1	1	
<i>Phoceana tubulifera</i> (Reuss, 1848)												1		
<i>Plagioecia rotula</i> (Reuss, 1848)													1	? as <i>P. eudesiana</i> & ? as <i>Berenicea congesta</i>
<i>Pleuronea pertusa</i> (Reuss, 1848)								1						
<i>Poricella garbovensis</i> sp.n.									1					
<i>Pseudofrondipora davidi</i> Mongereau, 1970												1		
<i>Puellina (Cribrilaria) rarecostata</i> (Reuss, 1848)									1					
<i>Puellina venusta</i> (Canu & Bassler, 1925)												1	1	as <i>P. radiata</i>
<i>Pyriporella</i> cf. <i>loxopora</i> (Reuss, 1848)													1	as <i>Hincksina</i>
<i>Reteporella</i> cf. <i>beaniana</i> (King, 1846)												1		
<i>Reteporella hluchovensis</i> Zăgoršek, 2010									1	1			1	as <i>Phidolopora labiata</i>
<i>Reteporella kralicensis</i> Zăgoršek & Holcová & Třasová, 2008		1							1					
<i>Reteporella</i> sp.		1		1				1	1	1	1	1	1	
<i>Rhynchozoon monoceros</i> (Reuss, 1848)		1							1				1	
<i>Scrupocellaria elliptica</i> (Reuss, 1848)									1			1	1	& <i>Sc. gracilis</i>
<i>Schedocleidochasma incisa</i> (Reuss, 1874)								1	1			1		
<i>Schizomavella protuberans</i> (Reuss, 1847)									1					
<i>Schizomavella tenella</i> (Reuss, 1847)								1	1				1	as <i>S. linearis</i>
<i>Schizoporella teragona</i> (Reuss, 1848)									1	1				
<i>Schizoporella? geminipora</i> (Reuss, 1848)								1	1	1		1	1	
<i>Schizostomella grinzgenensis</i> David & Pouyet, 1974										1				
<i>Smittina cervicomis</i> (Pallas, 1766)		1							1			1	1	
<i>Smittina gibbera</i>													1	??
<i>Sieginoporella cucullata</i> (Reuss, 1848)									1			1	1	
<i>Stomatopora subdivaricata</i>													1	??
<i>Tervia irregularis</i> (Meneghini, 1844)								1				1	1	as <i>T. vibicata</i>
<i>Therenia transylvanica</i> sp.n.									1					
<i>Trypostega rugulosa</i> (Reuss, 1874)										1				
<i>Tubulipora flabellaris</i> (Fabricius, 1780)									1			1		
<i>Tubulipora foliacea</i> Reuss, 1848									1					
<i>Turbicellepora coronopus</i> (Wood, 1844)												1	1	as <i>Schizumopora coronopus</i>
<i>Umbonula macrocheila</i> (Reuss, 1848)		1						1	1	1		1		as <i>U. endlicheri</i>
<i>Umbonula spinosa</i> (Procházka, 1893)								1	1					
<i>Vibracella trapezoidea</i> (Reuss, 1848)				1	1							1	1	as <i>Lunulites</i>
<i>Ybselosocia typica</i> (Manzoni, 1878)		1		1	1			1	1			1	1	
<b>Total number of species</b>	<b>0</b>	<b>14</b>	<b>0</b>	<b>3</b>	<b>3</b>	<b>0</b>	<b>23</b>	<b>42</b>	<b>14</b>	<b>4</b>	<b>7</b>	<b>40</b>	<b>46</b>	

$$Pc = (P \times 100) / [P + (Bt - Bi)],$$

where P is the number of planktonic foraminifera, Bt is the total number of benthic foraminifera and Bi is the number of deep infaunal species which are excluded from analysis because they are not directly dependent on the flux of organic matter to the sea floor. Calcareous nannoplankton was analysed by standard methods using an optical microscope. 200–500 specimens of calcareous nannoplankton were determined from individual samples and relative abundances of taxa were calculated. Changes of ratio between the most common taxa *Reticulofenestra minuta* and *Coccolithus pelagicus* were studied.

### Results

The fossil material was collected from the GY-1 and GY-2 sections (Fig. 1). The GY-1 samples were mainly collected from the late transgressive and highstand intervals of the late Early Badenian, while the GY-2 samples come from the highstand interval.

#### Biostratigraphy

The foraminiferal assemblages from Gârbova de Sus can be correlated with the Upper Lagenid Zone of the Paratethys (Papp et al. 1978) and *Orbulina suturalis* Zone of planktonic foraminifera (M5b and M6 Zones in the classification of Berggren et al. 1995).

The absence of the calcareous nannoplankton species *Helicosphaera ampliapertura* and the occurrence of *Sphenolithus*

*heteromorphus* enable a correlation with the NN5 Zone (Martini 1971; Hohenegger et al. 2007).

The analysed samples may, therefore, be correlated with the lower part of the NN5 Zone above the FO of *Orbulina* (Berggren et al. 1995; Lourens et al. 2004) (Fig. 2).

#### Taphonomy

As suggested by the sedimentological data and fossil assemblages (Filipescu & Gîrbacea 1997), the Badenian sedimentary environments at Gârbova de Sus were situated on a shallow shelf, affected by storms and tidal currents. The size sorting of tests as well as their different preservation indicate two ways of postmortal transport:

1) Occurrence of suspension-transported tests (Fig. 3) can be expected in samples GY-1/3 and GY-1/5 demonstrated by peaks of small tests. While in sample GY-1/3 the peak is represented by benthic foraminifera, only planktonic test were found in sample GY-1/5.

2) Abundant occurrence of recrystallized infaunal species (mainly *Bolivina* spp. and *Globocassidulina* sp.) together with well preserved cibicidoids in sample GY-1/5 suggests reworking of the recrystallized tests. Recrystallized tests also occur in overlying samples, but only rarely.

#### Bryozoan assemblages

Bryozoans from Gârbova de Sus are rare, but a very important part of the taphocoenosis. Previous research (Ghiurcă 1974) includes only a list of 55 species without any description. During these last investigations 68 species have been recognized in total. We also tried to revise the material of

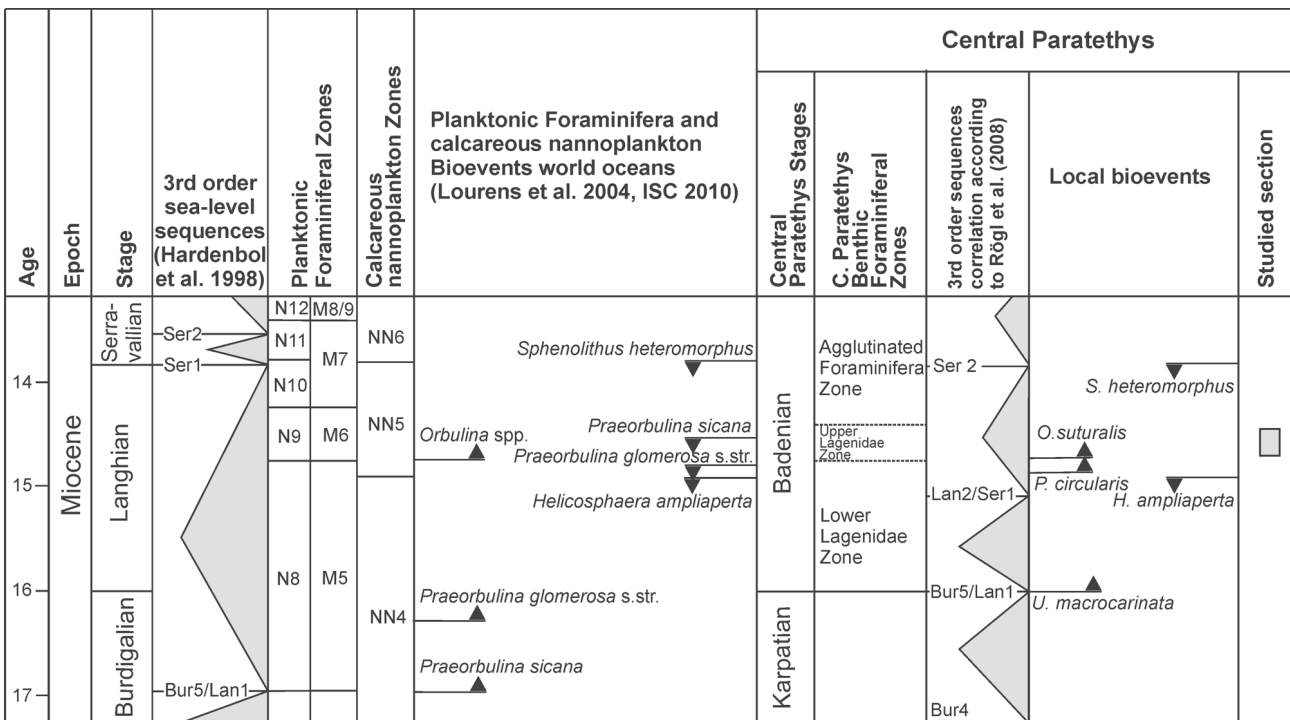


Fig. 2. Biostratigraphical correlation of the studied section.

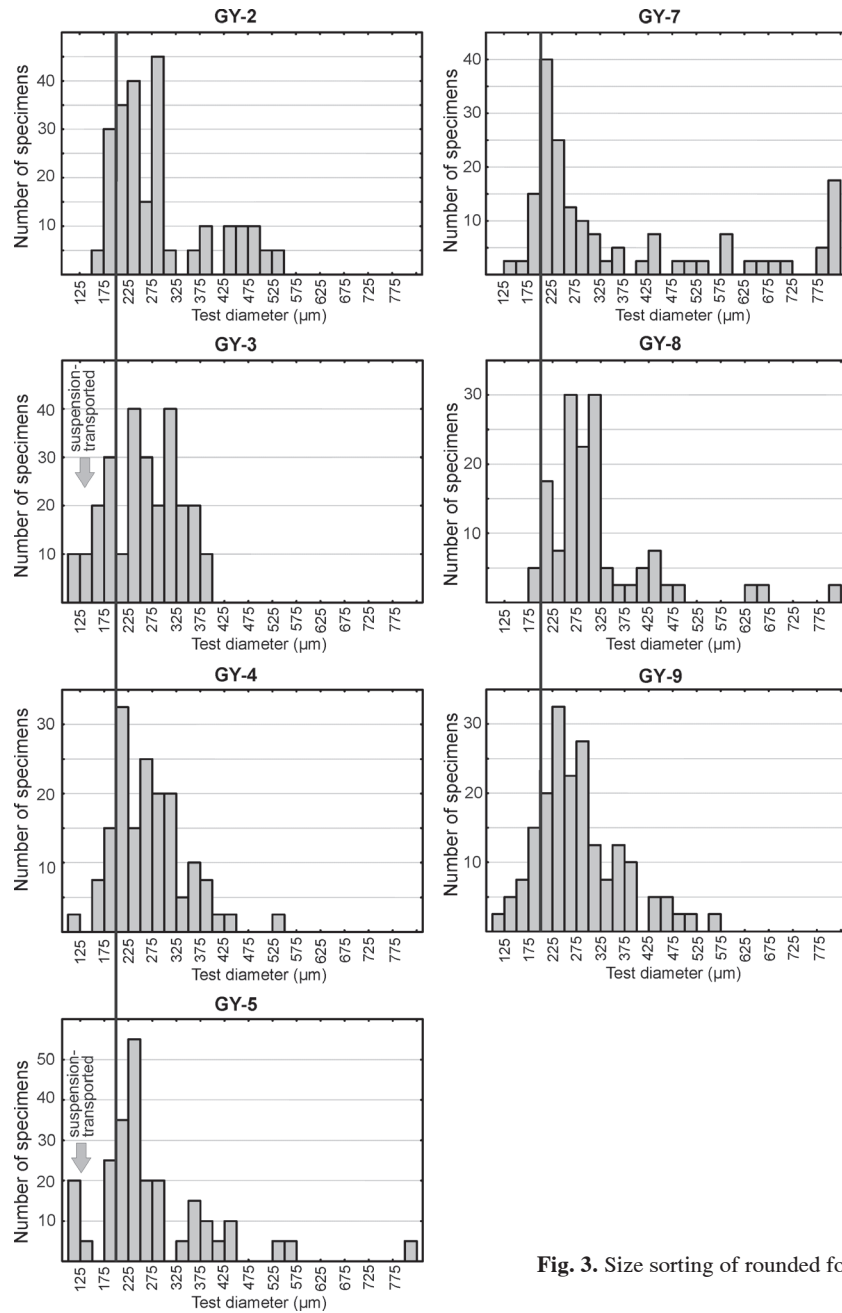


Fig. 3. Size sorting of rounded foraminiferal tests.

Ghiurcă, partly deposited at Babeş-Bolyai University. All previously known species with revised names, together with recently discovered species are listed in Table 1. The total number of known Bryozoan species from Gârbova is now 77, including two new species belonging to the genus *Poricella* and *Therenia*.

### Systematic paleontology

While a full taxonomic description is presented only for the new species described in this paper, only brief synonymies and remarks, as well as figures, are provided for the newly mentioned and important species; the other, usually well known, species have been only listed in Table 1.

Phylum: **Bryozoa** Ehrenberg, 1831  
 Class: **Stenolaemata** Borg, 1926  
 Order: **Cyclostomata** Busk, 1852  
 Suborder: **Tubuliporina** Milne Edwards, 1838  
 Family: **Tubuliporidae** Johnston, 1838  
 Genus: *Idmidronea* Canu & Bassler, 1920

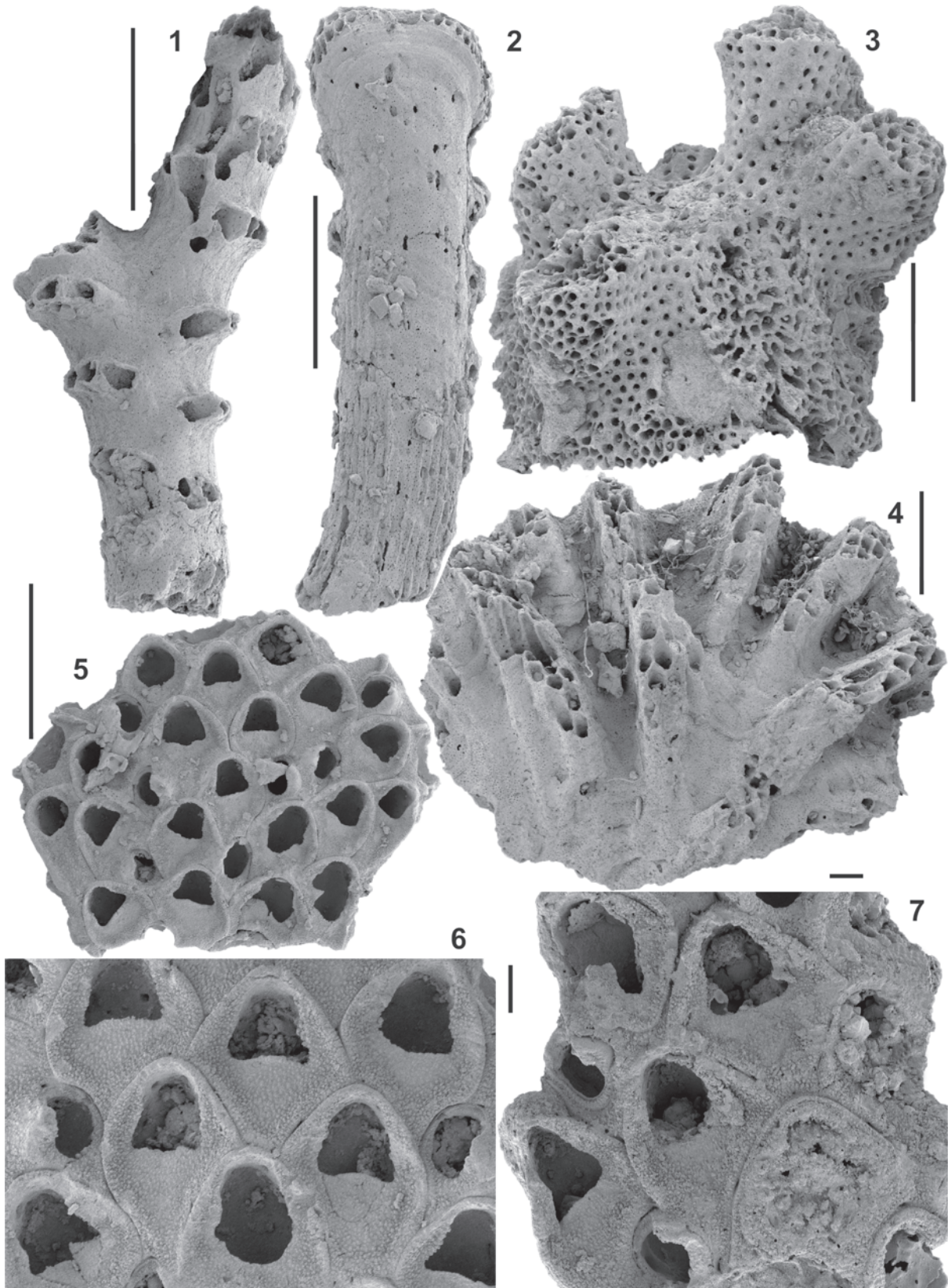
*Idmidronea coronopus* (Defrance, 1822)

Fig. 4.1–2

v. 1977 *Idmidronea coronopus* (Defrance, 1822) — Vávra p. 28 (cum syn.)

**Diagnosis:** Delicate, bifurcating colony with rectangular apertures arranged in alternating fascicles. Kenozoecia nar-





**Fig. 4.** 1–2 — *Idmidronea coronopus* (Defrance, 1822), frontal (1) and dorsal (2) view of the colony. 3 — *Bobiesipora fasciculata* (Reuss, 1847), general view showing the characteristic basis of the colony. 4 — *Coronopora* cf. *disticha* (Hagenow, 1851), part of the colony with long autozoocelial fascicles. 5–7 — *Vibracella trapezoidea* (Reuss, 1847), general view (5) and details of autozoecia with vibraculum (6 — scale bar 100 µm) and large endozoocelial ovicell with porous frontal wall (7 — scale bar 100 µm). All other scale bars are 1 mm.

row, parallel to colony axis, rarely opened on dorsal side of the colony. Gonozooecium not observed.

**Remarks:** This species is usually regarded as a deep water species (Zágoršek et al. 2008), but it may also often be found in a shallow water facies (Vávra 1974).

Suborder: **Cerrioporina** Hagenow, 1851  
Family: **Cerrioporidae** Reuss, 1866  
Genus: *Bobiesipora* Vávra, 1978

*Bobiesipora fasciculata* (Reuss, 1847)  
Fig. 4.3

\*v. 1847 *Apsendesia fasciculata* sp.n. — Reuss p. 40, pl. 6, fig. 8  
v. 2003 *Bobiesipora fasciculata* (Reuss) — Zágoršek p. 119, pl. 5, Fig. 3 (cum syn.)

**Diagnosis:** Colony erect, with circular basal part. The branches budding regularly around the basis and develop three-dimensional conical fans. Autozooecial tubes regularly alternating, perforated by large apertures and kenozoecia. The gonozooecium was not observed. Dorsal side of the colony is covered by typically arranged pores surrounded by a narrow and low rim.

**Remarks:** Only a somewhat dubious structure, which might be a gonozooecium with broken frontal wall was observed. However, the characteristic development of the colony and the pores on the branches are sufficient to identify this species.

*Bobiesipora* is usually listed under the Unassigned Cyclostome genera, but due to the presence of kenozoecia and the general characteristics of the colony it may be placed — with a question mark — into the family Cerrioporidae.

Suborder: **Fasciculina** d'Orbigny, 1853  
Family: **Lichenoporidae** Smitt, 1867  
Genus: *Coronopora* Gray, 1848

*Coronopora* cf. *disticha* (Hagenow, 1851)  
Fig. 4.4

\*? 1851 *Defrancia disticha* sp.n. — von Hagenow p. 142, pl. 4, fig. 1

**Diagnosis:** Colony is lobate, encrusting. Autozooecia are arranged in biserial to multiseriate radial rows with very long peristomes. Gonozooecium not found.

**Remarks:** The species is often reported as belonging to "*Tubulipora*". The true *Tubulipora* does not develop this kind of fascicle and have large globular gonozooecia (Hayward & Ryland 1985). Identical specimens with studied material found in Kralice nad Oslavou (Zágoršek 2010a) shows the same character of fascicles and have gonozooecia and the position of the oeciopore characteristic for the genus *Coronopora* as described by Hayward & Ryland (1985). Although *Coronopora* should grow in nodular colonies (Hayward & Ryland 1985), the studied specimen represents perhaps an encrusting base.

To confirm the identification, the type material of *Defrancia disticha* has still to be studied, however.

Class: **Gymnolaemata** Allman, 1896  
Order: **Cheilostomata** Busk, 1852  
Unassigned Anascan Genera  
Genus: *Vibracella* Waters, 1891

*Vibracella trapezoidea* (Reuss, 1847)  
Fig. 4.5–7

\* 1847 *Cellepora trapezoidea* m. — Reuss p. 96, pl. 11, fig. 21  
v. 1977 *Vibracella trapezoidea* (Reuss) — Vávra p. 91 (cum syn.)

**Diagnosis:** Colony is free. Autozooecia are rhomboidal to oval with well-developed cryptocyst and large, triangular openings. Vibraculata are adventitious, elongated without pivotal bar, but with protruding lateral lips. Endozooecial ovicell as large as autozooecia with porous frontal wall.

**Remarks:** Free living colonies of this species require a hard substrate to lie on. Usually this species is rare in other Miocene sections in the Alpine-Carpathian region (Zágoršek 2003), but here it is one of the most common species. It may indicate a hard bottom of the sea.

Suborder: **Ascophora** Levinsen, 1909  
Infraorder: **Acanthostega** Levinsen, 1902  
Superfamily: **Arachnopusioidea** Jullien, 1888  
Family: **Arachnopusiidae** Jullien, 1888  
Genus: *Poricella* Canu, 1904

*Poricella garbovensis* sp. nov.  
Fig. 5.1–3

**Differential diagnosis:** The characteristic features of this species include a deeply immersed ovicell, a very small umbo on the frontal wall, prominent marginal areolar pores, five oral spines in non-ovicelled autozooecia and 2 spines in ovicelled ones, and small interzooecial avicularia with pivotal bar.

**Holotype:** The specimen depicted in Fig. 5.1, from Gârbova de Sus, sample GY-1/8 deposited in the National Museum Prague under number PM2 — P 1931.

**Paratype:** One specimen from Gârbova de Sus, sample GY-1/8 deposited in the National Museum Prague under number PM2 — P 1932.

**Derivatio nominis:** According to the name of the locality (Gârbova de Sus), where the species has been found.

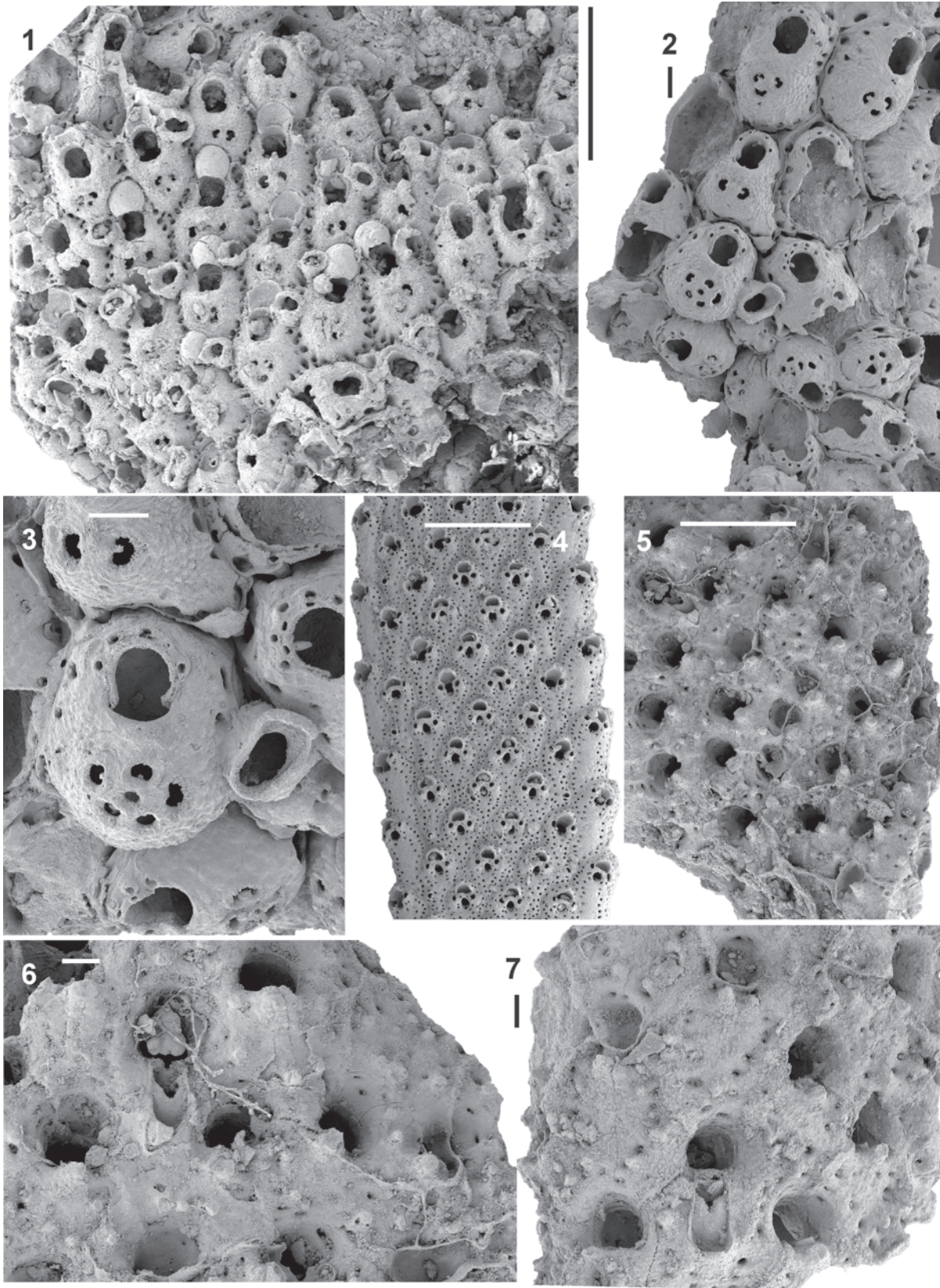
**Locus typicus:** Gârbova de Sus, sample GY-1/8.

**Stratum typicum:** Langhian–Lower Badenian.

**Dimensions** (in micrometers =  $\mu\text{m}$ ;  $\times$  = average): Length of autozooecia: 416–560;  $\times$  = 437. Width of autozooecia: 333–450;  $\times$  = 395. Length of autozooecial aperture: 101–165;  $\times$  = 135. Width of autozooecial aperture: 79–125;  $\times$  = 105. Length of ovicell: 175–205;  $\times$  = 181. Width of ovicell: 193–215;  $\times$  = 204. Length of adventitious avicularium: 185–257;  $\times$  = 203. Width of adventitious avicularium: 126–198;  $\times$  = 157.

**Description:** Colony encrusting unilaminar. Autozooecia oval, separated by deep grooves. Frontal wall very convex, with two to six rounded and/or semilunar, crescent-shaped foramina in the central area. The outer, convex margin of foramina may have small dentitions, the inner margin usually carries one large condyle. Marginal areolar pores are large, circular





**Fig. 5.** 1–3 — *Poricella garbovensis* sp. nov., general view of the holotype with visible ovicells (1), part of another colony with well developed avicularia (2 — scale bar 100 µm), detail of autozoecia (3 — scale bar 100 µm). 4 — *Adeonella polystomella* (Reuss, 1847), general view of the colony. 5–7 — *Umbonula spinosa* (Procházka, 1893), general view of the colony (5), detail of the autozoecia showing “spines” on frontal wall (6 — scale bar 100 µm), detail of the spatulate avicularium (7 — scale bar 100 µm). All other scale bars are 1 mm.



usually more than 20 around each autozoecium. The suboral umbo is very small, almost not observable. Apertures longer than wide, rounded distally and slightly concave proximally, with two short condyles. Oral spines large, five around distal margin of the aperture. The ovicelled autozoecia have only two oral spines. Avicularia small, interzooidal, oval to drop-like, with enlarged distal part of the rostrum. Pivotal bar rarely present. Ovicells globular, immersed into the distal part of a zooid with nonporous frontal wall.

**Comparison:** The most similar species is *Tremogasterina areolata* (Reuss, 1874) re-described by David & Poyuet (1974). The main differences are in the presence of central pores (*T. areolata* has three while *P. garbovensis* has often 5–6 pores), in size of oral spines (*P. garbovensis* has very prominent spine basis while *T. areolata* has small traces described, not visible in picture) and in size of marginal areolar pores (they are much larger in *P. garbovensis* than in *T. areolata*). Moreover ovicells are not illustrated in *T. areolata*.

The other similar species is *Poricella bugei* (el Hajjaji, 1987), re-described recently by Berning (2006). *Poricella garbovensis* sp. nov. differs mainly by the smaller size of autozoecia, the deeply immersed ovicell, the almost complete absence of an umbo on the frontal wall, by having more prominent marginal areolar pores, by less oral spines, and by the presence of avicularia.

The measurements for *Poricella bugei* as described by Berning (2006) are for autozoecia 495–667×301–476, for apertures 129–162×113–154 and for ovicells 200–253×192–241 (all in µm), thus it is in all dimensions larger than our new species. Moreover, *P. bugei* has a very prominent ovicell and an umbo on the frontal wall, almost invisible marginal areolar pores, more oral spines (6) and it has neither interzooidal nor vicarious avicularia. However, Cook (1977) mentioned that this feature may be extremely rare in some species, and therefore rarely observed in fragments of fossil colonies.

Another similar species is *P. pouyetae* (Cook, 1977) from the Middle Miocene of southern France, which, however, differs in having four to six spines, an enlarged distal margin of the aperture, no suboral umbo, more numerous and conspicuous marginal areolar pores and larger interzooidal avicularia.

Due to the presence of semilunar central pores, interzooidal avicularia, large oral spines and small ovicells, the species is listed under the *Poricella* (Canu, 1904).

Infraorder: **Umbonulomorpha** Gordon, 1989

Superfamily: **Adeonoidea** Busk, 1884

Family: **Adeonidae** Busk, 1884

Genus: *Adeonella* Busk, 1884

*Adeonella polystomella* (Reuss, 1847)

Fig. 5.4

\*v. 1847 *Eschara polystomella* m. — Reuss p. 70, pl. 8, fig. 27–28  
1989 *Adeonella polystomella* (Reuss) — Schmid p. 34, pl. 9, figs. 3, 4, 6 (cum syn.)

**Diagnosis:** Erect, bilaminar colonies. Autozoecia rhomboidal in the central part, longitudinal on marginal part of the colony. Lateral tubercles sometimes preserved on the margin

of the autozoecia. Aperture has a crossbar structure, forming proximally a small spiramen and carrying a pair of small, oral avicularia. Internal brooding, no ovicell developed.

**Remark:** This is a very common species, it occurs in almost all studied sections in Alpine-Carpathian region (Zágoršek et al. 2007, 2008, 2009). Usually it is regarded as a tropical element in the fauna (Holcová & Zágoršek 2008).

Superfamily: **Lepralielloidea** Vigneaux, 1949

Family: **Umbonulidae** Canu, 1904

Genus: *Umbonula* Hincks, 1880

*Umbonula spinosa* (Procházka, 1893)

Fig. 5.5–7

\*v. 1893 *Eschara spinosa* nov. spec. — Procházka p. 51 (67), pl. 12, fig. 5a–g

v. 2009 *Umbonula spinosa* (Procházka, 1893) — Zágoršek et al., p. 480, fig. 11D–G

**Diagnosis:** Colony erect, massive with oval cross-section. Autozoecia with small marginal areolar pores (about 10–15 pores around each autozoecium). Frontal wall with one “usual” large umbo with a small, adventitious avicularium without pivotal bar and additional small tubercles (umbones), resembling short spines, without any avicularia. An additional spatulate avicularium may be present. Primary orifice with wide lyrula. Ovicell not observed.

**Remarks:** Although no ovicell has been recognized in the studied material, the characteristic development of the frontal wall clearly characterizes this species. This occurrence is the first outside the Carpathian Foredeep in Moravia. Detailed description and discussion is given by Zágoršek et al. (2009).

Infraorder: **Lepraliomorpha** Gordon, 1989

Superfamily: **Smittinoidea** Levinsen, 1909

Family: **Bitectiporidae** MacGillivray, 1895

Genus: *Schizomavella* Canu & Bassler, 1917

*Schizomavella protuberans* (Reuss, 1847)

Fig. 6.1

\*v. 1847 *Cellepora protuberans* m. — Reuss p. 89, pl. 10, fig. 26

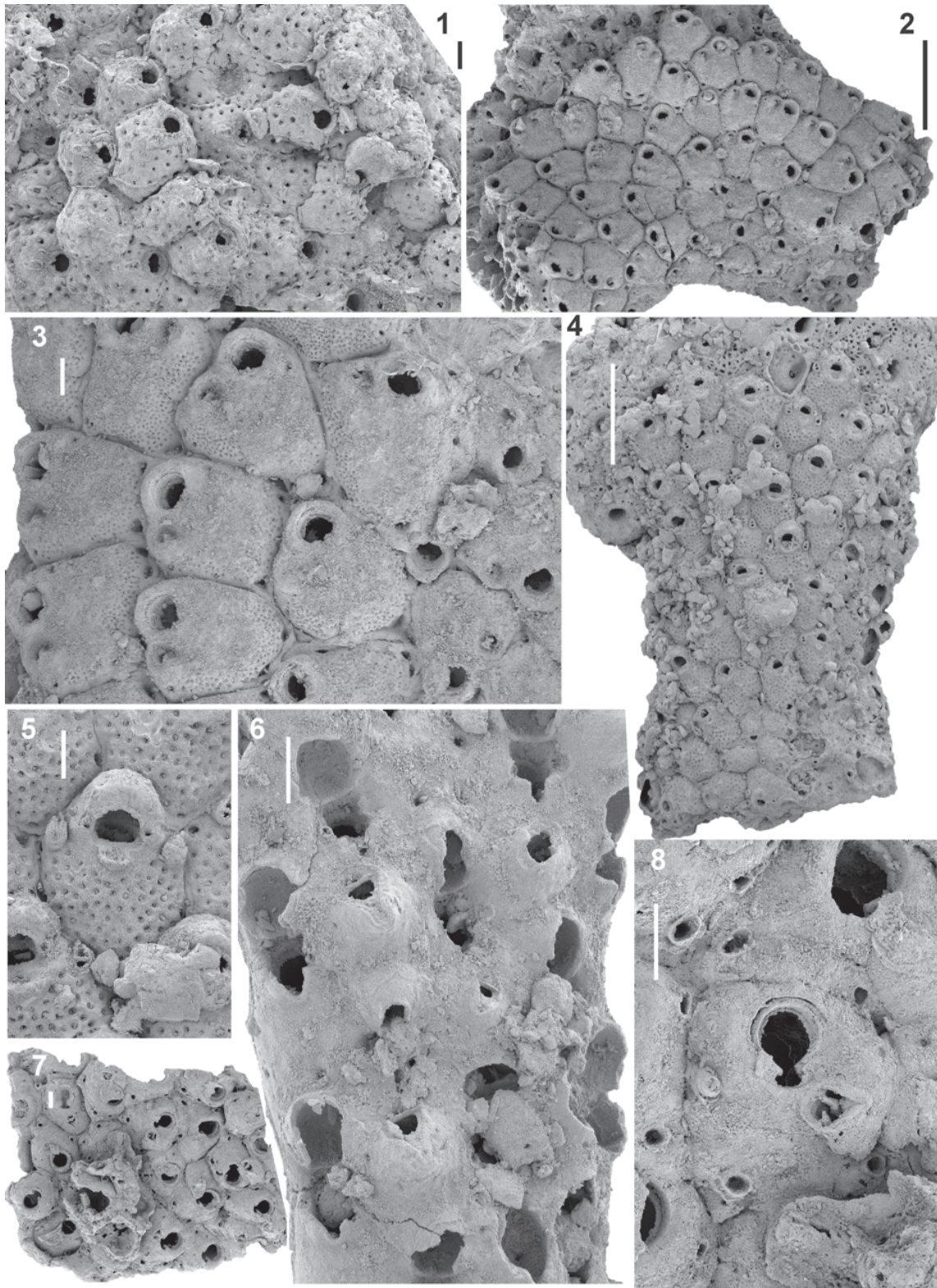
v. 2007 *Schizomavella protuberans* (Reuss, 1847) — Zágoršek et al. p. 211, fig. 9A–B (cum syn.)

**Diagnosis:** Colonies are encrusting, multilamellar, with autozoecia arranged in chaotic rows. Autozoecia are rectangular in shape, with a strongly perforated and convex frontal wall. Apertures have a prominent sinus and condyles. No oral spines. Avicularia are adventitious, suboral with pivotal bar always situated proximally and very close to the aperture in a median position, tapering proximally and associated with a prominent umbo. No ovicell observed.

**Remarks:** This is the first occurrence outside the Carpathian Foredeep in Moravia. Detailed description and discussion is given by Zágoršek et al. (2007).

Superfamily: **Schizoporelloidea** Jullien, 1882

Family: **Escharinidae** Tilbrook, 2006



**Fig. 6.** 1 — *Schizomavella protuberans* (Reuss, 1847), general view showing sinus of the aperture. 2–3 — *Therenia transylvanica* sp. nov., general view of the holotype showing arrangement of autozooezia (2 — scale bar 1 mm), detail of autozooezia showing laterally situated avicularium and porous frontal wall (3). 4–5 — *Microporella* cf. *inamoena* (Reuss, 1874), general view showing budding pattern (4 — scale bar 1 mm), detail of autozooezium showing the ovicell and paired avicularia (5). 6 — *Reteporella kralicensis* Zágoršek, Holcová & Trásoň, 2008, detail of the frontal surface of the colony showing large avicularia and ovicells with characteristic fissure. 7–8 — *Schedocleidochasma incisa* (Reuss, 1874), general view (7) and detail showing autozooezia with scattered marginal areolar pores and drop-like avicularium (8). All other scale bars are 100 µm.



Genus: *Therenia* David & Pouyet, 1978

*Therenia transylvanica* sp. nov.  
Fig. 6.2–3

**Differential diagnosis:** This species differs from all other known species of *Therenia* in having a very narrow and shallow sinus, a globular, recumbent ovicell, large marginal areolar pores and by the absence of any peristome.

**Holotype:** The specimen depicted in 6.2, from Gârbova de Sus, sample GY-1/8 deposited in the National Museum Prague under number PM2 — P 1933.

**Derivatio nominis:** According to the name of the area (Transylvanian Basin), where the species has been found.

**Locus typicus:** Gârbova de Sus, sample GY-1/8.

**Stratum typicum:** Langhian–Lower Badenian.

**Dimensions** (in micrometers =  $\mu\text{m}$ ;  $\times$  = average): Length of autozoecia: 530–617;  $\times$  = 574. Width of autozoecia: 463–614;  $\times$  = 504. Length of autozoecial aperture: 100–115;  $\times$  = 105. Width of autozoecial aperture: 127–145;  $\times$  = 135. Length of ovicell: 151. Width of ovicell: 219. Length of avicularium: 56–75;  $\times$  = 64. Width of avicularium: 87–108;  $\times$  = 95.

**Description:** Colony encrusting, unilaminar. Autozoecia rhomboidal, hexagonal or polygonal, separated by distinct grooves. Frontal wall slightly convex, very finely granular, perforated by numerous small pseudopores. Central area almost nonporous. Marginal areolar pores very large, rare, usually three of them are situated in the proximal corners of the autozoecium.

Apertures semicircular with straight proximal margin and a very narrow and shallow sinus. No peristome. Condyles small, more or less parallel to the proximal margin of the aperture. Avicularium situated proximolaterally from the aperture, circular to semicircular, with distinct, medial columella. Ovicell globular, recumbent without completely preserved frontal wall. Ancestrula not clearly observable because of overgrowth by younger autozoecia.

**Comparison:** *Therenia peristomata* Berning et al., 2008 from Madeira is the most similar species. The new species differs mainly by its shorter autozoecia (the length of autozoecia in *T. peristomata* is 567 to 718  $\mu\text{m}$ ), the absence of any peristome, the recumbent ovicell (*T. peristomata* has a deeply immersed ovicells) and the size of marginal areolar pores. The other features, for example the characteristic shape of avicularia with columella, the size of pseudopores on the frontal wall, and parallel condyles with proximal margin of the aperture are identical for these two species.

Another similar species is *Herentia montenati* (Pouyet, 1976) from the Miocene to Pliocene of Spain, placed into the genus *Therenia* by Berning (2006). It differs however from our new species in having larger frontal pores, a complete crossbar, no columella of the avicularia and circular apertures with a longer sinus. The size of the autozoecia is also slightly larger than in *Therenia transylvanica* sp. nov. (523–738 $\times$ 415–615  $\mu\text{m}$ ). Moreover, *Therenia porosa* (Smitt) as described by Berning et al. (2008) has much larger pores on its frontal wall, a complete pivotal bar of the avicularia and a larger sinus.

Family: **Microporellidae** Hincks, 1879  
Genus: *Microporella* Hincks, 1877

*Microporella berningi* Zágoršek, 2010  
Fig. 6.4–5

?1997 *Microporella inamoena* (Reuss) — Pouyet p. 67, pl. 6, fig. 1, pl. 7, fig. 8 (cum syn.)  
\*v. 2010b *Microporella berningi* sp.n. — Zágoršek p. 156, pl. 116, fig. 1–5 (cum syn.)

**Diagnosis:** Colony encrusting, unilaminar. Autozoecia (sub)hexagonal to oval, with frontal wall perforated by numerous large pores. Marginal areolar pores very rare, only two to three around each autozoecium. Aperture semicircular, wider than long, with a straight proximal margin and five to seven oral spines (one pair of spines in ovicelled autozoecia). Ascopore with crescent lumen situated very close to the aperture. Nonporous area is developed between the ascopore and proximal margin of the aperture. Avicularia adventitious, in pairs, suboral, tapering distally with complete pivotal bar. Ovicell small, globular, deeply immersed into frontal wall of distal autozoecium, with nonporous frontal wall. Ancestrula oval without avicularia.

**Remarks:** The studied specimens are identical with the material described by Zágoršek (2010b) from section Holubice (south Moravia — Czech Republic).

*Microporella inamoena* (Reuss, 1874) is very similar species differs however in having much smaller frontal pores, larger and less immersed ovicells and larger apertures without nonporous area developed between the ascopore and proximal margin of the aperture.

The specimens described by Pouyet (1997) from Poland exhibit identical features, however without detailed SEM study of this material questions of a possible synonymy remain unclear.

Family: **Phidoloporidae** Gabb & Horn, 1862  
Genus: *Reteporella* Busk, 1884

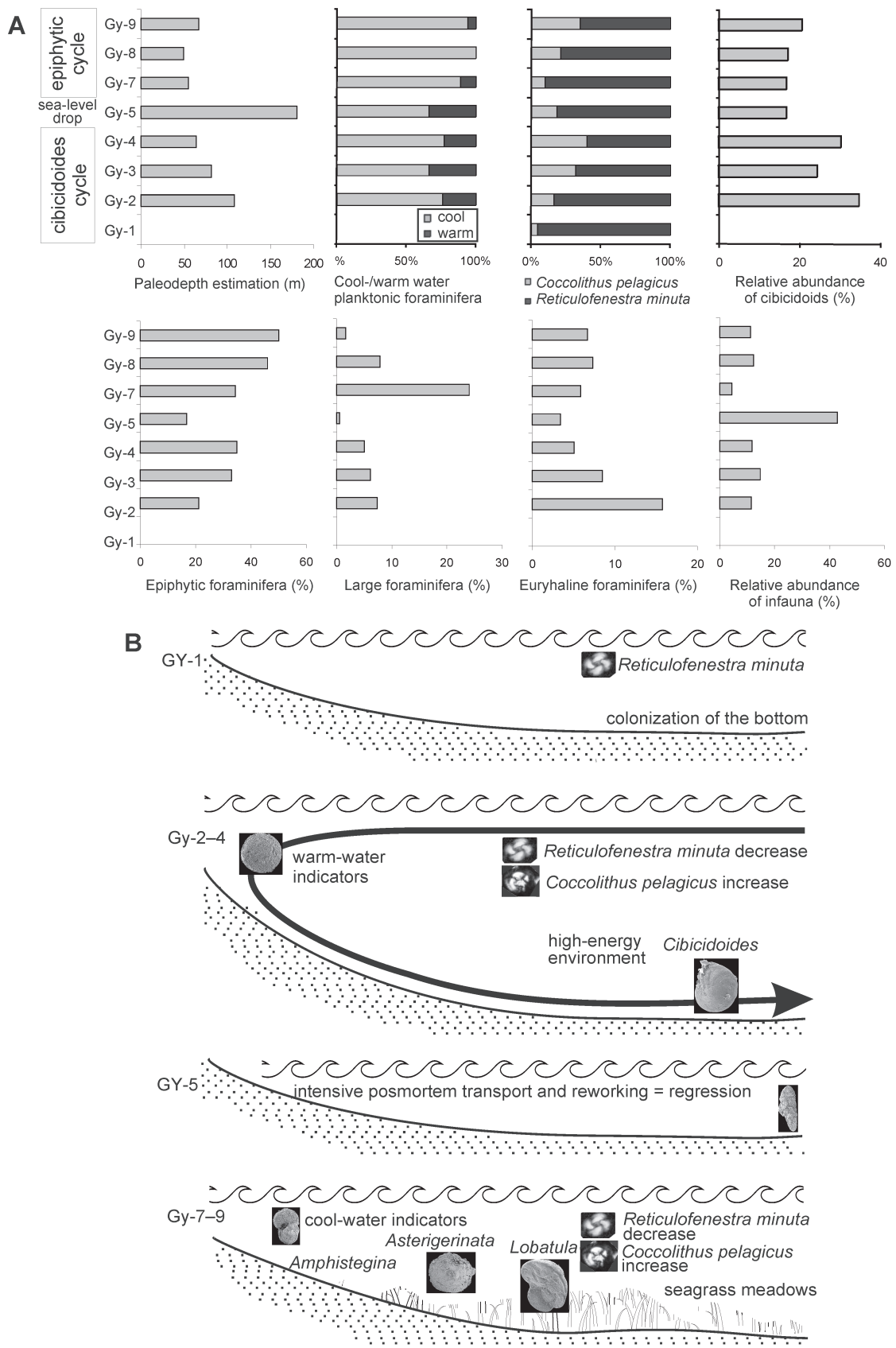
*Reteporella kralicensis* Zágoršek & Holcová & Trásoň, 2008  
Fig. 6.6

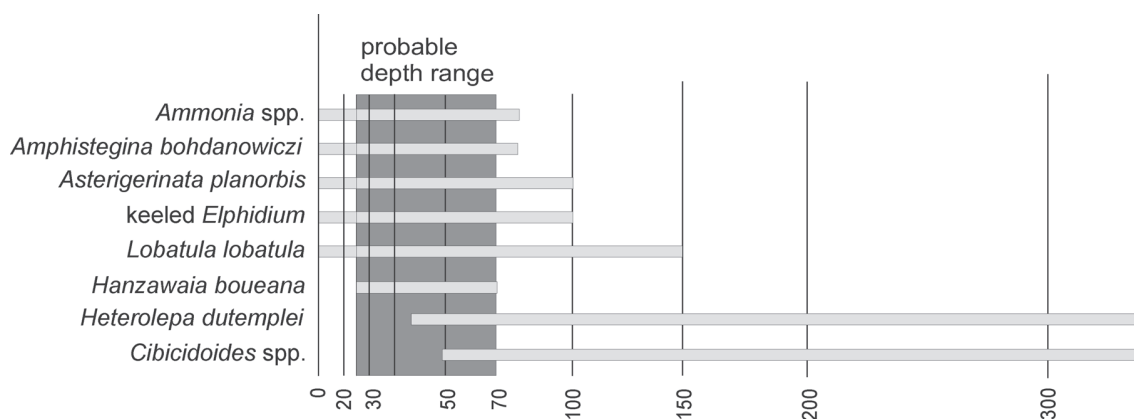
\*v 2008 *Reteporella kralicensis* sp.n. — Zágoršek et al. p. 843, fig. 7

**Diagnosis:** Colonies reticulating, with biserial or triserial branches. Frontal wall is smooth with small areolar pores only and a pseudo-spiramen. Apertures with sinus and a pair of oral spines. Large, adventitious avicularia forming separate polymorphs on the frontal wall, tapering usually proximally and having a complete pivotal bar. Rarely also small avicularia present, immersed into the frontal wall. Ovicells deeply immersed with open wide frontal fissure; frontal wall always damaged.

**Remarks:** The characteristic separate polymorphs — large avicularia — are present in the studied material. Even if the frontal walls of ovicells are always damaged, the open wide frontal fissure is recognizable and therefore an exact determination was possible.







**Fig. 8.** Estimation of paleodepth from the depth ranges of indigenous benthic foraminiferal taxa. Depth ranges of species based on data of Culver & Buzas (1980, 1981), Murray (1991, 2006), Hohenegger (2005), van Hinsbergen et al. (2005).

Genus: *Schedocleidochasma* Soule, Soule & Chaney, 1991

*Schedocleidochasma incisa* (Reuss, 1874)

Fig. 6.7–8

\* v. 1874 *Lepralia incisa* m. — Reuss p. 168, pl. 3, fig. 4

2006 *Schedocleidochasma incisa* (Reuss, 1874) — Berning p. 130, fig. 173–175 (cum syn.)

**Diagnosis:** Colony encrusting. Autozoecia oval with nonporous frontal wall, separated by grooves and prominent, scattered, rare marginal areolar pores. Apertures rounded cleithriate, with well developed condyles. Avicularia single, adventitious, situated laterally from the aperture as separate polymorphs, with complete pivotal bar. No oral spines, no ovicells observed.

**Remarks:** The studied specimen do not show any ovicells, but due to the presence of a cleithriate aperture, the small avicularia forming separate polymorphs and the absence of oral spines, the identification of this species is confirmed.

### Paleoecology

Bryozoans are generally rare in the sections at Gârbova de Sus and form only a part of the whole fauna studied (Koch 1900; Vadász 1915; Gábos & Ghiurcă 1969; Nicorici 1975; Filipescu 1996).

Indigenous benthic foraminifera usually indicate shallow-water (tens of meters), and a normal marine, well aerated paleoenvironment. The assemblages are well comparable with foraminifera from bryozoan-rich sediments in the Carpathian Foredeep (Zágoršek et al. 2007, 2008; Holcová & Zágoršek 2008) characterizing a similar paleoenvironment connected with a large transgression around the Middle Miocene Climatic Optimum. Bryozoa settled the narrow shallow-water zone of the basin earlier with a fauna typical for a high-energy environment, later with faunas indicating seagrass meadows.

A detailed analysis enables us to distinguish two intervals: the first one (samples GY-1/1 to GY-1/5) with generally warmer conditions than the second one (samples GY-1/6 to GY-1/9) (Fig. 7).

In the first interval, the foraminiferal assemblages show a progressive colonization during the transgression (Filipescu & Girbacea 1997). The transgressive trend can be observed in the lower samples of section GY-1 (GY-1/1, GY-1/2). *Cibicidoides lopjanicus* dominates among the first benthic foraminifera that colonized the substrate and continues to be present together with encrusting bryozoans up to sample GY-1/5. In calcareous nannoplankton assemblages, abundances of the opportunistic species *Reticulofenestra minuta* decrease in line with increase of abundance of *Coccolithus pelagicus* as a eutrophic indicator. Bloom of small reticulofenestrids characterizes transgression events in the Central Paratethys (Holcová 2009) and may indicate penetration of the warm-water during the Early Badenian transgression (Ćorić & Rögl 2004). The bloom can also be well correlated with conclusions by Haq (1980) that *Reticulofenestra minuta* dominates nannoplankton assemblages along continental margins. The species can probably tolerate oscillations of salinity (Wade & Bown 2006).

Bryozoa are most abundant in sample GY-1/2, where the environment was suitable for benthic organisms. This may prove the hypothesis of pioneer colonization behaviour of bryozoans as shown already in the section of Kralice nad Oslavou in the Moravian part of the Carpathian Foredeep (Zágoršek et al. 2008). The species composition is also similar, dominated by species of *Reteporella* and *Idmidronea*. Depth estimation based on the plankton/benthos (P/B) ratio yields 60–110 m. The reliability of the calculated paleodepth can be biased by the observation that the P/B-ratio is not only influenced by depth, but also by changes in oxygenation of bottom waters (Sen-Gupta & Machain-Castillo 1993; Jorissen et al. 1995). A discrepancy between calculated paleodepth and sedimentology has been pointed out, for example, in the Middle Miocene of the Central Paratethys (Hohenegger 2005). Therefore, the estimation of paleodepth using a modified P/B-ratio was compared with depth ranges of individual taxa (Culver & Buzas 1980, 1981; Murray 1991, 2006; Hohenegger 2005; van Hinsbergen et al. 2005). The paleodepth 20–70 m was estimated from these depth ranges (Fig. 8). This is also supported by sedimentological data (tempestites, tidal currents).

Dominant cibicidoids represent typical oxyphylic species (Kaiho 1994). In the Carpathian Foredeep, the "Cibicoides assemblage" accompanied by rich bryozoan assemblages was recorded in the higher energy environment (Holcová & Zágoršek 2008).

The assemblage in sample GY-1/5 contains many recrystallized probably reworked taxa and rare but well preserved specimens, mainly cibicidoids which may represent an indigenous part of an oryctocoenosis. Therefore, a paleoecological interpretation based on the whole assemblages can be biased and a decrease of oxygen content and deepening (Fig. 7) cannot be expected. Mixing of taxa may cause the highest diversity of benthic foraminifers. The high abundance of reworked tests characterizes regressive sediments (Holcová 1999).

*Asterigerinata planorbis* and *Lobatula lobatula* dominate the benthic foraminiferal assemblages; these typical epiphytic species indicate seagrass meadows (Murray 1991, 2006). Increases of relative abundance of small *Reticulofenestra* and small globigerinids (samples GY-1/6 to GY-1/9) can be related to floodings at the beginning of the parasequences.

Abundances of the opportunistic species *Reticulofenestra minuta* decreasing in line with an increase of the abundance of *Coccolithus pelagicus*.

The more diversified bryozoan assemblage, dominated by shallow water encrusters (see McKinney & Jackson 1989 and Hageman et al. 1997) and tropical elements (*Poricella*, *Vibracella* and *Therenia*), identified in sample GY-1/8, suggests warmer water conditions compared with the Carpathian Foredeep or the Vienna Basin.

### Conclusions

Two new Bryozoa species were described in detail and additional species, not yet reported from the Transylvanian Basin, were shortly described and illustrated. After the revision of Ghiurcă's (1974) material, altogether 77 species are known from the section at Gârbova de Sus now.

Foraminiferal and calcareous nannoplankton assemblages support the paleoenvironmental interpretations and suggest shallow marine conditions (first tens of meters) and two distinct paleoenvironmental settings, both in the later part of the Early Badenian. A high abundance of warm-water planktonic foraminifera and the presence of tropical elements among Bryozoa may indicate the Middle Miocene Climatic Optimum.

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Appendix 1a: List of benthic foraminiferal species and their relative abundances.

	GY-1	GY-2	GY-3	GY-4	GY-5	GY-7	GY-8	GY-9
<i>Ammonia beccarii</i> (Linné)	0.00	2.11	0.00	0.00	0.58	0.00	0.00	0.00
<i>Ammonia viennensis</i> (d'Orbigny)	0.00	0.00	3.66	0.00	0.00	0.00	2.45	1.67
<i>Amphistegina bohdanowiczi</i> Bieda	0.00	7.37	6.10	5.06	0.58	24.09	6.86	1.67
<i>Asterigerinata planorbis</i> (d'Orbigny)	0.00	10.53	13.41	21.91	2.50	21.17	25.98	25.56
(?) <i>Bitubulogerina reticulata</i> Cushman	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00
<i>Bolivina antiqua</i> d'Orbigny	0.00	1.05	6.10	3.93	8.67	0.73	1.47	2.78
<i>Bolivina dilatata</i> Reuss	0.00	3.16	0.00	1.69	2.77	0.00	1.96	0.56
<i>Bolivina scalprata</i> Cushman	0.00	0.00	0.00	0.00	2.89	0.00	0.00	0.00
<i>Bolivina hebes</i> Macfadyen	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.56
<i>Bolivina plicatella</i> Cushman	0.00	0.00	0.00	0.00	0.00	0.73	0.00	2.22
<i>Bolivina pokornyi</i> Cicha & Zapletalova	0.00	1.05	0.00	0.00	2.89	0.00	0.00	0.00
<i>Bolivina</i> sp. (recrystallized)	0.00	0.00	0.00	0.00	8.21	0.00	0.00	0.00
<i>Bulimina elongata</i> d'Orbigny	0.00	0.00	0.00	0.00	0.00	0.00	1.96	1.11
<i>Bulimina striata</i> d'Orbigny	0.00	1.05	2.44	0.00	0.00	0.00	0.00	0.00
<i>Cassidulina laevigata</i> d'Orbigny	0.00	3.16	6.10	2.25	4.05	1.46	4.41	4.44
<i>Cibicidoides lopjanicus</i> (Mjathuk)	0.00	22.11	20.73	26.40	8.67	0.00	3.21	17.22
<i>Cibicidoides austriacus</i> (d'Orbigny)	0.00	0.00	0.00	0.00	1.73	0.00	0.98	0.00
<i>Cibicidoides pachyderma</i> (Rzehak)	0.00	0.00	0.00	0.00	0.00	9.49	4.29	0.00
<i>Cibicidoides ungerianus</i> (d'Orbigny)	0.00	8.42	2.44	2.81	4.62	1.46	0.00	1.11
<i>Coryphostoma digitalis</i> (d'Orbigny)	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00
<i>Elphidium fichtellianum</i> (d'Orbigny)	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.56
<i>Elphidium</i> cf. <i>subtypicum</i> Papp	0.00	1.05	0.00	0.00	0.00	0.00	5.15	1.11
<i>Elphidium macellum</i> Fichtel & Moll	0.00	11.58	4.88	5.06	2.89	5.11	4.01	0.00
<i>Elphidium rugosum</i> (d'Orbigny)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33
<i>Elphidium</i> sp. (juvenile)	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
<i>Eponides repandus</i> (Fichtel & Moll)	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00
<i>Fursenkoina acuta</i> (d'Orbigny)	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00
<i>Globocassidulina oblonga</i> (Reuss)	0.00	1.05	1.22	1.69	1.16	1.46	0.98	1.11
<i>Hansenisca soldanii</i> (d'Orbigny)	0.00	1.05	0.00	0.00	0.58	0.73	0.00	0.00
<i>Hanzawaia boueana</i> (d'Orbigny)	0.00	1.05	0.00	3.93	1.16	1.46	0.00	0.00
<i>Heterolepa dutemplei</i> (d'Orbigny)	0.00	4.21	1.22	1.12	1.73	5.84	3.43	2.22
<i>Hoeglundina elegans</i> (d'Orbigny)	0.00	1.05	1.22	0.00	0.00	0.00	0.00	0.00
<i>Karrerella chilostoma</i> (Reuss)	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
<i>Lagena hexagona</i> Williamson	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
<i>Lapugyina schmidi</i> Popescu	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00
<i>Lenticulina inornata</i> (d'Orbigny)	0.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00
<i>Lenticulina</i> sp. (juvenile)	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
<i>Lobatula lobatula</i> (Walker & Jacob)	0.00	10.53	19.51	12.03	13.87	13.14	20.10	24.44
<i>Melonis pompiloides</i> (d'Orbigny)	0.00	0.00	1.22	0.00	2.89	0.73	0.98	1.11
<i>Nomion commune</i> (d'Orbigny)	0.00	0.00	1.22	0.56	0.00	2.19	0.49	1.11
<i>Nomion</i> sp.	0.00	2.11	3.66	0.00	0.00	0.00	2.94	2.78
<i>Pararotalia aculeata</i> (d'Orbigny)	0.00	1.05	0.00	1.69	0.00	0.00	0.49	2.22
<i>Planostegina costata</i> (d'Orbigny)	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00
<i>Porosonion granosum</i> (d'Orbigny)	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.00
<i>Pullenia bulloides</i> (d'Orbigny)	0.00	1.05	0.00	0.56	1.16	0.00	0.49	0.00
<i>Reussella spinulosa</i> (Reuss)	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00
<i>Rosalina obtusa</i> d'Orbigny	0.00	0.00	0.00	0.00	2.89	0.00	0.00	0.00
<i>Rosalina</i> sp.	0.00	0.00	1.22	0.00	1.16	0.00	0.00	0.00
<i>Sigmavirgulina tortuosa</i> (Brady)	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00
<i>Siphonina reticulata</i> (Czjzek)	0.00	1.05	1.22	0.00	1.36	0.73	0.00	0.00
<i>Spirorutilus carinatus</i> (d'Orbigny)	0.00	0.00	0.00	5.62	0.58	0.73	0.49	0.00
<i>Stilostomella elegans</i> (d'Orbigny)	0.00	0.00	0.00	0.00	4.05	0.73	0.00	0.56
<i>Textularia gramen</i> d'Orbigny	0.00	0.00	1.22	0.00	0.00	4.38	3.92	0.00
<i>Textularia</i> sp.	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00
<i>Trifarina bradyi</i> Cushman	0.00	1.05	0.00	0.56	2.89	0.00	0.98	0.56
<i>Uvigerina macrocarinata</i> Papp & Turnovsky	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00
<i>Uvigerina pygmaoides</i> Papp & Turnovsky	0.00	0.00	0.00	1.12	7.51	0.00	0.00	0.00
<i>Valvulineria complanata</i> (d'Orbigny)	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00
<i>Turborotalita quinqueloba</i> (Natland) group	0	10	19	0	0	39	5	52
<i>Globigerina praebulloides</i> Blow group	0	48	28	49	62	0	95	0
<i>Globigerina bulloides</i> d'Orbigny	0	3	0	0	0	28	0	23
(?) <i>Globoturborotalita druryi</i> (Akers)	0	0	0	0	0	22	0	3
<i>Globigerinoides bisphericus</i> Todd	0	4	16	4	3	0	0	0
<i>Globigerinoides quadrilobatus</i> (d'Orbigny)	0	0	5	10	0	0	0	3
<i>Globigerinoides trilobus</i> (Reuss)	0	20	12	16	19	0	0	3
<i>Orbulina suturalis</i> Bronnimann	0	0	0	0	10	11	0	0
<i>Globigerinella regularis</i> (d'Orbigny)	0	0	0	0	1	0	0	0
<i>Paragloborotalia mayeri</i> (Cushman & Ellisor)	0	5	15	21	4	0	0	11
<i>Globorotalia bykovae</i> (Aisenstat)	0	8	0	0	1	0	0	5
<i>Globoquadrina altispira</i> (Cushman & Jarvis)	0	0	5	0	0	0	0	0
<i>Globigerinita uvula</i> (Ehrenberg)	0	1	0	0	0	0	0	0
P/B-ratio	0	28.57	20.39	14.83	32.42	11.61	8.11	15.89



**Appendix 2:** List of calcareous nannoplankton species and their relative abundances.

	GY-1	GY-2	GY-3	GY-4	GY-5	GY-7	GY-8	GY-9
<i>Coccolithus pelagicus</i> (Wallich) Schiller	3.92	15.24	29.03	37.14	18.27	9.52	20.37	33.93
<i>Reticulofenestra minuta</i> Roth	86.27	79.05	61.29	55.24	79.33	85.71	75.93	62.50
<i>Reticulofenestra pseudoumbilicus</i> (Gartner) Gartner	1.96	2.86	4.84	0.95	0.00	0.00	0.00	0.00
<i>Cyclicargolithus abisectus</i> (Müller) Wise	0.00	1.90	1.61	0.00	0.00	0.00	0.00	0.00
<i>Reticulofenestra bisecta</i> (Hay) Roth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.79
<i>Cyclicargolithus floridanus</i> (Roth & Hay) Bukry	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00
<i>Helicosphaera carteri</i> (Wallich) Kamptner	0.00	0.95	0.00	0.95	0.48	0.00	1.85	0.00
<i>Helicosphaera walbersdorfensis</i> (Müller) Theodoridis	1.96	0.00	0.00	0.00	1.44	0.00	0.00	0.00
<i>Syracosphaera pulchra</i> Lohmann	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00
<i>Sphenolithus heteromorphus</i> Deflandre	0.00	0.00	0.00	0.95	0.00	0.00	0.00	1.79
<i>Pontosphaera multipora</i> (Kamptner) Roth	0.00	0.00	0.00	0.00	0.48	0.00	1.85	0.00
<i>Micrantholithus</i> sp.	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00
<i>Thoracosphaera</i> sp.	5.88	0.00	1.61	1.90	0.00	4.76	0.00	0.00
	rare	rare	very rare	common	abundant	rare	rare	rare