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TURONIAN SILICIFIED SEDIMENTS IN THE CZORSZTYN SUCCESSION OF THE PIENINY KLIPPEN BELT (WESTERN CARPATHIANS, SLOVAKIA)

MILAN SÝKORA[1], LADISLAVA OŽVOLDOVÁ[1] and DANIELA BOOROVÁ[2]

[1]Department of Geology and Paleontology, Faculty of Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovak Republic
[2]Slovak Geological Survey, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic

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Abstract: Silicified sediments, which occur from the Albian to the Campanian in the Czorsztyn Succession of the Pieniny Klippen Belt are known in several stratigraphic horizons in Slovak and Polish territory. The studied section, situated in Vršatec Castle Klippe contains the sediments of ?Upper Berriasian–Lower Campanian age. The silicified sequence is represented by cherty limestones and silicified marls with rich assemblages of foraminifers (Helvetoglobotruncana helvetica Zone) and radiolarians (Superbum Zone sensu O´Dogherty 1994) of Early Turonian (except for the lowermost part)–?Middle Turonian age. The new radiolarian species *Patellula andrusovi* Ožvoldová, n. sp. was described there.

Key words: Cretaceous, Western Carpathians, Pieniny Klippen Belt, Czorsztyn Succession, silicified sediments, radiolarians, foraminifers.

Introduction

A few horizons formed by silicified sediment with cherts, often with an abundance of radiolarian tests were distinguished in Albian–Campanian sequences of the Czorsztyn Succession of the Pieniny Klippen Belt on the territory of Poland and Slovakia.

Our research on the studied section, situated 400 m SW from Vršatecké Podhradie village (Fig. 1) had the aim of establishing the lithological and stratigraphic characteristics of the silicified horizon and the surrounding rocks. A line of the section partly covered by a thin layer of slope debris has been excavated.

The foraminiferal microfauna was determined mostly in the thin sections. The radiolarians and silicified foraminifers were retrieved from the samples by dissolving the rock matrix in acetic acid (negative results) and in hydrofluoric acid (rich microfauna). They were observed using the scanning electron microscope.

Summary of existing knowledge

The oldest horizon (see Fig. 2) of the silicified and radiolaria bearing sediments in the deposits of the Albian–Campanian interval belongs to the lower member of the Pomiedznik Formation (Birkenmajer 1977), which is represented by green, black, often spotty and silicified marly limestones with lenticles and intercalations of the greenish, brownish, reddish and black radiolarian cherts. They are of the Late Albian age (Birkenmajer & Jednorowska 1987).

The cherty limestones of greenish, pinkish and yellow-greenish colour were found in the locality Krety creek, southern of the village of Krempachy (Birkenmajer 1958). Birkenmajer (1963) assumed that they are of the Early Turonian age. He also described the black-blue and greenish-black (sometimes yellow-green) radiolarian shales with calcified tests of radiolarians of the Early Turonian age in the Szaflary

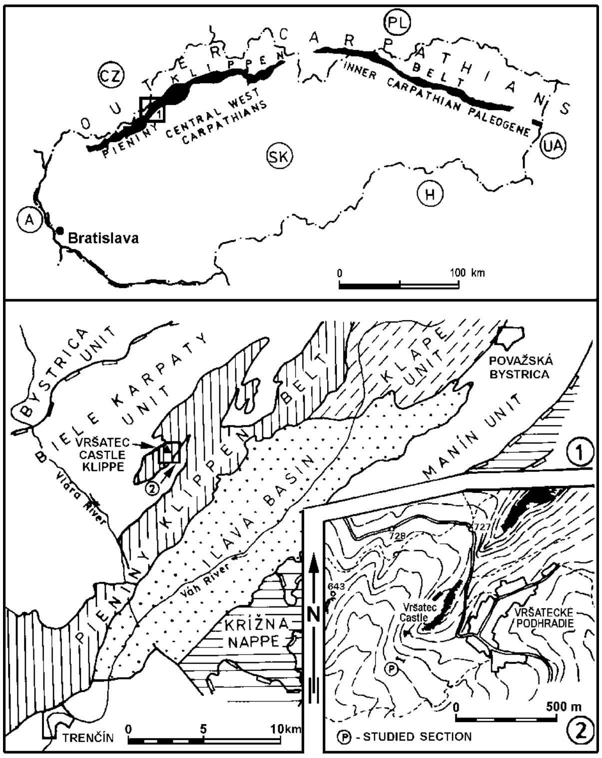


Fig. 1. Location of the studied section.

quarry. Both sequences represent the Altana Shale Bed (Birkenmajer 1977, see below).

Salaj (1961) and Samuel (1962) distinguished the beds by the amount of the radiolarian microfauna on the boundary of the Middle and Upper Cenomanian in the western and eastern part of the Pieniny Klippen Belt on the Slovak territory.

South of the village Krempachy (the Krety and Kizlinkowy creeks) Alexandrowicz (1966) and Birkenmajer (1958, 1963) described: a/ beds with a greater content of radiolarians and the layer of the light-red chert limestone in the sequence of the variegated marls and marly limestones (Globotruncanian Variegated Marls sensu Birkenmajer in Kokoszynska & Birkenmajer 1956) and b/ intercalations of cherty limestones or cherts in the sequence of the brick-red marls.

He assigned both these horizons with radiolarians to the Upper Cenomanian.

In 1968 Alexandrowicz et al. identified two radiolarian horizons: the “cherry red marls” with the Cenomanian microfauna with the intercalations of the radiolarian shales in the Dolný Mlyn Klippe, north of Stará Turá town and the green spotted marls and marly limestones with cherts (0.5 m thick) resembling the lower Pomiedznik Beds (Birkenmajer 1963) of the Albian age in the road cutting beneath Vršatec Castle.

In the previous locality the violet-red and greenish marls with intercalations of cherty limestones of the Turonian (?Late Cenomanian) age was also found by Andrusov & Samuel (1973).

Birkenmajer (1977) distinguished numerous lithostratigraphic units in the Pieniny Klippen Belt. The sequence, which has the stratigraphical range — upper part of the Lower Cenomanian–Maastrichtian was named by this author — Jaworki Marl Formation (now — Jaworki Formation). In the Czorsztyn Succession this formation is divided into Brynczkowa Marl Member, Skalski Marl Member, Macelowa Marl Member and Pustelnia Marl Member.

In the Brynczkowa Marl Member the silicification is quite exceptional (l.c.).

The Skalski Marl Member contains the Lorencowe Chert Bed and Altana Shale Bed (l.c.). The first one is represented by green-pinkish and yellow-greenish radiolarian and foraminiferal silicified limestone with cherts (Birkenmajer 1977), light-green silicified limestone and variegated (mostly red) marl (M. Bak 1996). The Altana Shale Bed is characterized by black-blue and greenish-black (sometimes yellow-green) shale with the calcified radiolarians (Birkenmajer 1977), black, blue-greenish and olive-green marly

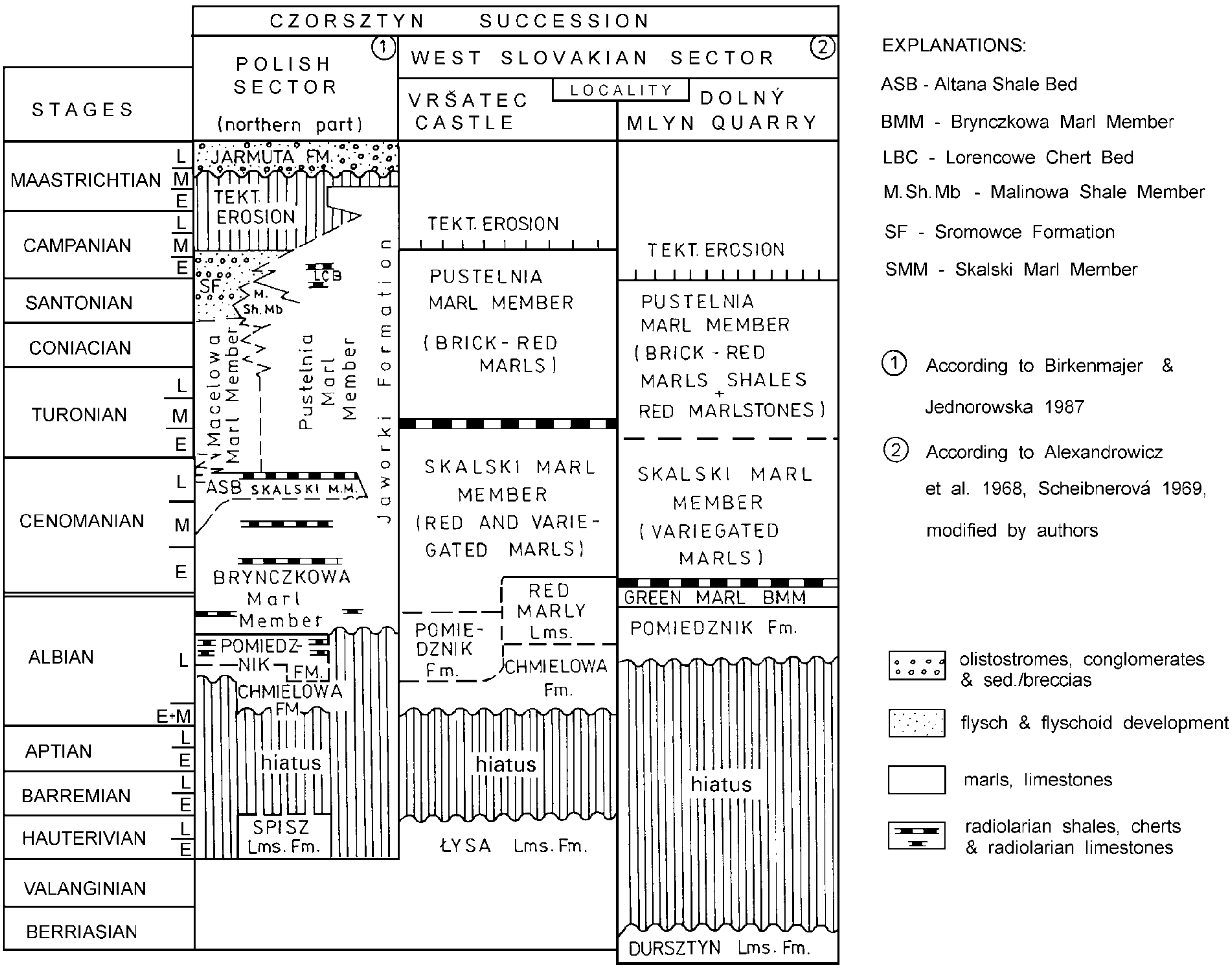


Fig. 2. Correlation of lithostratigraphical units (Berriasian–Maastrichtian) in the Czorsztyn Succession of the Pieniny Klippen Belt in the Polish and Slovak territory.

shale (M. Bak 1996). According to Alexandrowicz (1966), Alexandrowicz et al. (1968) and Birkenmajer (1977) both beds belong to the Upper Cenomanian.

Later Jednorowska (1979) revised the stratigraphical position of the Lorencowe Chert Bed according to a new determination of the foraminiferal microfauna from the marl, which was associated with this chert beds in the locality Krety creek, south of Krempachy village. The new age of this beds was established on the boundary Santonian-Campanian.

According to this data Birkenmajer & Jednorowska (1987) transformed the assignation of the Lorencowe Chert Bed from the Skalski Marl Member into Pustelnia Marl Member.

K. Bak (1994) and M. Bak (1994) confirmed the new stratigraphical position of the Lorencowe Chert Bed on the boundary Santonian-Campanian.

The Late Cenomanian age of Altana Bed was confirmed by K. Bak (1995) and M. Bak (1996).

The first results of radiolarian research from the Late Cretaceous sediments of the Czorsztyn Succession which belong to the Skalski Marl Member (Altana Shale Bed), Macelowa Marl Member and Pustelnia Marl Member (Lorencowe Chert Bed) of the Jaworki Formation were obtained by M. Bak (1996).

The lithostratigraphical characteristic of the studied section

The oldest stratigraphical horizon of the studied section (Fig. 3) is light-grey to grey organodetrital limestone.

The uppermost part of the sequence — (samp.1) is formed by carbonate breccia (several cm thick). It contains lithoclasts of biomicrites-wackestones with calcified radiolarians, ammonites, foraminifers (*Globuligerina* sp., *Ophthalmidium* sp., *Lenticulina* sp.), echinoderm ossicles and lamellibranchs, as well as biomicrites with calpionels — *Calpionella alpina* Lorenz, *Crassicollaria* sp., of the Tithonian-Berriasian age. The margin of the lithoclasts are uneven, the surface is very often dissected. At the same time the contact with the limestone, which forms the matrix of the breccia is often indistinct, therefore the main distinguishing mark between the lithoclasts mutually and the breccia matrix is the assemblage of microfossils. The age of the breccia is probably Late Berriasian-Valanginian (the youngest age of the lithoclasts is Late Tithonian-Early Berriasian).

These rocks were also identified by Scheibnerová (1969) and Mišík (1979). Scheibnerová (l.c.) assigned the youngest limestones of the Upper Jurassic and Lower Cretaceous in the Vršatec Castle Klippe to the Spisz Limestone Formation (Birkenmajer 1960 in Birkenmajer 1977).

Andrusov (in Andrusov & Samuel 1973) and also Mišík (1979) attributed them to the Lysa Limestone (Birkenmajer & Gasiorowski 1961), (later Lysá Limestone Formation according to Birkenmajer 1977).

In the uppermost parts of the breccia the unevennesses are filled up with a darker-grey biodetrital limestone with a clastic admixture (Fig. 3, samp. 2a), the assignation of which to the overlying Chmielowa Formation is questionable. It contains an association of planktonic and benthic foraminifers (Fig. 4, thin s. 22799, 23837), (Pl. I: Fig. 1; Pl. VI: Fig. 1). The planktonic specimens include a great number of representatives of the genus *Hedbergella* sp., *Biticinella breggiensis* (Gandolfi), *Planomalina (Planomalina) buxtorfi* (Gandolfi), *Planomalina (Globigerinnelloides)* sp. and frequent representantives of the genus *Ticinella* sp.

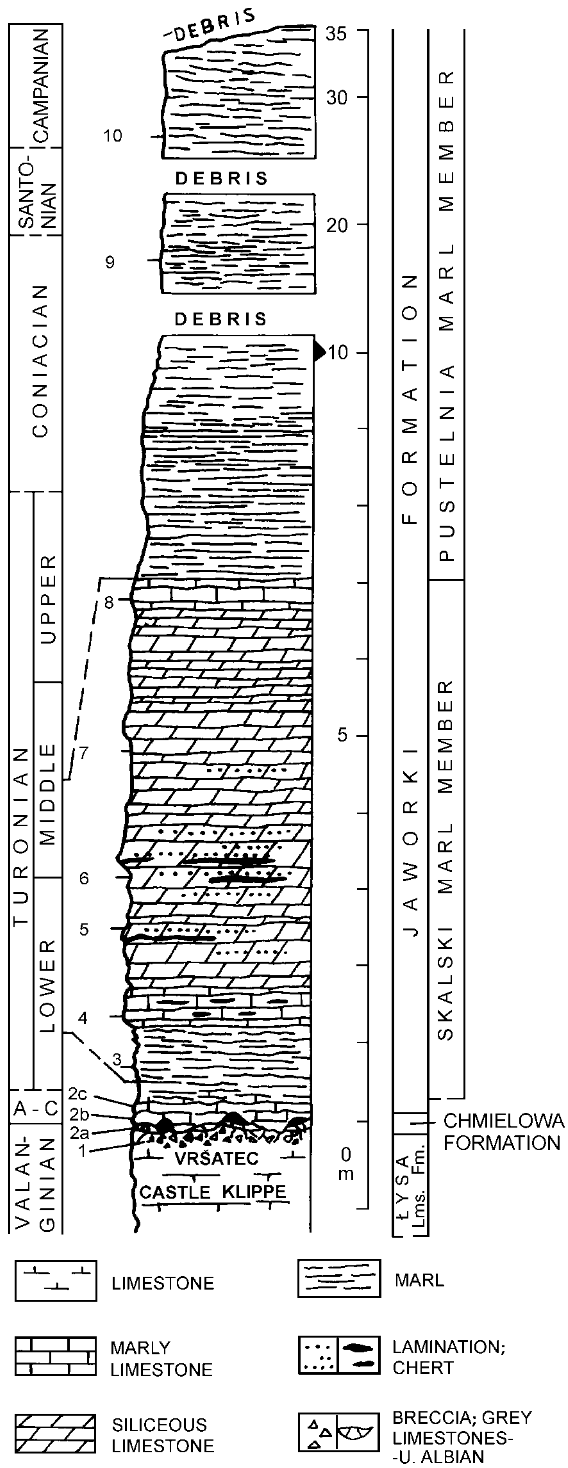


Fig. 3. Lithostratigraphic column of the studied section with the location of the samples.

Sample					4	5	6		8		
	thin s	thin s	thin s	thin s	thin s	thin s	thin s	thin s	thin s	thin. s	thin.
	22799	27799	22980	22977	22975	22983	22982	22801	22978	22973	22976
	23837	22981	23838	23840				22804			
		23839						22797			
								22796			
Foraminiferal microfauna											
Biticinella breggiensis (GANDOLFI)	x	x									
Clavihedbergella sp.						x					
Dicarinella biconvexa (SAMUEL - SALAJ)				x	x	x	x	x			
Dicarinella biconvexa gigantea (SAMUEL - SALAJ)						x		x			
Dicarinella carpathica (SCHEIBNEROVÁ)									x		
Dicarinella hagni (SCHEIBNEROVÁ)				x	x	x		x	x		
Dicarinella imbricata (MORNOD)				x	x	x		x	x		
The transitional form between D. imbricata (MORNOD)											
and D. hagni (SCHEIBNEROVÁ)					x				x		
Dicarinella oraviensis oraviensis (SCHEIBNEROVÁ)				x	x	x	x	x	x		
Dicarinella oraviensis trigona (SCHEIBNEROVÁ)						x	x	x	x		
Dicarinella sp.					x	x	x	x	x		
Dorothia oxycona (REUSS)		x									
Dorothia sp.	x	x	x	x							
Dorothia trochus (D´ ORBIGNY)		x									
Falsomarginotruncana coronata (BOLLI)										x	
Falsomarginotruncana pseudolinneiana (PESSAGNO)										x	
Falsomarginotruncana renzi (GANDOLFI)						x					
Falsomarginotruncana sinuosa (PORTHAULT)										x	
The transitional form between F. sinuosa (PORTHAULT)											
and F. angusticarinata (GANDOLFI)										x	
Gaudryina sp.	x										
Globotruncana arca (CUSHMAN)											x
Globotruncana cf. arca (CUSHMAN)											x
Globotruncana linneiana (D´ ORBIGNY)											x
Gyroidina sp.	x	x									
Hedbergella delrioensis (CARSEY)		x	x							x	
Hedbergella globigerinellinoides (SUBBOTINA)		x									
Hedbergella planispira (TAPPAN)		x	x	x							
Hedbergella sp.	x	x	x	x	x	x	x	x	x	x	x
Helvetoglobotruncana helvetica (BOLLI)							x	x	x		
Helvetoglobotruncana praehelvetica (TRUJILLO)						x					
Heterohelix globulosa (EHRENBERG)					x	x					
Heterohelix reussi (CUSHMAN)						x					
Heterohelix sp.				x		x	x	x	x	x	x
Lenticulina macrodisca (REUSS)	x										
Lenticulina secans (REUSS)	x										
Lenticulina sp.		x	x	x							
Osangularia infracretacea BUKALOVA	x										
Planomalina (Planomalina) buxtorfi (GANDOLFI)	x	x									
Planomalina (Globigerinelloides) sp.	x		x	x	x	x	x		x		
Pleurostomella sp.		x									
Praeglobotruncana delrioensis (PLUMMER)		x	x								
Praeglobotruncana sp.		x	x								
Praeglobotruncana stephani (GANDOLFI)		x	x								
Praeglobotruncana cf. stephani (GANDOLFI)				x							
Schackoina bicornis REICHEL						x					
Schackoina sp.						x					
Thalmanninella appeninnica (RENZ)			x								
Thalmanninella appenninica balernaensis (GANDOLFI)		x									
Thalmanninella brotzeni (SIGAL)			x								
Thalmanninella deeckei (FRANKE)			x								
Thalmanninella sp.		x									
Thalmanninella ticinensis ticinensis (GANDOLFI)		x									
Ticinella sp.	x										
Whiteinella gandolfi GAŠPARIKOVÁ and SALAJ		x									
Whiteinella gigantea (LEHMAN)						x			x		
Whiteinella cf. inornata (BOLLI)										x	
Whiteinella sp.		x		x				x		x	

Fig. 4. Distribution of foraminiferal microfauna in the samples of the studied section.

The benthic part of the association is represented by *Dorothia* sp., *Gaudryina* sp., *Gyroidina* sp., and frequent specimens of the genus *Lenticulina* (*L. macrodisca* (Reuss), *L. secans* (Reuss)) and *Osangularia infracretacea* Bukalova. The occurrence of the genus *Thalmanninella* is uncertain.

The association indicates the Late Albian age — Planomalina (Planomalina) buxtorfi–Thalmanninella appenninica balernaensis foraminiferal Zone (according to Maamouri et al. 1994).

Apart from foraminifers, echinoderm ossicles (usually bored by algae, Pl. I: Fig. 1), echinoid spines, fish teeth and bones (Pl. I: Fig. 2) with sporadic tests of ostracods occur there.

The terrigenous admixture is formed by clastic undulatory quartz (0.05–0.47 mm) about 1 %. Sporadic grains of glauconite and phosphates were found.

This limestone, which merges in colour with the underlying breccia of the Lysa Limestone Fm. is several milimeters or centimeters thick.

The above mentioned data show that there is a hiatus between the Upper Berriasian or Valanginian and the Upper Albian. A part of sediments was probably removed by dissolution and erosion.

The Upper Albian grey limestone is covered by a thin bed of Mn-Fe crust (up to 3 mm thick), which is of stromatolitic character — hard ground. This break lasted for a short time as the crust is covered by red and reddish-grey fine-grained limestone (20 cm), which again contains an assemblage of Late Albian foraminifers. In contrast to the underlying grey limestone, which is its age equivalent, the red limestone is formed by biomicrite-wackestones and packstones (Fig. 3, samp. 2b). It is composed mainly of foraminifers, thin-walled pelecipods and brachiopods, sporadic echionoid spines, echinoderm ossicles, teeth of fish, tests of ostracods and cadosins (*Cadosina semiradiata* Wanner). Clastic quartz (silt size) rarely occurs there. The red limestone belongs to the Chmielowa Formation (Birkenmajer 1977).

The foraminiferal assemblage (Fig. 4, thin s. 27799, 22981, 23839, Pl. VI: Fig. 2) represents the same stratigraphic interval — Planomalina (Planomalina) buxtorfi–Thalmanninella appenninica balernaensis foraminiferal Zone of the Late Albian age, but it is enriched by further planktonic foraminifers as: *Biticinella breggiensis* (Gandolfi) (Pl. VI: Fig. 4), *Hedbergella delrioensis* (Carsey), *H. globigerinellinoides* (Subbotina), *H. planispira* (Tappan), *Hedbergella* sp., *Planomalina (Planomalina) buxtorfi* (Gandolfi) (Pl. VI: Fig. 3; Pl. VII: Fig. 2), *Praeglobotruncana delrioensis* (Plummer), *P. stephani* (Gandolfi) (Pl. VII: Fig. 3), *Thalmanninella appenninica balernaensis* (Gandolfi), (Pl. VI: Fig. 6) *T. ticinensis ticinensis* (Gandolfi) (Pl. VI: Figs. 2, 5), *Thalmanninella* sp., *Whiteinella gandolfi* Gašpariková & Salaj. The benthic specimens are represented by *Dorothia oxycona* (Reuss), (Pl. VI: Fig. 2), *D. trochus* (D´Orbigny), *Dorothia* sp., *Gyroidina* sp., *Lenticulina* sp. and *Pleurostomella* sp.

Some hundred meters north of our section Mišík (1979) also mentioned Lower Albian red limestones with depressions, unevennesses and neptunic dykes on the older limestones. Scheibnerová (1969) described here reddish-violet, reddish-brown marly limestones (20–25 cm thick) containing the rostra of *Neohibolites minutus* Lister and the reddish small cherts in the same stratigraphical position. They gradually pass into the Lower to Middle Cenomanian marly limestones according to this author.

The Upper Albian limestones are overlain by thin layers of the brownish-red to brick-red marly limestones (Fig. 3, samp. 2c). They are packstones (Pl. I: Fig. 3) with abundant foraminiferal fauna, sporadically with fragments of fish scales and teeth and also with segments of lamellibranch ostracum of the genus *Inoceramus*. The clastic quartz admixture (silt and very fine sand) occurs there. Their assignation to the Chmielowa Formation is also questionable.

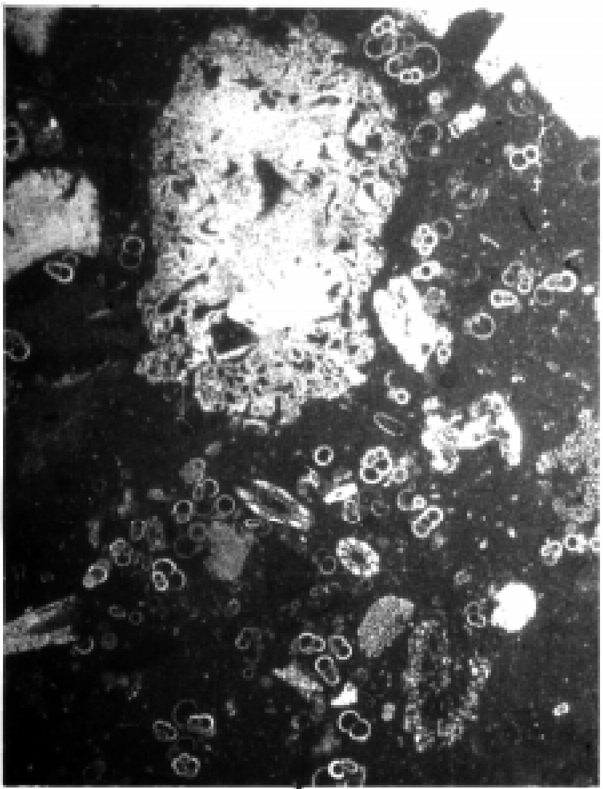
In the rich foraminiferal association (Fig. 4, thin s. 22980, 23838) planktonic specimens prevail — *Hedbergella delrioensis* (Carsey), *H. planispira* (Tappan), *Hedbergella* sp., *Planomalina (Globigerinelloides)* sp., *Praeglobotruncana delrioensis* (Plummer), *P. stephani* (Gandolfi), *Praeglobotruncana* sp., *Thalmanninella appenninica* (Renz) (Pl. VII: Fig. 5), *T. brotzeni* (Sigal) (Pl. VII: Figs. 1, 4, 6), *T. deeckei* (Franke). The benthic foraminifers are rare and they are represented by the genus as: *Dorothia* Plummer and *Lenticulina* Lamarck. This association corresponds to the Thalmanninella deeckei foraminiferal Zone (according to Salaj 1996) and indicates the upper part of Early Cenomanian.

Greyish-red to brick-red marls (1 m thick) (beginning of Skalski Marl Member of Jaworki Formation sensu Birkenmajer 1977) (Fig. 3, samp. 3) overlie the red marly limestones. Apart from the amount of foraminiferal fauna (Fig. 4, thin s. 22977, 23840) they contain fish scales, ostracum segments of the genus *Inoceramus* and ostracods and clastic quartz admixture (silt size).

The planktonic foraminiferal species and genera — *Dicarinella biconvexa* (Samuel & Salaj), *D. hagni* (Scheibnerová), *D. imbricata* (Mornod), *D. oraviensis oraviensis* (Scheibnerová), *Hedbergella planispira* (Tappan), *Hedbergella* sp., *Heterohelix* sp., *Planomalina (Globigerinelloides)* sp., *Praeglobotruncana* cf. *stephani* (Gandolfi), *Whiteinella* sp. prevail in the association. The benthic specimens are represented by *Dorothia* sp. and *Lenticulina* sp. The composition of the assemblage represents the Helvetoglobotruncana helvetica foraminiferal Zone (Salaj 1996).

Plate I: Fig. 1. Association of microfossils (see echinoderm ossicle bored by algae) in biomicrite-wackestone, Upper Albian, samp. 2a, thin s. 22799, 27×. **Fig. 2.** Fragment of fish bone in wackestone. Upper Albian, samp. 2a, thin s. 22799, 45×. **Fig. 3.** Foraminiferal packstone with *Thalmanninella deeckei* (Franke). Lower Cenomanian, samp. 2c, thin s. 22980, 27×. **Fig. 4.** Bioturbation and lamina in silicified limestone, lower Turonian (except for the lowermost part)–?middle Turonian, samp. 4, thin s. 22975, 27×.

Plate II: Fig. 1. Radiolarian biomicrite-wackestone with foraminifers. early Turonian (except for the lowermost part)–?middle Turonian, samp. 5, thin s. 22983, 27×. **Fig. 2.** Radiolarian biomicrite-wackestone with *Dicarinella oraviensis oraviensis* (Scheibnerová), early Turonian (except for the lowermost part)–?middle Turonian, samp. 5, thin s. 22983, 27×. **Fig. 3.** Lamination in silicified limestone, early Turonian (except for the lowermost part)–?middle Turonian, samp. 5, thin s. 22983, 27×. **Fig. 4.** *Falsomarginotruncata sinuosa* (Dorthault) and segment of ostracum of *Inoceramus*, Coniacian, samp. 9, thin s. 22973, 45×.



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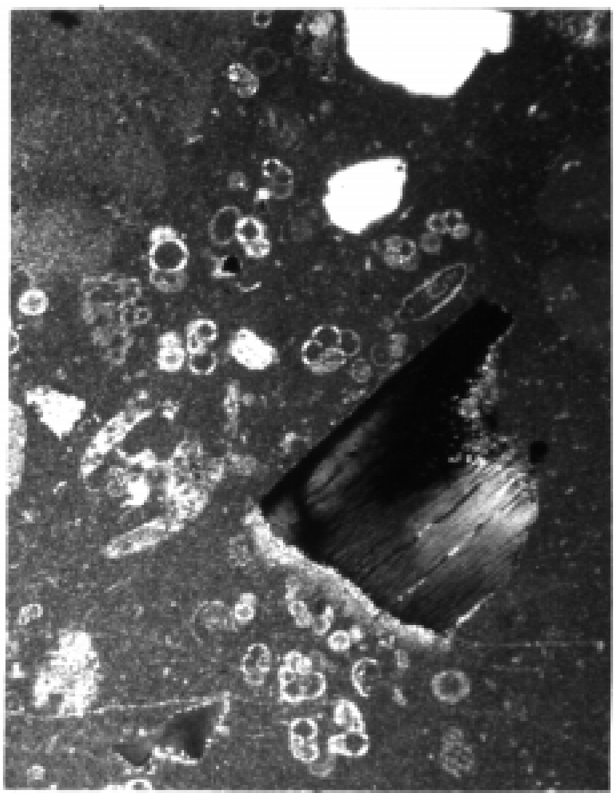

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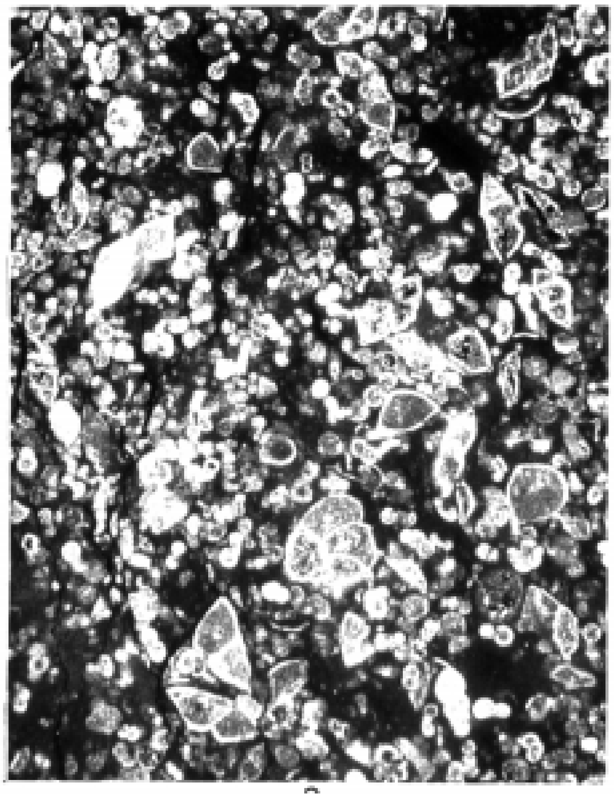

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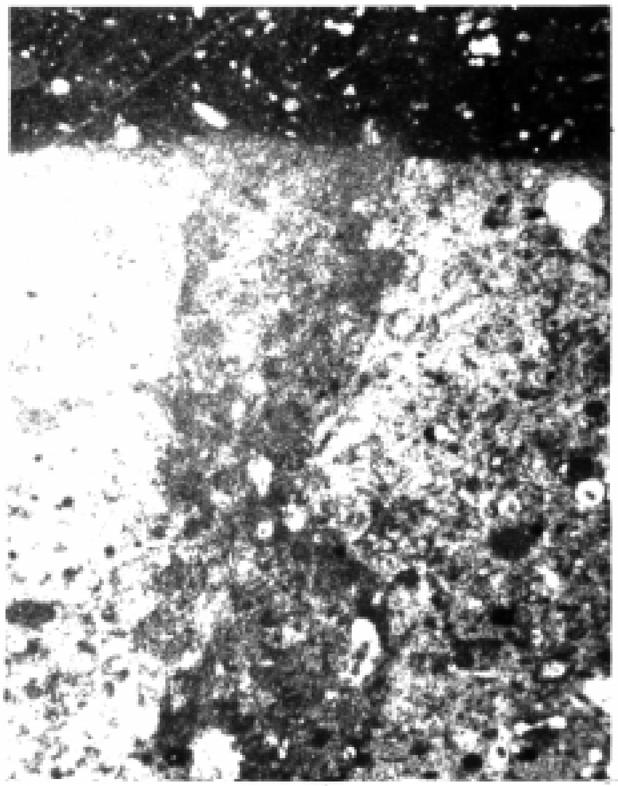

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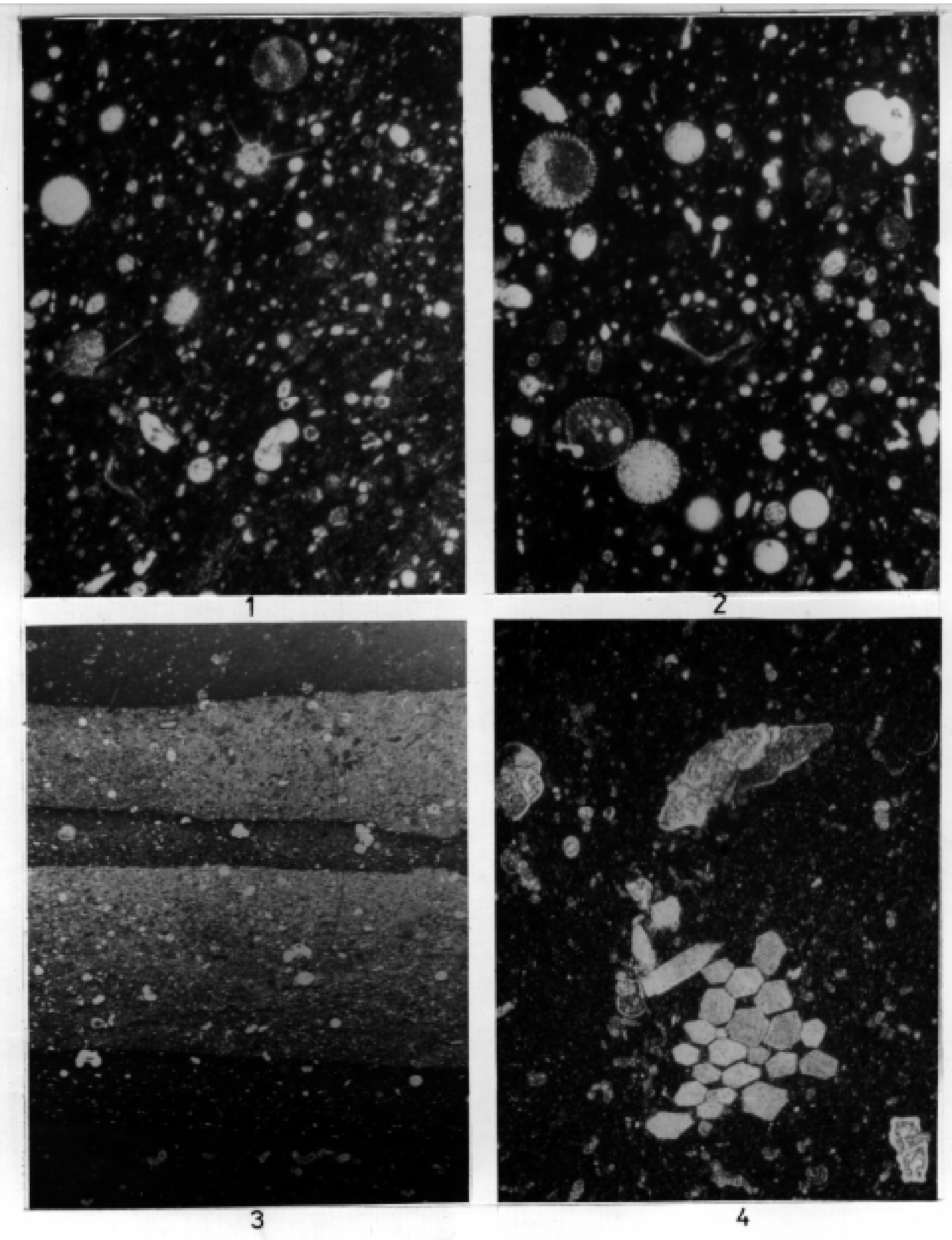
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A similar succession was described by Andrusov (in Andrusov & Samuel 1973). The Albian limestones (Chmielowa Fm.) with the genus *Ticinella* are followed by red marls of Middle Turonian age.

Sequence of Skalski Marl Member of Jaworki Formation continues with grey-greenish silicified limestones with brownish-red cherts (0.5 m thick) (Fig. 3, samp. 4), which contain radiolarians and silicified foraminifers (Fig. 4, samp. 4, thin s. 22975). These sediments are laminated and rarely bioturbated (Pl. I: Fig. 4). They are overlain by light-grey-green silicified limestones and silicified marly limestones with grey-green and yellowish cherts (4–5 m thick) (Fig. 3, samp. 5, 6, 7) and with frequent parallel lamination (some laminae with predominance of silica) (Pl. II: Fig. 3). These sediments contain abundant silicified foraminifers and radiolarians (Pl. II: Figs. 1, 2).

The uppermost part of this silicified horizon is of grey-red colour and forms the transitional beds with the overlying light-grey-red and red marls (Fig. 3, samp. 8). It contains the abundance of radiolarians, which prevail over foraminifers. Sporadically clastic quartz admixture (silt) was found.

The foraminiferal microfauna in the samples 4–8 was analyzed from the thin sections (Fig. 4, thin s. 22975, 22983, 22982, 22801, 22804, 22797, 22796, 22978), (Pl. VIII) and from the residuum as well (Fig. 4, samp. 4–6, 8), (Pl. IX). It contained planktonic specimens only. Benthic specimens are very rare.

The composition of the assemblages indicates the same Helvetoglobotruncana helvetica foraminiferal Zone as sample 3. According to Salaj (1996) this zone represents Middle Turonian, but the latest biozonation of Robaszynski & Caron (1995) assigns it to the stratigraphic range — early Turonian (except for the lowermost part)-middle part of middle Turonian.

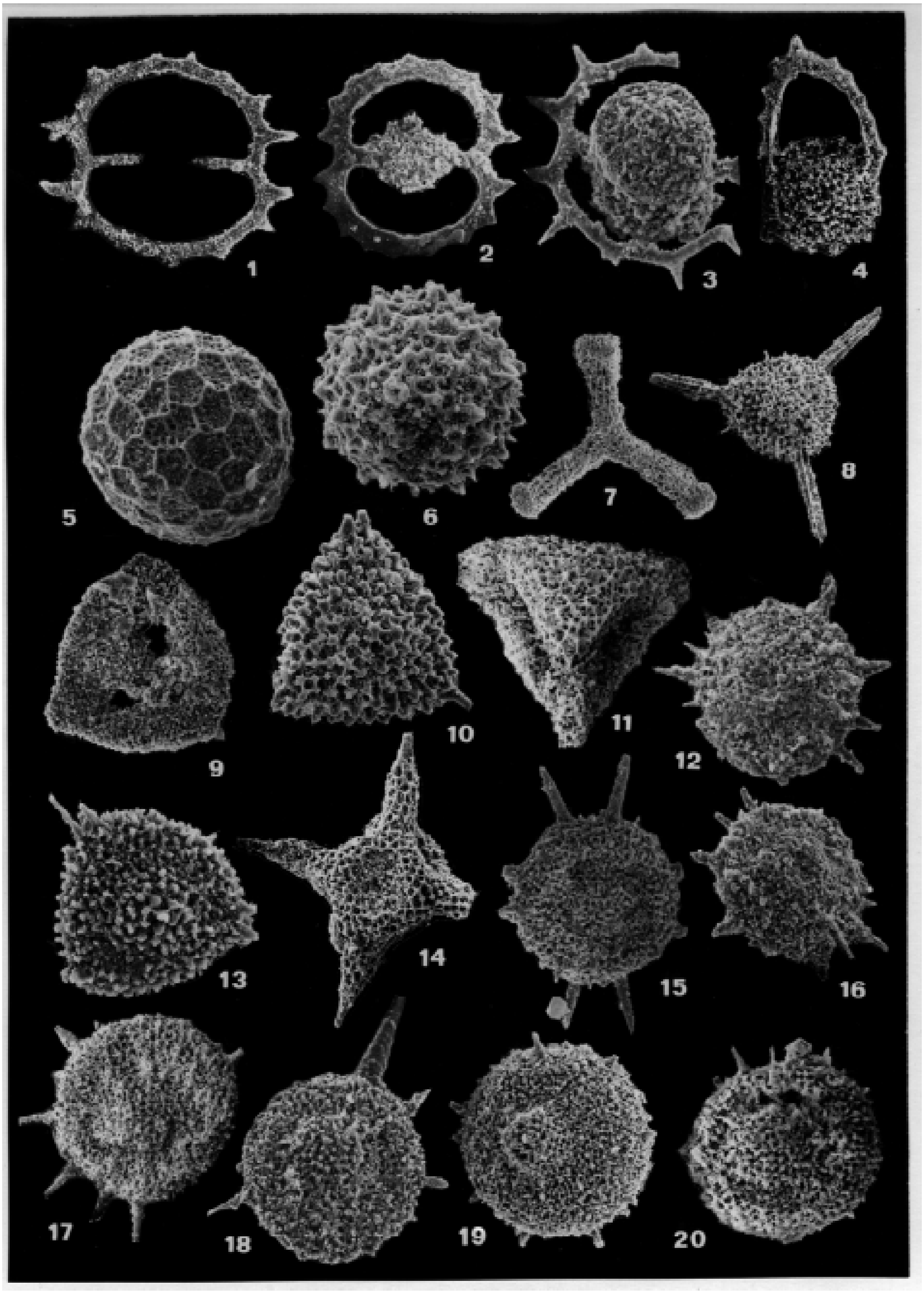
For the evaluation of the radiolarian microfauna (Fig. 5, samp. 5, 6, 8) (Pl. III–V) the detailed radiolarian zonation of O´Dogherty (1994), worked out for the middle Cretaceous of the Western Mediterranean was used. According to this zonation the associations represent the Superbum Zone, which begins in the lowermost Turonian. The top of this zone has not been recognized in this work. This zone is characterized by the first appearence of many species in the lower part and by the extinction of only a few species. The faunal changes of this zone reflect the favourable life conditions after a major interval of anoxia (l.c.).

The Superbum Zone comprises Unitary Associations UA 20 (in the lower part) and the overlying — UA 21. The index taxon of this zone is *Alievium superbum* (Squinabol). In the samp. 6 (Fig. 5) similar species with the broken spines occurred (*A.* cf. *superbum*, Pl. III: Fig. 10). Further species — *Acanthocircus tympanum* O´Dogherty, *A. venetus* (Squinabol), *Cavaspongia antelopensis* Pessagno, *Crucella cachensis* Pessagno, *Dictyomitra undata* Squinabol and *Patellula ecliptica* O´Dogherty also appear in UA 20. The species *Dictyomitra montisserei* (Squinabol) finishes in the same Unitary Association, but *Dictyomitra multicostata* Zittel, which appears in the following UA 21 can rarely be observed in samp. 8 (Fig. 5; Pl. IV: Fig. 14).

Plate III: Radiolarian microfauna in silicified limestone and marl — early Turonian (except for the lowermost part)-?middle Turonian. **Fig. 1.** *Acanthocircus venetus* (Squinabol) — samp. 6-3009, 150×. **Fig. 2.** *Acanthocircus venetus* (Squinabol) — samp. 8, 4626, 150×. **Fig. 3.** *Acanthocircus tympanum* O´Dogherty — samp. 8, 4649, 180×. **Fig. 4.** *Vitorfus campbelli* Pessagno — samp. 6, 3291,195×. **Fig. 5.** *Archaeocenosphaera? mellifera* O´Dogherty — samp. 8, 4625, 165×. **Fig. 6.** *Praeconocaryomma lipmanae* Pessagno — samp. 6, 3352, 190×. **Fig. 7.** *Pessagnobrachia fabianii* (Squinabol) — samp. 6, 3142, 90×. **Fig. 8.** *Pseudoaulophacus putahensis* Pessagno — samp. 6, 3005, 130×. **Fig. 9.** *Cavaspongia* sp. — samp. 8, 4614, 140×. **Fig. 10.** *Alievium* cf. *superbum* (Squinabol) — samp. 6, 3357, 200×. **Fig. 11.** *Cavaspongia antelopensis* Pessagno — samp. 6, 3299, 160×. **Fig. 12.** *Patellula* cf. *heroica* O´Dogherty — samp. 8, 4638, 170×. **Fig. 13.** *Pseudoaulophacus putahensis* Pessagno — samp. 8, 4611, 200×. **Fig. 14.** *Crucella cachensis* Pessagno — samp. 6, 3341, 135×. **Fig. 15.** *Patellula ecliptica* O´Dogherty — samp. 6, 3143, 150×. **Fig. 16.** *Patellula* cf. *heroica* O´Dogherty — samp. 8, 4645,150×. **Fig. 17.** *Patellula ecliptica* O´Dogherty — samp. 6, 3173, 150×. **Fig. 18.** *Patellula ecliptica* O´Dogherty — samp. 8, 4598, 170×. **Fig. 19.** *Patellula ecliptica* O´Dogherty — samp. 6, 3358, 135×. **Fig. 20.** *Patellula ecliptica* O´Dogherty — samp. 6, 3329, 165×.

Plate IV: Radiolarian microfauna in silicified limestone and marl — early Turonian (except for the lowermost part)-?middle Turonian. **Figs. 1–7, 9, 11** *Patellula andrusovi* Ožvoldová. n.sp., samp. 8: 1 — 0695, 140×; 2 — the lateral view of Fig. 5, 4654, 120×; 3 — 3156, 160×; 4 — 4651, 130×; 5 — holotype, 4655, 120×; 6 — the lateral view of Fig. 3, 3158, 165×; 7 — 4642, 135×; 9 — the lateral view of Fig. 3, 3159, 170×; 11 — 0698, 180×. **Fig. 8.** *Patellula* sp. A — samp. 6, 3154, 185×. **Fig. 10**. *Patellula ecliptica* O´Dogherty — samp. 6, 3150, 165×. **Fig. 12.** *Patellula* sp. B — samp. 8, 4644, 170×. **Fig. 13.** *Patellula* sp. B — the lateral view of Fig. 12, samp. 8, 4643, 170×. **Fig. 14.** *Dictyomitra multicostata* Zittel — samp. 8, 0697, 220×. **Fig. 15.** *Pseudodictyomitra pseudomacrocephala* (Squinabol) — samp. 5, 3361, 120×. **Fig. 16.** *Stichomitra stocki* (Campbell & Clark) — samp. 6, 3354, 400×. **Fig. 17.** *Holocryptocanium barbui* Dumitrica — samp. 5, 3364, 160×. **Fig. 18.** *Ultranapora* cf. *dumitricai* Pessagno — samp. 6, 3187, 250×.

Plate V: Radiolarian microfauna in silicified limestone and marl — early Turonian (except for the lowermost part)-?middle Turonian. **Fig. 1.** *Dictyomitra montisserei* (Squinabol) — samp. 6, 3345, 200×. **Fig. 2.** *Dictyomitra montisserei* (Squinabol) — samp. 8, 4612, 140×. **Fig. 3.** *Dictyomitra montisserei* (Squinabol) — samp. 6, 3144, 195×. **Fig. 4.** *Dictyomitra montisserei* (Squinabol) — samp. 5, 3367, 250×. **Fig. 5.** *Dictyomitra montisserei* (Squinabol) — samp. 8, 4601, 270×. **Fig. 6.** *Dictyomitra montisserei* (Squinabol) — samp. 8, 4609, 170×. **Fig. 7.** *Stichomitra communis* Squinabol — samp. 6, 3155, 130×. **Fig. 8.** *Dictyomitra undata* Squinabol — samp. 6, 3347, 195×. **Fig. 9.** *Dictyomitra undata* Squinabol — samp. 5, 3370, 220×. **Fig. 10.** *Pseudodictyomitra pseudomacrocephala* (Squinabol) — samp. 6, 3176, 200×. **Fig. 11.** *Dictyomitra* cf. *formosa* Squinabol — samp. 8, 4627, 250×. **Fig. 12.** *Dictyomitra formosa* Squinabol — samp. 5, 3362, 180×. **Fig. 13.** *Diacanthocapsa* sp. — samp. 8, 4604, 280×. **Fig. 14.** *Diacanthocapsa ovoidea* Dumitrica — samp. 8, 4647, 250×. **Fig. 15.** *Cryptamphorella conara* (Foreman) — samp. 6, 3348, 350×. **Fig. 16.** *Cryptamphorella conara* (Foreman) — the apical view of Fig. 15, samp. 6, 3349, 350×. **Fig. 17.** *Diacanthocapsa* cf. *brevithorax* Dumitrica — samp. 8, 4605, 300×. **Fig. 18.** *Stichomitra stocki* (Campbell & Clark) — samp. 5, 3380, 280×. **Fig. 19.** Gen. et sp. indet. — samp. 8, 4593, 240×.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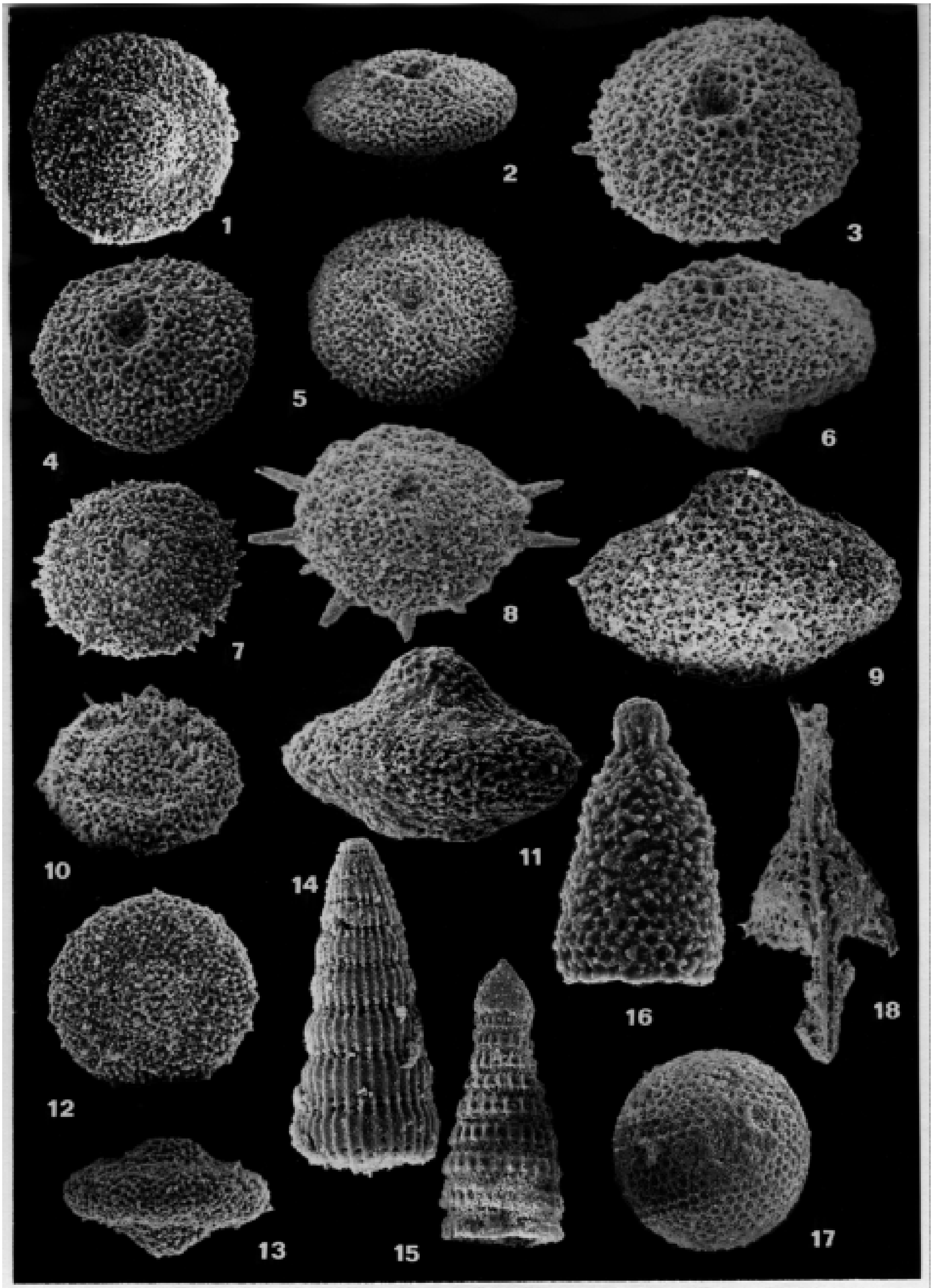
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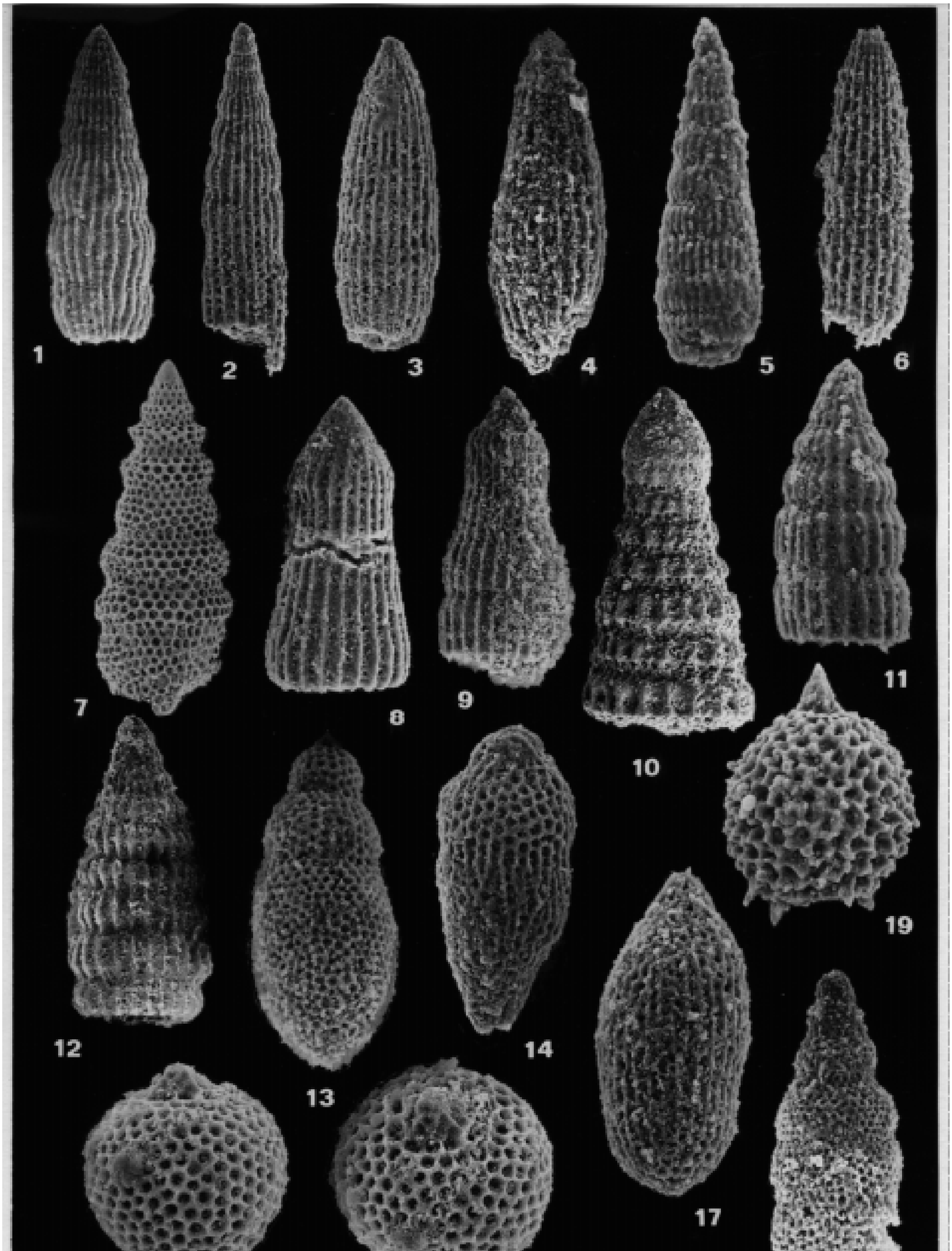
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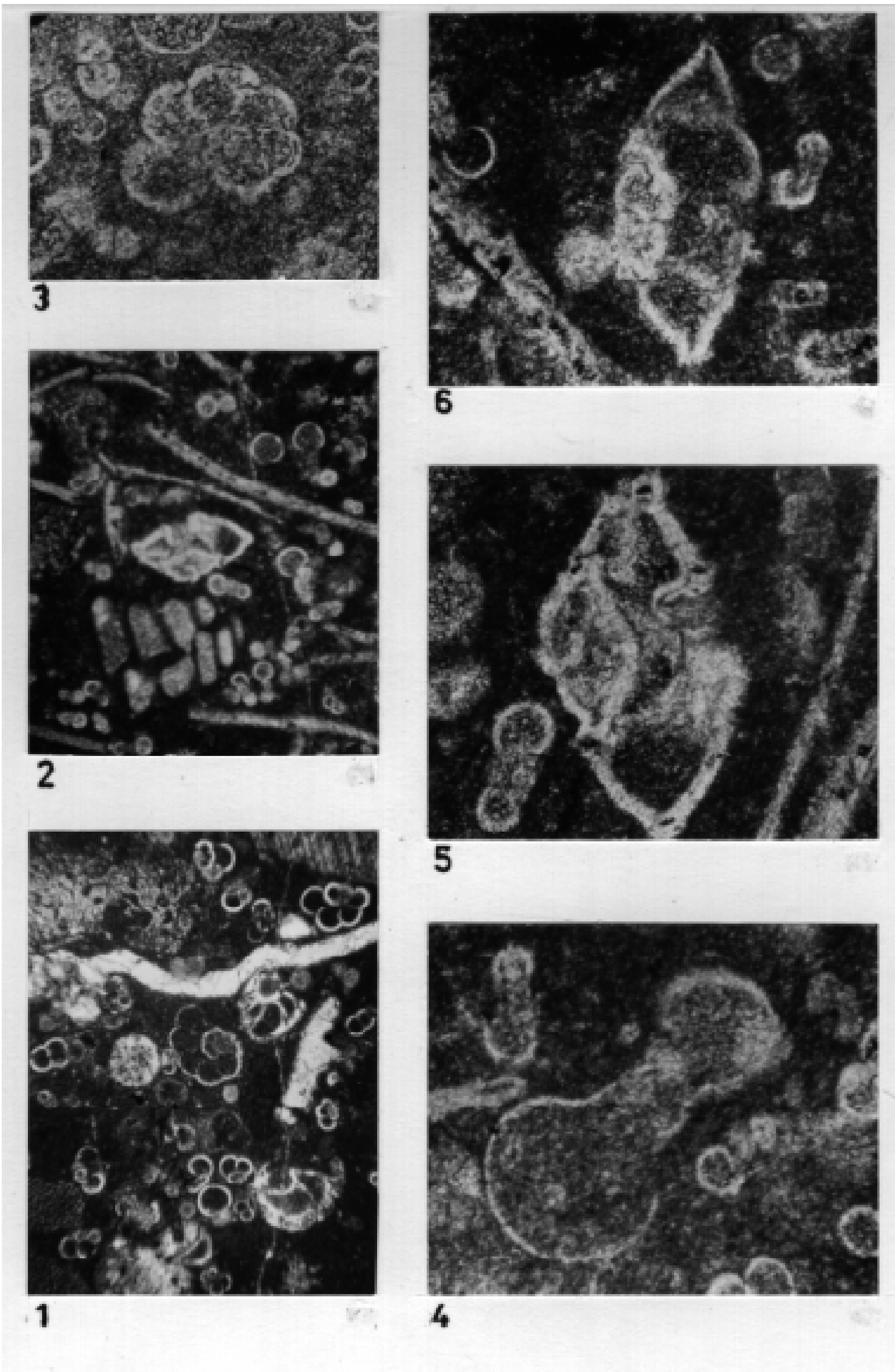


Plate VI: Fig. 1. Association of planktonic and benthonic forams of Planomalina (Planomalina) buxtorfi – Thalmanninella appenninica balernaensis Zone, Late Albian, thin s. 22799, 45×. **Fig. 2.** *Dorothia oxycona* (Reuss) — below *Thalmanninella ticinensis ticinensis* (Gandolfi) — center, Late Albian, thin s. 22799, 45×. **Fig. 3.** *Planomalina (Planomalina) buxtorfi* (Gandolfi), Late Albian, thin s. 22799, 130×. **Fig. 4.** *Biticinella breggiensis* (Gandolfi), Late Albian, thin s. 22799, 127×. **Fig. 5.** *Thalmanninella ticinensis ticinensis* (Gandolfi), Late Albian, thin s. 22799, 127×. **Fig. 6.** *Thalmanninella appenninica balernaensis* (Gandolfi), Late Albian, thin s. 22799, 125×.

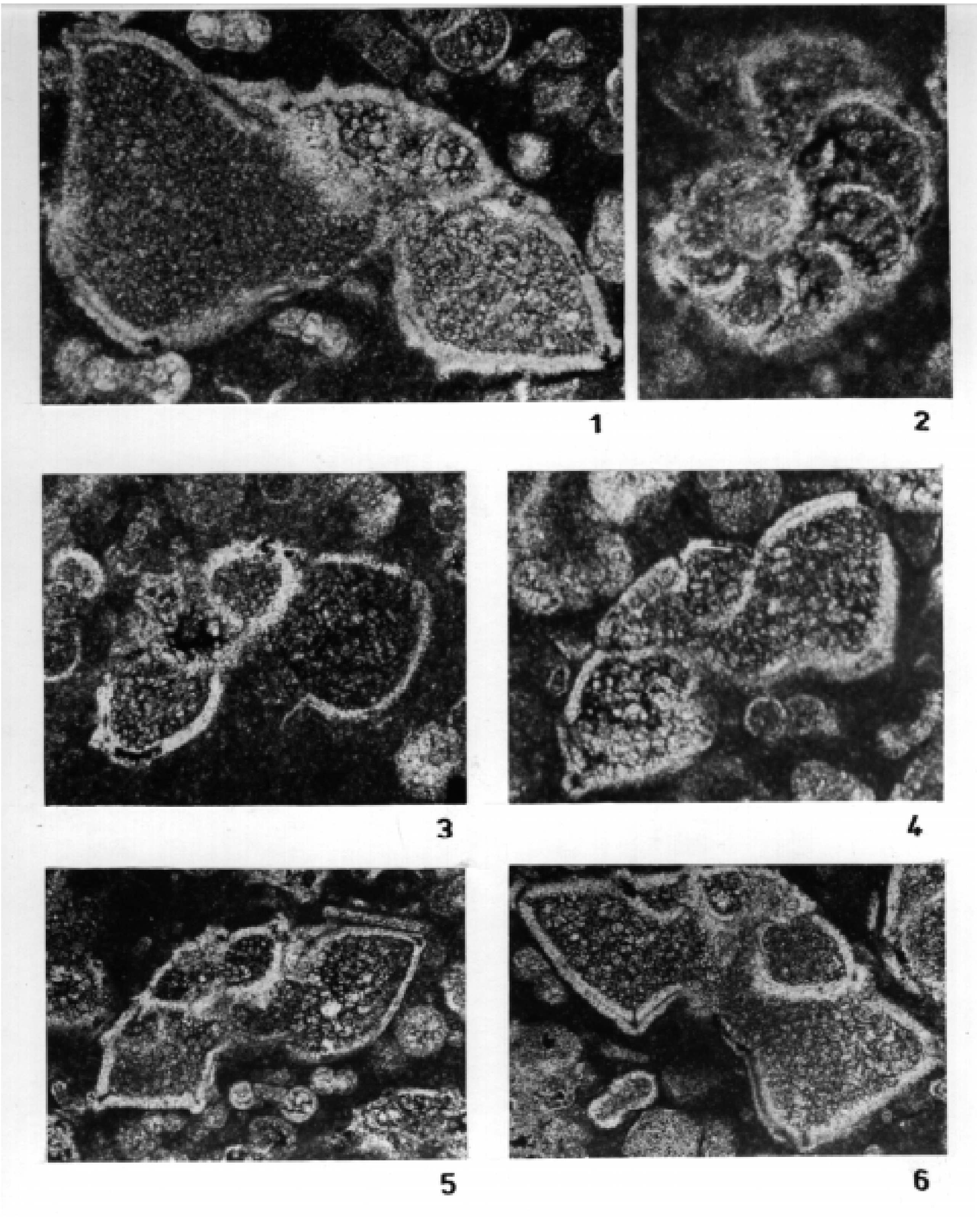


Plate VII: Figs. 1, 4, 6. *Thalmanninella brotzeni* (Sigal), thin s. 22980. Fig. 1 — 218×, Fig. 4 — 185×, Fig. 6 — 130×. Thalmanninella deeckei Zone, upper part of Early Cenomanian. **Fig. 2.** *Planomalina (Planomalina) buxtorfi* (Gandolfi), thin s. 22981, 175×, Planomalina (Planomalina) buxtorfi–Thalmanninella appenninica balernaensis Zone, Late Albian. **Fig. 3.** *Praeglobotruncana stephani* (Gandolfi) thin s. 22981, 170×, Zone see Fig. 2. Late Albian. **Fig. 5.** *Thalmanninella appenninica* (Renz), thin s. 22980, 125×, Thalmanninella deeckei Zone, upper part of Early Cenomanian.

Sample	5	6	8
Radiolarian microfauna			
Acanthocircus tympanum O´ DOGHERTY		x	x
Acanthocircus venetus (SQUINABOL)		x	x
Alievium cf. superbum (SQUINABOL)		x	
Archaeocenosphaera ? mellifera O´ DOGHERTY			x
Cavaspongia antelopensis PESSAGNO		x	x
Cavaspongia sp.			x
Crucella cachensis PESSAGNO		x	x
Cryptamphorella conara (FOREMAN)		x	
Diacanthocapsa ovoidea DUMITRICÃ			x
Diacanthocapsa cf. brevithorax DUMITRICÃ			x
Diacanthocapsa sp.			x
Dictyomitra formosa SQUINABOL	x	x	
Dictyomitra montisserei (SQUINABOL)	x	x	x
Dictyomitra undata SQUINABOL	x	x	x
Dictyomitra multicostata ZITTEL			x
Holocryptocanium barbui DUMITRICÃ	x		
Patellula ecliptica O´ DOGHERTY		x	x
Patellula cf. heroica O´ DOGHERTY			x
Patellula andrusovi n. sp.			x
Patellula sp. A		x	
Patellula sp. B			x
Praeconocaryomma lipmanae PESSAGNO		x	x
Praeconocaryomma universa PESSAGNO			x
Pseudoaulophacus putahensis PESSAGNO		x	x
Pessagnobrachia fabianii (SQUINABOL)		x	
Pseudodictyomitra pseudomacrocephala (SQUINABOL)	x	x	
Stichomitra communis SQUINABOL	x	x	x
Stichomitra stocki (CAMPBELL et CLARK)	x	x	x
Ultranapora cf. dumitricai PESSAGNO		x	
Vitorfus campbelli PESSAGNO		x	

Fig. 5. Distribution of radiolarian microfauna in the silicified limestone and marl.

The associations, therefore, can be assigned to the early Turonian (except for the lowermost part). The presence of middle Turonian is questionable.

It can be confirmed by the investigation of Thurow (1988) that the species *Pseudodictyomitra pseudomacrocephala* (Squinabol) (Pl. V: Fig. 10) finishes above the top boundary of CTBE (Cenomanian-Turonian Boundary Event, which comprises the uppermost part of Cenomanian and the lowermost part of Turonian) and the species *Dictyomitra multicostata* Zittel (Pl. IV: Fig. 14) appears a little below this boundary.

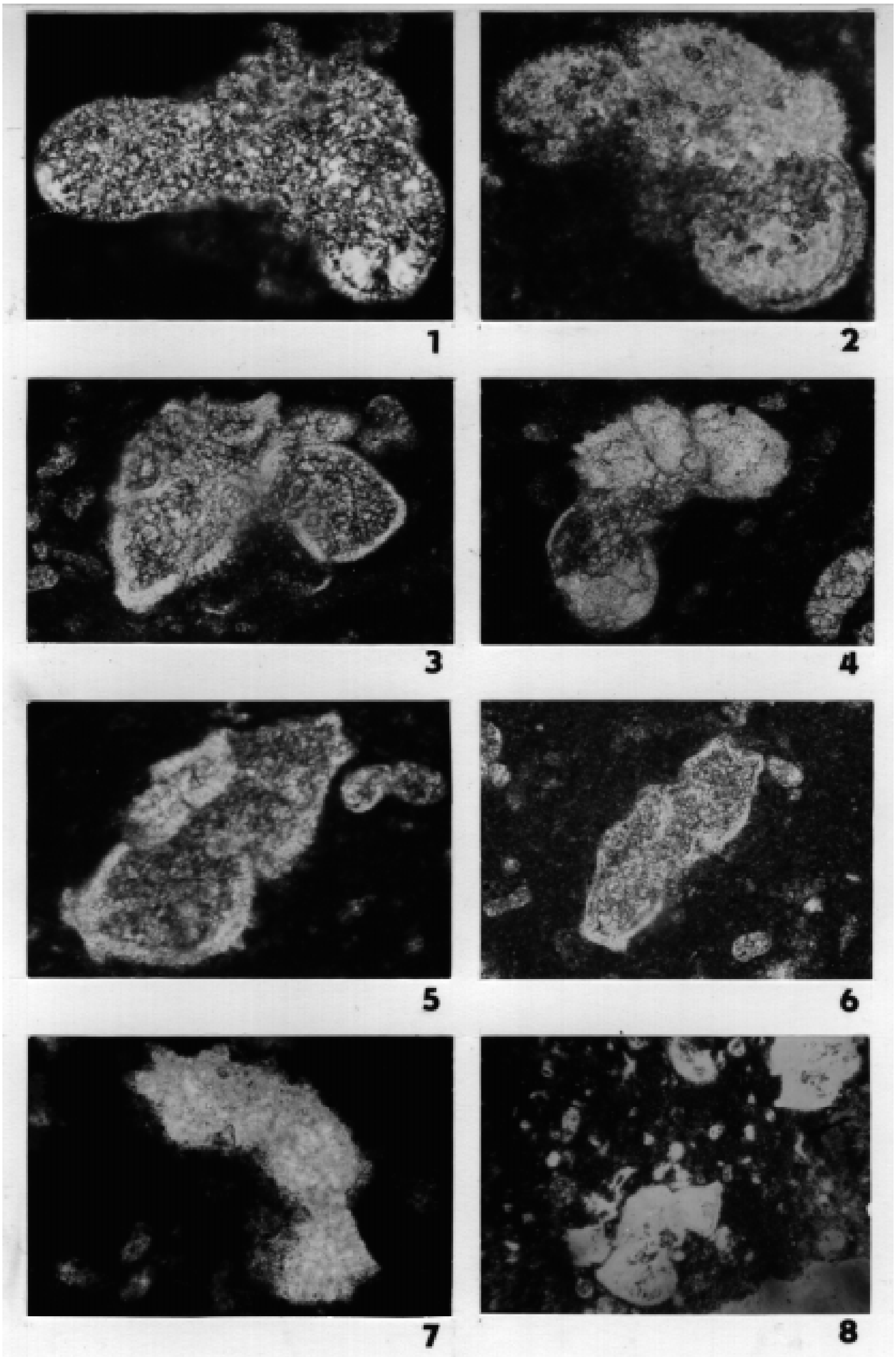
In the overlying complex of the red marls (Fig. 3, samp. 9, 10) (Pustelnia Marl Member of Jaworki Formation sensu Birkenmajer 1977) the sediments contain foraminiferal associations, fish remnants and ostracum segments of the genus *Inoceramus*. Terrigenous silt quartz was rarely found.

In sample 9 the foraminiferal microfauna (Fig. 4, thin s. 22973) is represented by the planktonic specimens only — *Falsomarginotruncata coronata* (Bolli), *F. pseudolinneiana* (Pessagno) (Pl. X: Fig. 3), the transitional form between *F. sinuosa* (Porthault) and *F. angusticarinata* (Gandolfi) (Pl. X: Fig. 4), *F. sinuosa* (Porthault) (Pl. II: Fig. 4), *Heterohelix* sp., *Hedbergella delrioensis* (Carsey), *Hedbergella* sp., *Whiteinella* cf. *inornata* (Bolli), *Whiteinella* sp. Benthic specimens are very rare. This composition indicates the Coniacian age. The presence of the index fossil *Dicarinella concavata* (Brotzen) was not determined. It can be explained by the absence of the optimal conditions for its origin (a deeper water environment).

In sample 10 the foraminiferal microfauna (Fig. 4, thin s. 22976) contains *Hedbergella* sp., *Heterohelix* sp., *Globotruncana arca* (Cushman) (Pl. X: Fig. 1), *Globotruncana* cf. *arca*

→

Plate VIII: Foraminifers of Helvetoglobotruncana helvetica Zone, middle Turonian (sensu Salaj 1996), early Turonian (except for the lowermost part)–middle part of middle Turonian (sensu Robaszynski & Caron 1995). **Fig. 1.** *Dicarinella oraviensis trigona* (Scheibnerová), silicified form, thin s. 22801, 130×. **Figs. 2, 3.** *Dicarinella oraviensis oraviensis* (Scheibnerová), silicified form, thin s. 22801, 22804, 130×, 135×. **Fig. 4.** *Helvetoglobotruncana helvetica* (Bolli), thin s. 22804, 120×. **Fig. 5.** Transitional form between *Dicarinella imbricata* (Mornod) and *Dicarinella hagni* (Scheibnerová), thin s. 22804, 130×. **Fig. 6.** *Dicarinella imbricata* (Mornod). thin s. 22804. 130×. **Fig. 7.** *Dicarinella biconvexa* (Samuel & Salaj), thin s. 22797, 120×. **Fig. 8.** *Dicarinella biconvexa gigantea* (Samuel & Salaj), thin s. 22796, 45×.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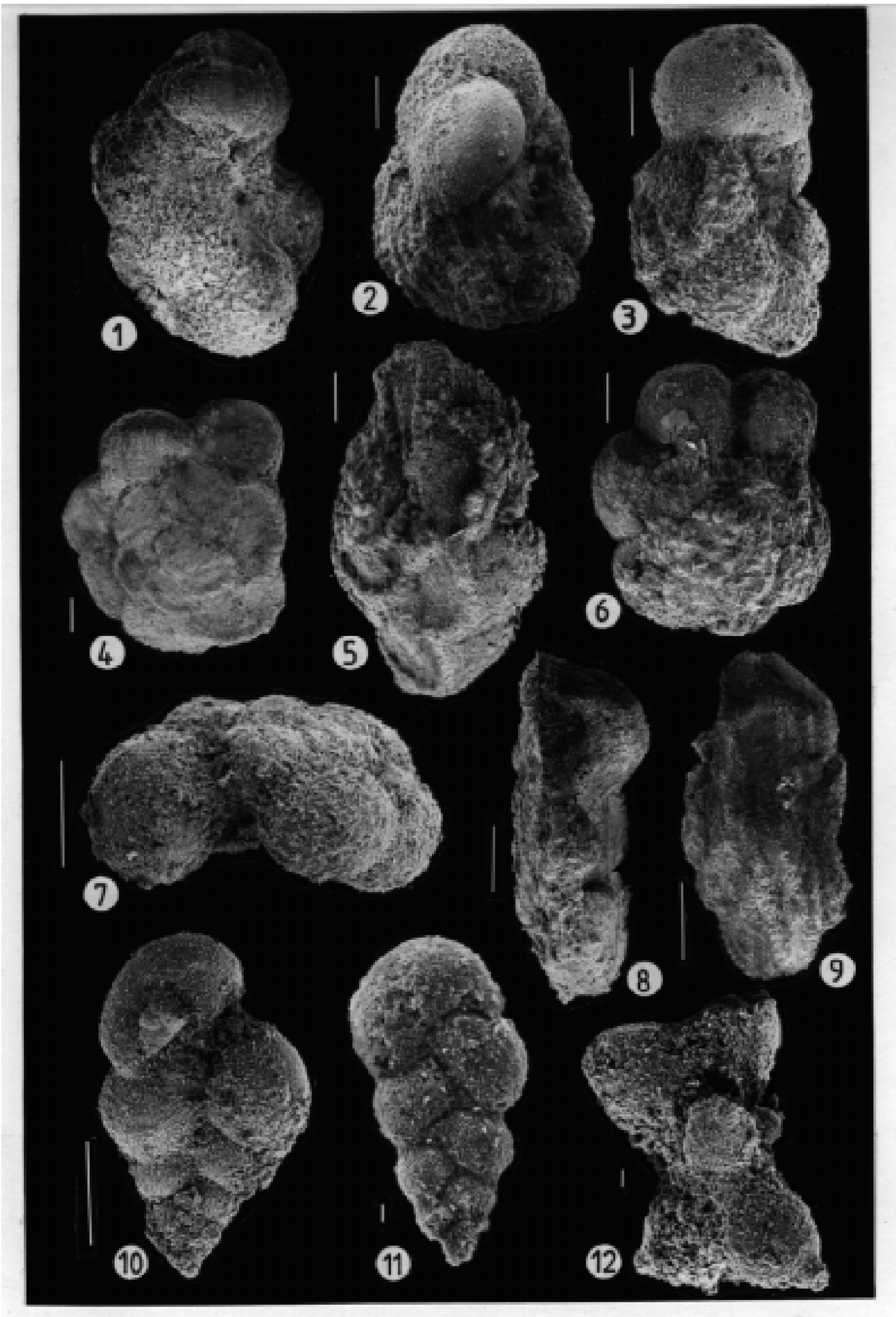

Plate IX: Foraminifers of Helvetoglobotruncana helvetica Zone, middle Turonian (sensu Salaj 1996), early Turonian (except for the lowermost part)–middle part of middle Turonian (sensu Robaszynski & Caron 1995), line code 10 µm. **Figs. 1, 2.** *Dicarinella oraviensis oraviensis* (Scheibnerová). Fig. 1 sample 5, Fig. 2 sample 8. **Fig. 3.** *Dicarinella oraviensis trigona* (Scheibnerová), sample 8. **Figs. 4, 5.** *Dicarinella biconvexa gigantea* (Samuel & Salaj), sample 5. **Fig. 6.** *Dicarinella carpathica* (Scheibnerová), sample 8. **Fig. 7.** *Whiteinella gigantea* (Lehmann), sample 5. **Fig. 8.** *Falsomarginotruncana renzi* (Gandolfi), sample 5. **Fig. 9.** Transitional form between *Dicarinella imbricata* (Mornod) and *Dicarinella hagni* (Scheibnerová), sample 8. **Fig. 10.** *Heterohelix reussi* (Cushman), sample 5. **Fig. 11.** *Heterohelix globulosa* (Ehrenberg), sample 4. **Fig. 12.** *Schackoina bicornis* (Reichel), sample 5.

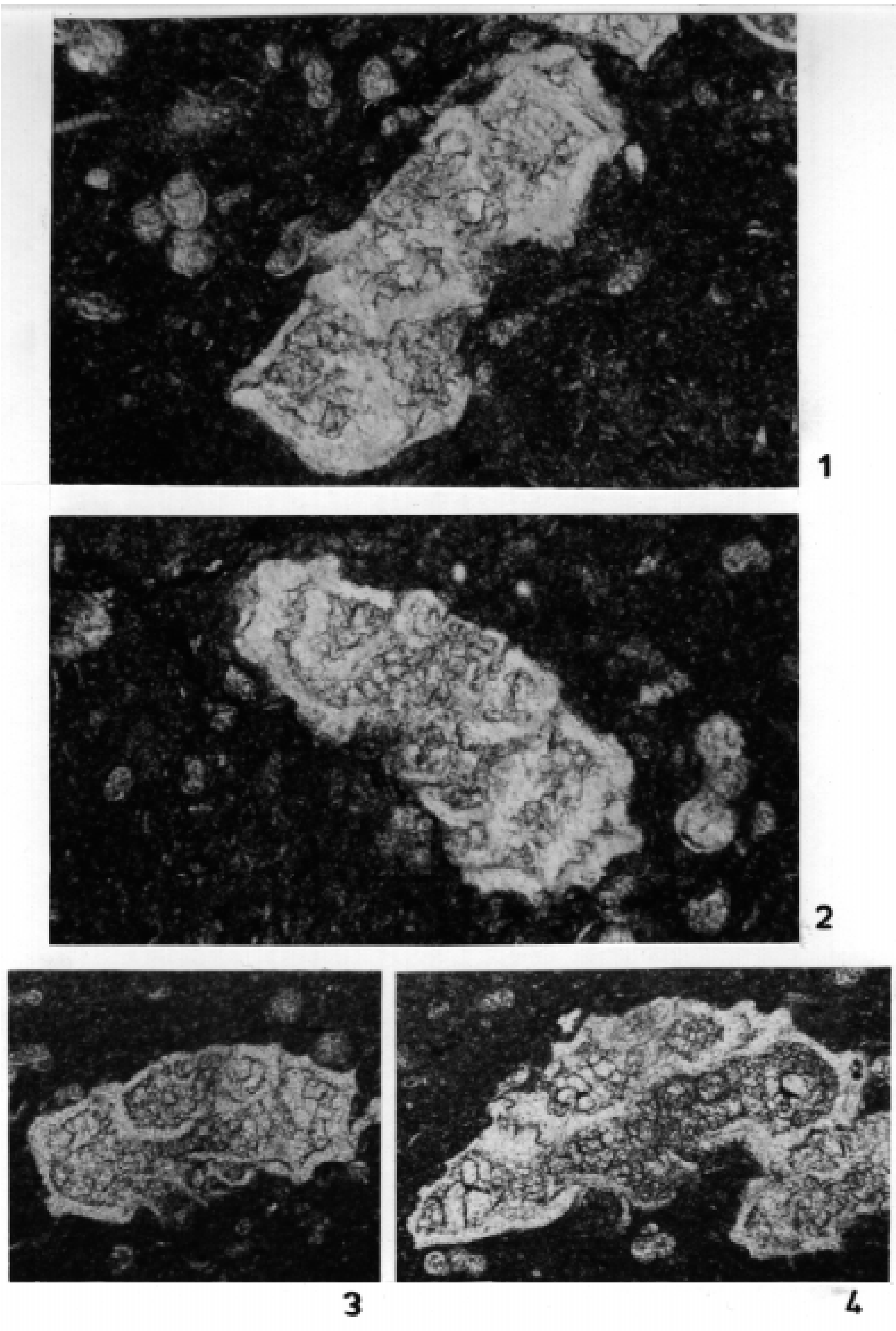

Plate X: Fig. 1. *Globotruncana arca* (Cushman), Zone Globotruncana arca, Early Campanian, thin s. 22976, 165×. **Fig. 2.** *Globotruncana* cf. *arca* (Cushman), Zone Globotruncana arca, Early Campanian, thin s. 22976, 170×. **Fig. 3.** *Falsomarginotruncana pseudolinneiana* (Pessagno), Coniacian, thin s. 22973, 120×. **Fig. 4.** Transitional form between *Falsomarginotruncana angusticarinata* (Gandolfi) and *Falsomarginotruncana sinuosa* (Porthault), Coniacian, thin s. 22973, 125×.

(Cushamn) (Pl. X: Fig. 2) and *G. linneiana* (D´Orbigny). Benthic specimen do not occur there. The assemblage most probably indicates the Globotruncana arca Zone — Lower Campanian (according to Salaj 1996).

The above mentioned data leads to the conclusion, that the stratigraphic position of the silicified horizons in the Cenomanian-Campanian sediments of the Czorsztyn Succession of the Pieniny Klippen Belt requires further investigation in Slovak as well as Polish territory.

Conclusions

A review of recent results shows that there are several stratigraphic horizons with silicified beds containing radiolarians in the Albian-Campanian sediments of the Czorsztyn Succession of the Pieniny Klippen Belt, which were identified in Polish as well as Slovak territory.

Our studied section (Fig. 3, samp. 1) in the Czorsztyn Succession of the Pieniny Klippen Belt begins with the upper part of the Lysa Limestone Formation (Birkenmajer 1977) (probably Upper Berriasian-Valanginian) and with the limestones of the Chmielowa Formation (l.c.) (Fig. 3, samp. 2b, probably 2a, 2c) (Upper Albian–Lower Cenomanian according to foraminiferal microfauna). Between these formations there is a hiatus/erosion and break of sedimentation. Rocks of the Middle-Upper Cenomanian and lowermost Turonian have not been found.

The section continues with Turonian beds (the upper part of Lower Turonian–?middle part of Middle Turonian according to the evaluation of foraminiferal and radiolarian microfauna) in facies of brick-red marls and grey-green silicified limestones and marls with reddish-brown, grey-green and scarcely yellowish cherts (Fig. 3, samp. 3–8) (Skalski Marl Member of Jaworki Formation) (l.c.). The upper part of these sediments has irregular red spots, in the uppermost part it is of grey-red colour only.

The transition to the overlying brick-red and red marls (Fig. 3, samp. 9, 10) (Pustelnia Marl Member of Jaworki Formation) (l.c.) is continuous. According to their foraminiferal microfauna these marls are ?Late Turonian to Early Campanian in age.

In the Polish part of the Pieniny Klippen Belt the occurrence of the silicified limestones and marls with foraminifers and radiolarians in the above mentioned stratigraphic interval is not known. At first the Lorencowe Chert Bed (Skalski Marl Member of Jaworki Formation) (l.c.) was assigned (Birkenmajer 1977) to the Upper Cenomanian–?Lower Turonian, but in later investigations they were assigned to the Pustelnia Marl Member (Jaworki Formation) (l.c.) on the Santonian-Campanian boundary (Jednorowska 1979; Birkenmajer & Jednorowska 1987; K. Bak 1994; M. Bak 1994; M. Bak 1996).

The silicified limestones and marls in the studied section (Samp. 4–8) have the same lithological characteristics as the Lorencowe Chert Bed (Birkenmajer 1977; M. Bak 1966 etc.), but the age of their microfauna is different. It represents the stratigraphic range — Lower Turonian (except for the lowermost part)–?the middle part of Middle Turonian.

As regards the Altana Shale Bed (Skalski Marl Member of Jaworki Formation) this sequence is represented by black-blue and greenish-black (sometimes yellow-green) marly shales with radiolarians (Birkenmajer 1977), black, blue-greenish and olive-green marly shales (M. Bak 1996) of Late Cenomanian age (l.c.). Its lithological characteristics and the stratigraphical position differ from those of the sediments in the studied section.

Paleontological part

Subclass **Radiolaria** Müller 1858
Order **Polycystina** Ehrenberg 1838, emend. Riedel 1967
Suborder **Spumellariina** Ehrenberg 1875
Family **Pseudoaulophacidae** Riedel 1967
Genus **Patellula** Kozlova, in Petrushevskaja & Kozlova 1972
Type species: *Stylospongia planoconvexa* Pessagno 1963

Patellula andrusovi Ožvoldová, n.sp.
(Pl. IV: Figs. 1–7, 9, 11)

Holotype: No. 4655, Pl. IV: Figs. 2, 5, deposited in the Slovak National Museum in Bratislava (SNM-21514)
Type locality: Vršatecké Podhradie village — Biele Karpaty Mts.
Stratotype: lower Turonian (except for the lowermost part) –?the middle part of middle Turonian of the Czorsztyn Succession of the Pieniny Klippen Belt (Western Carpathians)
Denomination: This species is named in honour of Prof. Dimitrij Andrusov, the great Slovak geologist (1897–1976)
Description: Test large, circular to subcircular in outline, asymmetrical with respect to the equatorial plane. Upper surface with a strongly raised central area. Lower surface less elevated because of crater-like cavity in the center. Very small mostly broken spines can be observed in equatorial plane. Meshwork composed mostly of hexagonal pore frames with nodes at vertices.
Oval to circular depression at lower surface with protruding rim of tetragonal to polygonal pore frames, which form an irregular, sometimes double chain of large, oval pores.
Comparison: The very similar species *Patellula verteroensis* (Pessagno) has a meshwork of equilateral triangles around the central depression at the lower surface. The species *Patellula planoconvexa* (Pessagno) lacks the depression at the lower surface and has an extensively developed triangular meshwork there.

Dimensions: (mm)	holotype	min.	max.	mean
Diameter of cortical shell	0.333	0.285	0.352	0.330
Diameter of central area	0.125	0.114	0.151	0.130
Diameter of depression with protruding rim	0.108	0.093	0.120	0.104

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