Cretaceous Radiolaria from Niedzica Succession of the Pieniny Klippen Belt in Polish Carpathians

MARTA BĄK

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Three radiolarian-rich intervals have been recognized in the late Cretaceous marls of the Niedzica Succession in the Polish part of the Pieniny Klippen Belt, Carpathians. Associated planktonic foraminifers show that they correspond to major transgressive events in the latest Albian, at the Cenomanian/Turonian boundary, and in the late Turonian. The abundance of radiolarians seems to be related to increased silica content in the sediment (protecting their skeletons against the alkaline environment of the limestone) and presumably in the sea water. Forty-three species of Radiolaria identified in the strata show generally wide ranges from the late Albian to Coniacian. Some of the first or last occurrences correspond to those in Japan and southern Europe.

Key words: Pieniny Klippen Belt, Cretaceous, Radiolaria, biostratigraphy.

Marta Bąk, Instytut Nauk Geologicznych, Uniwersytet Jagielloński, Oleandry 2a, 30-063 Kraków, Poland.

Introduction

Pieniny Klippen Belt in its present form represents a tectonically strongly deformed zone which separates two major structural units: the Inner Carpathians to the south and Outer Carpathians to the north. During the Late Cretaceous time the central part of the Pieniny Klippen Belt represented an elevated Czorsztyn ridge whereas the Niedzica Succession in its northern zone (in Poland and Slovakia) was a region of pelagic and flyschoid sedimentation (Fig. 1). Despite this, radiolarians are rare fossils in the Cretaceous deposits of the Niedzica Succession. They are common only in a few horizons, where a higher content of silica enabled their preservation in the limestone rock matrix.

The presence of radiolarians in the Cretaceous strata of the Pieniny Klippen Belt was reported previously by Birkenmajer (1977) and Birken-

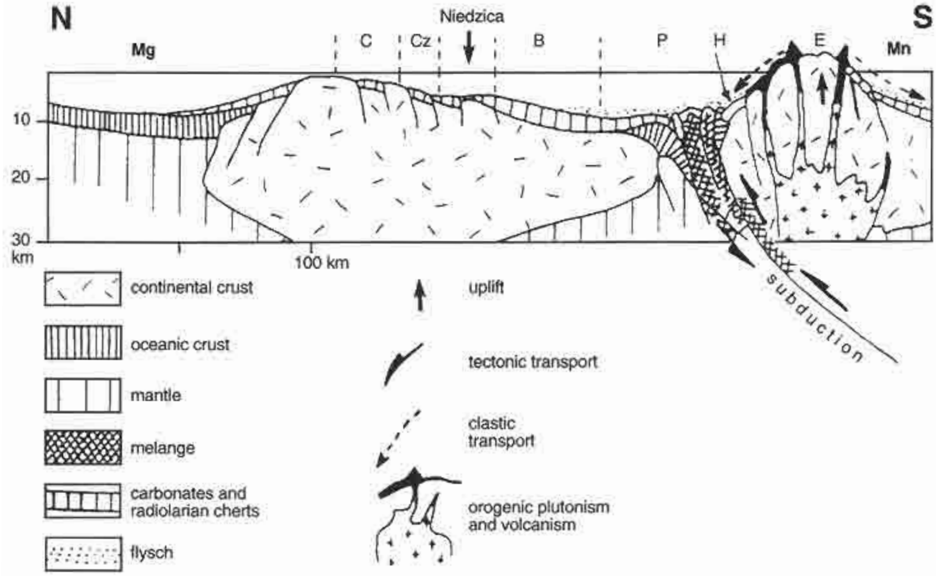


Fig. 1. Palinspastic-palaeotectonic section across the Pieniny Klippen Belt Basin in the Cenomanian (after Birkenmajer 1986).

majer & Jednorowska (1987), but the taxonomy and morphology of these microfossils remain poorly known. The main purpose of this paper is to describe in more detail the radiolarian assemblages of the Niedzica Succession and to interpret their occurrences in terms of the Cretaceous eustacy.

Exposures

Three sections of the Cretaceous Niedzica Succession were studied.

Kosarzyska Valley section. – The section is located in the river-bed of the Falsztyński creek (Fig. 2; Birkenmajer 1954, 1958; Alexandrowicz 1968; K. Bąk 1995). Green and black marly shales with black marly limestone intercalations representing the Rudina Member of the Kapuśnica Formation, occur at the base of the section (Figs 3, 4). These strata belong to the Late Albian *Rotalipora subticinensis–Rotalipora ticinensis* foraminiferal Zone. They are overlain by variegated and green-grey marls intercalated by black limestones and dark gray marly shales of the Brynczkowa Marl Member, which represents the *Rotalipora appenninica–Planomalina buxtorfi* and *Rotalipora brotzeni* foraminiferal Zones of Late Albian to Cenomanian age (Fig. 5). The Skalski Marl Member is represented in the section by red marls with bright gray marls and thin bedded sandstone intercalations. This member belongs to the *Rotalipora reichelli–Rotalipora greenhornensis* foraminiferal Zone (Cenomanian). There are red marls interbedded with sandstones of the Macelowa Marl Member in the

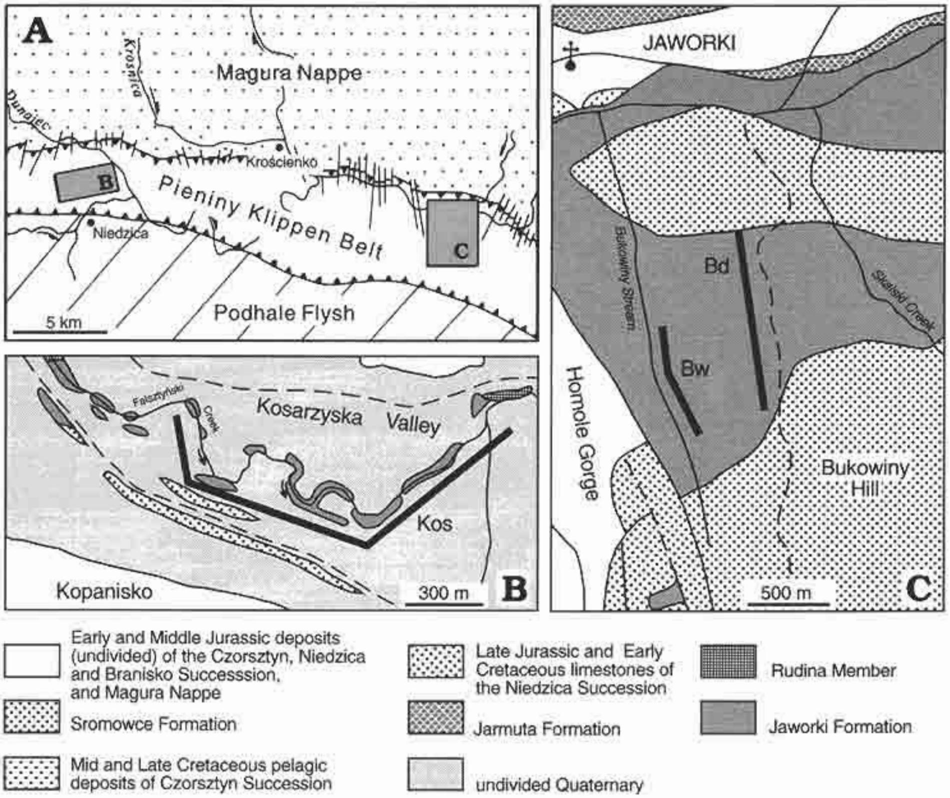


Fig. 2. ❑A. Location of the investigated sections in the Pieniny Klippen Belt, Carpathians (after Birkenmajer 1977, simplified). ❑B. Location of the Kosarzyska Valley section (after Birkenmajer 1958, simplified). ❑C. Location of the Bukowiny Valley and Bukowiny Hill sections (after Birkenmajer 1970, simplified).

upper part of the section. This represents the *Helvetoglobotruncana helvetica*, *Marginoglobatruncana sigali*, and *Dicarinella primitiva* (Early Turonian– Coniacian) foraminiferal Zones. The Macelowa Marl Member is overlain by olive-green marly shales and shaly flysch of the Osice Siltstone Member (K. Bąk 1995). These last deposits lack stratigraphically important microfauna.

Bukowiny Hill Section. – The section investigated is located in the scarf of the road from Jaworki to Bukowiny Hill (Fig. 2). The Skalski Marl Member is represented here by variegated marls (green and gray alternating with red marls) (Fig. 4). It belongs to the Cenomanian *Rotalipora reicheli* and *Rotalipora cushmani* foraminiferal Zones.

The Snežnica Siltstone Formation is represented by bright gray shaly marls with thin bedded siltstones and sandstone intercalations containing several beds of bright green pelitic limestones. These strata belong to the *Rotalipora cushmani* and *H. helvetica* foraminiferal Zones (Late Cenomanian–Early Turonian).

The Macelowa Marl Member consists of red marls tectonically strongly deformed. Stratigraphically it represents *H. helvetica*, *M.sigali*, *D. primitiva*, and *Dicarinella concavata* foraminiferal Zones (Early Turonian–Coniacian). The Macelowa Marl Member in this section is overlain by shaly flysch of the Osice Siltstone Member, which does not contain any microfauna of correlative value.

Bukowiny Valley section. — This section is located between the Homole Ravine and the earlier described road at Bukowiny Hill in the place where the stream strongly cuts the valley (Fig. 2; K. Bąk 1994). The Snežnica Siltstone and Macelowa Marl Members are exposed here (Figs 3, 4). The Snežnica Siltstone Member is represented by bright gray marls with thin sandstone intercalations. It belongs to the Late Cenomanian *R. cushmani* foraminiferal Zone. The Macelowa Marl Member consists of red marls with very thin intercalations of mudstones and sandstones. It is represented only by the Late Turonian *M. sigali* foraminiferal Zone.

Material and methods

The radiolarian tests were retrieved from samples (usually about 0.5 kg) by dissolving the marly matrix in hot acetic acid according to the methods described by Kostka & Widz (1986). Residua were washed through a 63 μm sieve. They were then dried out and all radiolarians from each sample were picked out.

The material is deposited in the Institute of Geological Sciences, Jagiellonian University, Cracow, Poland.

Radiolarian associations

Forty three species of Radiolaria were identified in 36 samples of Late Cretaceous variegated marly deposits from Polish part of the Pieniny Klippen Belt (Tabs 1, 2). The samples contain also planktonic foraminiferans that were used as a biostratigraphic control. The foraminiferal biozonation of the strata by K. Bąk (1994) is followed (Fig. 5).

Samples with abundant radiolarians are predominantly concentrated in the variegated marls of the Bukowiny Valley section (samples Bw-1, Bw-4, Bw-8, Bw-9, Bw-10) and green-grey marls of the Kosarzyska section (samples Kos-1, Kos-2, Kos-3).

Three intervals of radiolarian-rich sediments were recognized in the studied profiles. The first interval is represented in samples Kos-1, Kos-2, Kos-3. Radiolarians are abundant but generally poorly-preserved, with diagenetic transformation into zeolite. Nassellarians, especially *Holocryptocanium barbui*, are dominant in this interval.

The second interval occurs in the section Bukowiny Valley (samples Bw-1, Bw-8, Bw-10). The samples contain abundant and well-preserved

Tab. 1. Frequencies of the radiolarian species in the Bukowiny Hill and Bukowiny Valley sections. Abbreviations: Sn. St. – Snežnica Siltstone Member, Skal. Mr. – Skalski Marl Member.

	CENOMAN.					TURON.				CON.			CEN.		TURONIAN						
	M		L			L							L		E	L					
	Skal. Mr.		Sn. St.			Macelowa Mr. Mb.							Sn. St.			Mac. Mr. Mb.					
FORAMINIFERAL ZONE	D		E			G				H		I	E	F		G					
SAMPLE	Bd-13	Bd-27	Bd-25	Bd-23	Bd-21	Bd-22	Bd-28	Bd-29	Bd-19	Bd-10	Bd-14	Bd-13	Bw-1	Bw-8	Bw-10	Bw-9	Bw-4	Bw-2	Bw-5	Bw-7	Bw-3
Actinommidae sp. A														1-4			1-4		1-4		
Actinommidae sp. B														1-4		1-4	1-4				
Actinommidae sp. C													1-4						1-4		
Cryptamphorella conara		1-4		1-4				1-4					5-9		5-9	5-9	5-9	1-4	1-4	1-4	1-4
Cryptamphorella sp. A																			1-4		1-4
Cryptamphorella sp. B																	1-4				
Cryptamphorella sp. C															1-4						
Diacanthocapsa ? sp.											1-4								1-4		
Dictyomitra montisserei													1-4		1-4	1-4	1-4				
Dictyomitra multicostata													1-4								
Dictyomitra pulchra															1-4						
Heliocryptocapsa sp.										1-4			1-4								
Hemicryptocapsa tuberosa														1-4				1-4			
Hemicryptocapsa polyhedra						1-4										1-4					
Hemicryptocapsa ? sp.																	1-4				
Holocryptocanium barbui	5-9	10-19							1-4				> 20	> 20		10-19	> 20		5-9	1-4	
Holocryptocanium geysersensis	1-4											1-4	1-4				5-9				
Holocryptocanium tuberculatum						1-4							1-4								
Holocryptocanium sp.															1-4						
Obeliscoites giganteus														1-4							
Obeliscoites maximus													1-4				1-4				
Obeliscoites vinassai																1-4					
Orbiculiforma sp.		1-4															1-4				
Praeconocaryomma copiosa																1-4	1-4				
Praeconocaryomma globosa			1-4														1-4				
Praeconocaryomma universa						1-4		1-4							1-4	5-9	5-9				
Pseudodictyomitra pseudomacrocephala													1-4	1-4							
Rhopalosyringium euganeum													1-4								
Sethocapsa simplex													1-4								
Sethocapsa sp. A																1-4					
Sethocapsa ? sp. B													1-4								
Sethocapsa sp. C																	1-4				1-4
Squinabollum fossilis			1-4	1-4	1-4		1-4						5-9	1-4	1-4	5-9	10-19			1-4	
Squinabollum sp.																	1-4				
Stichomitra communis	1-4	1-4											1-4	1-4	5-9	1-4	5-9	1-4	1-4		
Stichomitra mediocris														1-4	1-4	1-4	1-4				
Stichomitra stocki														1-4							
Stichocapsa sp.					1-4												1-4				
Stichomitra sp.																	1-4				
Triactoma sp. A				1-4													1-4				
Triactoma sp. B																	1-4				
Xitus mclaughlini													1-4	1-4							
Xitus sp.																	1-4				

1 - 4 specimens; 5 - 9 specimens; 10 - 19 specimens; > 20 specimens

radiolarians. The most abundant in this interval are specimens of *Holocryptocanium barbui*, *Squinabollum fossilis*, and *Cryptamphorella conara*. *Stichomitra communis* and *Pseudodictyomitra pseudomacrocephala* are present in the material investigated and these are characteristic taxa of the Cenomanian/Turonian anoxic event (Kuhnt *et al.* 1986). Planktonic foraminiferans suggest a Late Cenomanian age of sample Bw-1, and Early Turonian age of samples Bw-8 and Bw-10.

Tab. 2. Frequencies of the radiolarian species in the Kosarzyska section. Abbreviations: Sn. — Snežnica Siltstone Member, Rud. Mb. — Rudina Member, Br. Mb. — Brynczkowa Marl Member.

	ALBIAN					CENOM.				TURONIAN					
	Vraconian									E	LATE				
	Rud. Mb.			Br. Mb.			Skal.		Sn.	Macelowa Mrl. Mb.					
FORAMINIFERAL ZONE	A			B		C	F			H	I				
SAMPLE	Kos-3	Kos-2	Kos-1	Kos-4	Kos-11	Kos-7	Kos-5	Kos-8	Kos-9	Kos-27	Kos-14	Kos-15	Kos-25	Kos-16	Kos-20
Actinommidae sp. C											░				
Cryptamphorella conara			▓			░				░				░	
Diacanthocapsa ? sp.											░				
Dictyomitra pulchra					░										
Hemicryptocapsa tuberosa												░			
Hemicryptocapsa polyhedra									░						
Histiastrum aster		░													
Holocryptocanium barbui	▓	■	■		■	░	░		░	▓		▓	▓		░
Holocryptocanium geysersensis								░							
Holocryptocanium tuberculatum												░			
Praeconocaryomma copiosa	░														
Praeconocaryomma globosa	■	■													
Praeconocaryomma universa											░	░	░	▓	
Squinabollum fossilis			▓			░				░	░		░		
Stichomitra communis	▓			░	░										

The third interval of radiolarian-rich sediments is represented by samples Bw-4 and Bw-9 which contain abundant, well-preserved and very diverse radiolarian fauna, including *Cryptamphorella*, *Dictyomitra*, *Hemicryptocapsa*, *Holocryptocanium*, *Praeconocaryomma*, *Stichomitra* and *Squinabollum*. Foraminiferal fauna suggests a Late Turonian age of these samples.

Radiolarian biozonation

The assemblages of the Niedzica Succession can be fit into radiolarian zonation schemes developed in other areas of the world. Dumitrica (1975) distinguished two radiolarian assemblages in the Cenomanian sequence of Romania. The assemblage investigated herein can be correlated with his older assemblage (*Holocryptocanium barbui–Holocryptocanium tuberculatum* assemblage), based on the high frequency of the index species *H. barbui* and *H. tuberculatum*, the co-occurence of other cryptothoracic Nassellaria (*Hemicryptocapsa*, *Cryptamphorella*, and *Squinabollum*) and also the associated occurrence of some multi-segmented nassellarians (*Dictyomitra* and *Stichomitra*). In my material there is no evidence for the presence of the younger *Holocryptocanium nanum–Excentropylomma cenomana* assemblage of Dumitrica (1975), because the index species are missing and *Alievium superbum*, the first occurrence of which limited the base of the *H. nanum–E. cenomana* assemblage, has not been observed.

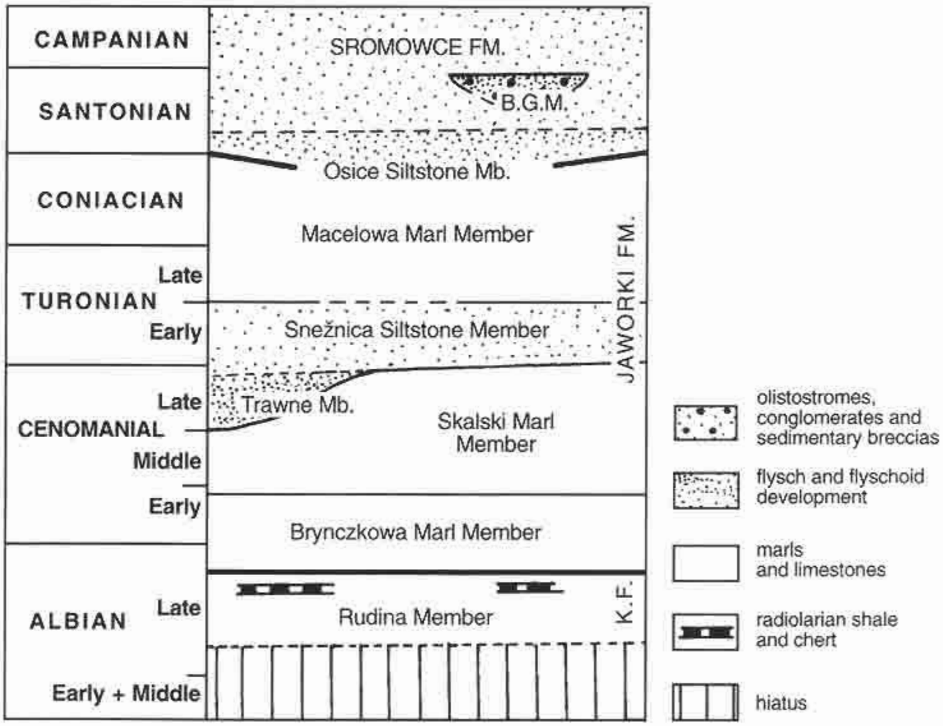


Fig. 3. Albian to Campanian lithostratigraphic units of the Niedzica succession in the Pieniny Klippen Belt (after Birkenmajer & Jednorowska 1987). Abbreviations: B.G.M. — Bukowiny Gravelstone Member, K.F. — Kapuśnica Formation.

The investigated fauna corresponds more closely to the *H. barbui–Holocryptocanium geysersensis* assemblage of Nakaseko & Nishimura (1981) from Southwest Japan, based on the co-occurrence of *H. barbui, H. geysersensis, P. pseudomacrocephala, A. vulgaris, C. conara, H. polyhedra, H. tuberosa, X. weyli, P. universa, S. fossilis*, and *S. communis*. Nakaseko & Nishimura (1981) dated their assemblages as approximately Albian–Cenomanian in age. Radiolarian fauna of Turonian age from the Pieniny Klippen Belt can be also included into the assemblage of Nakaseko & Nishimura (1981).

Taketani (1982) established the radiolarian zonation for mid-Cretaceous deposits of Hokkaido. For the Albian to Coniacian interval he distinguished five radiolarian biozones: the *H. barbui–Thanarla conica, Diacanthocapsa euganea–Thanarla elegantissima, Eusyringium spinosum, Dictyomitra formosa*, and *Squinabollum fossilis* Zone. In my assemblage, *H. barbui* does not co-occur with *T. conica* as is the case with the *Holocryptocanium barbui–Thanarla conica* zone of Taketani (1982). It is difficult to indicate the base of the *Diacanthocapsa euganea–Thanarla elegantissima* Zone because *H. geysersensis* and *H. polyhedra* (the first diagnostic for the base of this zone) do not appear together in my material.

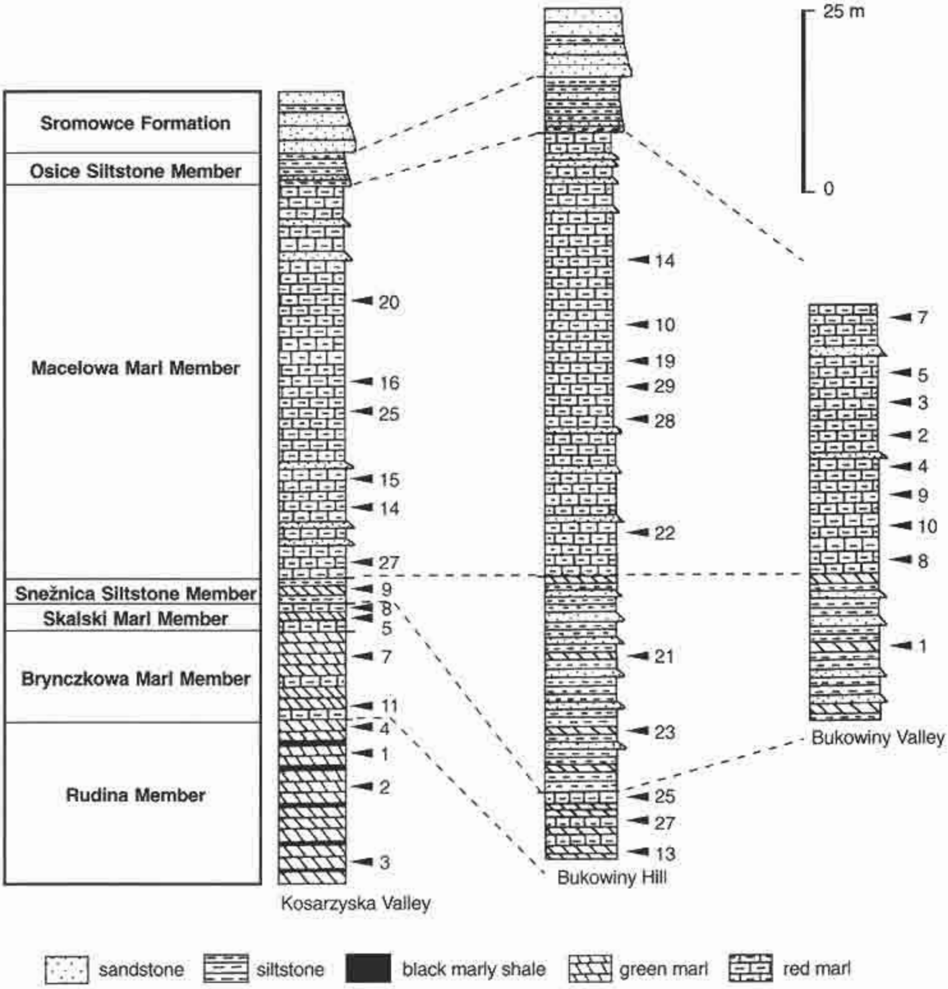


Fig. 4. Geological sections showing the lithological units and position of samples (after K. Bąk 1994).

T. elegantissima, the last occurrence of which is diagnostic for the top of the zone, is not present in my material. The species that define the base and the top of the *E. spinosum* Zone are also missing in the Pieniny Klippen Belt, but the last occurrences of *H. barbui*, *H. geysersensis*, and *P. pseudomacrocephala* are close to the top of *Eusyringium spinosum* Zone according to Taketani (1982). In the material investigated, the taxa which first occur at the base of the *D. formosa* Zone are not present but *Squinabollum fossilis*, the last occurrence of which defines the top of *S. fossilis* Zone of Taketani (1982), occurs in the Late Turonian.

Sanfilippo & Riedel (1985) established two Radiolarian biozones of Albian–Coniacian age. In the Niedzica Succession *Cryptamphorella conara*, *H. barbui*, and *P. pseudomacrocephala* occur widely but *Obesacapsula*

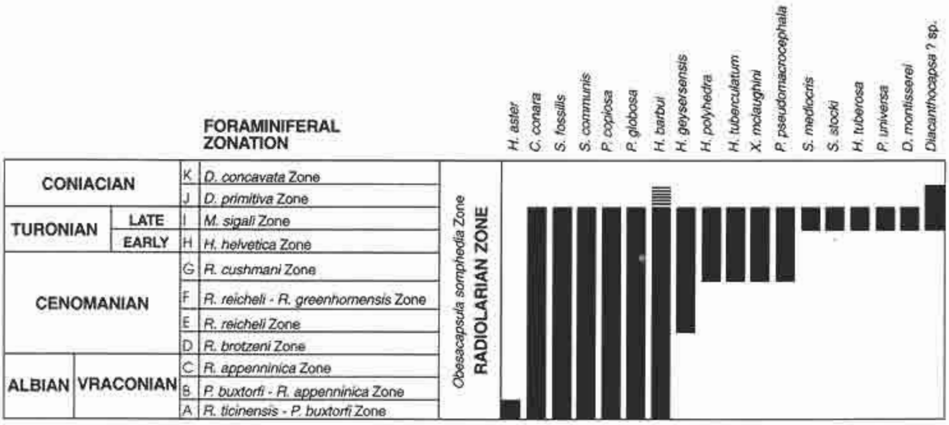


Fig. 5. Composite range chart of radiolarian species in the Niedzica Succession of the Pieniny Klippen Belt.

somphedia, the earliest appearance of which defines the boundary between the *O. somphedia* and *Acaeniotyle umbilicata* Zones, has not been identified. There are some difficulties with fitting the investigated radiolarian assemblage into other Cretaceous radiolarian zonations (e.g. Schaaf 1981; Thurow 1988) because some index radiolarians are missing. O'Dogherty (1994) proposed radiolarian zones based on Unitary Association for middle Cretaceous deposits in the Mediterraean Region. The radiolarian fauna presented by O'Dogherty (1994) shows a slight similarity with the fauna from Niedzica Succession. However, the species used for the definition of the radiolarian biozones by this author are absent in my material, probably because of different ecological conditions.

Review of identified species

Species are listed in alphabetical order. Distribution in samples is shown on Tabs 1–2.

***Actinommidae* gen et sp. indet. A**. — A few variably preserved specimens have a spherical cortical shell of the test with four massive spines. Meshwork is regular with hexagonal pores (Fig. 6A)

***Actinommidae* gen. et sp. indet. B**. — A few poorly preserved specimens of this form are usually associated with the previous species differ from it in irregular pore frames, and the lack of spines (Fig 6B).

***Actinommidae* gen. et sp. indet. C**. — This is another undetermined species of the family, known from a few moderately preserved specimens. The test bears two massive spines in the axial position. Meshwork is regular, with hexagonal pores (Fig. 6I).

***Cryptamphorella conara* (Foreman 1968)**. — Numerous variably preserved specimens from the deposits of the Niedzica Succession do not add any new information to the knowledge of the species (see Dumitrica 1970; Schaaf 1981; Sanfilippo & Riedel 1985; Górka 1989, 1991) (Fig. 9E).

***Cryptamphorella* sp. A**. — This form known from a few well-preserved specimens (Fig. 9A–C) differ from *Cryptamphorella conara* by having short conical spines protruding out of the apical part of the abdomen wall (eight spines around apical part of abdomen). This form probably represents a new species.

***Cryptamphorella* sp. B**. — One well-preserved specimen (Fig. 9D) differs from *C. conara* by having an oval abdomen. It differs from *C. macropora* Dumitrica 1970 by lacking individual sutural pore.

***Cryptamphorella* sp. C**. — One well-preserved specimen (Fig. 9F) has been found in the deposits investigated. It differs from *C. conara* by having thorax almost completely incased in the abdomen, and by having prominent sutural pore.

***Diacanthocapsa*? sp**. — Only poorly preserved specimens (Fig. 8M) are represented in the collection. The test consists of two externally visible segments, semicircular one in the upper part of the test with two broken spines, and the bigger segment in the lower part of the test. Pores are indistinct. This form is only tentatively assigned to *Diacanthocapsa* because it has two spines in the upper part of the test.

***Dictyomitra montisserei* (Squinabol 1903)**. — The species is represented only by few well-preserved specimens from Bukowiny Valley section (Fig. 7B–D). It differs from *A. vulgaris* by having more slender test in its distal part.

***Dictyomitra multicostata* Zittel 1876**. — Only one poorly preserved specimen has been found in sample of Bukowiny Valley section (Fig. 8E; see Campbell & Clark 1944; Kuhnt *et al.* 1986; Bąk 1993).

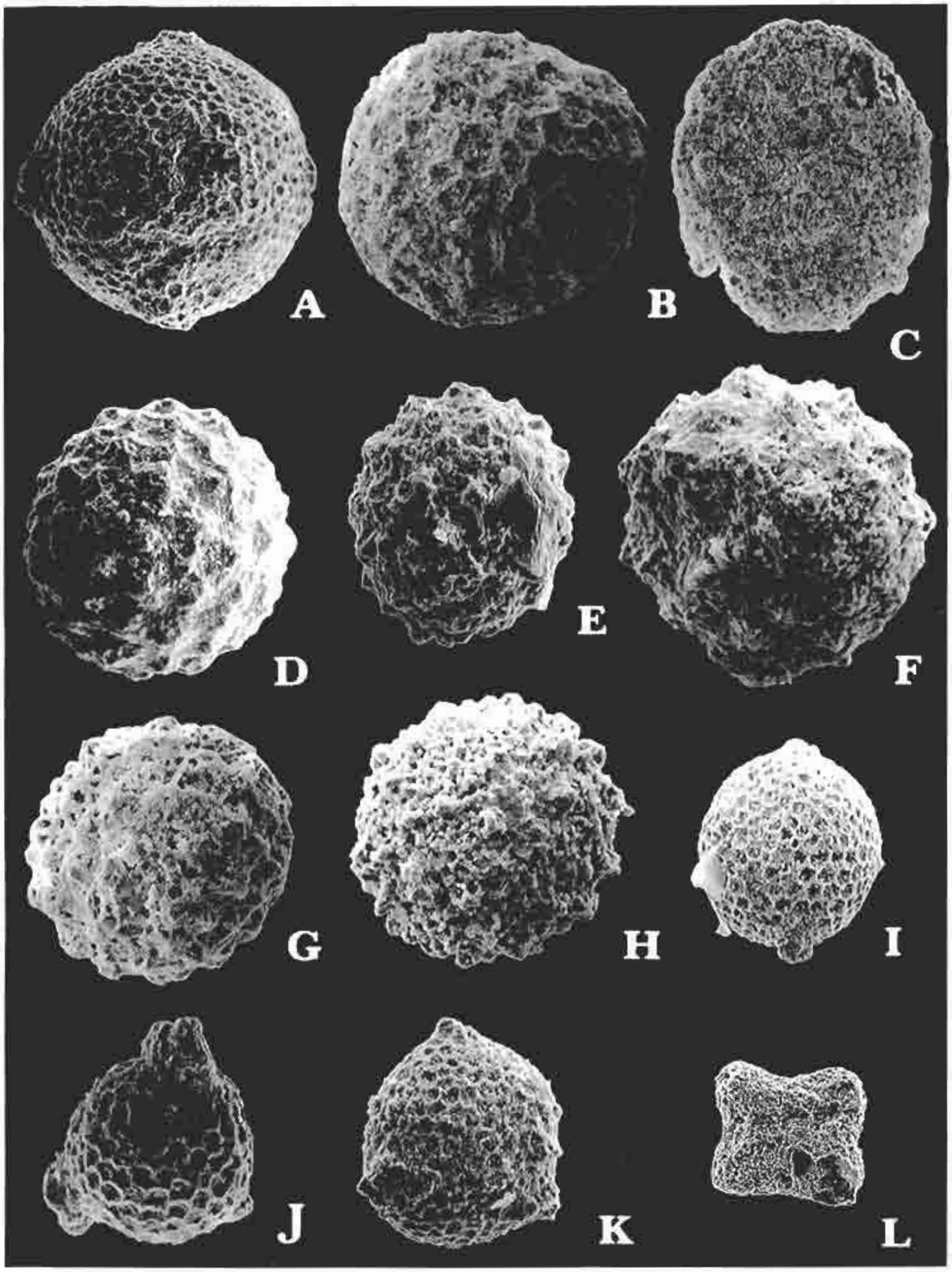
***Dictyomitra pulchra* (Squinabol 1903)**. — This one moderately preserved specimen (Fig. 7A) has its test conical in apical part, and cylindrical distally with about 14 vertical rows of pores (around the visible side of the test). Adjacent rows of pores are separated by slight rib. Ribs converge apically. Pores oval or irregular, large in distal part and smaller in apical part of the test.

***Heliocryptocapsa* sp**. — A few moderately preserved specimens (Fig. 9L) which have been found in the investigated sections are rather questionably assigned to the genus *Heliocryptocapsa* because of they having much bigger pores of abdominal wall.

***Hemicryptocapsa polyhedra* Dumitrica 1970**. — Only a few poorly preserved specimens are represented in the collection. These forms are closely related to *H. polyhedra* described by Thurow (1988).

***Hemicryptocapsa tuberosa* Dumitrica 1970**. — These forms (Fig. 8J) differ from H. *tuberosa* (see Dumitrica 1970) by having more conical tubercles.

Fig. 6. ☐A. *Actinommidae* gen. et sp. indet. A, Macelowa Marl Member, Bw-3, Late Turonian, × 100. ☐B. *Actinommidae* gen. et sp. indet. B, Macelowa Marl Member, Bw-4, × 150. ☐C. *Orbi-*



culiforma sp., Macelowa Marl Member, Bw-4, × 150. ❑D–E. *Praeconocaryomma universa* Pessagno 1976, Snežnica Siltstone Member, Bw-10, Early Turonian, × 150. ❑F–G. *Praeconocaryomma globosa* Hao-ruo 1986, Macelowa Marl Member, Bw-4, Late Turonian, × 150. ❑H. *Praeconocaryomma copiosa* Hao-ruo 1986, Macelowa Marl Member, Bw-4, × 150. ❑I. *Actinommidae* gen. et sp. indet. C, Macelowa Marl Member, Bw-3, × 100. ❑J. *Triactoma* sp. A, Macelowa Marl Member, Bw-4, × 150. ❑K. *Triactoma* sp. B, Macelowa Marl Member, Bw-4, × 150. ❑L. *Histiastrum aster* Lipman 1952, Rudina Member, Kos-2, latest Albian, × 100.

***Hemicryptocapsa*? sp.** – One well-preserved specimen has been found (Fig. 8I) in sample of Bukowiny Valley section. This form is only questionably assigned as *Hemicryptocapsa* because it has a short massive spine in the axial position of abdomen.

***Histiastrum aster* Lipman 1952.** – This is another single well-preserved specimen (Fig. 6L) which has been found in the deposits investigated. This form is closely related to *H. aster* described and illustrated by previous autors (see Lipman 1952; Schaaf 1981).

***Holocryptocanium barbui* Dumitrica 1970.** – The most characteristic and the most frequent species (Fig. 9G–H) in the deposits of the Niedzica Succession from Albian to Turonian. This species is also abundant in another successions of the Pieniny Klippen Belt and in the mid-Cretaceous deposits of the Flysch Carpathians (see M. Bąk 1993, 1994, 1995) The illustrated specimens are similar to those described by M. Bąk (in press) as form with small pores of abdominal wall.

***Holocryptocanium geysersensis* Pessagno 1977.** – A few moderately preserved specimens (Fig. 9K) have been found in the deposits investigated. These forms are closely related to those described and illustrated by previous authors (see Pessagno 1977; Taketani 1982; Thurow 1988).

***Holocryptocanium tuberculatum* Dumitrica 1970.** – Only a few moderately preserved specimens are represented in the collection (Fig. 9J; see Dumitrica 1970).

***Holocryptocanium* sp.** – This one well-preserved species (Fig. 9I) differs form *H. barbui* by having very large sutural pore with protruding rim around it.

***Obeliscoites giganteus* (Aliev 1968).** – One poorly-preserved specimen with broken test is represented in the collection (Fig. 7F). Only two last segments are visible. Last segment inflated with vertical rows of the pores, flattened distally.

***Obeliscoites maximus* (Squinabol 1903).** – Two forms (Fig. 7G) have been found with broken test which consists of two last segments. The upper one cylindrical, convex in outline, porate, with small mostly circular pores. Last segment much bigger, inflated with large irregular pores and coarse meshwork.

***Obeliscoites vinassai* (Squinabol 1903).** – Only one well-preserved specimen (Fig. 7H) is represented in the collection. Its test consists of ten segments, distally closed. Cephalis hemispherical, poreless. Thorax and

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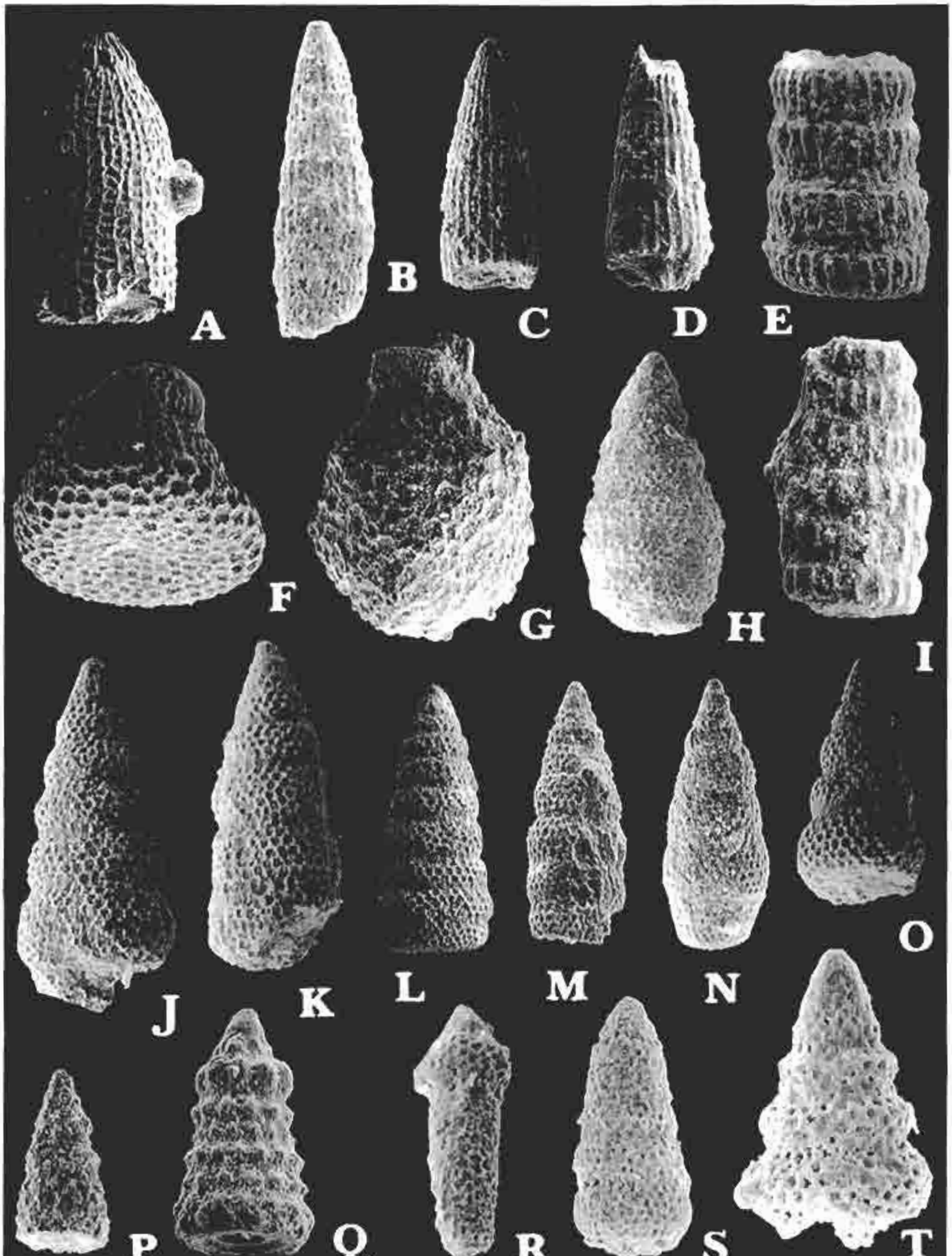
Fig. 7. ❑A. *Dictyomitra pulchra* (Squinabol 1903), Snežnica Siltstone Member, Bw-10, Early Turonian, × 100. ❑B–D. *Archaeodictyomitra sliteri* Pessagno 1976, Macelowa Marl Member, Bw-4, Late Turonian, Snežnica Siltstone Member, Bw-10, Early Turonian, Snežnica Siltstone Member, Bw-10, Early Turonian, × 100. ❑E. *Dictyomitra multicostata* Zittel 1876, Snežnica Siltstone Member, Bw-1, Late Cenomanian, × 150. ❑F. *Obeliscoites giganteus* (Aliev 1968), Snežnica Siltstone Member, Bw-8, × 100. ❑G. *Obeliscoites maximus* (Squinabol 1903), Snežnica Siltstone Member, Bw-1, × 100. ❑H. *Obeliscoites vinassai* (Squinabol 1903), Macelowa Marl Member, Bw-9, Late Cenomanian, × 75. ❑I. *Pseudodictyomitra pseudomacrocephala* (Squinabol 1903), Snežnica Siltstone Member, Bw-8, Late Cenomanian, × 150. →



❑J–O. *Stichomitra communis* Squinabol 1903, Snežnica Siltstone Member, O, Bw-8, N, Bw-2, Late Cenomanian, Macelowa Marl Member, J, Bw-9, K, Bw-8, L, Bw-9, M, Bw-4, Late Turonian, × 100. ❑P. *Xitus* sp., Macelowa Marl Member, Bw-4, Late Turonian, × 100. ❑Q. *Xitus mclaughlini* Pessagno 1977, Snežnica Siltstone Member, Bw-1, Late Cenomanian, × 100. ❑R. *Rhopalosyringium* ? *euganeum* (Squinabol), Macelowa Marl Member, Bw-4, Late Turonian, × 150. ❑S. *Stichocapsa* sp. B, Macelowa Marl Member, Bw-4, × 100. ❑T. *Stichomitra* gr. *asymbatos* Foreman 1968, Macelowa Marl Member, Bw-4, × 150.

abdomen trapezoidal in outline, sparsely porous. Post-abdominal segments porate with closely disposed circular pores hexagonal to irregular in outline. The distal part of the test (consists of six segments) inflated. Post-abdominal segments are divided from each other by constrictions.

***Orbiculiforma* sp.** – A few moderately preserved specimens (Fig. 6C) which have been found in the deposits of the Niedzica Succession have test disc-shaped, circular in lateral view. Central cavity is shallow and wide with small raised area. Meshwork is spongy. Shape of pores unidentifiable. Pores in the central cavity are smaller than in periphery. No specific determination can be proposed for this specimen.

***Praeconocaryomma copiosa* Hao-Ruo 1986**. – A few poorly-preserved specimens (Fig. 6H) have been found in the investigated sections.

***Praeconocaryomma globosa* Hao-Ruo 1986**. – Numerous moderately-preserved specimens (Fig. 6F–G) have been found in the deposits of the Niedzica Succession. This forms are closely related to specimens presented by Hao-Ruo (1986).

***Praeconocaryomma universa* Pessagno 1976**. – Numerous moderately preserved specimens are presented in the collection (Fig. 6D–E).

***Pseudodictyomitra pseudomacrocephala* (Squinabol 1903)**. – Only a few broken tests with post-abdominal chambers were found in the samples studied (Fig. 7I).

***Rhopalosyringium? euganeum* (Squinabol 1903)**. – Only the poorly preserved specimens (Fig. 7R) has been found in my material. It appear to be related to *R. euganeum* described by O'Dogherty (1994).

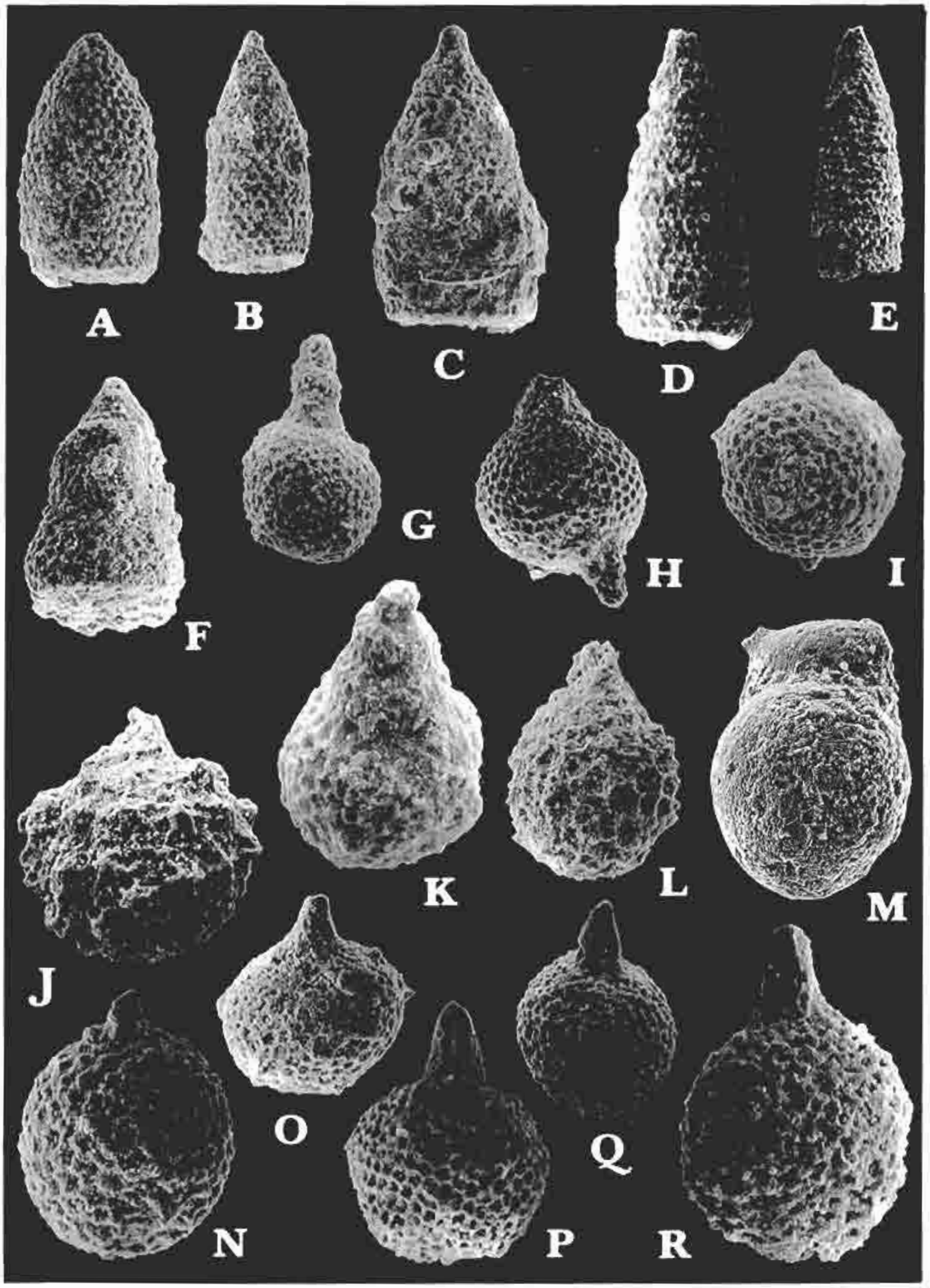
***Sethocapsa simplex* Taketani 1982**. – One moderately-preserved specimen (Fig. 8G) has been found in sample of Bukowiny Valley section. This species shows close relationships to *S. simplex* Taketani 1982 but it has a thinner and longer third segment of the test.

***Sethocapsa* sp. A**. – Form poorly-preserved (Fig. 8L). Test consists of three segments. The biggest inflated one with large hexagonal pore frames.

***Sethocapsa*? sp. B**. – This form is only questionably assigned to *Sethocapsa*, because it has three circular spines (one preserved, two broken) extending from the distal part of the final chamber (Fig. 8H).

***Sethocapsa* sp. C**. – This form (Fig. 8K) consists of four segments. Cephalis subspherical, without apical horn. Thorax and abdomen convex in outline with closely disposed circular pores. Fourth segment the biggest, circular in outline, inflated with the largest pores.

Fig. 8. ☐A. *Stichomitra stocki* (Campbell & Clark 1944). Snežnica Siltstone Member, Bw-1, Late Cenomanian, × 150. ☐B–D. *Stichomitra mediocris* (Tan 1927). Macelowa Marl Member. B. Bw-4, × 100, C. Bw-4. D. Bw-9, × 150. Late Turonian, Snežnica Siltstone Member. ☐E. *Dictyomitra multicostata* Zittel 1876, Bw-1, Late Cenomanian, × 100. ☐F *Stichomitra* sp., Macelowa Marl Member, Bw-9, Late Turonian, × 100. ☐G. *Sethocapsa simplex* Taketani 1982, Snežnica Siltstone Member, Bw-1, Late Cenomanian, ☐H. *Sethocapsa*? sp. B, Snežnica Siltstone Member, Bw-1, Late Cenomanian, × 150. ☐I. *Hemicryptocapsa*? sp., Macelowa Marl Member, Bw-4, Late Turonian, × 150. ☐J. *Hemicryptocapsa tuberosa* Dumitrica 1970, Snežnica Siltstone Member, Bw-8, Late Cenomanian, × 150. ☐K. *Sethocapsa* sp. C, Macelowa



Marl Member, Bw-4, Late Turonian, × 200. □L. *Sethocapsa* sp. A, Macelowa Marl Member, Bw-4, × 150. □M. *Diacanthocapsa*? sp., Macelowa Marl Member, Kos-14, × 200. □N, P–R. *Squinabollum fossilis* (Squinabol 1903), Snežnica Siltstone Member, N, Bw-1, Late Cenomanian, Macelowa Marl Member, P, Bw-5, Q, Bw-1, × 150, R, Bw-4, × 200, Late Turonian. □O. *Squinabollum* sp., Macelowa Marl Member, Bw-4, × 100.

***Stichocapsa* sp.** – This form (Fig. 7S) has test elongate and consists of eight segments. Cephalis conical, massive. Thorax and abdomen trapezoidal in outline, sparsely porous. Post-abdominal segments convex in their outline, porate, divided from one another by slight constrictions. Last segment hemispherical. This species differ from *Stichocapsa* sp. A by lacking the inflated part of the test.

***Stichomitra communis* Squinabol 1903.** – Numerous well-preserved specimens (Fig. 7J–O) have been found in the deposits investigated. These specimens vary in the number of the chambers, and test's width and length.

***Stichomitra mediocris* (Tan 1927).** – A few moderately preserved specimens from the deposits of the Niedzica Succession (Fig. 8B–D) do not add any new information to the knowledge of the species (see Tan 1927; Renz 1974; Nakaseko & Nishimura 1981; Górka 1991; O'Dogherty 1994).

***Stichomitra stocki* (Campbell & Clark 1944) emend. Foreman 1968.** – The specimens (Fig. 8A) vary considerably in their overall appearances. In the present study specimens identified as *S. stocki* have their tests thick walled, multi-segmented, conical to cylindrical distally. Cephalis knob-like. Test with small polygonal pores (see Campbell & Clark 1944; O'Dogherty 1994).

***Stichomitra* sp.** – No specific determination can be proposed for this specimen (Fig. 8F). Its test is campanulate and consists of five segments differing in outline. Cephalis semispherical, poreless. Thorax and abdomen conical, sparsely porous. Two last post-abdominal segments porate with moderately hexagonal pores. They are divided by pronounced strictures.

***Squinabollum fossilis* (Squinabol 1903).** – Numerous moderately preserved specimens (Fig. 8N, P–R) have been found in the material investigated. The forms vary in the length of apical horn.

***Squinabollum* sp.** – This species (Fig. 8O) differs from *S. fossilis* by having several short conical spines projecting out of its abdominal wall.

***Triactoma* sp. A.** – Two poorly-preserved specimens (Fig. 6J) are characteristic in having test ellipsoidal with three co-planar, thick spines, forming about 120° angles between them. Spines are broken. Cortical shell has circular pores.

***Triactoma* sp. B.** – This form (Fig. 6K) differs from *Triactoma* sp. A by having thinner spines and smaller pores of cortical shell.

***Xitus mclaughlini* Pessagno 1977.** – Only a few moderately preserved specimens are represented in the collection (Fig. 7Q). This form does not

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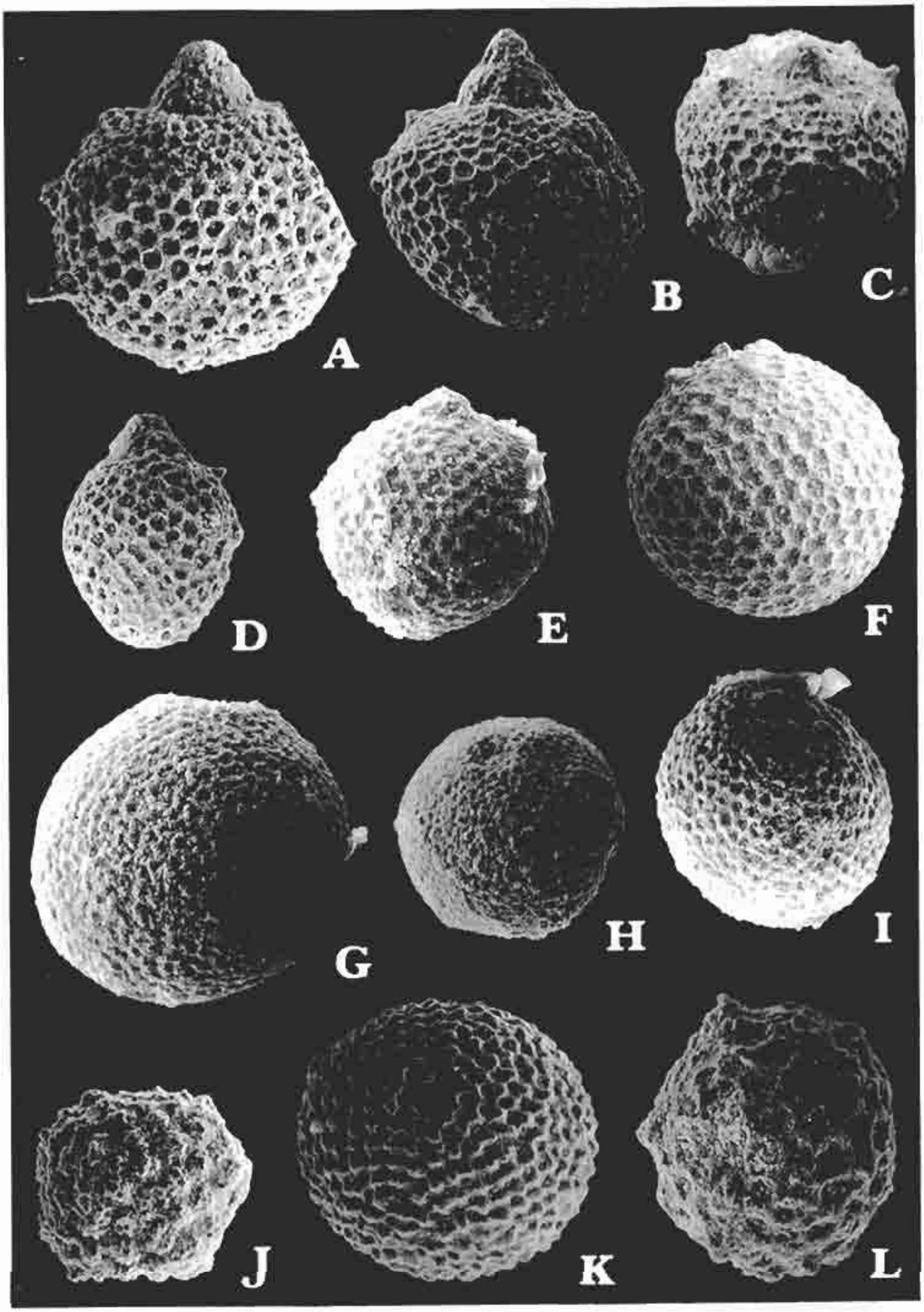
Fig. 9. ❑A–C. *Cryptamphorella* sp. A, Macelowa Marl Member, Bw-4, Late Turonian, Snežnica Siltstone Member, Bw-1, Late Cenomanian, × 150, Macelowa Marl Member, Bw-7, Late Turonian, × 100. ❑D. *Cryptamphorella* sp. B, Macelowa Marl Member, Bw-4, × 100. ❑E. *Cryptamphorella conara* (Foreman 1968), Snežnica Siltstone Member, Bw-10, Early Turonian, × 100. ❑F. *Cryptamphorella* sp. C, Snežnica Siltstone Member, Bw-10, × 75. ❑G–H. *Holocryptocanium barbui* Dumitrica 1970, Snežnica Siltstone Member, Bw-10, Early Turonian, × 200, Bw-1, Late Cenomanian, × 150. ❑I. *Holocryptocanium* sp., Snežnica Siltstone



Member, Bw-10, Early Turonian, × 200. ❑J. *Holocryptocanium tuberculatum* Dumitrica 1970, Snežnica Siltstone Member, Bw-1, × 150. ❑K. *Holocryptocanium geysersensis* Pessagno 1977, Snežnica Siltstone Member, Bw-1, × 150. ❑L. *Heliocryptocapsa* sp., Snežnica Siltstone Member, Bw-1, × 150.

add any new information to the knowledge of the species (Pessagno 1977; O'Dogherty 1994).

***Xitus* sp.** — Only one moderately-preserved specimen has been found in the material investigated (Fig. 7P). This form has test conical and post-abdominal chambers with rows of tubercles arranged circumferentially.

Conclusions

Cretaceous radiolarians are rare in the deposits of the Niedzica Succession and they are generally not well-preserved, but three short intervals of radiolarian-rich sedimentation are distinguished. These intervals have been calibrated with planktonic foraminifera co-occurring with Radiolaria within the section.

The older radiolarian 'bloom' (see Tab. 1) is restricted to the latest Albian (Vraconian) and coincides with a high increase of total silica content as mentioned by Arthur & Premoli Silva, (1982). Sedimentary silica protected fossil radiolarian skeletons against dissolution in alkaline environment of the limestone

The next horizon rich in radiolarians coincides with the Cenomanian–Turonian Boundary Event (see Fig. 4, Tab. 1), which is widely interpreted as a combined effect of sea-level highstand, surface productivity and coastal upwelling (see Schlanger & Jenkyns 1976; Kuhnt *at al.* 1986; Thurow 1988). The youngest 'bloom' (see Fig. 4, Tab. 1) is late Turonian in age. All these are transgressive events that resulted in local development of deep-water conditions of sedimentation.

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Streszczenie

W pracy po raz pierwszy opisano zespoły promienic występujących w kredowych utworach sukcesji niedzickiej pienińskiego pasa skałkowego. Rozpoznano i opisano 43 gatunki promienic w utworach od albu do koniaku. W obrębie badanych profili wyróżniono trzy poziomy osadów wzbogaconych w faunę promienic. Dają się one korelować z epizodami wzbogacenia osadów kredowych w faunę promienic na świecie. Dokładny wiek tych osadów został wyznaczony na podstawie fauny otwornicowej.