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Chitinozoans and acritarchs from the Ordovician of the Skibno 1 borehole, Pomerania, Poland: implications for stratigraphy and palaeogeography

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ABSTRACT:

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Biostratigraphical results of this palynological study agree with those of previous research on graptolites from the Ordovician of the Skibno 1 borehole in the Koszalin – Chojnice Structural Zone, Polish portion of the Pomerania Terrane. They indicate that the investigated core interval can be attributed to the uppermost Llanvirn (Llandeilo) – lower Caradoc, and correspond to the *teretiusculus* and *gracilis* through the *multidens* graptolite biozones. Recovered chitinozoan species, including *Belonechitina robusta, Conochitina chydaea, C. dolosa, Lagenochitina* aff. *capax, Spinachitina bulmani,* and the index species *Laufeldochitina stentor* are restricted to the upper Llanvirn – lower Caradoc, the latter species delimits the *stentor* chitinozoan biozone (upper Uhaku and Kukruse stages). The following identified acritarchs are regarded as biostratigraphically significant: *Goniosphaeridium splendens*, *Ordovicidium elegantulum*, *O. heteromorphicum*, *O. nanofurcatum*, *O. nudum*, and are characteristic for the Caradoc. The presence of conodont *Scabbardella altipes* and ichnofossil *Alcyonidiopsis pharmaceus*, both characteristic of high palaeolatitudes, as well as lithological similarities between the investigated strata and their equivalents from Rügen indicate that Pomerania could have been situated at relatively high latitudes during the upper Llanvirn to lower Caradoc. These observations together with palynological results support a hypothesis that Pomerania was a terrane derived from Avalonia and accreted to the margin of the East European Craton.

Key words: Chitinozoans, Acritarchs, Biostratigraphy, Palaeogeography, Baltica, Avalonia, Ordovician, Pomerania, Poland.

INTRODUCTION

The Ordovician succession of the Polish part of the Pomerania Terrane (POŻARYSKI 1990) is known from boreholes located in a narrow NW-SE zone of north-western Poland, called the Koszalin-Chojnice Structural Zone in Polish geological literature (POŻARYSKI 1969; DADLEZ 1978, 2000). The Ordovician succession is composed of claystones, siltstones and sandstones, with turbiditic greywacke inter-

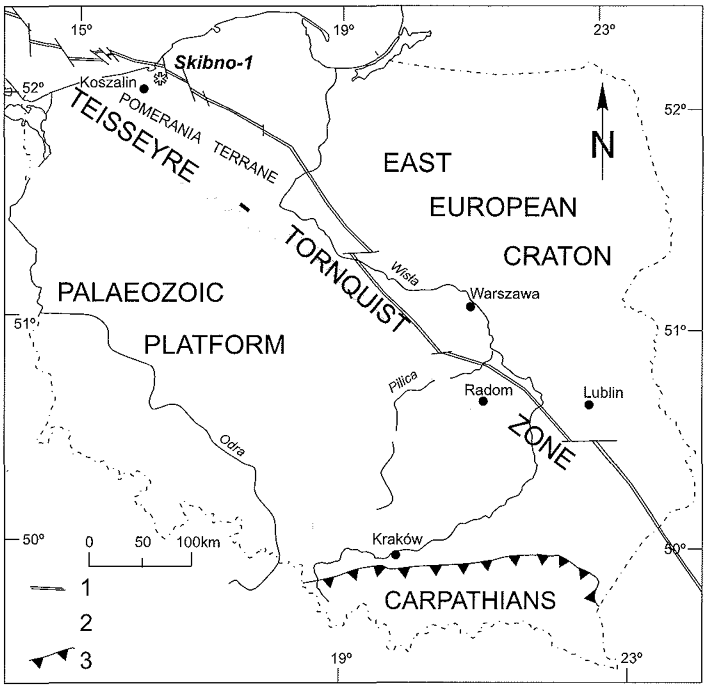

Fig. 1. Map of Poland showing location of the investigated borehole Skibno 1 (asterisk) and the structural framework. Legend: 1 – margin of the East European Craton, 2 – Variscan Deformation Front, 3 – boundary of the Carpathian Fore-Deep

calations. The oldest strata are Llanvirn in age, and the youngest are Caradoc in age as indicated by their graptolite fauna (MODLIŃSKI 1968; BEDNARCZYK 1974). The Ordovician rocks are unconformably overlain by Lower Devonian (Eifelian) conglomerates (ŁOBANOWSKI 1968) and Zechstein deposits (DADLEZ 1967, 1978). Rocks of Cambrian age have hitherto not been penetrated. Cores show beds to be horizontal or dipping at angles up to 90°. Overturned beds, faunally proven repeated beds (BEDNARCZYK 1974) and a major unconformity are caused by post-Přidoli – pre-Emsian deformation (TELLER 1974). The history of investigations of these strongly folded Lower Palaeozoic rocks regarded as the Pomeranian Caledonides and a manifestation of terrane tectonics has been recently reviewed by DADLEZ (2000). Irrespective of the deformation, most of these disturbed rocks are unmetamorphosed and uncleaved.

Since BEDNARCZYK's (1974) graptolite biostratigraphy of the Ordovician deposits from subsurface of Western Pomerania, no additional work has been undertaken until BEDNARCZYK & *al*'s. (1999) and SZCZEPANIK's (2000) recent acritarch investigations. Analogous deposits on adjacent Rügen Island have been extensively researched during the last decade (e.g., SERVAIS & KAZUNG 1993, GIESE & *al.* 1994, SERVAIS 1994, KATZUNG & *al.* 1995, ZAGORA 1997, MALETZ 1998, SAMUELSSON 1999, SAMUELSSON & *al.* 2000). These studies inspired us to initiate a modern biostratigraphical study of the Ordovician from boreholes of Pomerania (BEDNARCZYK & *al.* 1999). In this paper we present an account of the integrated graptolite, acritarch and chitinozoan biostratigraphy of the Ordovician interval of the Skibno 1 borehole. Previous graptolite taxonomy and biostratigraphy (BEDNARCZYK 1974) reconsidered by W. S. BEDNARCZYK is adopted in this paper and supplemented by palynological data (Text-fig. 2). Our palaeontological data also provide significant input for evaluation of current tectono-palaeogeographic hypotheses for the Pomerania Terrane accretion. The Skibno 1 borehole was selected from over a dozen drilled by the Polish Geological Institute and petroleum exploration teams during the 1960s because of its most completely cored Ordovician successions situated close to the margin of East European Craton. Also it is the closest borehole, in northern Poland, to island of Rügen (Text-fig. 1).

GEOLOGICAL SETTING

The Skibno 1 borehole is located in northwestern Poland, north of Koszalin, close to the Baltic Sea (Text-fig. 1). Ordovician strata here have been found between a depth of 1727.0 and 2807.0 m, directly underlying a Zechstein conglomerate (DADLEZ 1967). Ordovician age strata penetrated in the Skibno 1 borehole were subdivided into four lithologically based drillcore intervals (top to bottom):

First drillcore interval (1727.0-1838.4 m) comprises dolomitic dark grey greenish and red siltstones, with intercalations of grey dolomitic siltstones containing concentrations of pyrite. The observed dips in this interval are about 40°.

Second drillcore interval (1838.4-2435.0 m) comprises dolomitic dark grey siltstones with sporadic concentrations of pyrite and numerous muscovite flakes. In the lower part of this interval brownish and greenish siltstones have been observed. These beds are strongly slickensided and their observed dips vary from 10 to 60°.

Third drillcore interval (2435.0-2528.0 m) comprises dark grey siltstones with thin intercalations of dark brown limestone. These siltstones are strongly folded and slickensided. A cream-coloured dolomite fills fractures in these rocks. The observed dips in this interval are about 60°.

Fourth drillcore interval (2528.0-2807.0 m) comprises dark grey siltstones with laminations of dolomitic-sandy siltstones and with fine concentrations of pyrite and sporadic occurrences of muscovite flakes. These siltstones are strongly slickensided and their dips are about 90°.

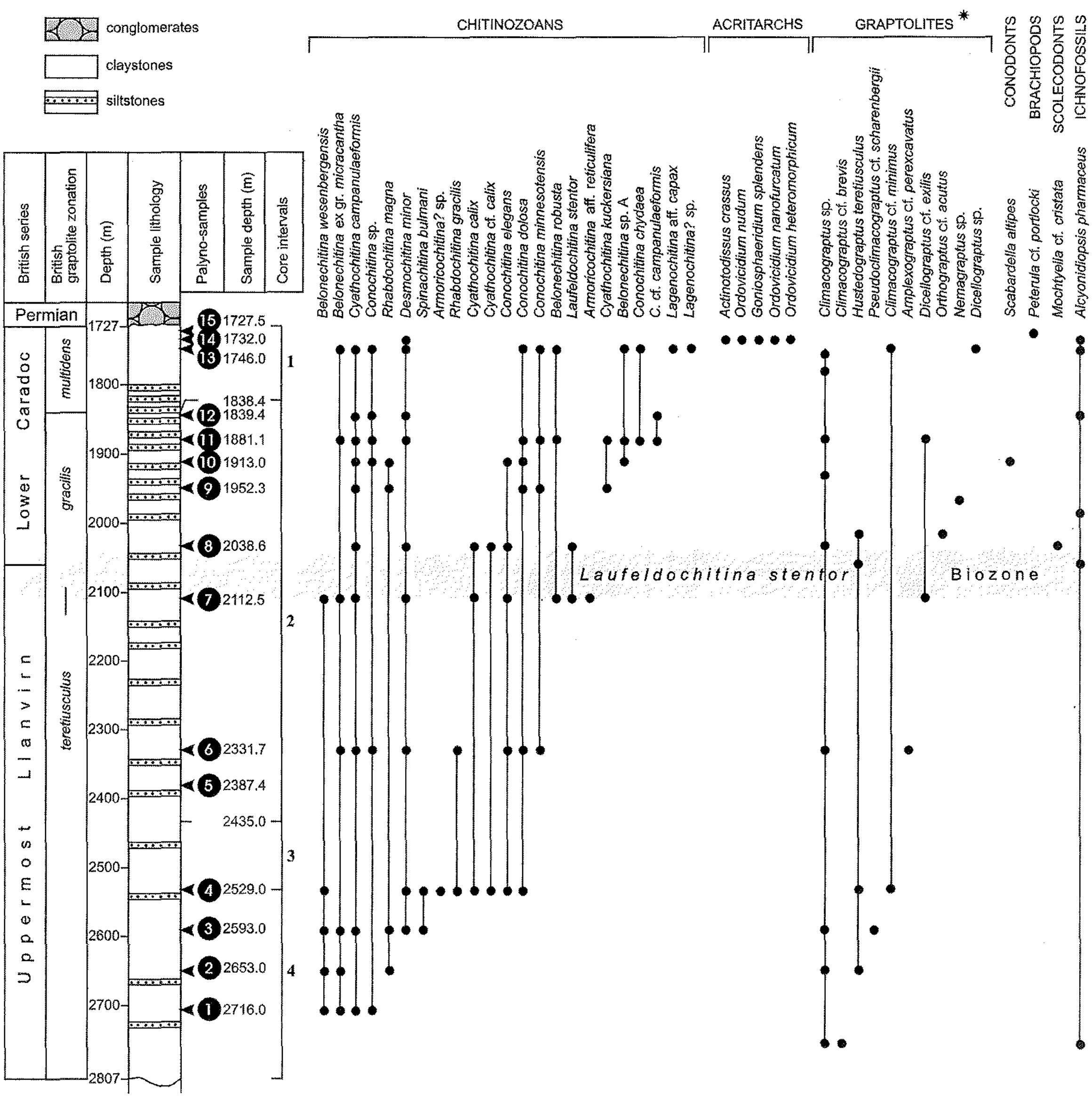

Fig. 2. Simplified lithological log and stratigraphical distribution of the chitinozoans and acritarchs for the Skibno 1 borehole. *Graptolites, brachiopods and ichnofossils distribution adopted from Bednarczyk (1974)

MATERIAL AND METHODS

Standard geological investigations were completed by W. BEDNARCZYK (1974) on the Skibno 1 core drilled by the Polish Oil and Gas Company-Geological Bureau "Geonafta." More recently 15 samples were collected for palynological analyses and their relative stratigraphical positions are indicated on the schematic lithological column in Text-fig. 2. All samples were weighed, crushed and sifted through 2 mm mesh at the laboratory of the Institute of Paleobiology in Warsaw. The small fraction (less than 2 mm) was used for acritarch processing by M. STEMPIEŃ–SAŁEK, whereas R. WRONA processed the larger pieces for chitinozoans.

Acritarch preparations were processed at the palynological laboratory of the Institute of Geological Sciences. Standard palynological methods were used in sample preparation including use of hydrochloric and hydrofluoric acids, and heavy liquid separation with zinc chloride, followed by oxidation with fuming nitric acid. The residues were mounted in glycerine jelly. Ten of the 15 samples processed were barren of acritarchs. The palynological slides with acritarchs are housed at the Institute of Geological Sciences of

Skibno 1 borehole															
Sample depth in m	2716.0	2653.0	2593.0	2529.0	2387.4	2331.7	2112.5	2038.6	1952.3	1913.0	1881.1	1839.4	1746.0	1732.0	1727.5
Sample number	Sk.1/1	Sk.1/2	Sk.1/3	Sk.1/4	Sk.1/5	Sk.1/6	Sk.1/7	Sk.1/8	Sk.1/9	Sk.1/10	Sk.1/11	Sk.1/12	Sk.1/13	Sk.1/14	Sk.1/15
Armoricochitina aff. *reticulifera*							3								
Armoricochitina? sp.				2											
Belonechitina ex gr. *micracantha*	11	9	24			1	1				7		4		
Belonechitina robusta							1				1		9		
Belonechitina wesenbergensis	4	1	6	1			2								
Belonechitina sp. A										8	11		5		
Conochitina chydaea											15		12		
Conochitina dolosa				1		15			31	16	10		95		
Conochitina elegans				2		4	3	9		9					
Conochitina minnesotensis						15			7		5		10		
Conochitina sp.	4					3				9	7	3	1		
Cyathochitina calix				9			1	11							
Cyathochitina cf. *calix*				18				6							
Cyathochitina campanulaeformis	1		5			1	4	7	44	3	33	35	2		
C. cf. *campanulaeformis*											7	3			
Cyathochitina kuckersiana									8		4				
Desmochitina minor			14	59		2	4	5			12	19	6	39	
Lagenochitina aff. *capax*													3		
Lagenochitina? sp.													4		
Laufeldochitina stentor							5	9							
Rhabdochitina gracilis				2		8									
Rhabdochitina magna		2	6						4	10					
Spinachitina bulmani			8	2											
Undetermined Chitinozoa	2	11	4	6	13	2	5	6	2	4	1	3	6	15	0
Number of chitinozoans in sample	22	23	67	102	13	51	29	53	96	59	113	63	157	54	0
Sample weight in gram	21	22	13	25	11	20	20	11	11	13	20	11	20	15	20
Number of Chitinozoa/g rock	1	1	5	4	1	3	1	5	9	4	5	6	8	4	0

Fig. 3. Distribution and abundance of chitinozoan species in the studied Ordovician interval of the Skibno 1 borehole

the Polish Academy of Sciences in Warsaw, abbreviated as ING.

Centimetre-sized and smaller fraction of the crushed samples were processed for chitinozoans at the laboratory of the Institute of Paleobiology in hydrochloric and/or hydrofluoric acid according to the standard method described by WRONA (1980). A small part of the wet chitinozoan residue (prior to washing and sieving) was also separated for acritarch processing. Chitinozoans were picked using a micropipette from the washed, wet residues and selected for SEM studies or stored in glycerine in plastic boxes. The collection of the studied chitinozoan specimens is housed at the Institute of Paleobiology of the Polish Academy of Sciences, Warsaw, abbreviated as ZPAL Ch.VII.

PALYNOLOGICAL RESULTS

All palynological samples were collected between 1730.0 and 2718.8 m (Text-figs 2-3). The first drillcore interval contains the chitinozoans *Desmochitina minor* EISENACK, 1931, arranged in cocoon-like clusters (Pl. 1, Fig. 13) or connected in chains (Pl. 1, Fig. 7), and *Belonechitina* ex gr. *micracantha* (EISENACK, 1931) *(see* Pl. 2, Fig. 5), *B. robusta* (EISENACK, 1959) (*see* Pl. 3, Figs 13-14), *B.* sp. A, *Conochitina chydaea* JENKINS, 1967, *C. dolosa* LAUFELD, 1967, *C. minnesotensis* (STAUFFER, 1933) (*see* Pl. 3, Fig. 6), *Conochitina* sp., *Cyathochitina campanulaeformis* (EISENACK, 1931), *Lagenochitina* aff. *capax* JENKINS, 1967 (*see* Pl. 3, Fig. 9) and *Lagenochitina*? sp. (*see* Pl. 3, Fig. 10).

The second interval contains abundant but flattened chitinozoan vesicles of *Armoricochitina* aff. *reticulifera* (GRAHN, 1981) (*see* Pl. 4, Fig. 10), *Belonechitina* ex gr. *micracantha* (EISENACK, 1931) (*see* Pl. 2, Fig. 10), *B. robusta*, *B.* cf. *wesenbergensis* (EISENACK, 1959) (*see* Pl. 2, Fig. 8), *Belonechitina* sp. A (*see* Pl. 3, Figs 11-12), *Conochitina chydaea* JENKINS, 1967 (*see* Pl. 1, Fig. 6), *C. dolosa* LAUFELD, 1967 (*see* Pl. 1, Figs 1-4), *C. elegans* Eisenack, 1931 (*see* Pl. 1, Fig. 5), *C. minnesotensis* (STAUFFER, 1933) (*see* Pl. 3, Figs 5, 7), *Conochitina* sp., *Cyathochitina campanulaeformis* (EISENACK, 1931) (*see* Pl. 4, Figs 2-4, 9), *Cy.* cf. *campanulaeformis* (EISENACK, 1931) (*see* Pl. 4, Figs 5-7), *Cy. calix* (EISENACK, 1931) (*see* Pl. 2, Figs 3-4, Pl. 4, Fig. 8), *Cy.* cf. *calix* (*see* Pl. 2, Figs 1-2), *Cy. kuckersiana* (EISENACK, 1934) (*see* Pl. 2, Fig. 11-12, Pl.4, Fig. 1), *Desmochitina minor* EISENACK, 1931 (*see* Pl. 1, Figs 10-12), *Rhabdochitina gracilis* EISENACK, 1962 (*see* Pl. 3, Fig. 1), *Rh. magna* EISENACK, 1931 (*see* Pl. 3, Figs 2-4). The index species *Laufeldochitina stentor* (EISENACK, 1937) (*see* Pl. 2, Figs 6-7) was recognized in this interval at 2038.6 to 2112.5 m.

The lowermost chitinozoan assemblage recognized in the fourth drillcore interval contains *Armoricochitina*? sp. (Pl. 4, Fig. 11), *Belonechitina* ex gr. *micracantha* (Eisenack, 1931) (*see* Pl. 2, Fig. 9), *B.* cf. *wesenbergensis* (EISENACK, 1931) (*see* Pl. 2, Fig. 7), *Conochitina dolosa* LAUFELD, 1967, *C. elegans* EISENACK, 1931, *Conochitina* sp., *Cyathochitina campanulaeformis* (EISENACK, 1931), *Cy. calix* (EISENACK, 1931) and *Cy.* cf. *calix* (EISENACK, 1931), *Desmochitina minor* EISENACK, 1931 (*see* Pl. 1, Fig. 8), *Rhabdochitina gracilis* EISENACK, 1962, *Rh. magna* EISENACK, 1931, and *Spinachitina bulmani* (JANSONIUS, 1964) (*see* Pl. 3, Fig. 8).

In the samples examined, chitinozoans are found in association with acritarchs, spherical green algae and scolecodonts. The prasinophycean green alga *Tasmanites* sp. is quite common in eight of the fifteen productive samples from sampled interval. The scolecodont *Mochtyella* cf. *cristata* KIELAN-JAWOROWSKA, 1961 is recorded from 2038.6 m. Ten acritarch samples from the 2718.8-23912.0 m interval were barren. The acritarchs from 2336.7-1745.0 m are poorly preserved and include following genera: *Baltisphaeridium, Micrhystridium, Solisphaeridium* and *Veryhachium.*

Only the first drillcore interval contains well-preserved acritarchs in one sample at 1732.0 m. They are represented by the genera: *Baltisphaeridium, Lophosphaeridium, Micrhystridium, Multiplicisphaeridium* (*see* Pl. 5, Fig. 4), *Solisphaeridium* (*see* Pl. 6, Fig. 5) and *Veryhachium* (*see* Pl. 6, Figs 1, 4) and species *Actinotodissus crassus* LOEBLICH & TAPPAN, 1978 (*see* Pl. 5, Fig. 1), *A.* cf. *crassus* (*see* Pl. 5, Fig. 3), *Goniosphaeridium splendens* (PARIS & DEUNFF) TURNER, 1984 (*see* Pl. 6, Fig. 2), *G.* cf. *splendens* (*see* Pl. 6, Fig. 6), *Ordovicidium elegantulum* TAPPAN & LOEBLICH, 1971 (*see* Pl. 5, Fig. 6), *Ordovicidium heteromorphicum* (KJELLSTRÖM) LOEBLICH & TAPPAN, 1978 (*see* Pl. 6, Fig. 3), *Ordovicidium nanofurcatum* (KJELLSTRÖM) UUTELA & TYNNI, 1991 (*see* Pl. 5, Figs 2, 5), *Ordovicidium nudum* (EISENACK) LOEBLICH & TAPPAN, 1978 (*see* Pl. 5, Fig. 7).

Review of chitinozoans

The chitinozoan species are typically represented by relatively few specimens, usually less than three specimens per gram of rock. The abundances of specimens from studied samples ranges from a few specimens, as *L. stentor*, up to several dozens, in the case of *C. campanulaeformis*, *D. minor* and *B.* ex gr. *micracantha*, (Text-fig. 3). The preservation of the microfossils is generally poor, chitinozoan vesicles are compressed, deformed, with damaged sculpture and broken spines. They were measured in micrometers (μm) and the diameters of completely flattened specimens were corrected using a factor of 0.7 following PARIS (1981); abbreviations vesicle measurements are: L=total length of vesicle, Ln=length of neck, Dmax=maximum diameter of vesicle, Da=diameter of aperture. The chitinozoans represent described taxa and do not need formal descriptions. The species discussed below are listed in alphabetic order.

Armoricochitina aff. *?reticulifera* (GRAHN, 1981); Pl. 4, Fig. 10

REMARKS: Small *Armoricochitina* species with a truncated to ovoid chamber and a cylindrical or subconical short neck tapering towards the straight aperture (dimensions: L=192, Dmax=138, Da=72). The flexure is rounded and the flanks are convex. The maximum diameter is situated in the lower half of the chamber. The vesicle surface is covered with irregular ridges. The basal edge has a very short carina. *A. reticulifera* is an index species for chitinozoan subzone in Baltoscandia (NÕLVAK & GRAHN 1993): early Nabala Stage (late Caradoc); not known up to now outside Baltoscandia. BEDNARCZYK (1999) recovered *A. reticulifera* from the lower Caradoc Sasino Formation in the Baltic Syneclise.

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 2112.5 m.

Armoricochitina? sp.; Pl. 4, Fig. 11

REMARKS: Small vesicle (dimensions: L=246, Dmax=135, Da=70) with a subconical chamber and a cylindrical or subconical very short (broken?) neck slightly flared at the indented aperture. Shoulders and flexure weakly developed or absent, and the flanks are convex. The maximum diameter is situated in the lower half of the chamber. The vesicle surface is covered with fine regular longitudinal ribs. The base is flat to concave with a basal edge possessing a very short carina. It cannot be excluded that this specimen is a part of the vesicle belonging to e.g., *Cyathochitina jenkinsi* NEVILLE or *Cyathochitina dispar* (BENOÎT & TAUGOURDEAU), possessing similar ornamentation.

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 2529.0 m.

Belonechitina ex gr. *micracantha* (EISENACK, 1931); Pl. 2, Figs 5, 9-10

REMARKS: The numerous specimens of *B.* ex gr. *micracantha* from Pomerania are within the range of variation for shape and dimensions (dimensions: L=149-424, Dmax=60-98, Da=50-60) of the type specimens placed in *Conochitina micracantha micracantha* by EISENACK (1965). Pomeranian specimens show also great similarities with those described from Baltoscandia (GRAHN 1981, 1982), France and Portugal (PARIS 1981), Belgium (SAMUELSSON & VERNIERS 2000), and North America (NEVILLE 1974, GRAHN & BERGSTRÖM 1984; ACHAB & ASSELIN 1995). The vesicles are covered with closely spaced spines, which are frequently damaged or broken off. Vesicles are strongly damaged and folded, with often obscured spinose ornament. All specimens are compressed. These poorly preserved specimens do not allow more precise taxonomic designation.

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0-2716.0 m.

Belonechitina robusta (EISENACK, 1959); Pl. 3, Figs 13-14

REMARKS: The specimens of *B. robusta* from Pomerania are within the range of variation of shape and dimensions (L=295-394, Dmax=62-91, Da=44-62) when compared with type material (EISENACK 1959). The vesicle is covered with closely spaced multirooted spines (Pl. 3, Fig. 13b), which are frequently damaged or broken off, but the surface pattern of spine scars suggests coalescent bases and/or lambda spines.

OCCURRENCE: Baltoscandia, early Caradoc (LAUFELD 1967, NÕLVAK & GRAHN 1993). Similar forms were described from Portugal, France and North America; for detailed stratigraphical information about these occurrences see e.g., PARIS (1981), GRAHN & BERGSTRÖM (1984) and ACHAB & ASSELIN (1995); Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0-2112.5 m.

Belonechitina wesenbergensis (EISENACK, 1959); Pl. 2, Fig. 8

REMARKS: The specimens from Pomerania are within the range of variation for shape and dimensions (dimensions: L=167-324, Dmax=60-93, Da=45-64) compared with type specimens designated by EISENACK (1965) to the more robust form *B. wesenbergensis brevis*. They are also identical with that figured by ACHAB & ASSELIN (1995, pl. 4, fig. 3). The vesicle is covered with spines, which are frequently damaged or broken off.

OCCURRENCE: Baltoscandia; Podolia, Ukraine; Germany, Rügen (SAMUELSSON 1999) and North America, Arctic Canada, from upper Llanvirn to lower Ashgill (Pirgu Stage); for detailed stratigraphic information about these occurrences see GRAHN & MILLER (1986) and ACHAB & ASSELIN (1995); Poland, Baltic Syneclise, Caradoc-lower Ashgill (BEDNARCZYK 1999); Western Pomerania, Skibno 1 borehole, depth 2112.5-2716.0 m.

Belonechitina sp. A; Pl. 3, Figs 11-12

REMARKS: The vesicles of *Belonechitina* sp. A are smaller (dimensions: L=156-220, Dmax=57-78, Da=44-57) and more conical than those of *B. robusta*. The vesicle is covered with densely spaced fine spines, which are frequently damaged or broken off. All specimens are compressed.

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 1446.0-1913.0 m.

Conochitina chydaea JENKINS, 1967; Pl. 1, Fig. 6

REMARKS: The club shape vesicles are slightly larger and compressed (dimensions: L=263-354, Dmax=70-87, Da=66-70) than the holotype, but comparable with population from Shropshire (JENKINS 1967) and south western Europe (PARIS 1981). Specimens are similar in shape to those of *C. decipiens* TAUGOURDEAU & JEKHOWSKY, recovered in Baltoscandia (GRAHN & *al.* 1996), but the latter species is smaller. All specimens are compressed.

OCCURRENCE: Welsh Borderland, Shropshire (JENKINS 1967), upper Llanvirn-lower Caradoc; for detailed stratigraphic information about occurrences forms from Portugal, Spain and France see PARIS (1981); Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0-1881.1 m.

Conochitina dolosa LAUFELD, 1967; Pl. 1, Figs 1-4

REMARKS: The vesicles of *C. dolosa* are larger (dimensions: L=507-1005, Dmax=75-101, Da=50-75) and more conical to club-shaped than those of *C. elegans*. All specimens are compressed.

OCCURRENCE: Baltoscandia, Sweden, Dalarna, lower Caradoc (LAUFELD 1967). Similar forms were described as *C.* cf. *dolosa* or *C.* aff. *dolosa* from Portugal, France and North America (Anticosti Island, eastern Canada and Appalachians), for detailed stratigraphic information about these occurrences see GRAHN & BERGSTRÖM (1984); Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0-2529.0 m.

Conochitina elegans EISENACK, 1931; Pl. 1, Fig. 5

REMARKS: Vesicles of this species are elongated and slightly conical (dimensions: L=375-875, Dmax=63-85, Da=44-85), with broadly rounded basal edge and a perfectly smooth vesicle wall. All specimens are compressed. Vesicles are more cylindricaly shaped than those from the type material (EISENACK 1931) and compare with *C.* cf. *elegans* figured by GRAHN & MILLER (1986). The lenticular or hemispherical widening of the cylindrical chamber characteristic for pistillaform vesicles were never observed.

OCCURRENCE: Baltoscandia, Uhaku to Pirgu stages, known also from the Welsh Borderland and Sardinia, for stratigraphic occurrences see GRAHN & MILLER (1986); Poland, Western Pomerania, Skibno 1 borehole, depth 2038.6-2529.0 m.

Conochitina minnesotensis (STAUFFER, 1933); Pl. 1, Figs 5-7

REMARKS: The characteristic subconical to claviform vesicles, frequently slightly curved, with broadly rounded, convex base and commonly present basal mucron. Specimens vary in size (dimensions: L=587-875, Dmax=75-126, Da=53-76). All specimens are compressed.

OCCURRENCE: This species is cosmopolitan, first described from the lower Caradoc Decorah Formation at Ford Bridge, Minneapolis, Minnesota (STAUFFER 1933), known also from the Arbuckle Mountains, Oklahoma (JENKINS 1969; GRAHN & MILLER 1986) and the Caradoc formations of the Central Basin of Tennessee (SISSER & *al.* 1998); Baltoscandia, Sweden, Dalarna, early Caradoc (LAUFELD 1967; NÕLVAK & *al.* 1999), but in Estonia it appears in the Volkhov Stage (Arenig) and disappears in the Porkuni Stage (upper Ashgill); for detailed stratigraphic information about these occurrences see GRAHN (1984) and GRAHN & BERGSTRÖM (1984); Poland, Łeba Elevation, lower Caradoc (PODHALAŃSKA 1979), Western Pomerania, Skibno 1 borehole, depth 1446.0-2331.7 m.

Cyathochitina calix (EISENACK, 1931); Pl. 2, Figs 3-4, 8

REMARKS: Specimens vary in shape and size (dimensions: L=280-440, Dmax=85-153, Da=50-70), but some forms seem to be conspecific with those described from the Welsh Borderland by JENKINS (1967, pl. 71, figs 5-7). They are stouter, as British specimens, than those described by EISENACK (1962) from Baltica, but closely fit their range of dimensions.

OCCURRENCE: Baltoscandia, Volkhov to Jõhvi stages, but known also in this range from the Welsh Borderland; Brittany; France; North America; Podolia, Ukraine; see GRAHN (1984) or NÕLVAK & GRAHN (1993) for a review of stratigraphic occurrences; Poland, Baltic Syneclise (BEDNARCZYK 1999), Western Pomerania, Skibno 1 borehole, depth 2038.6-2529.0 m.

Cyathochitina cf. *calix* (EISENACK, 1931); Pl. 2, Figs 1-2

REMARKS: *Cy.* cf. *calix* differs from *Cy. calix* in having more conical and slender shape (dimensions: L=139-438, Dmax=117-153, Da=57-81). The flexure and shoulders are less distinct and neck is shorter. All specimens are usually compressed and damaged. They show similarities with some specimens described from the lower Caradoc (*D. multidens* graptolite Biozone) Sularp Shale of Skåne Sweden (SCHALLREUTER, 1981, pl. 17, fig. 4-7).

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 2038.6-2529.0 m.

Cyathochitina campanulaeformis (EISENACK, 1931); Pl. 4, Figs 2-4, 9

REMARKS: Vesicles of *Cy. campanulaeformis* are very variable in shape and size, (dimensions: L=121-330, Dmax=107-165, Ln=59-89, Da=34-57), and are usually compressed.

OCCURRENCE: Baltoscandia, Volkhov Stage (Arenig) up to the Silurian (*Monograptus triangularis* Biozone); Welsh Borderland; Brittany; France; Westphalia, Germany; Bohemia; North America; Podolia, Ukraine; see GRAHN (1984) and BEDNARCZYK (1999) for stratigraphical occurrences; Poland, Baltic Syneclise (PODHALAŃSKA 1979, BEDNARCZYK 1999), Western Pomerania, Skibno 1 borehole, depth 1746.0-2716.0 m.

Cyathochitina kuckersiana (EISENACK, 1934); Pl. 2, Figs 11-12; Pl. 4, Fig. 1

REMARKS: Vesicles of *Cy. kuckersiana* are rather very variable in shape and size, (dimensions: L=137-326, Dmax=115-176, Da=43-53), and are compressed. The characteristic wide carina is frequently in part or completely broken off.

OCCURRENCE: Baltoscandia, Lasnamägi Stage (upper Llanvirn) up to the Pirgu Stage (lower Ashgill); Welsh Borderland; Western Europe; North America; Podolia, Ukraine; see GRAHN (1984) for stratigraphical occurrences; Poland, Baltic Syneclise (BEDNARCZYK 1999), Western Pomerania, Skibno 1 borehole, depth 1881.1-1952.3 m.

Cyathochitina cf. *campanulaeformis* (EISENACK, 1931); Pl. 4, Figs 5-7

REMARKS: Vesicles of *Cy.* cf. *campanulaeformis*, with a long neck are variable in shape and size (dimensions: L=151-364, Dmax=137-225, Ln=95=160, Da=44-70), and are usually compressed. Separation of these forms from typical *C. campanulaeformis* on the available material would be rather difficult, since they are infrequent in the sample and represent a gradation of intermediate forms.

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 1839.4-21881.1 m.

Desmochitina minor EISENACK, 1931; Pl. 1, Figs 7-13

REMARKS: Vesicles are slightly damaged, with obscured surface ornament. Their shape and dimensions (L=75-102, Dmax=50-92, Da=34-52) match well with typical forms. They originally occur in clusters (Pl. 1, Figs 10-11) or in chains (Pl. 1, Figs 6, 8). Specimens are most similar in morphology and preservation to those from the Southern Appalachians illustrated by GRAHN & BERGSTRÖM (1984, fig. 3 C, F). However, all *Desmochitina* species originally were arranged in chains, but linkage between vesicles of some species (e.g., *D. nodosa*) was an unusually strong one. Therefore their vesicles more often occur in chains than others. This catenary arrangement no longer has a taxonomic significance because according to PARIS & NÕLVAK (1999, p. 319) it is interpreted as an immature stage in the development of the eggs, assuming that chitinozoans represent eggs laid by marine metazoans.

OCCURRENCE: This long ranging species first appears in the Hunneberg Stage (Arenig) in Baltoscandia and disappears in the Porkuni Stage (latest Ashgill). It is a cosmopolitan species also known from Portugal; Oklahoma; North America and Podolia, Ukraine; see GRAHN (1984) for a summary of occurrences; Poland, Western Pomerania, Skibno 1 borehole, depth 1732.0-1881.1 m.

Lagenochitina aff. *capax* JENKINS, 1967; Pl. 3, Fig. 9

REMARKS: Vesicle with ovoid chamber and short, wide cylindrical neck. Pomeranian specimens are similar in size and shape (L=177-202, Dmax=81-116, Ln=52-75, Da=54-77) to the Welsh specimens and more similar to Baltic, slightly smaller specimens of *L.* sp. A aff. *capax* figured by GRAHN & *al.* (1996), who found their virtual identity with *L. deunffi* PARIS, 1974. Moreover, examined specimens from Pomerania show great similarities with those specimens from Dalby Limestone in Dalarna, Sweden illustrated by NÕLVAK & *al.* (1999). However, they differ markedly in the width and length of neck from *Lagenochitina* sp. A aff. *deunffi* vesicles recovered by GRAHN & *al.* (1994) from the lower Caradoc Arnestad Formation of the Oslo region.

OCCURRENCE: *L. capax* JENKINS, 1967 is known from the basal Glenburrell Beds, Shropshire, lower Caradoc of the Welsh Borderland; Baltoscandian *L.* sp. A aff. *capax* ranges from the upper Kukruse to the lower Idavere stages (GRAHN & *al.* 1996; NÕLVAK & *al.* 1999); Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0 m.

Lagenochitina? sp.; Pl. 3, Fig. 10

REMARKS: Large vesicle (dimensions: L=420, Dmax=80, Da=56) with a ovoidal chamber and a subconical long neck slightly flare at the aperture. The shoulders and flexure weakly developed or absent, and the flanks are slightly convex, with a glabrous surface. The base is round with a wide basal mucron. It cannot be excluded that this specimen is a chamber part of the vesicle belonging to e.g., *Conochitina minnesotensis*. Deformed and broken specimens may be confused with *Lagenochitina*? *dalbyensis* (LAUFELD 1967).

OCCURRENCE: Poland, Western Pomerania, Skibno 1 borehole, depth 1746.0 m.

Laufeldochitina stentor (EISENACK, 1937); Pl. 2, Figs 6-7

REMARKS: The shape, average dimensions (L=787, Dmax=170, Da=91) and ornamentation closely compare with the holotype and those well-illustrated specimens from Baltoscandia (cf. NÕLVAK & GRAHN 1993). Even a strongly deformed single specimen is still recognizable as species of *L. stentor* due to its resistant diagnostic ornamentation and characteristic large carina at the basal edge (Pl. 2, Fig. 6).

OCCURRENCE: An index species for Baltoscandia (NÕLVAK & GRAHN 1993): Uhaku Stage (late Llanvirn); known up to now outside Baltoscandia from Germany: Herscheider Shale of Westphalia (EISENACK 1939); France: Traveoust Formation (HERROUIN & PARIS 1984) and the Andouillé Formation (Paris, personal com. 2001) in Brittany; Poland: Baltic Syneclise, Łeba Elevation (PODHALAŃSKA 1980; BEDNARCZYK 1999); Western Pomerania, Skibno 1 borehole, depth 2038.6-2112.5 m.

Rhabdochitina gracilis EISENACK, 1962; Pl. 3, Fig. 1

REMARKS: A slender and cylindrical vesicle, with average dimensions (L=up to 875, Dmax=44-62) comparable to the type species.

OCCURRENCE: This long ranging species occurs from the Volkhov Stage (upper Arenig) to the Porkuni Stage (latest Ashgill) in Baltoscandia. It is a cosmopolitan species; see GRAHN (1984) and PARIS (1981) for a summary of occurrences; Poland, Łeba Elevation (PODHALAŃSKA 1980), Western Pomerania, Skibno 1 borehole, depth 2331.7 -2529.0 m.

Rhabdochitina magna EISENACK, 1931; Pl. 3, Figs 2-4

REMARKS: A larger species than *R. gracilis*, with the shape almost cylindrical to slightly conical (dimensions: Lmax=up to 1025, Dmax=79-98, Da=84-107).

OCCURRENCE: This long ranging species first appears in the upper Arenig in Baltoscandia and disappears in the Porkuni Stage (latest Ashgill). It is a cosmopolitan species, see GRAHN (1982), PARIS (1981) and ACHAB & ASSELIN (1995) for a summary of occurrences; Poland, Western Pomerania, Skibno 1 borehole, depth 1913.0-2653.0 m.

Spinachitina bulmani (JANSONIUS, 1964); Pl. 3, Fig. 8

REMARKS: Small vesicles are strongly damaged, with characteristic larger spines at the basal edge (Pl. 3, Fig. 8b). The shape, average dimensions (L=127-160, Dmax=60-80, Da=29-42; basal spine length up to 15) and ornamentation closely compare with the holotype (JANSONIUS 1964) and those from Shropshire (JENKINS 1967). They show also similarities with some specimens figured as *S. suecica* (LAUFELD) from the lower Caradoc (*D. multidens* graptolite Biozone) Sularp Shale of Skåne, Sweden (SCHALLREUTER, 1981, pl. 14, fig. 1-4.).

OCCURRENCE: Scotland, Laggan Burn limestone (JANSONIUS 1964) and Welsh Borderland, Glenburrell Beds, Shropshire (JENKINS 1967), lower Caradoc; Northern Africa, Morocco (MOLYNEUX & PARIS 1985), lower Ashgill; Poland, Western Pomerania, Skibno 1 borehole, depth 2529.0-2593.0 m.

Review of acritarchs

Acritarch assemblages are poorly preserved. The acritarch species are generally represented by relatively small numbers of specimens. Only in one sample at 1732.0 m acritarchs are more abundant and reasonably well preserved. They are represented by the following species:

Actinotodissus crassus LOEBLICH & TAPPAN, 1978; Pl. 5, Fig. 1

OCCURRENCE: Caradoc, central North America, (LOEBLICH & TAPPAN 1978); Ashgill (MOLYNEUX & PARIS 1985; HILL & MOLYNEUX 1988)

Goniosphaeridium splendens (PARIS & DEUNFF) TURNER, 1984; Pl. 6, Fig. 2

OCCURRENCE: Llanvirn, France (PARIS & DEUNFF 1970); Middle Ordovician, Britain (TURNER 1984); Lower Ordovician to Lower Silurian, Estonia (UUTELA & TYNNI 1991).

Ordovicidium elegantulum TAPPAN & LOEBLICH, 1971; Pl. 5, Fig. 6

OCCURRENCE: Llandeilo-Caradoc, Oklahoma (TAPPAN & LOEBLICH 1971); Caradoc, Indiana (COLBATH 1979); Gotland, Viruan (GÓRKA 1987); Middle to Upper Ordovician, Estonia (UUTELA & TYNNI 1991); Middle Ordovician, Britain (TURNER 1984).

Ordovicidium heteromorphicum (KJELLSTRÖM) LOEBLICH & TAPPAN, 1978; Pl. 6, Fig. 3

OCCURRENCE: Middle Ordovician, Gotland (KJELLSTRÖM 1971); Middle Ordovician, Finland (TYNNI 1982); Viruan, Gotland (GÓRKA 1987); Middle Ordovician, Britain (Turner 1984); Ordovician Baltic erratics, Finland (UUTELA 1989); Viruan, Gotland (GÓRKA 1987); Middle Ordovician, Estonia (UUTELA & TYNNI 1991).

Ordovicidium nanofurcatum (KJELLSTRÖM) UUTELA & TYNNI, 1991; Pl. 5, Fig. 2, 5

OCCURRENCE: Middle Ordovician, Gotland (KJELLSTRÖM 1971); Middle Ordovician, Britain (TURNER 1984); Ordovician Baltic erratics, Finland (UUTELA 1989); Middle Ordovician, Estonia (UUTELA & TYNNI 1991).

Ordovicidium nudum (EISENACK) LOEBLICH & TAPPAN, 1978; Pl. 5, Fig. 7

OCCURRENCE: Middle Ordovician, Sweden (STAPLIN & *al.* 1965), Middle Ordovician, Gotland (KJELLSTRÖM 1971); Middle Ordovician, Finland (TYNNI 1982); Llanvirn-Caradoc, Poland (GÓRKA 1980); Middle Ordovician, Estonia (UUTELA & TYNNI 1991).

The mode of classification used in this paper for the genus *Ordovicidium* is that introduced by EISERHARDT (1992, p. 65): " *Ordovicidium* TAPPAN & LOEBLICH, 1971 is characterized by hollow processes and the absence of a peteinos". To the contrary, *Peteinosphaeridium* STAPLIN & *al.*, 1965 - is characterized by "...appendages typically not hollow, but spiny; peteinos are fundamental but possibility of regression must be allowed for...."

BIOSTRATIGRAPHY

The chitinozoans recorded in the Skibno 1 borehole have broad stratigraphical ranges, but restricted to the Ordovician and even to the Middle-Upper Ordovician as in the case with *Belonechitina robusta*, *Conochitina chydaea*, *C. dolosa*, *Cyathochitina campanulaeformis*, *Cy. kuckersiana*, *Spinachitina bulmani*, *Lagenochitina* aff. *capax*, *Armoricochitina* aff. ? *reticulifera*.

Excellent specimens of the chitinozoan *Laufeldochitina stentor* (EISENACK) have been recorded from the 2038.6-2112.5 m interval. This index chitinozoan occurs with *Cyathochitina campanulaeformis*, *Cy. calix*, *Desmochitina minor*, and graptolites *Hustedograptus teretiusculus* (HISINGER) and *Nemagraptus* sp. in the Skibno 1 borehole, as well as in many neighboring boreholes located on the East European Craton (PODHALAŃSKA 1979, 1980; BEDNARCZYK 1999). *L. stentor* (EISENACK) is the index species of the *Laufeldochitina stentor* Biozone (NÕLVAK & GRAHN 1993). This chitinozoan biozone corresponds to the upper Uhaku and Kukruse stages on the East European Craton (Baltoscandia) and the uppermost Llanvirn to lowermost Caradoc in terms of the British series (NÕLVAK & GRAHN 1993; FORTEY & *al.* 1995; NÕLVAK 1999). *Lagenochitina* aff. *capax* recovered from the uppermost sample (1732.0 m) of the borehole represent the *Lagenochitina*? *dalbyensis* – *L.* aff. *capax* – *L. deunffi* chitinozoan assemblage (NÕLVAK 1999) which defines *Lagenochitina*? *dalbyensis* Biozone equivalent to the lower-middle Idavere Stage (NÕLVAK & GRAHN 1993), and corresponding to the *Diplograptus multidens* graptolite Biozone.

Also the acritarchs recorded from the borehole, e.g., *Ordovicidium nanofurcatum, Actinotodissus crassus, Goniosphaeridium splendens* and *Ordovicidium nudum* may be indicative of Caradoc age. The Ordovician acritarchs from Pomerania were recently investigated by SZCZEPANIK (2000). By using quantitative data, three local palynozones (A, B, C) were recognized. The small number of species (only six) from Skibno 1 borehole makes application of that division difficult. Among the assemblages described by SZCZEPANIK (2000) and those from Skibno 1 borehole there are only three species in common: *Ordovicidium elongatum, O. heteromorphicum,* and *O. nudum*. All of these occur in local palynozones B and C. These palynozones B and C correspond to uppermost Llanvirn-lower Caradoc (SZCZEPANIK 2000).

The rather scarce and poorly preserved graptolites from the Koszalin-Chojnice area allowed BEDNARCZYK (1974) in his pioneering work to distinguish two local biozones, which correspond to the *Hustedograptus teretiusculus* and *Dicranograptus clingani* biozones. The Ordovician succession in the Skibno 1 borehole contains a portion of the above mentioned graptolite biozones (*see* BEDNARCZYK 1974, tab. 2). The lower part of the section (1802.3-2807.0 m), containing graptolites (BEDNARCZYK 1974, tab. 5-6.) *Nemagraptus* sp., *Dicellograptus* cf. *sextans exilis* (ELLES & WOOD), *Amplexograptus* cf. *perexcavatus* (LAPWORTH), *Climacograptus* cf. *brevis* (ELLES & WOOD), *Orthograptus* cf. *acutus* (LAPWORTH) and *Hustedograptus teretiusculus* (HISINGER), probably represents the *Hustedograptus teretiusculus* and *Nemagraptus gracilis* biozones (upper Llanvirn-lowermost Caradoc; FORTEY & *al.* 1995). The upper part (1727.0-1802.3 m), containing graptolites (BEDNARCZYK 1974, tab. 2 and 5.) *Amplexograptus* cf. *perexcavatus* (LAPWORTH) and *Climacograptus* cf. *minimus* (CARRUTHERS), probably represents the *Diplograptus multidens* Biozone (lower Caradoc).

The conodont *Scabardella altipes* (HENNINGSMOEN, 1948) recorded at the 1913.0 m level is also characteristic for the Upper Ordovician (BERGSTRÖM 1990).

The brachiopod valves of *Paterula* cf. *portlocki* (GEINITZ), which were recorded from the 1728.0-1729.0 m level, are known from the Upper Ordovician (WILLIAMS 1969).

PALAEOGEOGRAPHY

The Ordovician of the Koszalin-Chojnice Structural Zone and in the Skibno 1 borehole belongs to a sedimentary sequence which stretches along the southwestern border of the East European Craton through the Rügen Island in northeastern Germany (JAEGER 1967), the southern Baltic Sea (MALETZ 1998, cf. Rügen 5/1966 well; MALETZ & *al.* 1998) and up to the Koszalin-Chojnice Structural Zone (cf. BEDNARCZYK 1974). These subsurface sedimentary strata are differentiated by their strong deformation, similar lithologies and thicknesses compared with nearby outcrops on Bornholm Island (e.g., POULSEN 1965) and Skåne (e.g., JAANUSSON 1973; BERGSTRÖM 1982). These two areas are on the East European Craton. The Caradoc strata drilled in boreholes of the Koszalin-Chojnice Structural Zone seem to be lithologically most similar to those of Rügen Island (GIESE & *al.* 1994). Moreover, facies and petrologic analyses of the Ordovician deposits on Rügen Island and those of the Koszalin-Chojnice Structural Zone indicated that terrigenous greywackes were transported over a rather short distance from a source area situated to the south or southwest (JAEGER 1967; MODLIŃSKI 1968; KATZUNG & *al.* 1995). These analyses reinforce the concept of a southern source (archipelago) existing in the same basin during the Ordovician (JAANUSSON 1973; BEDNARCZYK 1974). Recent investigations of the Ordovician acritarch assemblages in Rügen boreholes show their species composition comparable with the cold Mediterranean palaeogeographic province and have no similarities to the Baltic palaeoprovince (SERVAIS & KATZUNG 1993; SERVAIS 1994; KATZUNG & *al.* 1995).

Besides their biostratigraphical value, Chitinozoa also provide palaeogeographic information (PARIS 1992). However, in this paper based on one borehole, only some brief results can be presented. Most of the Ordovician chitinozoans from the Skibno 1 core are cosmopolitan species; however, some forms such as *Lagenochitina* aff. *capax* (Pl. 3, Fig. 9), *Spinachitina bulmani* (Pl. 3, Fig. 8) and *Cyathochitina calix* (Pl. 2, Figs 3-4) are similar to coeval specimens illustrated by JENKINS (1967) from England, and together with some examples of *Belonechitina* ex gr. *micracantha*, *B. robusta* and *B. wesenbergensis* are known from Avalonia (PARIS 1992, 1999) and Baltica (GRAHN & *al.* 1996). The comparisons between chitinozoan and acritarch assemblages from Skibno 1 borehole and those from the neighboring Rügen Island are only partially possible due to the considerably earlier age of the latter assemblage, extending from the early late Tremadoc up to the Abereiddian, early Llanvirn-Caradoc (SAMUELSSON & *al.* 2000).

The acritarch assemblage from the Skibno 1 contains cosmopolitan species (e.g., *Actinotodissus crassus, Goniosphaeridium splendens* and species of *Ordovicidium*). Typical "Mediterranean" genera, such as *Arkonia, Striatotheca* and *Frankea* (SERVAIS 1995), are absent. Acritarch assemblages on both side of the East European Craton margin show relationships with acritarch assemblages from neighboring areas recorded from the eastern part of the Baltic Syneclise and the Podlasie Depression (GÓRKA 1979, 1980), Scandinavia (KJELLSTRÖM 1971, 1976; GÓRKA 1987) and Rügen (SERVAIS & KAZUNG 1993) and suggest that, in the upper Llanvirn and Caradoc, there was only little palaeogeographic separation between the sedimentary basins of Baltica and Pomerania (SZCZEPANIK 2000); i.e., the Tornquist Ocean was quite narrow.

The most important palaeobiogeographic data come from the limited biogeographic range of the ichnofossil *Alcyonidiopsis pharmaceus* (RICHTER & RICHTER, 1939), burrows filled with faecal pellets which were known under the name *Tomaculum problematicum* (GROOM, 1902), referring to individual cylindrical faecal pellets with rounded ends, but not to the overall pellet-filled burrow (cf. GROOM 1902). These ichnofossils have been recently revised based on the rich ichnofaunal assemblage from the early Ordovician Skiddaw Group of the Lake District in England (ORR 1996). This benthic marine ichnofauna have been recorded from Pomerania as well as from many other Ordovician localities in England, Lake District (GROOM 1902; CRIMES 1970; ORR, 1996), Spain (RADIG 1964), northwestern Brittany, southern Montagne Noire (THORAL 1935), the Vogese Mountains (PENEAU 1941; ROSS 1964; TERMIER & TERMIER 1964), the Rheinisches Schiefergebirge (MALETZ & SERVAIS 1993), Thuringia (ERDTMANN 1991) Bohemia and Rügen Island (RICHTER & RICHTER 1941; VOLK 1941; JAEGER 1967; ZAGORA 1997). On the contrary, this ichnofauna not known yet from Scandinavia (JAANUSSON 1973) and northeastern Poland (cf. BEDNARCZYK 1974), suggests its high southterly latitudinal extension, especially in low temperature water conditions during the Ordovician. However, such palaeogeographic distribution needs a further revision since some elements of the ichnofaunal assemblage from the Lake District were also found in the localities off the margin of Laurentia (cf. ORR 1996).

It is worthy of note that the conodont *Scabbardella altipes,* recorded in the investigated borehole, is also a characteristic form for high paleolatitudes during the Ordovician (BERGSTRÖM 1990).

The investigated core interval of the Skibno 1 borehole, documents too short time span for full reconstruction of the drift history of the Pomerania Terrane and its amalgamation time with the East European Craton, but it could be assumed to be similar to the neighboring elements of eastern Avalonia, e.g., Rügen (SERVAIS 1994; SAMUELSSON 1999; SAMUELSSON & *al.* 2000) and Brabant Massif (SAMUELSSON & VERNIERS 2000).

CONCLUSIONS

The Ordovician succession of the Koszalin-Chojnice region can be compared with analogous successions from Rügen Island (MALETZ & *al.* 1998, SAMUELSSON & *al.* 2000), the Brabant Massif (MALETZ & SERVAIS 1998; SAMUELSSON & VERNIERS 2000) and the Rheinisches Schiefergebirge in Germany (ERDTMANN 1991; MALETZ & SERVAIS 1993) and the Skiddaw Group of the Lake District in England (FORTEY & *al.* 1989; ORR 1996), which were all part of the Avalonia palaeocontinent (MALETZ & *al.* 1998).

The biostratigraphical potential of chitinozoans and acritarchs for the investigated Ordovician core has been realized. The biostratigraphically significant chitinozoan species including *Belonechitina robusta*, *Conochitina chydaea*, *C. dolosa*, *Cyathochitina campanulaeformis, Cy. kuckersiana*, *Spinachitina bulmani*, *Lagenochitina* aff. *capax*, *Armoricochitina* aff. *? reticulifera*, and the index species *Laufeldochitina stentor* indicate that the investigated core interval can be attributed to the uppermost Llanvirn–lower Caradoc (upper Lasnamägi–lower Idavere stages), and correspond to the *teretiusculus* and *gracilis* up to the *multidens* graptolite biozones. This biostratigraphical results based on chitinozoans and acritarchs agree with previous research on graptolites from the same core interval of the Skibno 1 borehole.

Close similarities of the chitinozoan and acritarch assemblages of Skibno 1 borehole in the Western Pomerania with coeval assemblages of Baltica (*see* SZCZEPANIK 2000), and Avalonia (Welsh Borderland, Shropshire, *see* JENKINS 1967); Rügen (*see* SERVAIS 1994; SAMUELSSON & *al.* 2000), and Brabant Massif (*see* SAMUELSSON & VERNIERS 2000) suggest their close palaeobiogeographic relationships.

Additionally, the paleogeographical distribution of the ichnospecies *Alcyonidiopsis pharmaceus*, as well as lithological similarities with the Rügen Island and the Lake District in England (COOPER & *al.* 1993), may indicate a possible connection of the Pomerania Terrane with the eastern part of the Avalonia microcontinent. The investigated core interval of the Skibno 1 borehole, documents too short time span for complete reconstruction of the drift history of the Pomerania Terrane and its amalgamation time with Baltica, but their fate could be presumed to be analogous to those of the neighboring elements of Avalonia; e.g., Rügen (SERVAIS 1994; SAMUELSSON 1999; SAMUELSSON & *al.* 2000) and Brabant Massif (SAMUELSSON & VERNIERS 2000). The deeper boring in the Western Pomerania penetrating the Lower Ordovician deposits is urgently needed for further study and evaluating the knowledge of the palaeogeographic relationships between northern Gondwana, Avalonia and Baltica.

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PLATE 1

Stereoscan micrographs of the Ordovician chitinozoans from the Skibno 1 borehole, Pomerania, Poland

1-4 – *Conochitina dolosa* LAUFELD, 1967; 1 – Lateral view, depth 1881.1 m, ZPAL Ch.VII/126S25. Scale bar is 100 μm; 2 – Lateral view, depth 1881.1 m, ZPAL Ch.VII/126S26. Scale bar is 200 μm; 3 – Lateral view, depth 1881.1m, ZPAL Ch.VII/126S45. Scale bar is 200 μm; 4 – Lateral view, depth 1881.1 m, ZPAL Ch.VII/126S9. Scale bar is 200 μm.

5 – *Conochitina elegans* EISENACK, 1931; Lateral view, depth 2331.7 m, ZPAL Ch.VII/126S70. Scale bar is 100 μm.

6 – *Conochitina chydaea* JENKINS, 1967; Lateral view, depth 1881.1 m, ZPAL Ch.VII/126S28. Scale bar is 100 μm.

7-13 – *Desmochitina minor* EISENACK, 1931; 7 – Vesicles connected in linear chain, depth 1746.0 m, ZPAL Ch.VII/123S38. Scale bar is 100 μm; 8 – Vesicles in coiled chain (spiral), laterally compressed, depth 2529.0 m, ZPAL Ch.VII/127S6. Scale bar is 100 μm; 9 – Single vesicle in oblique lateral view, depth 1746.0 m, ZPAL Ch.VII/123S49. Scale bar is 50 μm; 10 – Compressed vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S9. Scale bar is 50 μm; 11 – Fragment of flattened cocoon-like cluster, note four joined vesicles in a coiled structure keeping the opening free (the opercula still in place), depth 1881.1 m, ZPAL Ch.VII/126S12. Scale bar is 100 μm; 12 – Four joined vesicles, a fragment of cocoon-like cluster, depth 1881.1 m, ZPAL Ch.VII/126S11. Scale bar is 50 μm; 13 – Fragment of flattened cocoon-like cluster, depth 1732.0 m, ZPAL Ch.VII/123S69. Scale bar is 100 μm.

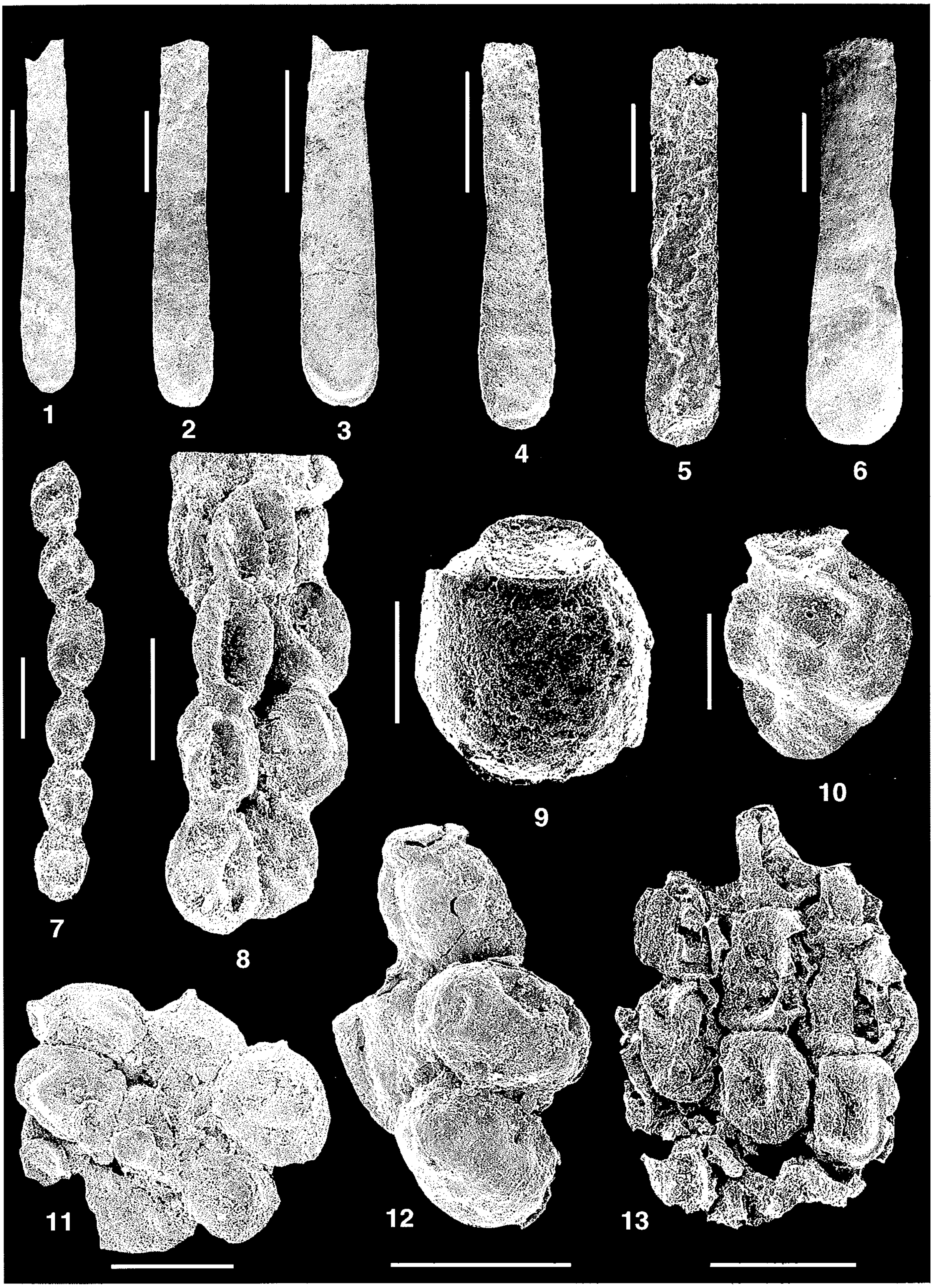
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PLATE 2

Stereoscan micrographs of the Ordovician chitinozoans from the Skibno 1 borehole, Pomerania, Poland

1-2 – *Cyathochitina* cf. *calix* (EISENACK, 1931); 1 – Damaged, uncompressed vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S5. Scale bar is 200 μm; 2 – A slightly damaged vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S13. Scale bar is 200 μm.

3-4 – *Cyathochitina calix* (EISENACK, 1931); 3 – Compressed vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S18. Scale bar is 100 μm; 4 – Broken, uncompressed vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S24. Scale bar is 100 μm.

5 – *Belonechitina* ex gr. *micracantha* (EISENACK, 1931); Compressed vesicle in lateral view, depth 1746.0 m, ZPAL Ch.VII/123S39. Scale bar is 100 μm.

6-7 – *Laufeldochitina stentor* (EISENACK, 1937); 6a – Vesicle in lateral view, depth 2038.6 m, ZPAL Ch.VII/123S4. Scale bar is 200 μm; 6b – Detail of the basal part. Scale bar is 50 μm; 7 – Compressed and strongly deformed vesicle in lateral view, note that diagnostic ornament for the species is still recognizable, depth 2112.5 m, ZPAL Ch.VII/126S47. Scale bar is 100 μm.

8 – *Belonechitina wesenbergensis* (EISENACK, 1959); Compressed vesicle in lateral view, depth 2112.5 m, ZPAL Ch.VII/126S53. Scale bar is 100 μm.

9-10 – *Belonechitina* ex gr. *micracantha* (EISENACK, 1931); 9 – Compressed and deformed vesicle in lateral view, depth 2716.0 m, ZPAL Ch.VII/123S61. Scale bar is 100 μm; 10 – Detail of the vesicle basal part, note the bases of broken off spines, depth 1881.1 m, ZPAL Ch.VII/123S59. Scale bar is 50 μm.

11-12 – *Cyathochitina kuckersiana* (EISENACK, 1934); 11 – Compressed and damaged vesicle in aboral view, base partly pressed into the vesicle, depth 1881.1 m, ZPAL Ch.VII/126S20. Scale bar is 100 μm; 12 – Damaged vesicle in oblique aboral view, base partly pressed into the vesicle, depth 1952.3 m, ZPAL Ch.VII/127S10. Scale bar is 100 μm.

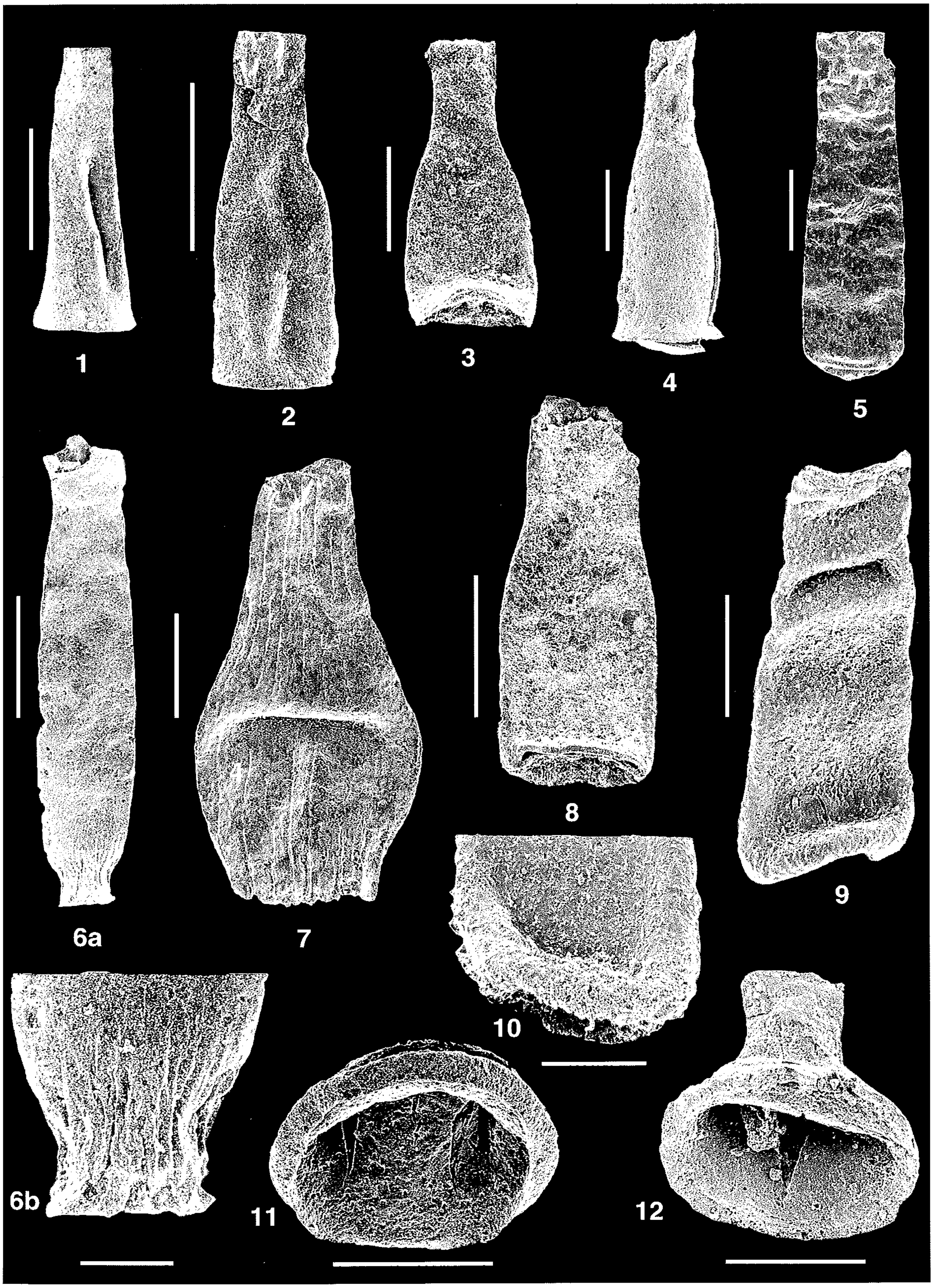
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PLATE 3

Stereoscan micrographs of the Ordovician chitinozoans from the Skibno 1 borehole, Pomerania, Poland

1 – *Rhabdochitina gracilis* EISENACK, 1931; Compressed vesicle in lateral view, depth 2331.7 m, ZPAL Ch.VII/126S59. Scale bar is 200 μm.

2-4 – *Rhabdochitina magna* EISENACK, 1931; 2 – Compressed vesicle in lateral view, depth 1913.0 m, ZPAL Ch.VII/126S38. Scale bar is 200 μm; 3 – Compressed and curved vesicle in lateral view, depth 1952.3 m, ZPAL Ch.VII/127S11. Scale bar is 200 μm; 4 – Compressed vesicle in lateral view, depth 1952.3 m, ZPAL Ch.VII/127S8. Scale bar is 200 μm.

5-7 – *Conochitina minnesotensis* (STAUFFER, 1933); 5 – Lateral view, depth 2331.7 m, ZPAL Ch.VII/126S69. Scale bar is 200 μm; 6 – Lateral view, depth 1746.0 m, ZPAL Ch.VII/123S44. Scale bar is 200 μm; 7 – Lateral view, depth 1881.1 m, ZPAL Ch.VII/126S16. Scale bar is 200 μm.

8 – *Spinachitina bulmani* (JANSONIUS, 1964); 8a. Compressed vesicle in lateral view, depth 2593.0 m, ZPAL Ch.VII/135S1. Scale bar is 50 μm; 8b. Detail of the vesicle basal part, note the basal margin with spines. Scale bar is 20 μm.

9 – *Lagenochitina* aff. *capax* JENKINS, 1967; Compressed vesicle in lateral view, depth 1746.0 m, ZPAL Ch.VII/135S17. Scale bar is 100 μm.

10 – *Lagenochitina*? sp.; Compressed vesicle in lateral view, depth 1746.0 m, ZPAL Ch.VII/135S15. Scale bar is 200 μm.

11-12 – *Belonechitina* sp. A; 11 – Compressed vesicle in lateral view, depth 1881.1 m, ZPAL Ch.VII/126S22. Scale bar is 100 μm; 12 – Compressed vesicle in lateral view, depth 1881.1 m, ZPAL Ch.VII/126S32. Scale bar is 100 μm.

13-14 – *Belonechitina robusta* (EISENACK, 1959); 13a – Compressed vesicle in lateral view, depth 1746.0 m, ZPAL Ch.VII/135S9. Scale bar is 100 μm; 13b – Detail of the vesicle surface, note the coalescent bases of spines. Scale bar is 20 μm. 14 – Uncompressed, damaged vesicle in lateral view, depth 1746.0 m, ZPAL Ch.VII/135S16. Scale bar is 100 μm.

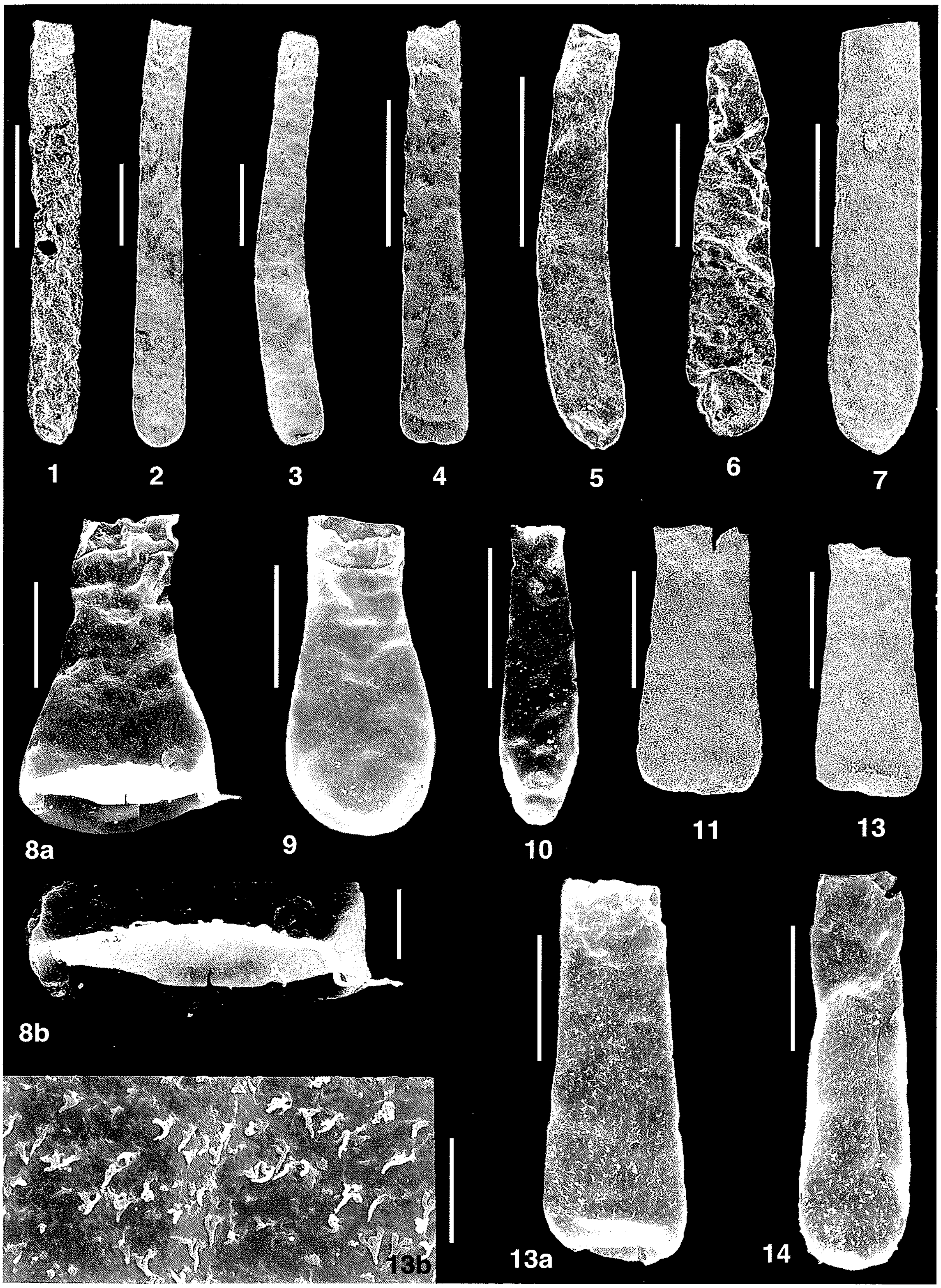
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PLATE 4

Stereoscan micrographs of the Ordovician chitinozoans from the Skibno 1 borehole, Pomerania, Poland

1 – *Cyathochitina kuckersiana* (EISENACK, 1934); Compressed vesicle in lateral view, depth 1952.3 m, ZPAL Ch.VII/127S15. Scale bar is 100 μm.

2-4, 9 – *Cyathochitina campanulaeformis* (EISENACK, 1931); 2 – Compressed and damaged vesicle in lateral view, depth 2112.5 m, ZPAL Ch.VII/126S57. Scale bar is 100 μm; 3 – Compressed vesicle in lateral view, depth 1952.3 m, ZPAL Ch.VII/127S14. Scale bar is 100 μm; 4 – Compressed vesicle in lateral view, depth 1881.1 m, ZPAL Ch.VII/126S31. Scale bar is 100 μm. 9 – Compressed and damaged vesicle in aboral view, base partly pressed into the vesicle, depth 1839.4 m, ZPAL Ch.VII/123S85. Scale bar is 100 μm.

5-7 – *Cyathochitina* cf. *campanulaeformis* (EISENACK, 1931); 5 – Compressed vesicle in lateral view, depth 1881.1 m, ZPAL Ch.VII/126S24. Scale bar is 100 μm; 6 – Compressed vesicle in lateral view, base damaged and partly broken off, depth 1881.1 m, ZPAL Ch.VII/126S17. Scale bar is 100 μm; 7 – Compressed vesicle in lateral view, depth 1839.4 m, ZPAL Ch. VII/123S82. Scale bar is 100 μm;

8 – *Cyathochitina calix* (EISENACK, 1931); Vesicle in aboral view, note basal scar, depth 1881.1 m, ZPAL Ch.VII/126S10. Scale bar is 100 μm;

10 – *Armoricochitina* aff. *?reticulifera* (GRAHN, 1981); Compressed vesicle in lateral view, depth 2112.5 m, ZPAL Ch.VII/126S52. Scale bar is 100 μm.

11 – *Armoricochitina*? sp.; Compressed vesicle in lateral view, depth 2529.0 m, ZPAL Ch.VII/135S4. Scale bar is 100 μm.

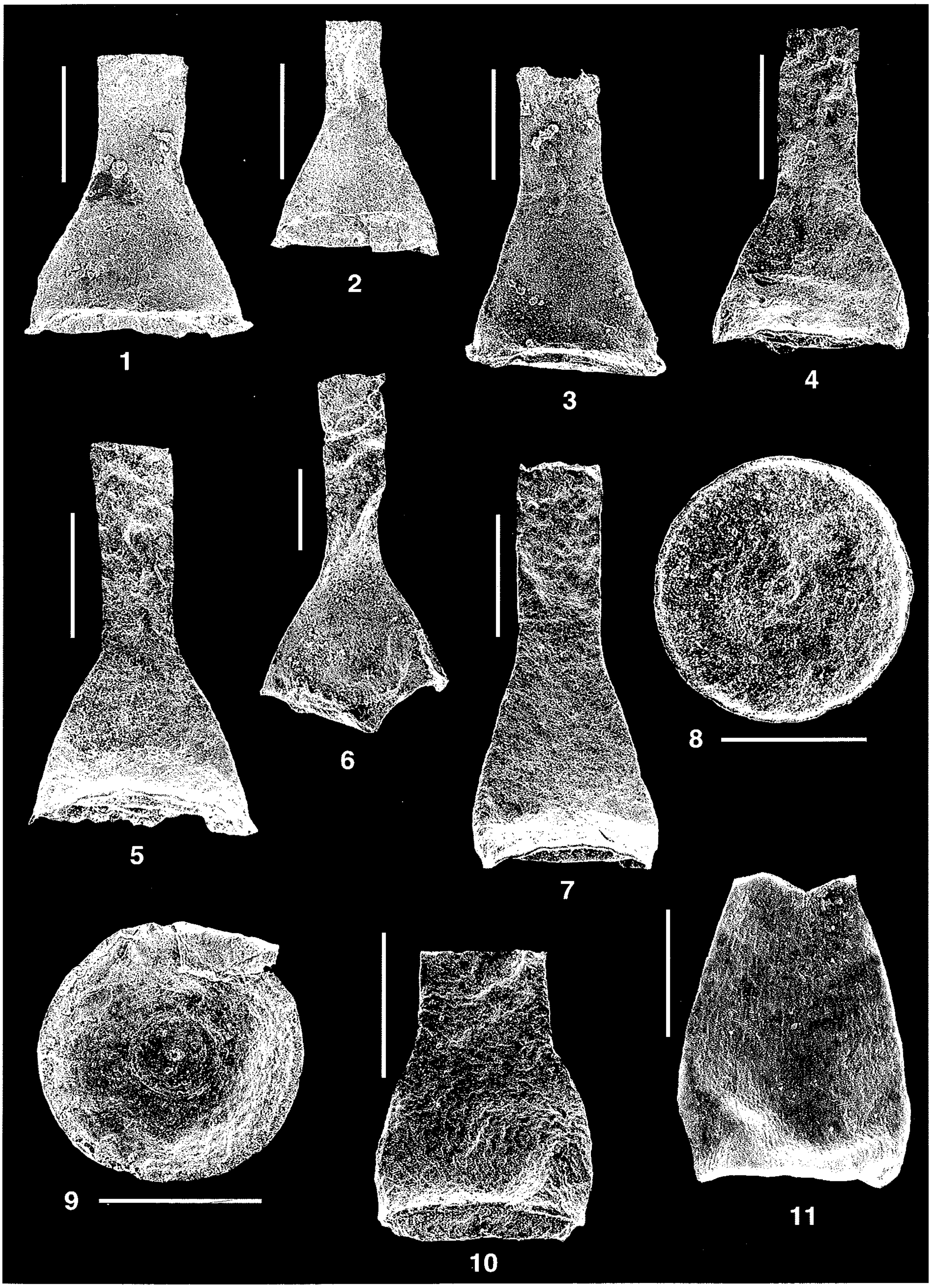
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PLATE 5

Ordovician acritarchs from the Skibno 1 borehole, Pomerania, Poland; depth 1732.0 m; all microphotographs × 1000 from slide ING Sk/14

1 – *Actinotodissus crassus* LOEBLICH & TAPPAN, 1978.
2, 5 – *Ordovicidium nanofurcatum* (KJELLSTRÖM) UUTELA & TYNNI, 991.
3 – *Actinotodissus* cf. *crassus* LOEBLICH & TAPPAN, 1978.
4 – *Multiplicisphaeridium* sp.
6 – *Ordovicidium elegantulum* TAPPAN & LOEBLICH, 1971.
7 – *Ordovicidium nudum* (EISENACK) LOEBLICH & TAPPAN, 1978.

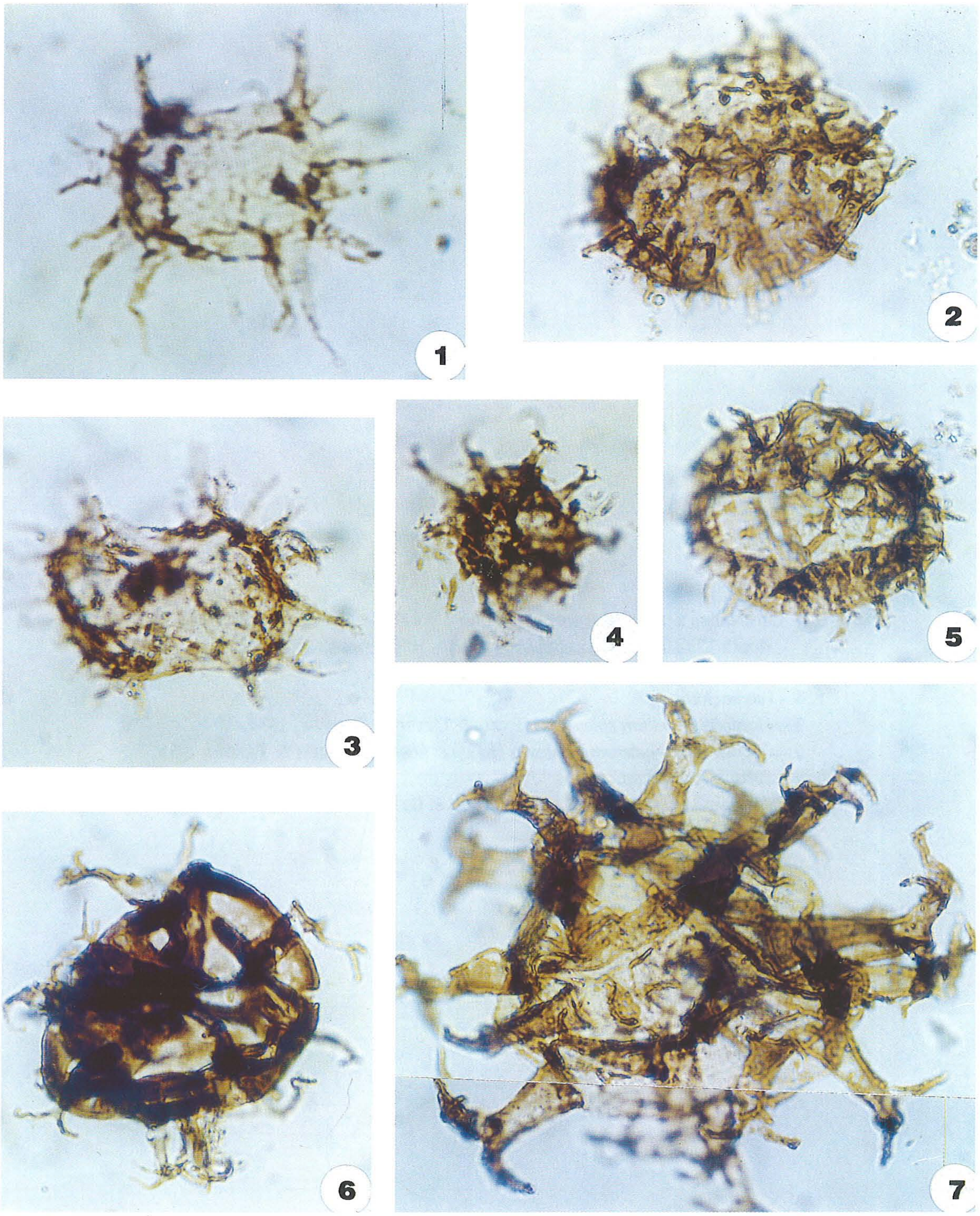
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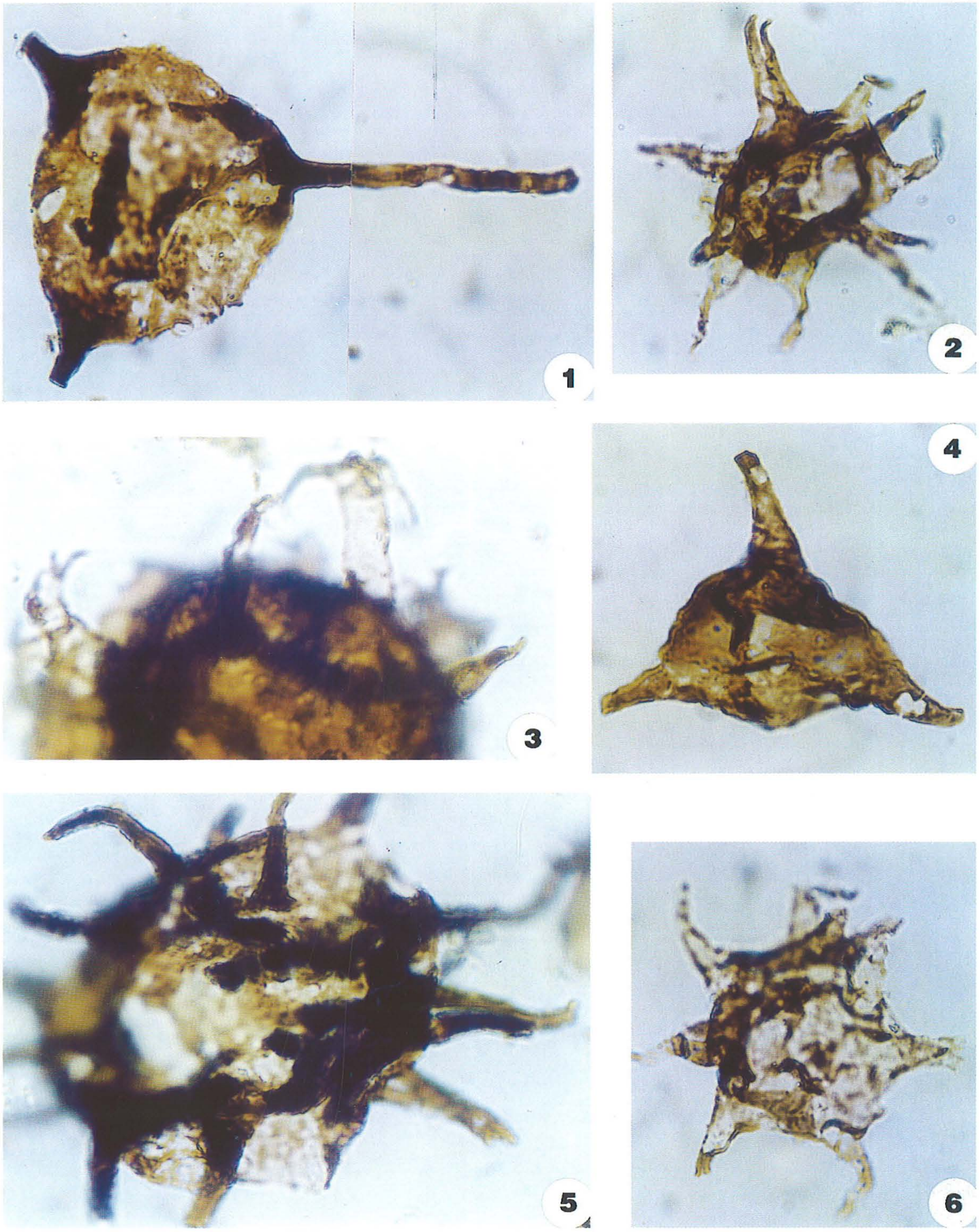
PLATE 6

Ordovician acritarchs from the Skibno 1 borehole, Pomerania, Poland; depth 1732,0 m; all microphotographs × 1000 from slide ING Sk/14

1, 4 – *Veryhachium* sp.
2 – *Goniosphaeridium splendens* (PARIS & DEUNFF) TURNER, 1984.
3 – *Ordovicidium heteromorphicum* (KJELLSTRÖM) LOEBLICH & TAPPAN, 1978.
5 – *Solisphaeridum* sp.
6 – *Goniosphaeridium* cf. *splendens* (PARIS & DEUNFF) TURNER, 1984.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