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

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ABSTRACT:


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 (Llandeil) – lower Caradoc, and correspond to the teretiusculus and gracilis through the multidentes 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 splendenum, Ordovicidium elegantulum, O. heteromorphicum, O. nanofurcatum, O. nudum, and are characteristic for the Caradoc. The presence of conodont Scabbardella altipes and ichnofossil Alyconiodopsis 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-
calcations. The oldest strata are Llanvirn in age, and the youngest are Caradoc in age as indicated by their graptolite fauna (MODLINSKI 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-Pridoli – pre-Emsonian 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 Pomeranian 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°.

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**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. STEMPIEJ-SALEK, 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

<table>
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<tr>
<th>Skibno 1 borehole</th>
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<tr>
<td>Sample depth in m</td>
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<tr>
<td>Sample number</td>
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<tr>
<td>Sk.1/1 2716.0</td>
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<td>Sk.1/2 2653.0</td>
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<td>Sk.1/3 2593.0</td>
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<td>Sk.1/14 1732.0</td>
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<td>Sk.1/15 1727.5</td>
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| Armoricochitina aff. reticulifera | 3 |
| Armoricochitina? sp. | 2 |
| Belonechitina ex gr. micracantha | 11 9 24 1 1 7 4 |
| Belonechitina robusta | 1 1 9 |
| Belonechitina wessenbergensis | 4 1 6 1 2 |
| Belonechitina sp. A | 8 11 5 |
| Conochitina chydaea | 15 12 |
| Conochitina dolosa | 1 15 31 10 95 |
| Conochitina elegans | 2 4 3 9 |
| Conochitina minnesotensis | 15 7 5 10 |
| Conochitina sp. | 4 3 9 3 1 |
| Cyathochitina calix | 9 1 11 |
| Cyathochitina cf. calix | 18 6 |
| Cyathochitina campanulaeformis | 1 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 |
| Spinachitina bulmani | 8 2 |
| Undetermined Chitinozoa | 2 11 4 6 13 2 5 6 2 4 1 3 8 15 0 |
| Number of chitinozoans in sample | 22 23 67 102 13 51 29 53 96 59 113 63 157 54 0 |
| Number of Chitinozoa/g rock | 1 1 5 4 1 3 1 5 9 4 5 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 Lauferd, 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 (Grahm, 1981) (see Pl. 4, Fig. 10), Belonechitina ex gr. micracantha (Eisenack, 1931) (see Pl. 2, Fig. 10), B. robusta, B. cf. wessenbergeri (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 Lauferd, 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), C. cf. campanaeiformis (Eisenack, 1931) (see Pl. 4, Figs 5-7), C. calx (Eisenack, 1931) (see Pl. 2, Figs 3-4, Pl. 4, Fig. 8), C. cf. calx (see Pl. 2, Figs 1-2), C. kueckersiana (Eisenack, 1934) (see Pl. 2, Fig. 11-12, PL4, 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. wessenbergeri (Eisenack, 1931) (see Pl. 2, Fig. 7), Conochitina dolosa Lauferd, 1967, C. elegans Eisenack, 1931, Conochitina sp., Cyathochitina campanulaeformis (Eisenack, 1931), C. calx (Eisenack, 1931) and C. cf. calx (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 scolecodons. The prasinophycean green alga Tasmanites sp. is quite common in eight of the fifteen productive samples from sampled interval. The scolecodont Mochytella cf. cristata Kielan-Jaworowska, 1961 is recorded from 2038.6 m. Ten acritarch species from 2718.8-23912.0 m interval were barren. The acritarchs from 2336.7-1745.0 m are poorly preserved and include following genera: Baltsphaeridium, 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: Baltsphaeridium, Lophospheraeidium, 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 (Kjellstrom) Loeblich & Tappan, 1978 (see Pl. 6, Fig. 3), Ordovicidium nanofurcatum (Kjellstrom) Utetela & Tynn, 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 (NOLVAK & GRAHN 1993): early Nabala Stage (late Caradoc); not known up to now outside Baltoscandia. BEDNARCZYK (1999) recovered A. reticulifera from the lower Caradoc Sassino Formation in the Baltic Syncline.

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 indent ed 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 (BENOIT & 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 microcantha microcantha 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 & BERGSTROM 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, NOLVAK & 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 & BERGSTROM (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 of 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 Syncline, 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=66-85) than the holotype, but comparable with population from Corkbridge, County Antrim, Ireland (JENKINS, 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 see GRAHN (1984) or MILLER (1986). The lenticular or hemispherical vesicles are more conical than those from the type material (EISENACK, 1931) and compare with Cyathochitina decipiens (GRAHN, 1967, PI. 1, Fig. 6), but the latter species is smaller. All specimens are compressed.

Conochitina dolosa LAUFELD, 1967; Pl. 1, Figs 1-4
REMARKS: The club shape vesicles are slightly larger and compressed (dimensions: L=263-354, Dmax=70-87, Da=66-85) than the holotype, but comparable with population from Shropshire (JENKINS 1967) and south western Europe (PARIS 1980). 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 see GRAHN (1984) or MILLER (1986). The club shape vesicles are more conical than those from the type material (EISENACK, 1931) and compare with Cyathochitina decipiens (GRAHN, 1967, PI. 1, Fig. 6), but the latter species is smaller. All specimens are compressed.

Conochitina elegans EISENACK, 1931; Pl. 1, Fig. 5
REMARKS: Vesicles of this species are elongated and slightly conical (dimensions: L=375-875, Dmax=63-153, Da=44-85), with broadly rounded basal edge and a perfectly smooth vesicle wall. All specimens are compressed. Vesicles are more cylindrically shaped than those from the type material (EISENACK 1931) and compare with C. cf. elegans figured by GRAHN & MELLER (1986). The lenticular or hemispherical widening of the cylindrical chamber characteristic for pistilliform vesicles was never observed.

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 & MELLER 1986) and the Caradoc formations of the central basin of Tennessee (SISSEK & al. 1998); Baltoscandia, Sweden, Dalarna, early Caradoc (LAUFELD 1967; NOLVAK & al. 1999), but in Estonia it appears in the Volkhov Stage (Arenig) and disappears in the Pzakni Stage (upper Ashgill); for detailed stratigraphic information about these occurrences see GRAHN (1984) and GRAHN & BERGSTROM (1984); Poland, Leba elevation, lower Caradoc (PODHALANSKA 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 Jöhvi stages, but known also in this range from the Welsh Borderland; Brittany; France; North America; Podolia, Ukraine; see GRAHN (1984) or NOLVAK & GRAHN (1993) for a review of stratigraphic occurrences; Poland, Baltic Synecilise (BIDNARCZYK 1999), Western Pomerania, Skibno 1 borehole, depth 2038.6-2529.0 m.

Cyathochitina cf. calix (EISENACK, 1931); Pl. 2, Figs 1-2
REMARKS: C. cf. calix differs from C. 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. Separation of these forms from typical *Dmax=137-225, Ln=95-160, Da=44-70,* and are usually compressed. The characteristic wide carina is frequently in part or completely broken off.

**OCCURRENCE:** Baltoscandia, Volkov 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 Syncline (*Podhalaska 1979, Bednarczyk 1999*), Western Pomerania, Skibno 1 borehole, depth 1746.9-2716.0 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 of *Cy. kuckersiana* 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 Syncline (*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.

**Desmochnita 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 & BERGSTROM (1984, fig. 3 C, F). However, all *Desmochnita* species originally were arranged in chains, but linkage between vesicles of some specimens (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 & NOLVAK (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 Dalarne, Sweden illustrated by NOLVAK & 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; NOLVAK & 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 Lagochitina dalbyensis (LAEUGELD 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. NOLVAK & 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 (NOLVAK & GRAHN 1993): Ulaku 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 Synecles, Leba Elevation (PODLAŃSKA 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 Volkov Stage (upper Arenig) to the Purtoki Stage (latest Ashgill) in Baltoscandia. It is a cosmopolitan species; see GRAHN (1982), PARIS (1981) and ACHAR & ASSELIN (1985) for a summary of occurrences; Poland, Western Pomerania, Skibno 1 borehole, depth 1913.0-2653.0 m.

*Spinachitina bulmanii* (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) Salarp 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)

*Goniophaeridium 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 (ÜUTELA & TYNNI 1991)

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

**OCCURRENCE:** Llandeilo-Caradoc, Oklahoma (TAPPAN & LOEBLICH 1971); Caradoc, Indiana (COBBLATH 1979); Gotland, Viruan (GÖRKA 1987); Middle to Upper Ordovician, Estonia (ÜUTELA & TYNNI 1991); Middle Ordovician, Britain (TURNER 1984).
Ordovicidium heteromorphicum (KISSLSTRÖM) LOEBLICH & TAPPAN, 1978; Pl. 6, Fig. 3

OCCURRENCE: Middle Ordovician, Gotland (KISSLSTRÖM 1971); Middle Ordovician, Finland (TYNNI 1982); Viruun, Gotland (GÖRKA 1987); Middle Ordovician, Britain (TURNER 1984); Ordovician Baltic erratics, Finland (UTTELA 1989); Viruun, Gotland (GÖRKA 1987); Middle Ordovician, Estonia (UTTELA & TYNNI 1991).

Ordovicidium nanofurcatum (KISSLSTRÖM) UTTELA & TYNNI, 1991; Pl. 5, Fig. 2, 5

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

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

OCCURRENCE: Middle Ordovician, Sweden (STAPLIN et al. 1965), Middle Ordovician, Gotland (KISSLSTRÖM 1971); Middle Ordovician, Finland (TYNNI 1982); Llanvirn-Caradoc, Poland (GÖRKA 1980); Middle Ordovician, Estonia (UTTELA & 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 et 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 Belnochitina robusta, Conochitina clydaea, C. dolosa, Cyathochitina campanulaeformis, Cy. kuckeriana, Spinachitina bulbani, Lagnochitina aff. capax, Armoricochitina aff. ? reticulifera.

Excellent specimens of the chitinozoan Lasfeldochitina 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 (PODHALANSKA 1979, 1980; BEDNARCZYK 1999). L. stentor (EISENACK) is the index species of the Lasfeldochitina stentor Biozone (NOŁŁAK & 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 (NOŁŁAK & GRAHN 1993; FORTEY & al. 1995; NOŁŁAK 1999). Lagnochitina aff. capax recovered from the uppermost sample (1732.0 m) of the borehole represent the Lagnochitina? dalbyensis - L. aff. capax - L. demni chitinozoan assemblage (NOŁŁAK 1999) which defines Lagnochitina? dalbyensis Biozone equivalent to the lower-middle Idavere Stage (NOŁŁAK & GRAHN 1993), and corresponding to the Diplograptus multidentis 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 SZCZEPAŃSKI (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 SZCZEPAŃSKI (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 (SZCZEPAŃSKI 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 cligangi 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. saxanensis (ELLES & WOOD), Amplexograptus cf. perexavatus (LAPWORTH), Climacograptus cf. brevis (ELLES & WOOD), Orthograptus cf. acuta (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. perexavatus (LAPWORTH) and Climacograptus cf. minimus (CARRUTHERS), probably represents the Diplograptus multidentis 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. porlocki (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 border of the East European Craton through the lithologically most similar to those of the Baltic palaeoprovince.

Similarities to the Baltic palaeoprovince 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 Synclise and the Podlasie Depression (Görka 1979; 1980), Scandinavia (Kjellström 1971; 1976; Görka 1987) and Rügen (Servais & Katzung 1993) and suggest that, in the upper Llanvirn and Caradoc, there was only little palaeogeographic separation between the sedimentary basins of Baltica and Pomerania (Szczepaniak 2000); i.e., the Torridic Ocean was quite narrow.

The most important palaeobiogeographic data come from the limited biogeographic range of the ichnofossil Ancyritisphyrnaeous (Richiter & Richiter, 1939), burrows filled with faecal pellets which were known under the name Tomactum 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 (Radio 1964), northwestern Brittany, southern Montagne Noire (Thoral 1935), the Voges Mountains (Peneau 1941; Ross 1964; Termier & Termier 1964), the Rheinische Schiefergebirge (Maletz & Servais 1993), Thuringia (Erdtmann 1991) Bohemia and Rügen Island (Richiter & Richiter 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 southerly 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 (Bergrström 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 Skidaw 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 campantulaeformis, Cy. lauckersiana, Spinachitina bulburi, 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 terrissculus and gracilis up to the multideni graphotolite 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 Szczepaniak 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 palaeobiogeographical relationships.

Additionally, the paleogeographical distribution of the ichnospecies Aplyonidopsis pharmaceutus, 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 palaeocontinent. 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 1881.1 m, 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.
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 2176.0 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.
PLATE 3

Sterescan 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 – Belomechitina 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 – Belomechitina 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.
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/135S54. Scale bar is 100 μm.
PLATE 5

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

2, 5 – *Ordovicidium nanofurcatum* (KJELLSTRÖM) UUTELA & TYNNI, 991.
4 – *Multiplicisphaeridium* sp.
PLATE 6

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

1, 4 – *Veryhachium* sp.
5 – *Solisphaeridium* sp.