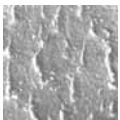


Ordovician Chitinozoa and biostratigraphy from Skåne and Bornholm, southernmost Scandinavia – an overview and update

YNGVE GRAHN & JAAK NÖLVAK



Ordovician chitinozoans from Skåne (Sweden) and Bornholm (Denmark), in southernmost Scandinavia, are discussed. Previously published information on Ordovician chitinozoans from these two provinces is reviewed and complemented with new data. Characteristic Baltoscandian chitinozoan faunas have been found from the uppermost Tremadocian (*H. copiosus* Zone) to the Ordovician–Silurian boundary interval. Besides the uppermost Tremadocian strata, the Lower Ordovician part of the Tøyen Formation (Floian to lowermost Darriwilian) has not been investigated. The *Belonechitina micracantha* – *robusta* – *wesenbergensis* complex is discussed in some detail. The forty-nine species, of which twelve in open nomenclature, are from fifteen genera. One species, *Conochitina scabra* n. sp., from the uppermost Lindegård Mudstone and lower Tommarp Formation (uppermost Katian–lower Hirnantian) in Skåne, is newly described. • Key words: Ordovician, Chitinozoa, Scandinavia, Skåne, Bornholm.

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Yngve Grahn, Universidade do Estado do Rio de Janeiro, Faculdade de Geologia, Bloco A – Sala 4001, Rua São Francisco Xavier 524, 20550-013 Rio de Janeiro, R.J., Brazil; yngvegrahn@hotmail.com • Jaak Nölvak, Tallinn University of Technology, Institute of Geology, Ehitajate tee 5, 19086 Tallinn, Estonia; nolvak@gi.ee

Skåne (Sweden) and Bornholm (Denmark) comprise the southernmost Ordovician outcrop areas in Scandinavia. Ordovician chitinozoans from Skåne have earlier been discussed (or mentioned) by J. Bergström *et al.* (1968), S.M. Bergström *et al.* (1997, 2000), Eisenack (1968, p. 186), Grahn (1978, 1980, p. 34), Lindström (1953), Nilsson (1960, 1977), Nölvak & Grahn (1993, p. 247), Schallreuter (1981, 1983), and Vandenbroucke (2004). S.M. Bergström & Nilsson (1974, p. 31) and Laufeld (1967, p. 281) have mentioned Ordovician chitinozoans from Bornholm. The present study reviews and updates upper Tremadocian to Hirnantian chitinozoans from these two regions. The sample size is, in general, 50 g. The chronostratigraphy follows that of Ogg (2004).

Geological setting

Skåne and Bornholm are situated along the Tornquist Line, on the southwestern margin of the Baltic Shield; and towards the Wendean Basin (Jaanusson 1976). Ordovician rocks are present as a series of outliers along this border zone (Fig. 1). Scandinavia can be divided into three confa-

cies belts (*sensu* Jaanusson 1995) during the Ordovician, *viz.* the Oslo belts, Scanian Lithofacies belt and the Central Baltoscandian Confacies belt. The Scanian Lithofacies belt is predominantly developed in a graptolitic facies along the margin of the Baltic Shield; whereas the other two confacies belts are dominated by carbonate facies with shelly fossils (Fig. 1). The Scanian Lithofacies belt includes Ordovician rocks of Bornholm, Skåne and the western part of Västergötland (Halleberg-Hunneberg district). In the Early–Middle Ordovician, at least until the lowermost Darriwilian (upper Arenig), this lithofacies belt reached into the Oslo Region (Lindholm 1991, Jaanusson 1995).

Skåne

Skåne, the southernmost province of Sweden, is situated on the southwestern margin of the Baltic Shield. Palaeozoic rocks occur in a belt stretching SE–NW. Ordovician rocks are restricted to fault blocks, concentrated to six areas, *i.e.* SE Skåne, Fågelsång, Albjåra, Rävatofta, Röstånga, and NW Skåne (Fig. 2). The lithologies are predominantly graptolitic shales and mudstones; and only three limestone

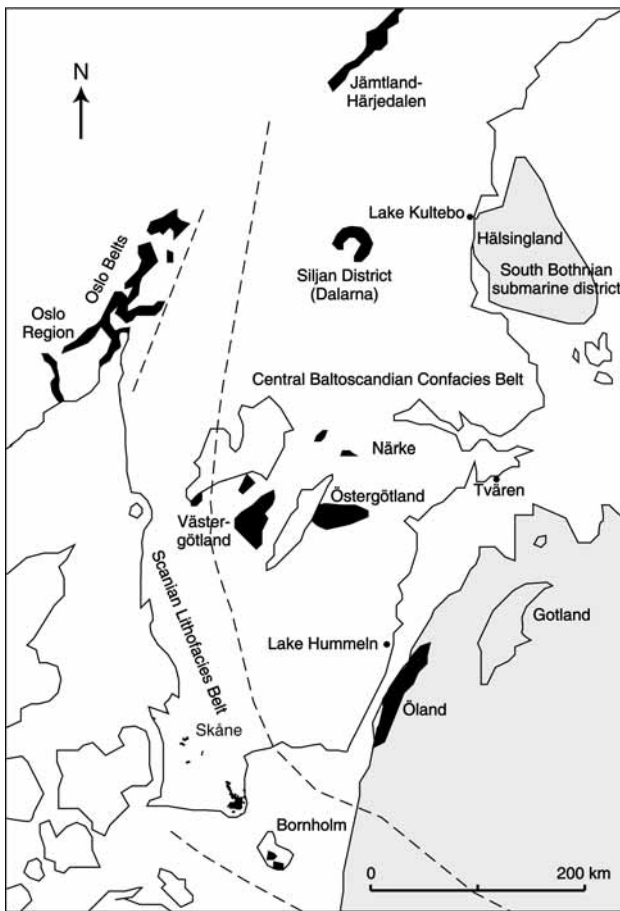


Figure 1. Map showing extent of Ordovician rocks and confacies belts (*sensu* Jaanusson 1995) in Scandinavia. Black color shows Ordovician outcrop areas, and grey color is submarine occurrences of Ordovician rocks.

levels of significance in the Ordovician are known, *i.e.* Björkåsholmen Formation, Komstad Limestone, and Ska-gen Formation. The total thickness of the Ordovician is about 200 m. The re-visited localities are described below in stratigraphic order.

Krapperrup core (*loc. 1* on Fig. 2). – This well was drilled by Wargön AB in 1946, and is located on the beach about 950 m W of Krapperrup Castle, and about 500 m NNW of the village of Lerhamn. The hole penetrated Ordovician rocks to a total depth of 155.06 m. One sample at 150.50 m, in the *Hunnegraptus copiosus* Zone (uppermost Tremadocian), yielded *Lagenochitina esthonica*, a long-ranging Tremadocian to early Darriwilian species. Graptolites from this core have been described by Lindholm (1991).

Lovisefred core (*loc. 3* on Fig. 2). – This well was drilled by TGB for the Geological Survey of Sweden in 1977, and is located about 1 km S of Lovisefred Farm, and about 4 km NNE of Höganäs church. The core penetrates Early Silurian to Stage 3 (Arenig; *D. hirundo* Zone) strata to a total

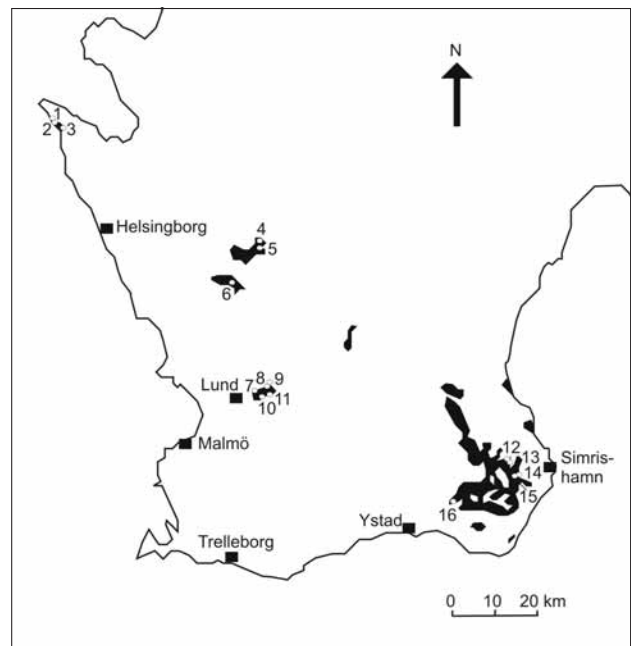


Figure 2. Map showing Ordovician outcrop areas in Skåne. Abbreviations: 1 – Krapperrup core, 2 – Nyhamnsläge, 3 – Lovisefred core, 4 – Kyrkbäcken, 5 – Röstånga core, 6 – Rävatofta, 7 – Koängen core, 8 – Cementa 27 core, 9 – Cementa 20 core, 10 – Fågelsång E14b, 11 – Fågelsång core, 12 – Flagabro, 13 – Killeröd, 14 – Ö. Tommarp, 15 – Ö. Tommarp 1-2, 16 – Gärarpsbäcken. Black color shows Ordovician outcrop areas.

depth of 480.80 m (Ragnar Nilsson, unpublished material, S.M. Bergström 1989). Three samples from the lower Almelund Shale (*Didymograptus artus* Zone, 426.75–454.00 m) were investigated. A sample at 432.10 m yielded no chitinozoans. At 437.02 m *Lagenochitina esthonica* and *Rhabdochitina gracilis* occur, and at 439.05–439.10 m *Belonechitina micracantha* s.l., *Conochitina minnesotensis*, *Cyathochitina calix*, *Cyathochitina hunderumensis*, *Lagenochitina esthonica* and *Rhabdochitina gracilis* are present. This is a characteristic early Darriwilian (Llanvirn) chitinozoan assemblage.

Fågelsång core (*loc. 11* on Fig. 2). – This well was drilled by Svenska Diamantbergborrnings AB in 1941, and is located by Sularp Brook in the Fågelsång area, about 900 m SSW of Södra Sandby church. The core penetrates beds from the *N. gracilis* Zone to the Upper Cambrian at a total depth of 55 m. Lithology and macrofossil content were described by Hede (1951), and S.M. Bergström *et al.* (2002) discussed the well's stratigraphy. Chitinozoans from the Almelund Shale (top within the *N. gracilis* Zone to the base of the *D. murchisoni* Zone) are investigated in this study (Fig. 3). The chitinozoan fauna is little diversified, compared to fauna from carbonate facies, but zonal index species are present in the upper Darriwilian to lowermost Sandbian sequence (*i.e.* *Conochitina clavaherculi*, *Laufeldochitina striata*, and *L. stentor*). Conodonts were discussed by S.M. Bergström *et al.* (2000).

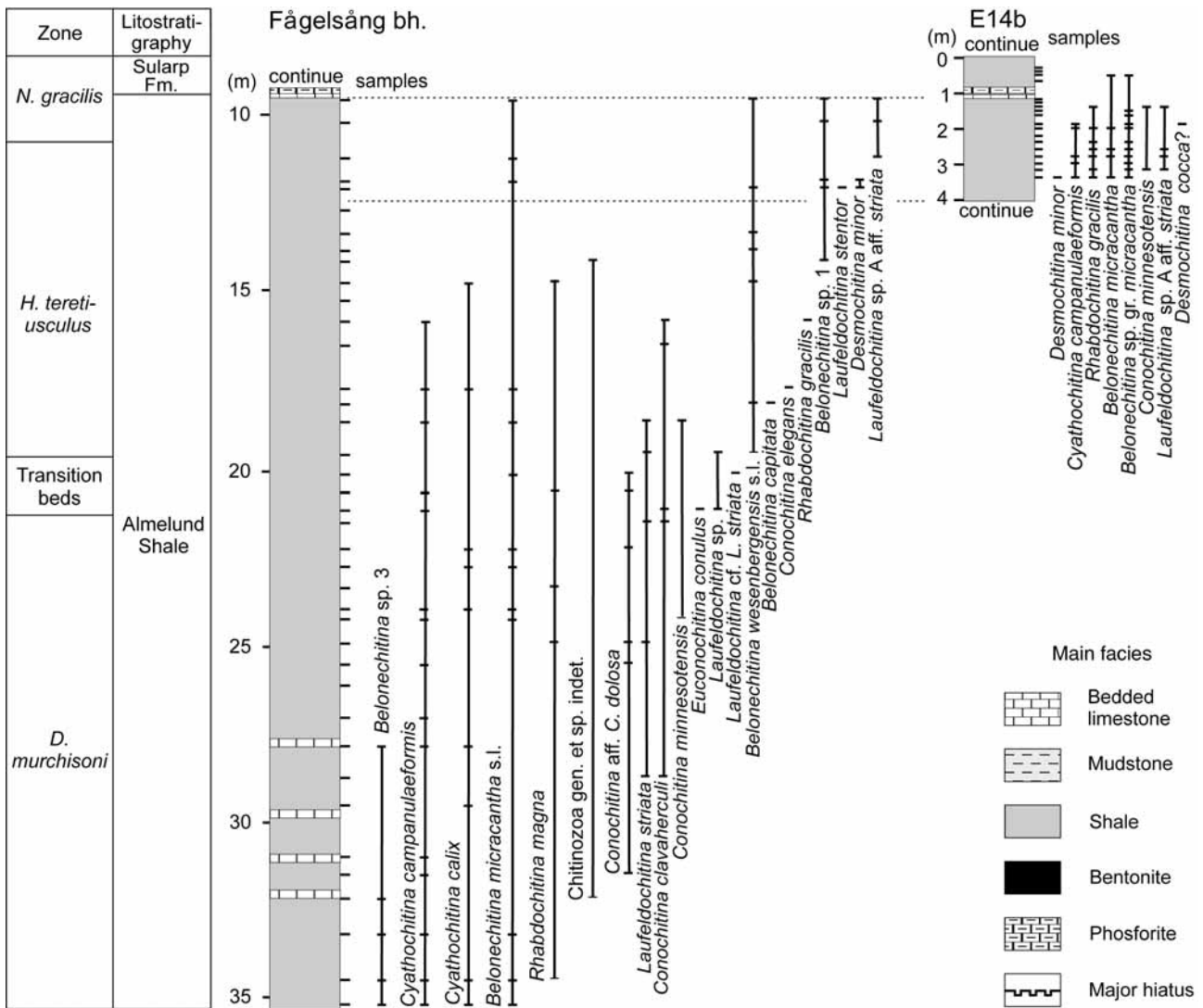


Figure 3. Lithology, sample levels and chitinozoan ranges at the E 14b locality and the Fågelsång core. The E 14b locality after Grahn in S.M. Bergström *et al.* (2000).

Fågelsång E 14 b (loc. 10 on Fig. 2). – This section at Sularp Brook (Fig. 3), about 8 km E of the centre of Lund, is the global boundary stratotype for the base of the Upper Series of the Ordovician System (S.M. Bergström *et al.* 2000). Moberg (1910) was the first to describe the section, and subsequent work has been performed by Hadding (1913), Lindström (1955), S.M. Bergström & Nilsson (1974), Finney & S.M. Bergström (1986), S.M. Bergström *et al.* (1998, 2000), as well as others. The chitinozoans were described by Grahn in S.M. Bergström *et al.* (2000) and Vandenbroucke (2004). The presence of *Laufeldochitina* sp. A aff. *striata*, across the Darriwilian–Sandbian boundary, shows that this interval is situated within the upper part of the *L. stentor* Zone. Lindström (1953) mentioned *Conochitina cf. calix* (= *Cyathochitina campanulaeformis*) from the Sularp Formation 40 m E of Moberg’s locality E 38 (about 190 m W of locality E 14 b).

Koängen core (loc. 7 on Fig. 2). – This drilling was carried out by the Svenska Diamantborrningsbolaget in 1954, about 200 m SE of Koängen Farm, situated about 4.7 km E of the centre of Lund. Lithology and biostratigraphy were described by Nilsson (1960, 1977). The core penetrates a succession, from the lower part of the Lindegård Mudstone downwards to the upper part of the Almelund Shale, for a total depth of 70.30 m. The chitinozoans are investigated in this study (Fig. 4). The chitinozoan biostratigraphy confirms that the Darriwilian–Sandbian boundary to be within the upper part of the *L. stentor* Zone. The base of Haljala Stage (*Armoricochitina granulifera* Zone) is distinct, and the occurrence of important key species above (*e.g.*, *Spinachitina multiradiata*, *Desmochitina nodosa*, and *Belonechitina robusta*) makes it easy to correlate the graptolitic facies in the Koängen core with the carbonate facies elsewhere in Sweden. The level of the first occurrence of

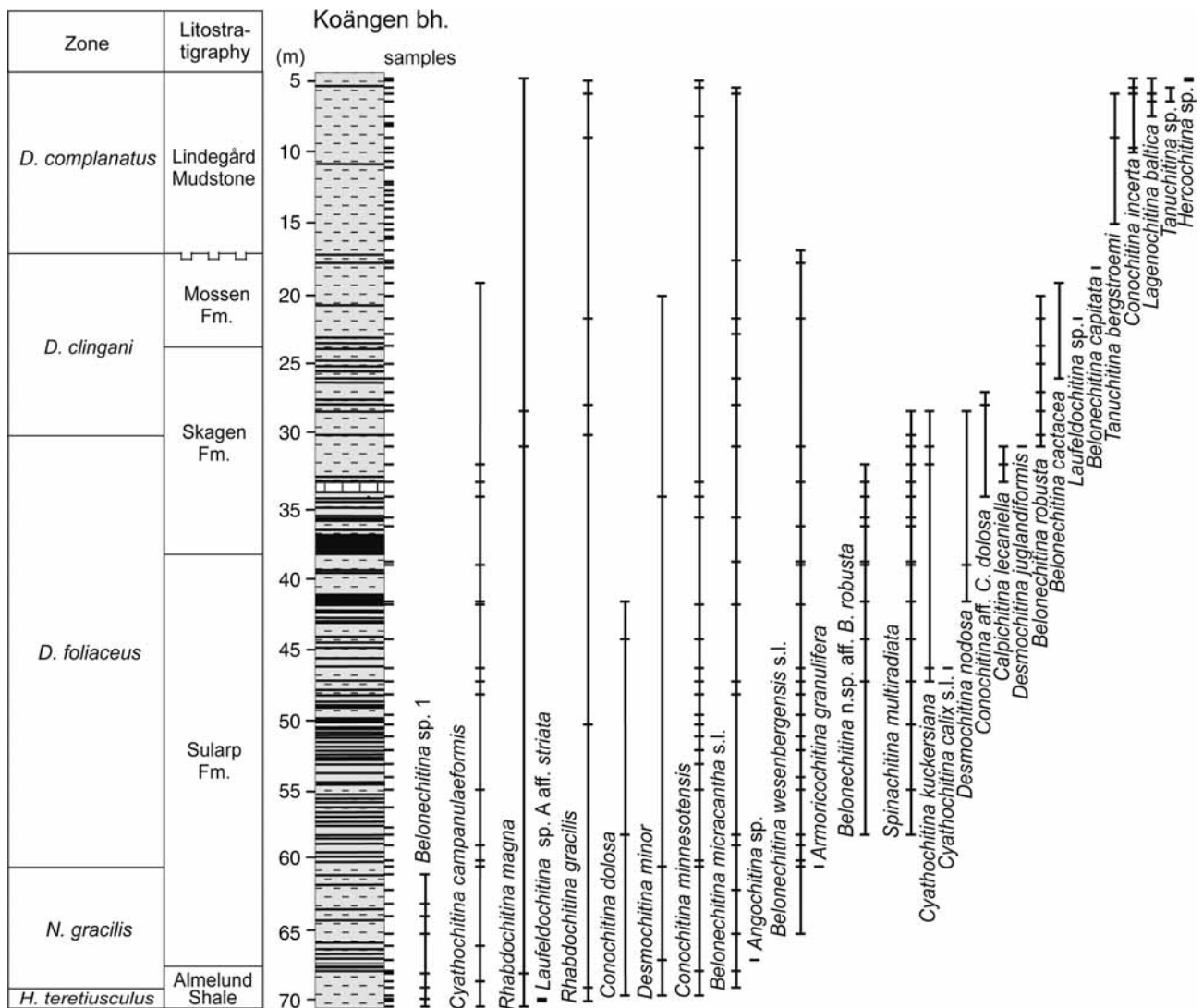


Figure 4. Lithology, sample levels and chitinozoan ranges in the Koängen core.

B. robusta is, roughly, near the base of the *Dicranograptus clingani* Zone. The presence of the index species *Tanuchitina bergstroemi* in the Katian sequence restricts the Lindegård Mudstone in the core to the lower part of that unit.

Rävatofta (loc. 6 on Fig. 2). – A temporary ditch-section located at Källeskog Farm 1 km S of Rävatofta, and about 4 km NE of Svalöv, was excavated in 1967, and exposed Upper Cambrian through Middle Ordovician strata. These rocks and their fossil content were described by J. Bergström *et al.* (1968). The Skagen Formation yielded *Conochitina minnesotensis*, *Cyathochitina campanulaeformis*, *Desmochitina minor*, and *Desmochitina nodosa*.

Kyrkbäcken (loc. 4 on Fig. 2). – Along Kyrkbäcken Brook, from about 400–500 m SE of Röstånga church a succession of rocks, representing lower Lindegård Mudstone to the Su-

larp Formation, are exposed (Tullberg 1880; Olin 1906; Moberg 1910; Pålsson 1996; S.M. Bergström *et al.* 1997, 1999). Chitinozoans from the Sularp and Skagen formations were described by Charles Hart *in* S.M. Bergström *et al.* (1997), and additional samples from the Mossen Formation were collected by the present authors in 1996 (Fig. 5). The occurrence of *Belonechitina robusta* in the uppermost part of the Sularp Formation, as well as *Euconochitina conulus* in both the upper part of the Sularp Formation and in the Skagen Formation, that were reported but not illustrated by S.M. Bergström *et al.* (1997), are doubtful. Other chitinozoan species present in the section along Kyrkbäcken Brook are confirmed by this study, as well as others (for a summary, see Grahn 1984, Nölvak & Grahn 1993).

Gärarpsbäcken (loc. 16 on Fig. 2). – This locality, situated about 850 m NNW of the Tosterup church, corresponds to

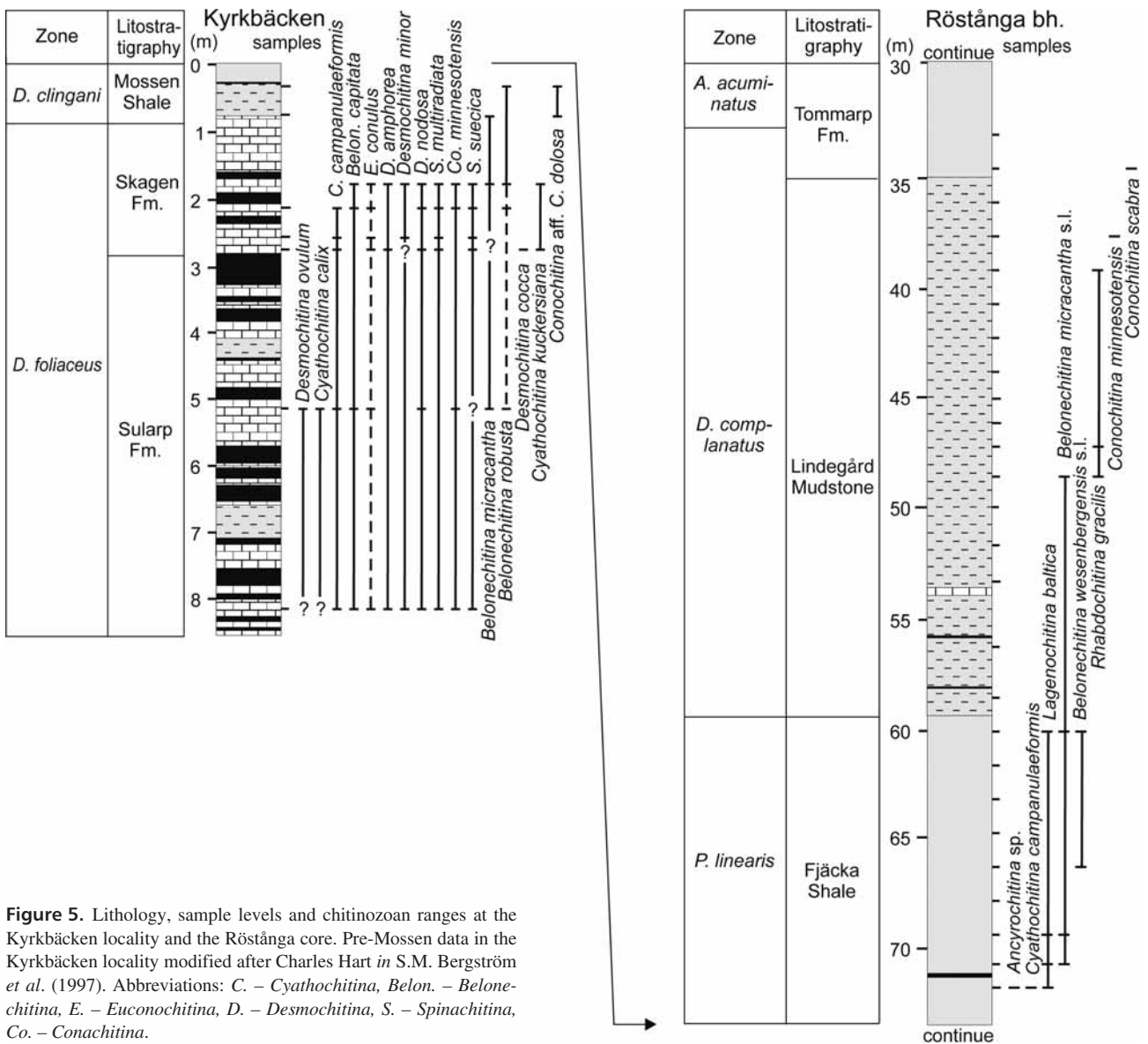


Figure 5. Lithology, sample levels and chitinozoan ranges at the Kyrkbäcken locality and the Röstånga core. Pre-Mossen data in the Kyrkbäcken locality modified after Charles Hart in S.M. Bergström *et al.* (1997). Abbreviations: C. – *Cyathochitina*, Belon. – *Belonechitina*, E. – *Euconochitina*, D. – *Desmochitina*, S. – *Spinachitina*, Co. – *Conachitina*.

locality BIII: 7 by Moberg (1910, p. 164). It is in the SE valley of the Gärarpsbäcken Brook dark shales, belonging to the Mossen Formation, and crops out in a ~ 2 m thick section. Here the graptolites indicate the upper part of the *D. clingani* Zone. The chitinozoans present, *Cyathochitina campanulaeformis* and *Lagenochitina baltica*, agree with this age.

Röstånga core (loc. 5 on Fig. 2). – This drilling was carried out by Borrbolaget (Västra Frölunda), in 1997, about 800 m SE of Röstånga church. The lithology and biostratigraphy was described by S.M. Bergström *et al.* (1999). The core penetrates lower Silurian to the upper part of the Sularp Formation to a total depth of 132.59 m. Scattered samples through the Lindegård Mudstone and Fjäcka Shale were examined for chitinozoans (Fig. 5). Chitinozoan biostrati-

graphy in the Röstånga core is hampered by insufficient sampling; but noteworthy is the presence of *Lagenochitina baltica* in the Fjäcka Formation, and *Conochitina scabra* n. sp. in the lower Tommarp Formation, which establish the presence of the *C. scabra* Zone in the core.

Östra Tommarp 1-2 (loc. 15 on Fig. 2). – Ditch-sections, no longer accessible, about 370–380 m WSW of the Östra Tommarp church. In two sections (ÖT 1: from the *M. revolutus* = *cyphus* Zone to the base of Silurian, as well as the uppermost 20 cm of *N. persculptus* Zone and the upper part of the Lindegård Mudstone; and ÖT 2: the upper 74 cm of *N. persculptus* Zone) comprise a section across the Ordovician–Silurian boundary. Twenty-five samples were collected from the Tommarp Formation and Lindegård Mudstone and investigated for chitinozoans (Grahn 1978) as

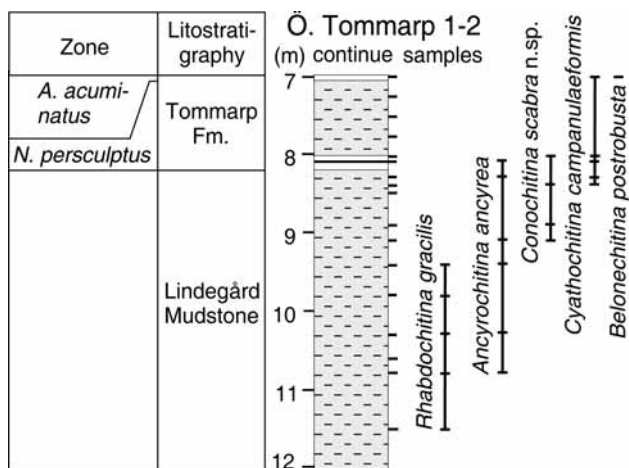


Figure 6. Lithology, sample levels and chitinozoan ranges at the Östra Tommarp 1-2 locality.

well as graptolites (Ragnar Nilsson *in* Grahn 1998). Chitinozoan biostratigraphy of the lowermost Tommarp Formation (*N. persculptus* Zone) and Lindegård Mudstone are shown in Fig. 6. The occurrence of the *C. scabra* Zone at this locality is noteworthy (Grahn 1978).

Cementa 20 core, Fågelsång (loc. 9 on Fig. 2). – This shallow well was carried out by Skånska Cement AB in 1961 about 250 m S of the Södra Sandby church. Twenty-three samples from the Lindegård Mudstone (10.87–23.40 m) were investigated. Only one sample at 17.00 m yielded *Cyathochitina campanulaeformis*, a long-ranging, Ordovician to early Silurian, species.

Cementa 27 core, Fågelsång (loc. 8 on Fig. 2). – This shallow well was carried out by Skånska Cement AB in 1961 about 160 m NW of the Lindegård Farm, and about 850 m WNW of the Södra Sandby church. The macrofossils were described by Nilsson (1979) and the chitinozoans by Grahn (1978 as Södra Sandby 27). From the Ordovician sequence, four samples from the lower part of the Tommarp Formation (*N. persculptus* Zone) and upper part of the Lindegård Mudstone (from 17.40 m downwards) were investigated. Three species are present, *i.e.* *Ancyrochitina ancyrea* at 17.60–17.70 m, *Conochitina scabra* (*Conochitina robusta* by Grahn, 1978) at 17.00–17.05 and 17.15–17.30 m, and *Cyathochitina campanulaeformis* at 17.00–17.05 and 18.00–18.05 m. S.M. Bergström *et al.* (1999) used the Hirnantian and Silurian stratigraphy of the well in a regional correlation.

Nyhamnsläge (loc. 2 on Fig. 2). – Surface exposure across the Ordovician–Silurian boundary at the beach about 3150 m WSW of the Brunnby church (Grahn 1978). The locality has also been described by Lundgren (1874), Lindström (1880), Törnquist (1875), Troedsson (1918, 1920), and

Grahn (1978). *Rhabdochitina gracilis*, a long-ranging Ordovician species, is present in the upper part of the Lindegård Mudstone (Sven Laufeld, pers. comm. 1978).

The following samples were barren of chitinozoans: The Björkåsholmen Formation at Flagabro Farm (loc. 12 on Fig. 2), 1960 m NNE of the Smedstorp church (Regnéll 1955, 1960; Eisenack 1968, p. 186; Tjernvik 1958), and the Alum Shale Formation along Flagabro Brook (unpublished information).

The Killeröd Formation (Nilsson 1952; Regnéll 1960; J. Bergström 1982; and Månsson 1995) at Killeröd (loc. 13 on Fig. 2), situated about 500 m SE of Flagabro Farm, and the Komstad Limestone in the adjacent Killeröd quarry.

A ditch section at Östra Tommarp (loc. 14 on Fig. 2), no longer accessible, about 600 m WSW of the Östra Tommarp church, described by Olin (1906) and Funkquist (1919), and commented upon by both S.M. Bergström & Nilsson (1974) and S.M. Bergström *et al.* (1997). That section yielded a condensed sequence from the Komstad Limestone to the Mossen Formation (S.M. Bergström *et al.* 1997).

Bornholm

The Danish island of Bornholm is situated ca 33 km south-east of the mainland of Sweden (Fig. 1). The island is located along the southwestern margin of the Baltic Shield, and it was a stable Precambrian platform until Ludlow time (Troedsson 1932, Bjerreskov & Stouge 1985). Small outliers of Ordovician rocks occur in fault blocks, tilted in low angles, in the southwestern part of the island, along the main streams Læså and Øleå (Fig. 7). Relief was re-activated by the Caledonian orogeny and caused huge amounts of sediment accumulation in the Polish trough (Bjerreskov & Stouge 1985). Hiatuses in the Ordovician sequence of Bornholm are of a magnitude difficult to explain by periods of marine non-sedimentation; and according to Poulsen & Poulsen (1979) the area was continental during periods of the Ordovician. However, this is not supported by sedimentological data (Krarup Pedersen 1989). The total thickness is estimated to be about 40 m. Three localities have been investigated, and are described below in stratigraphic order.

Vasegård (Fig. 7). – This classical locality along Læså Brook, and about 2.7 km SW of the Åkirkeby church, displays strata from the lowermost part of the Skagen Formation to the lower part of the Lindegård Mudstone. Lithology and stratigraphy have been described by, among others, Hadding (1915a, b), Funkquist (1919), and Gry (1948). Beds 2–3 in Funkquist’s well section at Vasegård (Funkquist 1919, p. 31) have yielded *Spinachitina* (*Belonechitina*) *suecica* and *Desmochitina* “*rugosa*” according to Sven Laufeld *in* S.M. Bergström & Nilsson (1974, p. 31).

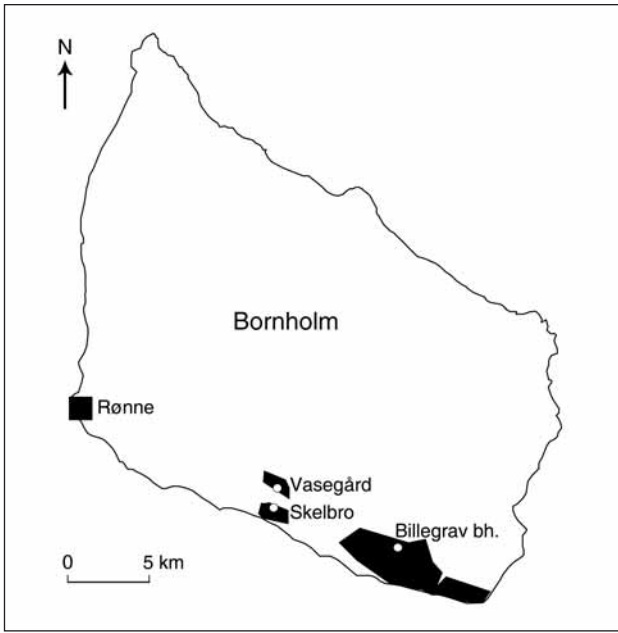


Figure 7. Map showing Ordovician outcrop areas and the localities on Bornholm. Black color shows Ordovician outcrop areas.

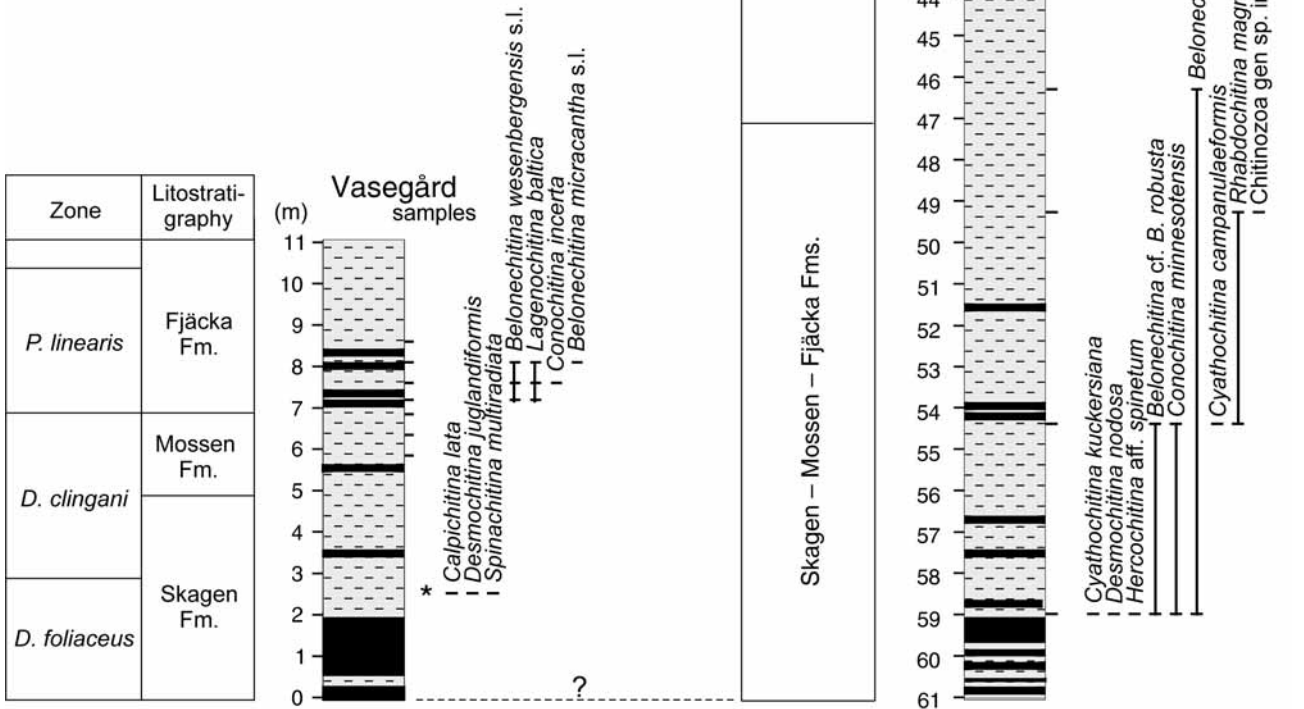


Figure 8. Lithology, sample levels and chitinozoan ranges at the Vasegård locality and the Billegrav core. * – chitinozoan occurrences after Laufeld in S.M. Bergström & Nilsson (1974, p. 31).

Specific levels were sampled for chitinozoans by S.M. Bergström & Nilsson (1974, p. 31) and by the senior author in 1990 (Fig. 8). The chitinozoans shows a striking similarity to those in Skåne.

Billegrav core (Fig. 7). – This shallow well, performed by

the Geological Survey of Greenland in 1984, and situated about 1875 m ESE of Pederskirke, penetrates the lowermost Silurian down to the lowermost part of the Skagen Formation (Krarup Pedersen 1989). Ordovician rocks from the uppermost part of the Lindegård Mudstone to the base of the well have been investigated in this study (Fig. 8).

The few chitinozoans encountered are the same as contemporaneous species in Skåne.

Samples from the Komstad Limestone at Skelbro Quarry (Fig. 7), about 4150 m SW of the Åkirkeby church, yielded no chitinozoans. However, Laufeld (1967, p. 281) reported the presence of chitinozoans in this limestone from Bornholm, although, without any taxonomic information.

Systematic palaeontology

Systematic inventory of chitinozoan species in alphabetical order by genus and species:

Ancyrochitina ancyrea (Eisenack, 1931)
Ancyrochitina sp. – Fig. 11A, B
Angochitina sp. – Fig. 11C
Armoricochitina granulifera Nölvak & Grahn, 1993
Belonechitina cactacea (Eisenack, 1937)
Belonechitina capitata (Eisenack, 1962)
Belonechitina micracantha s.l. (Eisenack, 1959) – Fig. 11D
Belonechitina robusta (Eisenack, 1959)
Belonechitina cf. *B. robusta* (Eisenack, 1959) – Fig. 11E
Belonechitina n. sp. aff. *B. robusta* (Eisenack, 1959) – Fig. 11F
Belonechitina wesenbergensis s.l. (Eisenack, 1959) – Fig. 11G
Belonechitina sp. 1 *sensu* Vandenbroucke, 2004
Belonechitina sp. 3 *sensu* Vandenbroucke, 2004
Calpichitina lata (Schallreuter, 1963)
Calpichitina lecaniella (Eisenack, 1965)
Conochitina clavaherculi Eisenack, 1959
Conochitina dolosa Laufeld, 1967
Conochitina aff. *C. dolosa* Laufeld, 1967 – Fig. 11H
Conochitina elegans Eisenack, 1931
Conochitina incerta Eisenack, 1962
Conochitina minnesotensis Stauffer, 1933
Conochitina scabra n. sp. – Fig. 11I
Cyathochitina calix (Eisenack, 1931)
Cyathochitina campanulaeformis (Eisenack, 1931)
Cyathochitina hunderumensis Grahn, Nölvak & Paris, 1996
Cyathochitina kuckersiana (Eisenack, 1934)
Desmochitina amphorea Eisenack, 1931
Desmochitina cocca Eisenack, 1931
Desmochitina juglandiformis Laufeld, 1967
Desmochitina minor Eisenack, 1931
Desmochitina nodosa Eisenack, 1931
Desmochitina ovulum Eisenack, 1962
Desmochitina “rugosa” Eisenack, 1962
Euconochitina conulus (Eisenack, 1955)
Hercochitina aff. *spinetum* Melchin & Legault, 1985
Hercochitina sp. – Fig. 11J
Lagenochitina baltica Eisenack, 1931

Lagenochitina esthonica Eisenack, 1955
Laufeldochitina stentor (Eisenack, 1937)
Laufeldochitina striata (Eisenack, 1937)
Laufeldochitina cf. *L. striata* (Eisenack, 1937) – Fig. 11K
Laufeldochitina sp. A aff. *striata* Grahn, Nölvak & Paris, 1996
Laufeldochitina sp. – Fig. 11L
Rhabdochitina gracilis Eisenack, 1962
Rhabdochitina magna Eisenack, 1931
Spinachitina multiradiata (Eisenack, 1959)
Spinachitina suecica (Laufeld, 1967)
Tanuchitina bergstroemi Laufeld, 1967
Tanuchitina sp. – Fig. 11M

The regional stratigraphic ranges for the Ordovician chitinozoans from Skåne and Bornholm are given in Fig. 9. The taxonomy follows the scheme by Paris *et al.* (1999). Chitinozoan species in open nomenclature, not earlier discussed in the literature and problematic species will be described below.

Group Chitinozoa Eisenack, 1931
Order Operculatifera Eisenack, 1972
Family Desmochitinidae Eisenack, 1931
Subfamily Desmochitinae Paris, 1981

Genus Desmochitina Eisenack, 1931

Type species. – *Desmochitina nodosa* Eisenack, 1931.

Desmochitina “rugosa” Eisenack, 1962

Remarks. – The rugose nature of the vesicle wall of this species is not an original feature, mainly *D. minor* and *D. amphorea* and sometimes *D. ovulum* are probably covered with a secondary layer, which makes the identifications uncertain, without specific preparations. *Desmochitina “rugosa”* is therefore considered as a complex of different *Desmochitina* species.

Occurrence. – Vasegård section, lower part of the Skagen Formation, Bornholm.

Order Prosomatifera Eisenack, 1972
Family Conochitinidae Eisenack, 1931 emend. Paris, 1981
Subfamily Conochitinae Paris, 1981

Genus Conochitina Eisenack, 1931 emend. Paris, Grahn, Nestor & Lakova, 1999

Type species. – *Conochitina claviformis* Eisenack, 1931.

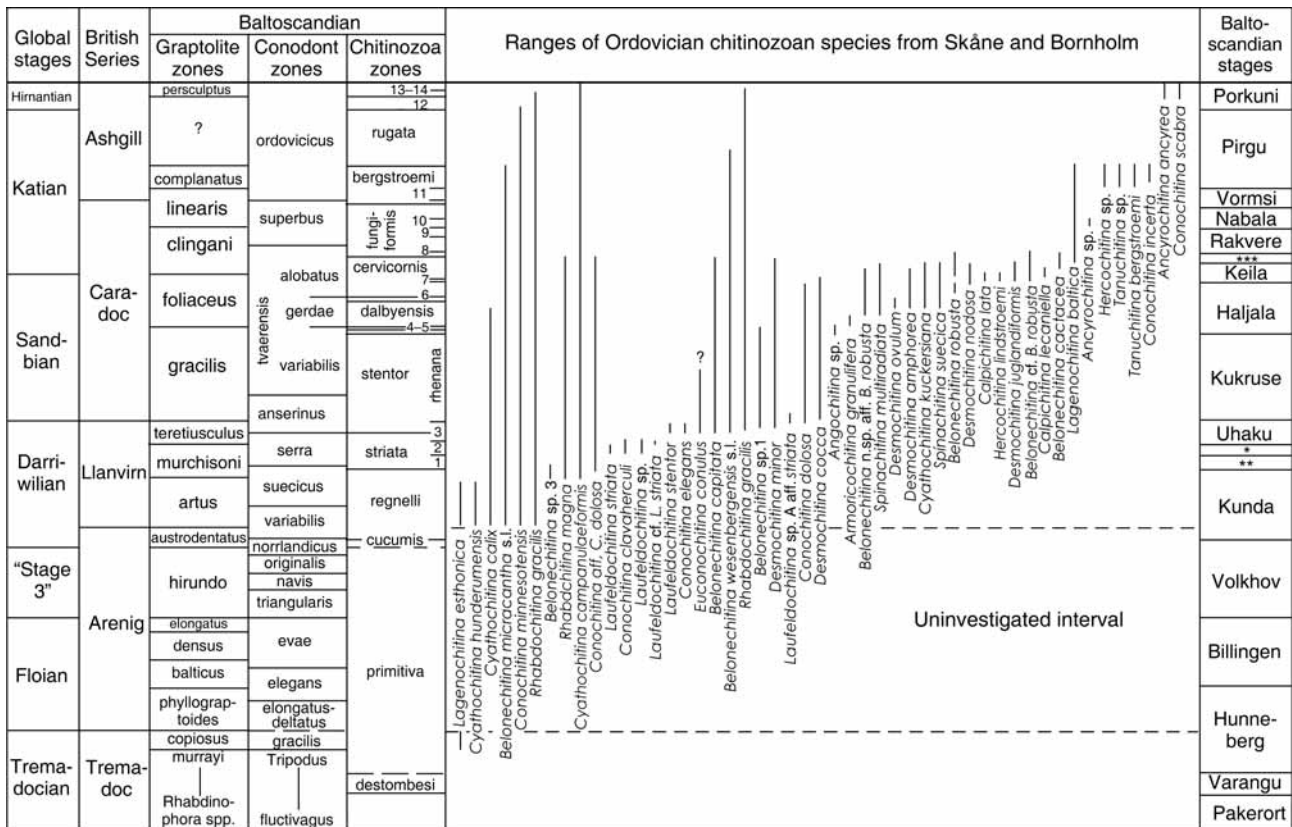


Figure 9. Correlation table of Ordovician strata and the stratigraphic ranges of chitinozoan species in Skåne and Bornholm. Abbreviations: 1 – *Cyathochitina sebyensis* subzone, 2 – *Conochitina clavaherculi* subzone, 3 – *Conochitina tuberculata* subzone, 4 – *Armoricochitina granulifera* Zone, 5 – *Angochitina curvata* Zone, 6 – *Belonechitina hirsuta* Zone, 7 – *Angochitina multiplex* subzone, 8 – *Ancyrochitina* sp. 1 subzone, 9 – *Cyathochitina angusta* subzone, 10 – *Armoricochitina reticulifera* subzone, 11 – *Acanthochitina barbata* subzone, 12 – *Belonechitina gamachiana* Zone, 13 – *Spinachitina taugourdeau* Zone, 14 – *Conochitina scabra* Zone, * – Lasnamägi Stage, ** – Aseri Stage, *** – Oandu Stage.

***Conochitina* aff. *C. dolosa* Laufeld, 1967**

Figure 11H

Description. – An elongated conical almost claviform species with smooth vesicle wall.

Remarks. – *Conochitina* aff. *C. dolosa* differs from *C. dolosa* Laufeld, 1967 in having a weakly developed mucro and an indistinct flexure.

Occurrence. – Lower part of the Almelund Shale to lower part of the Mossen Formation, Skåne.

***Conochitina scabra* n. sp.**

Figure 11I

1978 *Conochitina robusta* Grahn; Fig. 4A, B, D, G.

1993 *Conochitina scabra* nom. nud.; Nõlvak & Grahn, pl. IVE.

Derivation of name. – Latin, *scaber*, rough or rugged, referring to the surface ornamentation.

Holotype. – Ch 914/7609, Kardla core, level 167.5 m, Kuldiga Formation, Porkuni Stage, South Estonia, Nõlvak & Grahn 1993, Pl. IVE.

Type interval and locality. – Kardla core, interval 167.5–181.3 m.

Holotype dimensions (µm). – Total length 217, maximum width 77, width of aperture 56.

Dimensions (µm). – 45 specimens from different samples from the Kardla core interval 167.5–181.3 m. Total length 140–266, mean 223; maximum width 63–98, mean 78; width of aperture 56–63, mean 58.

Diagnosis. – A species of *Conochitina* with a subcylindrical glabrous chamber provided with a mucron; flexure and shoulder lacking or inconspicuous; vesicle wall sometimes randomly ornamented with less than 2 µm high microgranules.

Description. – This species displays the main characteristics of the genus *Conochitina* Eisenack, 1931, emend. Pa-

Global stages	British Series	Baltoscandian			Bornholm	SE Skåne	Central Skåne	NW Skåne	Balto-scandian stages				
		Graptolite zones	Conodont zones	Chitinozoa zones									
Hirnantian		persculptus		13-14	Tommarp Fm.	Tommarp Fm.	Tommarp Fm.	Tommarp Fm.	Porkuni				
Katian	Ashgill	?	ordovicicus	rugata	Lindegård Mudstone	Lindegård Mudstone	Lindegård Mudstone		Pirgu				
		complanatus		bergstroemi									
	Caradoc	linearis	superbus	11	Fjåcka Fm.	Fjåcka Fm.	Fjåcka Fm.		Vormsi				
		clingani		fungi-formis	10	?	?		?	Nabala			
Sandbian	Caradoc	foliaceus	alobatus	8	Mossen Fm.	Mossen Fm.	Mossen Fm.	Mossen Fm.	Rakvere				
				cervicornis	7	Skagen Fm.	Skagen Fm.		Skagen Fm.	***			
		gracilis		gerdae	6					Keila			
	Llanvirn	teretiusculus	tvaerensis	variabilis	4-5					Sularp Fm.	Haljala		
		murchisoni			anserinus	3						K	Uhaku
		artus			serra	2							*
"Stage 3"	Arenig	austrodentatus	norrlandicus	1	Komstad Limestone	Komstad Limestone	Komstad Limestone	Tøyen Fm.	**				
Floian		hirundo		regnelli						Kunda			
		elongatus		originalis	primitiva						Volkhov		
		densus		navis							Billingen		
balticus	triangularis						Hunneberg						
Tremadocian	Tremadoc	phylograptoides	elegans					Bjørkåsholmen Fm.					
		copiosus	elongatus-deltatus										
		murrayi	gracilis										
		Rhabdinophora spp.	Tripodus	destombesi	Alum Shale Fm.	Alum Shale Fm.	Alum Shale Fm.	Alum Shale Fm.	Varangu				
			fluctivagus						Pakerort				

Figure 10. Chrono- and lithostratigraphy in the Ordovician of Skåne and Bornholm. Abbreviations: K – Killeröd Formation. For other abbreviations, see Fig. 9.

ris, Grahn, Nestor & Lakova, 1999. The vesicle is subcylindrical with straight to slightly convex flanks. Shoulders and flexure are absent or weakly developed, and the neck, if present, is about 1/3 of the total length of the vesicle. The maximum width of the vesicle is just above the basal margin. The basal part or body sometimes bears conical tubercles or microgranules, which are better developed near the rounded basal margin, decreasing gradually towards the aperture. Microgranules sometimes also occur on the marginal part of the convex base. Their density varies in different specimens. Microgranules are more characteristic in populations from both the lowermost and uppermost parts of the species' stratigraphical range. If well preserved, rare specimens may have a spiny aperture.

Discussion. – *C. scabra* n. sp. is a polymorph species and

differs from the Silurian zonal index species *Belonechitina postrobusta* (Nestor, 1980) mainly in having no spines, whereas dimensions often are similar. The same is true comparing with the very variable *B. micracantha* (Eisenack, 1931), where typical specimens are spiny and more conical, and they have a more distinct flexure and a more pronounced basal edge. However, transitional forms occur. *B. gamachiana* (Achab, 1989) and *B. parvispinata* Soufiane & Achab, 2000 have a more pronounced ornamentation, and the latter also has a club-shaped body. *C. scabra* n. sp. is the index species for the *C. scabra* total range Zone (Nölvak & Grahn 1993).

Occurrence. – In the topmost part of the Porkuni Stage, as the uppermost Ordovician zonal index species (Nölvak & Grahn 1993), found in core sections of southern Estonia:

Valga (Nõlvak 2001), Ruhnu (Nõlvak 2003), Kardla, Taa-gepera (Brenchley *et al.* 2003), Ohesaare, Tartu, Elva, and Laeva; in Latvia at: Riekstini (Brenchley *et al.* 2003), Baldone, Baltinava, and Vilcini; in western Lithuania at: Butkunai, and Taučionys; in northwestern Russia at: Iljinskoje (Brenchley *et al.* 1997); an in southern Sweden at: Ö. Tommarp 1-2 section, uppermost part of the Lindegård Mudstone to lowermost part of the Tommarp Formation (lower *N. persculptus* Zone), as well as the Röstånga core (level 34.5 m), lowermost part of the Tommarp Formation, Skåne.

Material. – About one thousand specimens from different sections.

Subfamily Tanuchitinae Paris, 1981

Genus *Laufeldochitina* Paris, 1981

Type species. – *Cyathochitina stentor* (Eisenack, 1937).

***Laufeldochitina* cf. *L. striata* (Eisenack, 1937)**

Figure 11K

Description. – *Laufeldochitina* cf. *L. striata* differs from *L. striata* in its smaller size and in not having a striate ornamentation on the vesicle wall.

Occurrence. – Fågelsång core (level 20.06–20.16 m), middle part of the Almelund Shale, Skåne.

***Laufeldochitina* sp.**

Figure 11L

Description. – A *Laufeldochitina* species with an ovoid body with truncated base and a short carina below the basal margin. The neck is long, cylindrical and with a straight aperture. Vesicle wall smooth.

Remarks. – This species precedes *Laufeldochitina stentor* in the stratigraphic column in Skåne, and differs from that species in the lack of vesicle wall ornamentation.

Occurrence. – Fågelsång core (levels 19.4–19.5 m and 21–21.2 m), middle part of the Almelund Shale, Skåne.

Genus *Tanuchitina* Jansonius, 1964 emend. Paris, Grahn, Nestor & Lakova, 1999

Type species. – *Tanuchitina ontariensis* Jansonius, 1964.

***Tanuchitina* sp.**

Figure 11M

Description. – A *Tanuchitina* species with an ovoid and elongated vesicle. The base is truncated, and a short carina occurs at the margin. The flexure is indistinct. Vesicle wall smooth.

Remarks. – The bad preservation and the scarce occurrence of this species prevent its description as a new species.

Occurrence. – Koängen core (levels 5.55–5.65 m and 6.40–6.45 m), lower part of the Lindegård Mudstone, Skåne.

Subfamily Belonechitinae Paris, 1981

Genus *Belonechitina* Jansonius, 1964

Type species. – *Conochitina micracantha* subsp. *robusta* Eisenack, 1959.

***Belonechitina micracantha* s.l. (Eisenack, 1931)**

Figure 11D

Remarks. – Some of the specimens designated as *Belonechitina* sp. gr. *micracantha* by Grahn (*in* S.M. Bergström *et al.* 2000) were later subdivided into *Belonechitina* sp. 1–3 by Vandenbroucke (2004). This subdivision has been maintained in all investigated sections except for the section at Fågelsång E 14b (Fig. 3). Eisenack (1959) defined *Belonechitina micracantha* (his *Conochitina micracantha micracantha*) as a species with an elongated conical body provided with a constriction aperturewards of the basal edge (Eisenack 1959, pl. 1, fig. 5 therein), and a vesicle covered by simple spines. Specimens that fit the general description of *B. micracantha micracantha*, but do not clearly display the constriction near the basal edge are here included in *Belonechitina micracantha* s.l., which also includes specimens with a more rounded base than the type material.

Occurrence. – Lower part of the Almelund Shale to lower part of the Lindegård Mudstone, Skåne.

***Belonechitina* cf. *B. robusta* (Eisenack, 1959)**

Figure 11E

Description. – The nature of the complete ornamentation of this species has not been observed. The general outline is that of *Belonechitina robusta*, and it is therefore referred to as *Belonechitina* cf. *B. robusta*.

Occurrence. – Billegrav core (levels 54.35 and 59 m), lowermost part of the Skagen Formation to Mossen Formation, Bornholm.

***Belonechitina* n. sp. aff. *B. robusta* (Eisenack, 1959)**

Figure 11F

Description. – This species differs from *Belonechitina robusta* in having predominantly simple spines. The present material is not numerous or well-preserved to allow a formal designation to a new species.

Remarks. – Schallreuter (1981, 1983) included this species from Gotland and Västergötland (Sweden) in his *Belonechitina repsinata*, a species that has multirooted spines, and thus is a junior synonym to *Belonechitina robusta* (Eisenack, 1959). Furthermore, Schallreuter's type material came from erratics, presumably from the Sularp Formation in Skåne. Our observations show that rare occurrences of *B. robusta* are known from the same stratigraphic interval in carbonate facies from Dalarna, north central Sweden.

Occurrence. – Upper part of the Sularp Formation to middle part of the Skagen Formation, Skåne.

***Belonechitina wesenbergensis* s.l. (Eisenack, 1959)**

Figure 11G

Remarks. – Eisenack (1959) defined *Belonechitina wesenbergensis* (his *Conochitina wesenbergense*) as a species with an elongated conical, almost cylindrical, body and a cylindrical neck, and a vesicle covered by simple spines. Later (Eisenack 1972) divided this species into a short form defined as *C. wesenbergensis brevis* and a longer form defined as *C. wesenbergensis elongata*. The difference between these two subspecies is the size. In the Scandinavian material these two subspecies have not been separated. In Estonia they have the same stratigraphic range, although they might be mutually exclusive. Specimens that fit the general description of *B. wesenbergensis*, but do not clearly display a distinct flexure and the cylindrical neck, as well as the two subspecies defined by

Eisenack (1965), are here included in *Belonechitina wesenbergensis* s.l.

Occurrence. – Upper part of the Almelund Shale to lower part of the Lindegård Mudstone, Skåne and from the Skagen Formation to the lower part of the Lindegård Mudstone, Bornholm.

Genus *Hercochitina* Jansonius, 1964

Type species. – *Hercochitina crickmayi* Jansonius, 1964.

***Hercochitina* sp.**

Figure 11J

Description. – A *Hercochitina* species with a conical body, rounded base, and a short cylindrical neck. About 16–18 ridges of connected simple spines cover the vesicle. The vesicle wall between these ridges is smooth. The flanks are convex and the aperture straight.

Remarks. – Similar specimens (*Hercochitina* sp. B) occur at the same stratigraphic position in the Oslo Region (Grahns *et al.* 1994), but they differ from the present material in their more cylindrical body.

Occurrence. – Koängen core (levels 4.85 and 4.92–4.96 m), lower part of the Lindegård Mudstone, Skåne.

Family Lagenochitiniidae Eisenack, 1931

Subfamily Angochitiniinae Paris, 1981

Genus *Angochitina* Eisenack, 1931

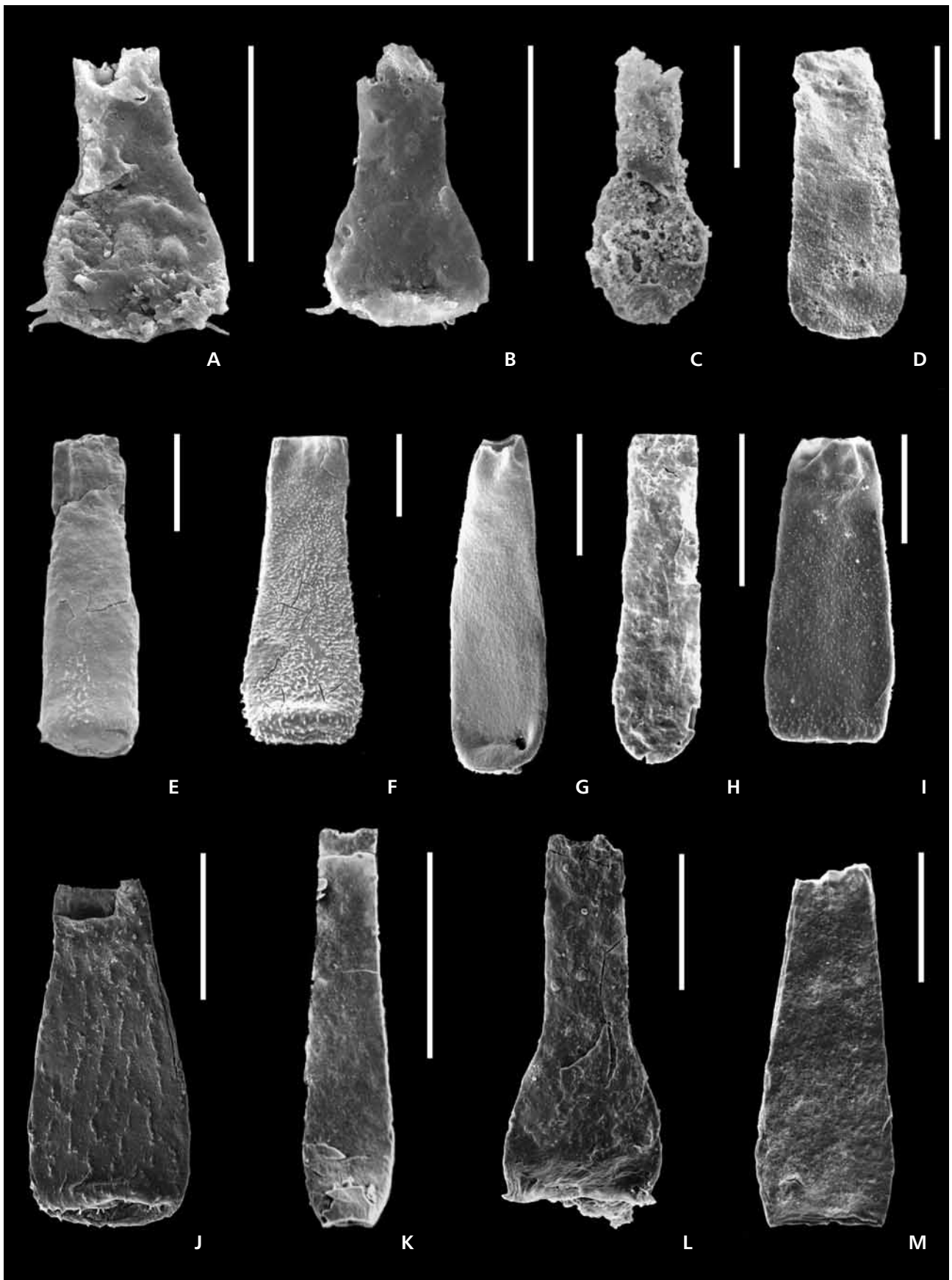
Type species. – *Angochitina echinata* Eisenack, 1931.

***Angochitina* sp.**

Figure 11C

Description. – An *Angochitina* species with an ovoid body and cylindrical neck. The vesicle wall is provided with ran-

Figure 11. Selected Ordovician Chitinozoa from Skåne and Bornholm. The scale bar represents 100 µm. • A – *Ancyrochitina* sp. Röstånga core, level 72 m. Fjäckå Formation. • B – *Ancyrochitina* sp. Röstånga core, level 72 m. Fjäckå Formation. • C – *Angochitina* sp. Koängen core, level 67 m. Sularp Formation. • D – *Belonechitina micracantha* s.l. (Eisenack, 1931). Vasegård section, ca 1 m above top of the Mossen Formation. Fjäckå Formation. • E – *Belonechitina* cf. *B. robusta* (Eisenack, 1959). Billegrav core, level 59 m. Skagen Formation. • F – *Belonechitina* n. sp. aff. *B. robusta* (Eisenack, 1959). Koängen core, level 34.02–34.12 m. Skagen Formation. • G – *Belonechitina wesenbergensis* s.l. (Eisenack, 1959). Billegrav core, level 59 m. Skagen Formation. • H – *Conochitina* aff. *C. dolosa* Laufeld, 1967. Fågelsång core, level 31.50–31.60 m. Almelund Shale. • I – *Conochitina scabra* n. sp. Röstånga core, level 34.5 m. Tommarp Formation. • J – *Hercochitina* sp. Koängen core, level 4.92–4.96 m. Lindegård Mudstone. • K – *Laufeldochitina* cf. *L. striata* (Eisenack, 1937). Fågelsång core, level 20.06–20.16 m. Almelund Shale. • L – *Laufeldochitina* sp. Fågelsång core, level 21.00–21.20 m. Almelund Shale. • M – *Tanuchitina* sp. Koängen core, level 5.55–5.65 m. Lindegård Mudstone.



domly distributed simple spines. Flexure distinct. It differs from *Angochitina curvata* mainly in having simple spines.

Dimensions. – The dimensions given by Vandenbroucke (2004) for his *Angochitina curvata*?, as well as *Lagenochitina dalbyensis* are representative for this species.

Remarks. – Specimens illustrated as *Angochitina curvata*? and *Lagenochitina dalbyensis* by Vandenbroucke (Plate 1, fig. 15 and Plate 3, figs 12–15 therein) correspond to *Angochitina* sp. in this study (Fig. 4) and have no similarity to *A. curvata* and *L. dalbyensis*. It should also be noted that *Armoricochitina granulifera*, which precedes *A. curvata* and *L. dalbyensis* in the stratigraphic column, occurs in the correct stratigraphic position (base of *D. foliaceus* Zone) in the Koängen core (Fig. 4). Furthermore, *A. curvata* is a very rare species, and the biozone is, in general, only a few cm thick in Baltoscandia.

Occurrence. – Koängen core (level 67 m), lowermost part of the Sularp Formation, Skåne.

Subfamily Ancyrochitinae Paris, 1981

Genus *Ancyrochitina* Eisenack, 1955

Type species. – *Conochitina ancyrea* Eisenack, 1931.

Ancyrochitina sp.

Figure 11A, B

Description. – This small *Ancyrochitina* species (total length between 116 and 136 µm) is characterized by a short conical body and a short cylindrical neck. Aperture straight. Basal edge rounded and base slightly convex. Flexure distinct. The basal edge has eight short simple appendices (length up to 8 µm). The vesicle wall aperturewards of the appendices is smooth.

Occurrence. – Röstånga core (level 72 m), lowermost part of the Fjäckå Formation, Skåne.

Chitinozoan biostratigraphy

The Ordovician chrono- and lithostratigraphy of Skåne and Bornholm is summarized in Fig. 10. The chitinozoan biostratigraphy in this study confirms the general outline of the Ordovician chitinozoan biozonation of Baltoscandia (Nölvak & Grahn 1993, Nölvak 1999). Except for strata coeval with the *H. copiosus* Zone (uppermost Tremadocian), the Lower Ordovician part of the Tøyen Formation

(Floian to lowermost Darriwilian, which is roughly equal to Arenig) was not investigated in this study. Noteworthy, is the low diversity of chitinozoan species in graptolitic facies compared to the diversity in carbonate facies of the Central Baltoscandian Confacies Belt. Although the Ordovician chitinozoan zones of Baltoscandia are based on faunas in mostly carbonate facies, it is not difficult to correlate with faunas in the graptolitic facies.

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