SVERIGES GEOLOGISKA UNDERSÖKNING

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CARADOCIAN AND ASHGILLIAN CHITINOZOA FROM THE SUBSURFACE OF GOTLAND

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ABSTRACT

Grahn, Yngve, 1981-10-22: Caradocian and Ashgillian Chitinozoa from the subsurface of Gotland. Sveriges geologiska undersökning, Ser. C, No. 788, pp. 1–66, Uppsala 1982.

The chitinozoans from three borings penetrating the Caradocian and Ashgillian sequence and erratic boulders of late Ashgillian age from Gotland have been investigated. Forty-three species of the genera *Acanthochitina, Ancyrochitina, Angochitina, Conochitina, Coronochitina, Cyathochitina, Desmochitina, Eisenackitina, Eremochitina, Fungochitina, Lagenochitina, Rhabdochitina, Spinachitina,* and *Tanuchitina* are described. *Conochitina villosa* and *Cyathochitina costata* are described as new species. Local range zones of the Caradocian and Ashgillian subsurface of Gotland are established. The Chitinozoa are compared with those from the Swedish mainland and Estonia and show great similarity with the chitinozoans from Estonia. Chitinozoan palaeoecology is briefly discussed.

INTRODUCTION

The Isle of Gotland is situated in the Baltic, about 100 km east of the mainland of Sweden. Rocks of Ordovician age are entirely covered by 100–500 m of Silurian marine sediments which in turn form the supramarine bedrock of the island. On Gotska Sandön, about 40 km north of Gotland, Ordovician rocks occur at the base of Pleistocene. The Ordovician has a thickness of about 75–125 m, and the beds strike approximately NE–SW and dip 0.15–0.3°, roughly towards the SE (Laufeld 1974:7).

Caradocian and Ashgillian Chitinozoa from three core borings (Fig. 1) are described in this paper. Also mentioned in this study are chitinozoans from late Ashgillian erratic boulders at Oil Myr (often cited in earlier literature as Öjle Myr; Fig. 1). With the exception of erratic boulders, published information about Ordovician rocks from Gotland is scanty and limited to a score of papers and a few scattered notes. Our knowledge of the Ordovician of Gotland is based chiefly on five borings. In addition to the three borings described in this paper, Ordovician rocks have been described from the Visby and När borings (Fig. 1).

At present it is not possible to correlate the British series with Baltoscandian series and stages. For practical reasons the Idavere-an-Kukrusean boundary is treated as the equivalent of the Caradoc-Llandeilo boundary. The Ashgill-Caradoc boundary is correlated approximately with the Vormsian-Nabalan boundary.

Eisenack (1968a) reported on nine species of Chitinozoa in erratic boulders from Oil Myr, two of which, *Coronochitina (Conochitina) taugourdeaui* and *Rhabdochitina magna,* have not been recovered in this study.

Fig. 2 summarizes the Caradocian and Ashgillian stratigraphy of Gotland as presently known.

Fig. 1. Map showing localities on Gotland from which Ordovician rocks have been described. Filled circles indicate borings discussed in this paper, open circles other borings and triangle erratic boulders.

SAMPLES AND LOCALITIES

In all, 524 samples from Caradocian and Ashgillian subsurface beds in Gotland have been examined. Altogether about 68 000 specimens of Chitinozoa were recovered. About 61% of the samples yielded chitinozoans. The laboratory methods used have been described earlier (Grahn 1980). The localities (Fig. 1) are described in alphabetical order.

FILE HAIDARBORRNINGEN 1, CK 6165 0005, c. 4 150 m ESE of Tingstäde church.

Topographical map sheet 7J Fårösund SV. Geological map sheet Aa 169 Slite.

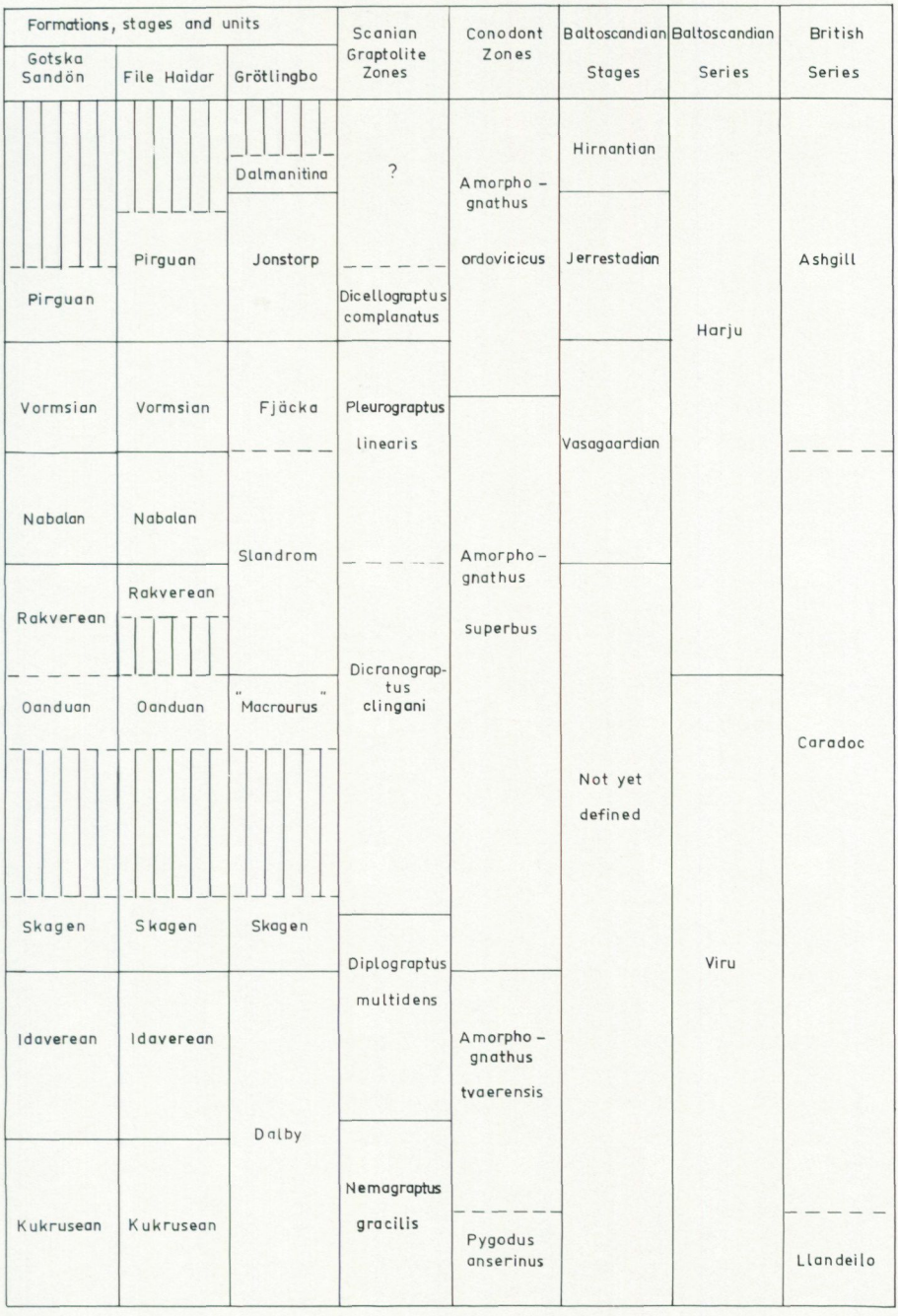


Fig. 2. Diagram showing correlation of Caradocian and Ashgillian subsurface rocks on Gotland. Based on Jaanusson (unpub. mat., pers. comm. 1981), Kjellström (1971a), Männil (1966), Martinsson (unpub. mat.), and Thorslund & Westergård (1938).

Core drilling (T.D. 507.5 m) made by the Skånska Cement AB in 1935 c. 4 850 m SW of Othem church and close to a limestone quarry. The diameter of the core is 8.5 cm between 200 and 304.65 m, 7 cm between 304.65 and 412.67 m and 6 cm between 412.67 and 507.5 m.

Precambrian – Slite Beds (Middle Wenlock).

References: Thorslund & Westergård 1938, pp. 1–56; Martna 1955, pp. 240–241, 247–248, 250, Fig. 11; Klaaman 1971, pp. 73–77.

219 samples from the uppermost Kukrusean – Pirguan part of the core were processed (Figs. 3–5).

GOTSKA SANDÖBORRNINGEN 1, CK 9550 6790, c. 100 m SE of the lighthouse at Hamnudden.

Topographical map sheet 8J-K Gotska Sandön. Geological map sheet Aa 161 Gotska Sandön.

Core drilling (T.D. 240.96 m) made by the Palaeontological Institute of Uppsala University in 1957 at the beach at Hamnudden in the SW corner of Gotska Sandön, situated c. 40 km N of Gotland. The diameter of the core is 6 cm.

Precambrian–Pirguan.

References: Thorslund 1958, pp. 190–197; Gorbatschev 1962, pp. 1–30.

From the interval 75.00–136.10 m 181 samples were processed (Figs. 6–8).

GRÖTLINGBOBORRNINGEN 1, CJ 4545 3367, c. 6 300 m ESE of Grötlingbo church.

Topographical map sheet 5J Hemse NV. Geological map sheet Aa 152 Burgsvik.

Core drilling (T.D. 690 m) made by the Geological Survey of Sweden in 1968 immediately S of where the road from Grötlingbo church to Grötlingboudd ends. The diameter of the core is 6.5 cm.

Precambrian–Burgsvik Beds (Upper Ludlow).

References: Anderegg, Norling & Skoglund 1968, D 10–17; Kjellström 1971a, pp. 1–75; 1971b, pp. 1–35; Snäll 1977, pp. 1–80.

119 samples in the interval 397.00–436.00 m were processed (Figs. 9–10).

NÄRBORRNINGEN 1, CJ 5612 4905, c. 700 m WNW of När church.

Topographical map sheet 6J Roma SV. Geological map sheet Aa 156 Ronehamn.

Core drilling (T.D. 651.80 m) made by the Geological Survey of Sweden in 1968 c. 90 m SW of Närkån. The diameter of the core is 6.5 cm.

Precambrian–Hemse Beds (Lower Ludlow).

References: Anderegg, Norling & Skoglund, 1968, D 5–9; Snäll 1977, pp. 6–8.

OIL MYR 1, CJ 4390 6808, c. 1 675 m WSW of Guldrupe church.

Topographical map sheet 6J Roma SV.Geological map sheet Aa 160 Klintehamn.

Erratic boulders occur in a drainage-ditch from Oil Myr about 750 m SW of the main road between Guldrupe and Väte, towards the village of Guldrupe.

Pirguan–Porkunian (Upper Ashgill).

References: Wiman 1902, pp. 149–222; Eisenack 1968a, pp. 81–94. There are more than one Oil Myr in Gotland. It is therefore uncertain if the following references refer to Oil Myr 1 or not: Nestler 1968, pp. 1219–1225; Schallreuter 1969a, pp. 204–215; 1969b, pp. 344–357; 1969c, pp. 877–879; 1971, pp. 423–431; 1972, pp. 205–212; 1973, pp. 37–49; 1975a, pp. 727–733; 1975b, pp. 270–293; 1977a, pp. 32–51: 1977b, pp. 720–734; 1978, pp. 175–178 (further references in the enumerated papers).

Five erratic boulders from Oil Myr 1 have been investigated. Their age is late Ashgill and each consists of grey calcilutities with flint. Four of these boulders yielded chitinozoans.

Boulder 1. *Ancyrochitina* cf. *ancyrea, Conochitina minnesotensis, Cyathochitina campanulaeformis, Cyathochitina kuckersiana,* and *Desmochitina minor.*

Boulder 2. *Cyathochitina campanulaeformis, Desmochitina minor,* and *Rhabdochitina gracilis.*

Boulder 3. *Conochitina incerta, Conochitina minnesotensis, Cyathochitina campanulaeformis, Cyathochitina kuckersiana,* and *Desmochitina minor.*

Boulder 4. *Conochitina incerta, Conochitina minnesotensis. Cyathochitina campanulaeformis, Cyathochitina kuckersiana, Desmochitina minor,* and *Rhabdochitina gracilis.*

VISBYBORRNINGEN 1, CJ 3743 9087, c. 1 875 m SW of Visby cathedral.

Topographical map sheet 6I Visby NO. Geological map sheet Aa 183 Visby & Lummelunda.

Core drilling (T.D. 406.66 m) made by the Geological Survey of Sweden 1911–12 in a now abandoned and water-filled quarry at Kopparsvik, c. 370 m SW of point 26.89 and c. 75 m E of the shore of the Baltic sea. The diameter of the core is 2.1 cm.

Precambrian–Lower Visby Beds (Upper Llandovery).

References: Hedström 1923a, pp. 1–13; 1923b, pp. 1–26; Thorslund & Westergård 1938, pp. 40–41.

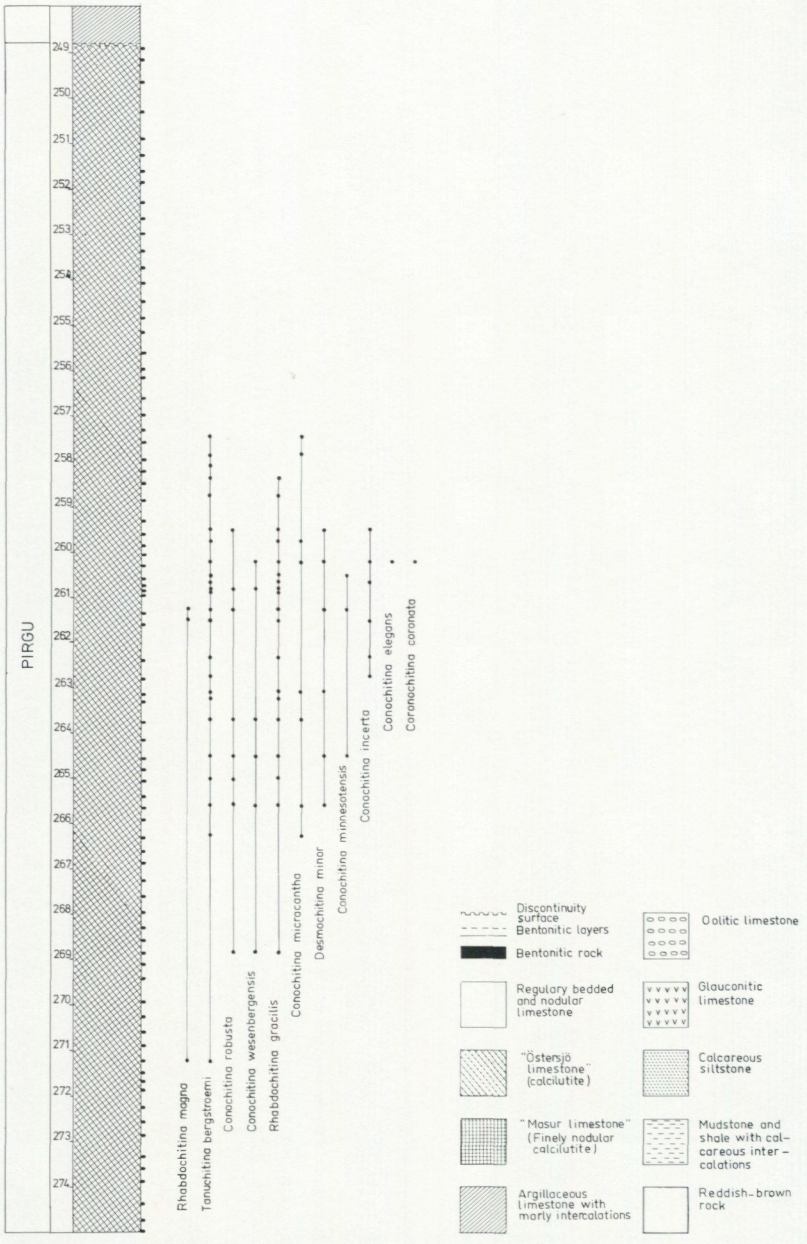


Fig. 3. File Haidarborrningen 1, lithology and sample levels in the Upper Pirguan part of the core. Based on Männil (1966) and Thorslund & Westergård (1938).

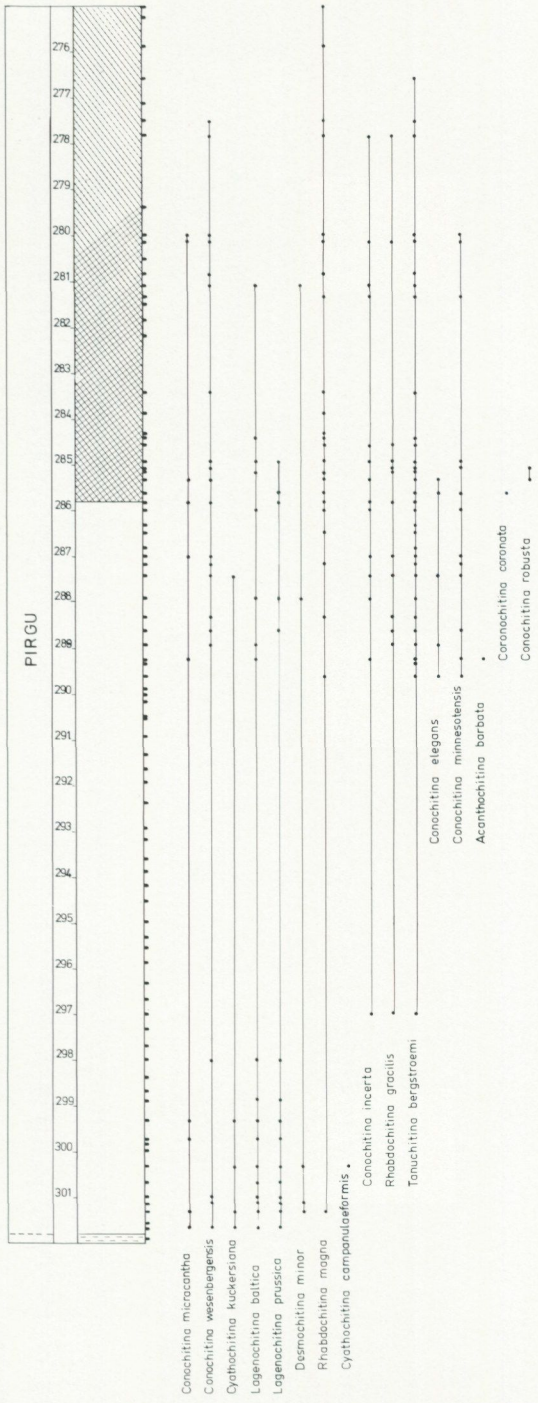


Fig. 4. File Haidarborrningen 1, lithology and sample levels in the Lower Pirguan part of the core. Based on Männil (1966) and Thorslund & Westergård (1938). For legend, see Fig. 3.

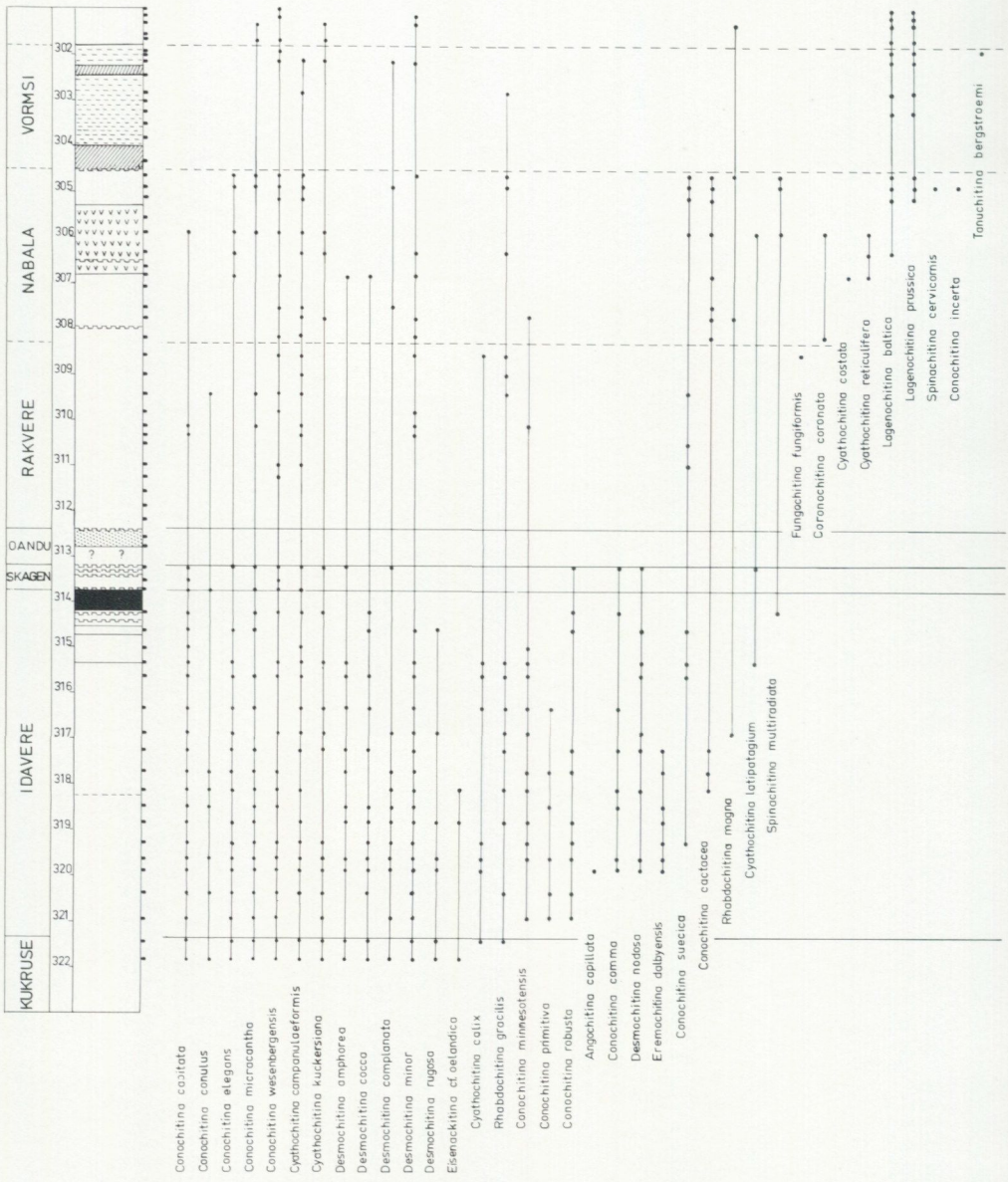


Fig. 5. File Haidarborrningen 1, lithology and sample levels in the Upper Kukrusean to Vormsian part of the core. Based on Jaanusson (unpub. mat.), Männil (1966) and Thorslund & Westergård (1938). For legend, see Fig. 3.

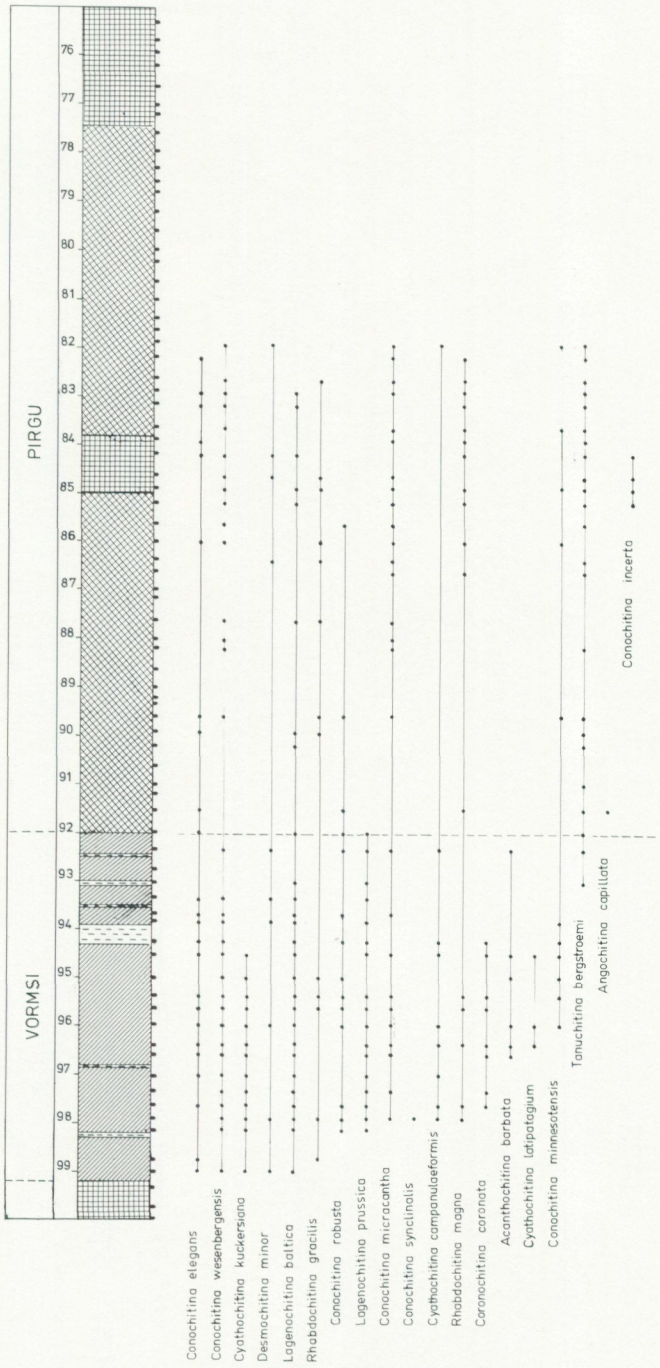


Fig. 6. Gotska Sandöborrningen 1, lithology and sample levels in the Vormsian to Pirguan part of the core. Based on Männil (1966) and Martinsson (unpub. mat.). For legend, see Fig. 3.

Fig. 7. Gotska Sandöborrningen 1, lithology and sample levels in the Nabalan part of the core. Based on Männil (1966) and Martinsson (unpub. mat.). For legend, see Fig. 3.

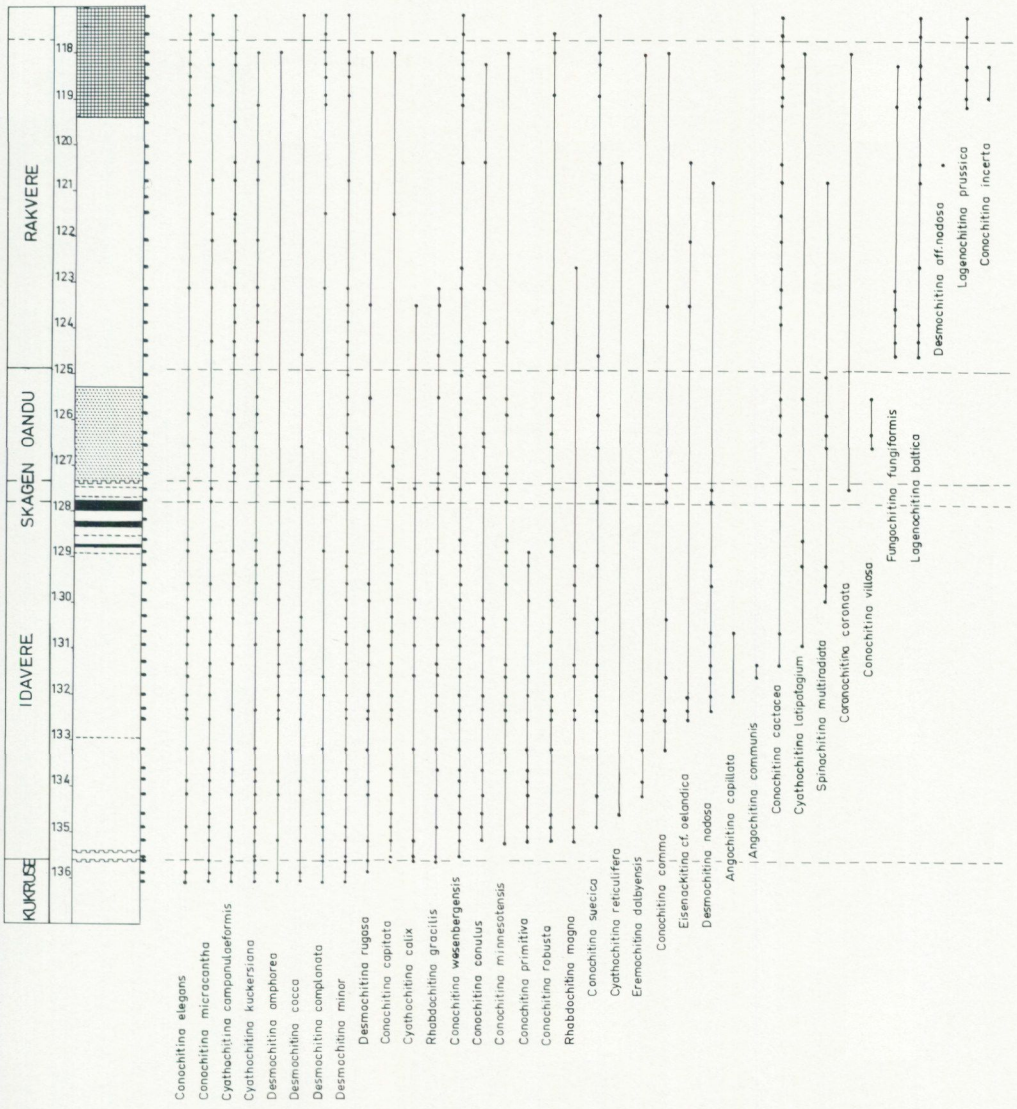


Fig. 8. Gotska Sandöborrningen 1, lithology and sample levels in the Upper Kukrusean to Rakverean part of the core. Based on Jaanusson (unpub. mat.), Männil (1966) and Martinsson (unpub. mat.). For legend, see Fig. 3.

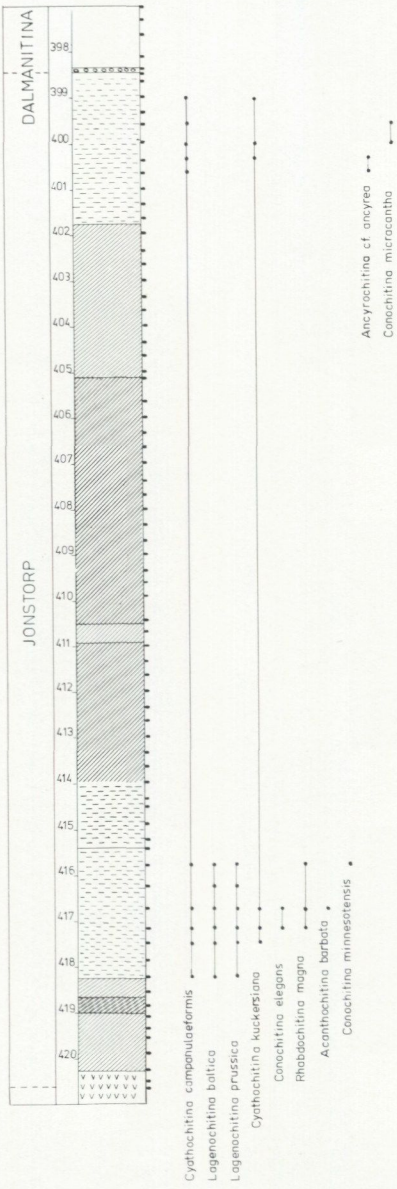


Fig. 9. Grötlingboborrningen 1, lithology and sample levels in the Jerrestadian to Hirnantian part of the core. Based on Kjellström (1971a), Snäll (1977) and the drill-hole record. For legend, see Fig. 3.

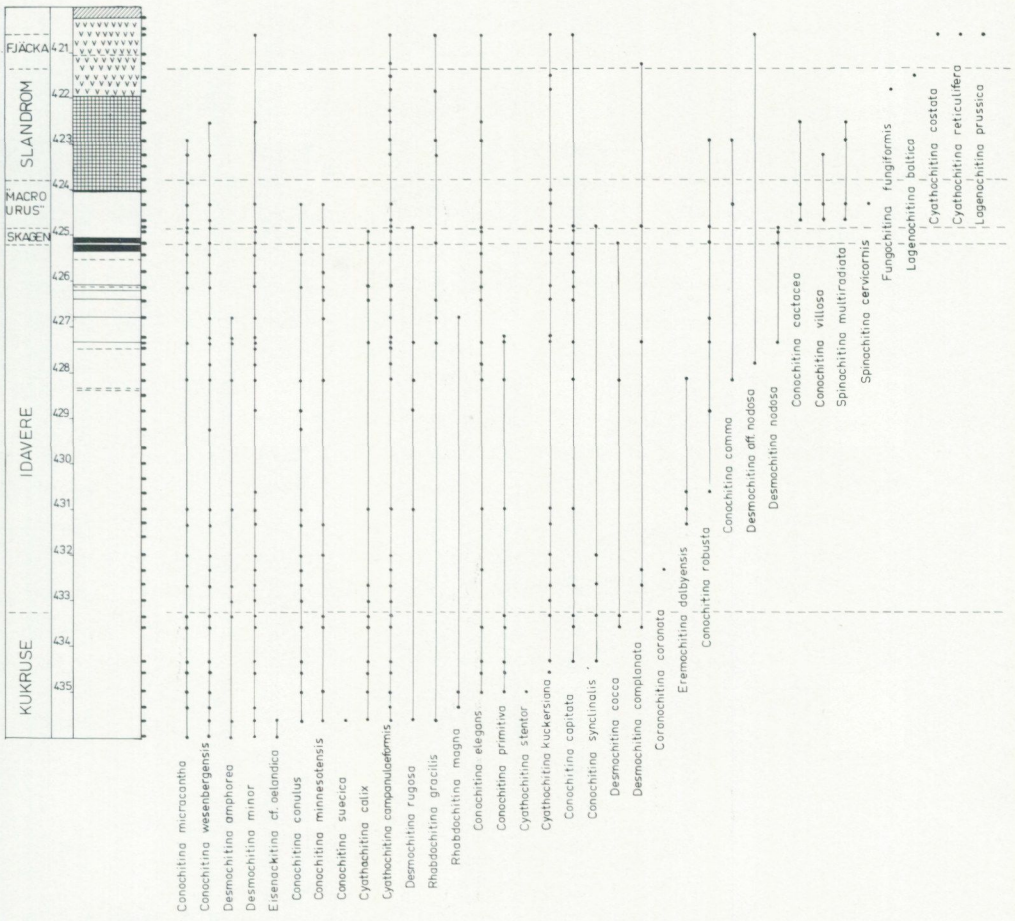


Fig. 10. Grötlingboborrningen 1, lithology and sample levels in the Upper Kukrusean to Vasagaardian part of the core. Based on Kjellström (1971a), Snäll (1977) and the drill-hole record. For legend, see Fig. 3.

OUTLINE OF THE CARADOCIAN AND ASHGILLIAN STRATIGRAPHY OF GOTLAND

During most of Ordovician time the Gotland area was divided into two depositional areas, the North Estonian confacies belt in the north and the central Baltoscandian confacies belt in the south (cf. Jaanusson 1973:28, Fig. 6; 1976:308–309, Fig. 7). Caradocian and Ashgillian sedimentation took place in a shallow epicontinental sea probably situated in a temperate climatic zone (Jaanusson 1973). A regression at the end of the Harjuan constitutes the final stage in the development of the Ordovician Baltoscandian sea. Strata of the different Baltoscandian stages which underlie Gotland are discussed below. It should be added that the correlations are uncertain, except for the pre-Harjuan sequences in the Gotska Sandön and File Haidar borings. Furthermore, the lithologies are known in some detail only in parts of the Gotska Sandön boring (Jaanusson, unpublished; Martinsson, unpublished). Except for the Skagen Limestone and the Oandu Stage (Martna 1955), the lithologies in the File Haidar boring have been only briefly discussed by Thorslund & Westergård (1938). The Caradocian and Ashgillian lithologies in the Grötlingbo boring have been mentioned by Snäll (1977), but otherwise the well log is the only source of information for the lithologies in the Grötlingbo boring. There is an obvious difference between the lithologies of the Grötlingbo boring, and the Gotska Sandön and File Haidar borings.

IDAVEREAN – The lithologies are micritic calcarenites with argillaceous intercalations. Bentonitic beds occur frequently in the sequence (cf. Figs. 5, 8 and 10), and the Skagen–Idaverean boundary is drawn at the top of the most extensive bentonite. A distinct discontinuity surface that can be traced from north Estonia (cf. Nõlvak 1972) to Gotska Sandön and File Haidar marks the Kukrusean–Idaverean boundary in an otherwise uniform lithology.

SKAGEN – The Skagen Limestone consists of grey argillaceous limestones, described as calcarenitic calcilutites in the File Haidar boring (Martna 1955). A discontinuity surface, representing a hiatus in the lower part of *Dicranograptus clingani* chronozone (Fig. 2), marks the upper boundary of the Skagen Limestone. Only the lowermost part of this formation is present in the Gotland area.

OANDUAN/"*MACROURUS*" – The beds are composed of yellowish-grey calcareous siltstones in the File Haidar and Gotska Sandön borings, but in the Gotska Sandön boring they are overlain by a grey calcilutite. In the Grötlingbo boring equivalent beds consist of grey argillaceous limestones. The lime content in the siltstone increases from north to south (Jaanusson 1981, pers. comm.). According to ostracode information (Jaanusson, unpublished) the siltstone in these borings comprises only the Oandu Stage.

RAKVEREAN AND NABALAN/SLANDROM – A sequence of calcilutites which partly are glauconitic in its upper part in the File Haidar and Grötlingbo borings, constitutes the rocks of Rakverean and Nabalan age in the Gotland area. In the File Haidar boring there is a hiatus throughout most of the Rakvere Stage (Jaanusson 1963:137). The Slandrom Formation is recognized in the Grötlingbo boring. It is synchronous with the Rakvere and Nabala Stages, but it is not known to which extent the sequences overlap.

VORMSIAN/FJÄCKA – In the Gotska Sandön and File Haidar borings the rock consists of grey argillaceous limestones and marls, and in the Grötlingbo boring the rocks consist of grey-green glauconitic and argillaceous limestones. It is unclear whether the Fjäcka Formation corresponds entirely or partly only to the Vormsi Stage (cf. Jaanusson 1963:138).

PIRGUAN/JONSTORP – The Pirguan in the Gotska Sandön and File Haidar borings consists mainly of calcilutites belonging to the Östersjö Limestone, which partly is enriched in calcareous algae, while equivalent beds in the Grötlingbo boring, the Jonstorp Formation, are composed of greenish-grey mudstones with intercalations of grey and reddish marly limestones. Some time in lower Pirguan time a regression began, evidenced first in the north, and then moved southward. At the end of Pirguan time sedimentation ceased in the North Estonian confacies belt in the Gotland area.

DALMANITINA – The *Dalmanitina* Beds are known from south Gotland and consist of grey calcilutites. In the Grötlingbo boring the lowermost 10 cm of the *Dalmanitina* Beds yield calcium carbonate ooids, about 1 mm in diameter.

SYSTEMATICS

The taxonomic principles, terminology, methods of measurements and photography have been described earlier (Grahn 1980). All dimensions are in micrometres.

Genus *Acanthochitina* Eisenack, 1931

Acanthochitina barbata Eisenack, 1931
Fig. 11 A–D

1931 *Acanthochitina barbata* n.sp. – Eisenack, pp. 82–83; Pl. 1:10–11
1967 *Acanthochitina barbata* – Jenkins, pp. 443–445; Pl. 68:1–9; Text fig. 3
1967 *Acanthochitina barbata* – Laufeld, pp. 297–298; Fig. 8 A–D
1976a *Acanthochitina barbata* – Eisenack, p. 648; Fig. 19 A–B, 26
1977a *Acanthochitina barbata* – Achab, p. 416; Pl. 1:1–5
1980 *Acanthochitina barbata* – Nõlvak; Pl. 29:1
1980 *Acanthochitina barbata* – Wrona; Pl. 31–32

DESCRIPTION – *Acanthochitina* species with an elongated conical vesicle and inconspicuous flexure. The neck is subcylindrical and has a width somewhat greater than the maximum width. The aperture is straight. The basal edge is broadly rounded and the base is convex to ovoid. The vesicle wall is covered by a spinose ornamentation, of which many spines are multiramose in both ends, thus forming a complicated network.

DIMENSIONS – The specimens encountered have the same dimensions as those described by Laufeld 1967.

REMARKS – In the present material *Acanthochitina barbata* specimens are poorly preserved. The spinose ornamentation is easily lost in preparation, especially along the flanks.

OCCURRENCE – Gotland: Upper Vormsian to Lower Pirguan/Jonstorp. Upper *Onnia* Beds (uppermost Caradoc), Welsh Borderland (Jenkins 1967). Fjäcka Shale, Dalarna, Sweden (Laufeld 1967). Vormsian, Estonia (Nõlvak 1980). Vauréal Formation (Lower Ashgill), Anticosti Island, Canada (Achab 1977a).

Genus *Ancyrochitina* Eisenack, 1955

Ancyrochitina cf. *ancyrea* (Eisenack, 1931)
Fig. 11 E–F

1978 *Ancyrochitina ancyrea* – Grahn, p. 10; Fig. 5 A–B

DESCRIPTION – *Ancyrochitina* species with a conical body and a cylindrical neck that comprises 1/2 or less of the total length. The flexure is

distinct and the aperture is straight. The basal edge is rounded and provided with 6–8 appendices which are branched distally. The base is convex.

DIMENSIONS – Total length 85–120, width 72–97, width of aperture 26–39, max. height of ornamentation 30.

REMARKS – *Ancyrochitina ancyrea* has been reported from the Upper Ordovician through the Devonian. As restricted by Laufeld (1974:39) it is a species known from Upper Ashgill to Lochkov (lowermost Devonian). Laufeld (1974:39) has suggested that more than one taxon is probably involved.

Ancyrochitina cf. *ancyrea* differs from *Ancyrochitina ancyrea* in having a comparatively short neck and no spines at the aperture. Silurian specimens in general have a neck that comprises 1/2–2/3 of the total length. Upper Ashgillian specimens from Skåne (southernmost Sweden) figured by Grahn (1978; Figs. 5 A–B), are similar to those described here. Hence, it is possible that the Ordovician specimens of *Ancyrochitina ancyrea* generally have a shorter neck than the Silurian populations.

OCCURRENCE – Gotland: Upper Jonstorp and erratics of late Ashgillian age (cf. also Eisenack 1968a).

Dalmanitina Beds to the Zone of *Monograptus revolutus* (Lower Llandovery), Skåne, Sweden (Grahn 1978).

Genus *Angochitina* Eisenack, 1931, emend. 1968

Angochitina capillata Eisenack, 1937
Fig. 11 G–H

1937 *Angochitina capillata* n.sp. – Eisenack, p. 225; Pl. 15: 12–13
1962a *Angochitina capillata* – Eisenack, p. 300; Pl. 15:9–10
1965 *Angochitina capillata* – Eisenack, p. 122; Pl. 11:3
1969 *Angochitina capillata* – Jenkins, p. 10; Pl. 1:7–11

DESCRIPTION – *Angochitina* species with a spherical to ellipsoidal body and a subcylindrical neck that widens at the aperture. The width of the neck is about half the body, and the length about 1/3–1/2 of the total length. The vesicle wall is covered with simple spines.

DIMENSIONS – Total length 147–180, width 64–89, width of aperture 40–62.

OCCURRENCE – Gotland: Idaverean, Nabalan and Pirguan.

Folkeslunda (Upper Llanvirn–lowermost Llandeilo) and Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Nabalan to Pirguan, Estonia

(Eisenack 1962a, 1965). Viola Limestone (Upper Caradoc–Lower Ashgill), Oklahoma, U.S.A. (Jenkins 1969).

Angochitina communis Jenkins, 1967
Fig. 11 I–J

1967 *Angochitina communis* sp. nov. – Jenkins, pp. 450–451; Pl. 69:14–17; Text fig. 7
1981b *Angochitina communis* – Grahn, p. 7; Fig. 3 A–D

DESCRIPTION – See Grahn 1981b.

DIMENSIONS – Total length 102–125, width 76–98, width of aperture 35–53, max. height of ornamentation 20.

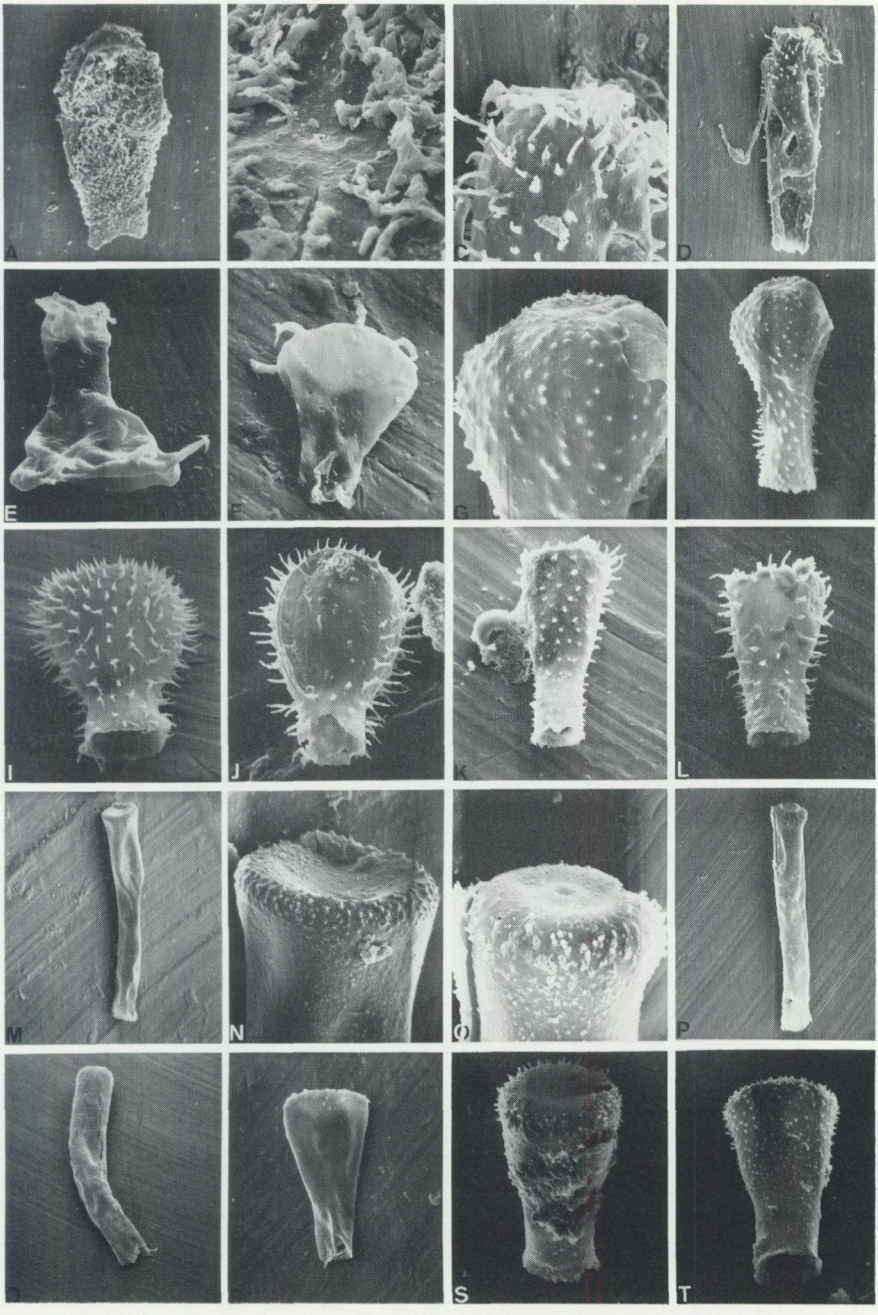
REMARKS – The Gotland specimens are similar to those originally described by Jenkins 1967. Both populations have a neck with a length about 1/5 of the total length. Grahn (1981b:7) remarked that *Angochitina communis* specimens from Västergötland have a neck with a length about 1/3 of the total length. They are similar to *Conochitina hirsuta* Laufeld 1967, but differ in having a more cylindrical neck and a less conspicuous ornamentation.

OCCURRENCE – Gotland: Idaverean.

Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). *Onnia* Beds (Upper Caradoc), Welsh Borderland (Jenkins 1967).

Fig. 11. A–D. *Acanthochitina barbata* Eisenack, 1931. A–B. Gotska Sandöborrningen 1, Vormsi Stage (96.34–96.40 m). C–D. File Haidarborrningen 1, Pirgu Stage (289.26 m). E–F. *Ancyrochitina* cf. *ancyrea* (Eisenack, 1931). E–F. Grötlingboborrningen 1, Jonstorp Formation (400.35 m). G–H. *Angochitina capillata* Eisenack, 1937. G–H. Gotska Sandöborrningen 1, Pirgu Stage (91.51 m). I–J. *Angochitina communis* Jenkins, 1967. I. Gotska Sandöborrningen 1, Idavere Stage (131.60 m). J. Gotska Sandöborrningen 1, Idavere Stage (131.30 m). K–L. *Conochitina cactacea* Eisenack, 1937. K. Gotska Sandöborrningen 1, Idavere Stage (131.30 m). L. Gotska Sandöborrningen 1, Idavere Stage (130.65 m). M–P. *Conochitina capitata* Eisenack, 1962. M–N. Gotska Sandöborrningen 1, Idavere Stage (135.55 m). O–P. Gotska Sandöborrningen 1, Idavere Stage (129.95 m). Q. *Conochitina comma* Eisenack, 1959. Q. Gotska Sandöborrningen 1, Idavere Stage (133.20 m). R–T. *Conochitina conulus* Eisenack, 1955. R. Gotska Sandöborrningen 1, Rakvere Stage (118.17–118.26 m). S. Gotska Sandöborrningen 1, Idavere Stage (132.00 m). T. Gotska Sandöborrningen 1, Idavere Stage (130.95 m).

A–B. SGU Type 1267. A. Lateral view, SEM ×60; B. Detail of the vesicle wall, SEM ×360. C–D. SGU Type 1271. C. Aboral part in lateral view, SEM ×170; D. Lateral view, SEM ×50. E. SGU Type 1275. Lateral view. Note the form of the spine, SEM ×300. F. SGU Type 1276. Lateral view, SEM ×220. G–H. SGU Type 1268. G. Aboral part in lateral view, SEM ×480; H. Lateral view, SEM ×205. I. SGU Type 1281. Lateral view, SEM ×230. J. SGU Type 1283. Lateral view, SEM ×250. K. SGU Type 1287. Lateral view, SEM ×180. L. SGU Type 1288. Lateral view, SEM ×190. M–N. SGU Type 1289. M. Lateral view, SEM ×75; N. Aboral part in lateral view, SEM ×380. O–P. SGU Type 1291. O. Aboral part in lateral view, SEM ×410; P. Lateral view, SEM ×70. Q. SGU Type 1295. Lateral view, SEM ×60. R. SGU Type 1299. Lateral view, SEM ×160. S. SGU Type 1304. Oblique lateral view, SEM ×195. T. SGU Type 1305. Lateral view, SEM ×200.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Genus *Conochitina* Eisenack, 1931, restricted 1955

Conochitina cactacea Eisenack, 1937
Fig. 11 K–L

1981a *Conochitina cactacea* – Grahn, pp. 17–19; Fig. 6 B–D, F (further references)

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 114–165, width 56–90, width of aperture 26–45, max. height of ornamentation 15.

OCCURRENCE – Gotland: Idaverean and Oanduan/"*Macrourus*" to Nabalan.

Rakverean, Estonia (Eisenack 1962b, 1965). Dalby and Slandrom Limestones, Dalarna, Sweden (Laufeld 1967). Sylvan Shale (Lower Ashgill), Oklaholma, U.S.A. (Jenkins 1970). Baltic erratics of Lower *Macrourus* Siltstone (Grahn 1981a).

Conochitina capitata Eisenack, 1962
Fig. 11 M–P

1981a *Conochitina capitata* – Grahn, p. 19; Fig. 6 G–J (further references)
1981b *Conochitina capitata* – Grahn, pp. 7–9; Fig. 3 E–H

DESCRIPTION – see Grahn 1981a.

DIMENSIONS – Total length 218–500, width 46–86, width of aperture 26–61.

REMARKS – In agreement with the Dalarna specimens (Laufeld 1967:301) those from Gotland have simple spines on the basal edge.

OCCURRENCE – Gotland: Upper Kukrusean to Fjäcka.

Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Lower Gullhögen Formation (Lower Llandeilo) and Upper Dalby Limestone to Bestorp (Lower Ashgill) Limestone, Västergötland, Sweden (Grahn 1981b). Aserian to Uhakuan (Upper Llanvirn–Llandeilo) through Jõhvian (Middle Caradoc), Estonia (Eisenack 1962a). Upper Dalby Limestone, Dalarna, Sweden (Laufeld 1967). Baltic erratics of Lower *Macrourus* Siltstone and undifferentiated late Caradocian age (Grahn 1981a).

Conochitina comma Eisenack, 1959
Fig. 11 Q

1959 *Conochitina micracantha* subsp. *comma* n. subsp. – Eisenack, pp. 7–8; Pl. 1:4
1965 *Conochitina micracantha* subsp. *comma* – Eisenack, p. 125; Pl. 10:1–2
1968b *Conochitina micracantha* subsp. *comma* – Eisenack, p. 163; Pl. 26:33

DESCRIPTION – *Conochitina* species with a curved, subcylindrical vesicle that gently tapers towards a straight aperture. The base is slightly convex and the basal edge is rounded. The vesicle wall is smooth.

DIMENSIONS – Total length 175–461, width 46–84, width of aperture 33–70.

OCCURRENCE – Gotland: Upper Kukrusean to Nabalan.
Rakverean, Estonia (Eisenack 1959, 1965).

Conochitina conulus Eisenack, 1955
Fig. 11 R–T

1981a *Conochitina conulus* – Grahn, pp. 21–23; Fig. 8 A–D (further references)
1981b *Conochitina conulus* – Grahn, p. 9; Fig. 3 I–L

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 85–174, width 65–90, width of aperture 45–70.

OCCURRENCE – Gotland: Upper Kukrusean to Nabalan.
Seby (Upper Llanvirn) to Lower Dalby Limestones except Källa Limestone (Lower Llandeilo), Öland, Sweden (Grahn 1981a). Aserian to Uhakuan (Upper Llanvirn–Lower Llandeilo), Estonia (Eisenack 1955). Middle Gullhögen Formation (Lower Llandeilo) to Skagen Limestone, Västergötland, Sweden (Grahn 1981b). *Calymene* Shale (Llanvirn), Normandie, France (Rauscher & Doubinger 1967a, 1967b).

Conochitina elegans Eisenack, 1931
Fig. 12 A–D

1931 *Conochitina elegans* n.sp. – Eisenack, p. 87; Pl. 2:4
1934 *Rhabdochitina conocephala* – Eisenack, pp. 61–62; Pl. 4:10–12; Text fig. 32
1959 *Conochitina elegans* – Eisenack, pp. 3–4; Pl. 2:4–5; Text fig. 1
1965 *Conochitina elegans* – Eisenack, pp. 126, 133; Pl. 10:9
1967 *Conochitina elegans* – Jenkins, p. 455; Pl. 71:1–4
1973 *Conochitina elegans* – Laufeld, pp. 1–5; Pl. 1:1–4
1980 *Conochitina* cf. *elegans* – Nõlvak; Pl. 30:4

DESCRIPTION – *Conochitina* species with an elongated conical vesicle. The base is flat to convex, and the basal edge is slightly rounded. The vesicle tapers slightly towards the straight aperture. There is a minor constriction oralward of the basal edge, and some specimens show a slight convexity in the middle of the vesicle. The vesicle wall is perfectly smooth.

DIMENSIONS – Total length 306–952, width 64–113, width of aperture 44–77.

REMARKS – The Caradocian and Ashgillian specimens of *Conochitina elegans* from Gotland are conspecific with those originally described by Eisenack (1931, 1959) from Caradocian rocks. The Öland and Västergötland specimens assigned as *Conochitina* aff. *elegans* by Grahn (1980, 1981a, 1981b) probably belong to a new species.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan/Jonstorp.

Coston to *Onnia* Beds (Caradoc), Welsh Borderland (Jenkins 1967). Vormsian, Estonia (Nõlvak 1980), Caradocian, Sardinia (Laufeld 1973). Baltic erratics of Caradocian age (Eisenack 1934, 1959, 1965).

Conochitina incerta Eisenack, 1962
Fig. 12 E–H

1962a *Conochitina incerta* n.sp. – Eisenack, p. 309; Pl. 14:14; Text fig. 7
1965 *Conochitina incerta* – Eisenack, p. 126; Pl. 10:6

DESCRIPTION – *Conochitina* species with an elongated conical vesicle. The base is provided with a conical basal process and the basal edge is sharp. The vesicle tapers towards the straight aperture, and the vesicle wall is perfectly smooth.

DIMENSIONS – Total length 398–896, width 67–90, width of aperture 43–75.

OCCURRENCE – Gotland: Rakverean to Nabalan and Pirguan.

Baltic erratics of Late Caradocian and Ashgillian age (Eisenack 1962a, cf. also 1968a).

Conochitina micracantha Eisenack, 1931
Fig. 12 I–L

1980 *Conochitina micracantha* – Grahn, pp. 18–20; Fig. 10 E–H (further references)
1980 *Conochitina micracantha* – Nõlvak; Pl. 29:6
1981a *Conochitina micracantha* – Grahn, pp. 23–25; Fig. 8 I–L
1981b *Conochitina micracantha* – Grahn, pp. 10–11; Fig. 3 Q–T

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 146–324, width 53–91, width of aperture 40–61.

REMARKS – The Gotland specimens have a vesicle wall covered by simple spines, although they are concentrated on the basal part. Furthermore, they have a fringed aperture. Thus, these specimens are more similar to those described from Estonia (cf. Nõlvak 1980) than the west Baltic area (cf. Grahn 1980, 1981a, 1981b). Whether the degree of ornamentation is due to ecological conditions or interspecific variation is a task for a special study.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan/Jonstorp.

Upper Langevojan (Eisenack 1976b) to Hunderumian (uppermost Arenig–Lower Llanvirn) and Upper Aluojan (Lower Llanvirn). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Aserian (Upper Llanvirn) to Nabalan, Estonia (Eisenack 1959, 1965, 1968b; Nõlvak 1980). Skövde to Bestorp Limestones (uppermost Llanvirn–Lower Ashgill), Västergötland, Sweden (Grahn 1981b). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Paris 1979). Upper Viola Limestone (Upper Caradoc–Lower Ashgill), Oklahoma, U.S.A. (Jenkins 1969). Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Baltic erratics of Lower *Macrourus* Siltstone and undifferentiated late Caradocian age (Grahn 1981a).

Conochitina minnesotensis (Stauffer, 1933)
Fig. 12 M–N

1980 *Conochitina minnesotensis* – Grahn, pp. 20–22; Fig. 12 A–D (further references)
1980 *Conochitina minnesotensis* – Nõlvak; Pl. 30:3
1981a *Conochitina minnesotensis* – Grahn, p. 25; Fig. 9 A
1981b *Conochitina minnesotensis* – Grahn, p. 11; Fig. 4 A–D

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Length up to 1379, width 75–122, width of aperture 56–86.

OCCURRENCE – Gotland: Idaverean to Pirguan/Jonstorp.

Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Persnäs (Lower Llandeilo) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Volkhovian to Porkunian (Upper Arenig–Upper Ashgill), Estonia (Eisenack 1962b, 1965; Nõlvak 1980). Lower Dalby to Bestorp (Lower Ashgill) Limestones, Västergötland, Sweden (Grahn 1981b). Decorah Formation (Lower Caradoc), Minnesota, U.S.A. (Stauffer 1933). Upper Dalby and Skagen Limestones, Dalarna, Sweden (Laufeld 1967). Herscheider Shale (Caradoc?), Westphalia, West Germany (Eisenack 1939). Upper Viola Limestone (Upper Caradoc–Lower Ashgill), Oklahoma, U.S.A. (Jenkins 1969). Baltic erratics of Lower *Macrourus* Siltstone (Grahn 1981a).

Conochitina primitiva Eisenack, 1939
Fig. 12 O–P

1980 *Conochitina primitiva* – Grahn, pp. 22–23; Fig. 12 E–H (further references)
1980 *Conochitina primitiva* – Paris, p. 184; Pl. 15:6
1981a *Conochitina primitiva* – Grahn, p. 26; Fig. 9 F–H
1981b *Conochitina primitiva* – Grahn, p. 13; Fig. 4 I–L

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 98–242, width 61–78, width of aperture 29–47.

REMARKS – The Gotland specimens of *Conochitina primitiva* show the same variation as those from Öland.

OCCURRENCE – Gotland: Upper Kukrusean to Idaverean.

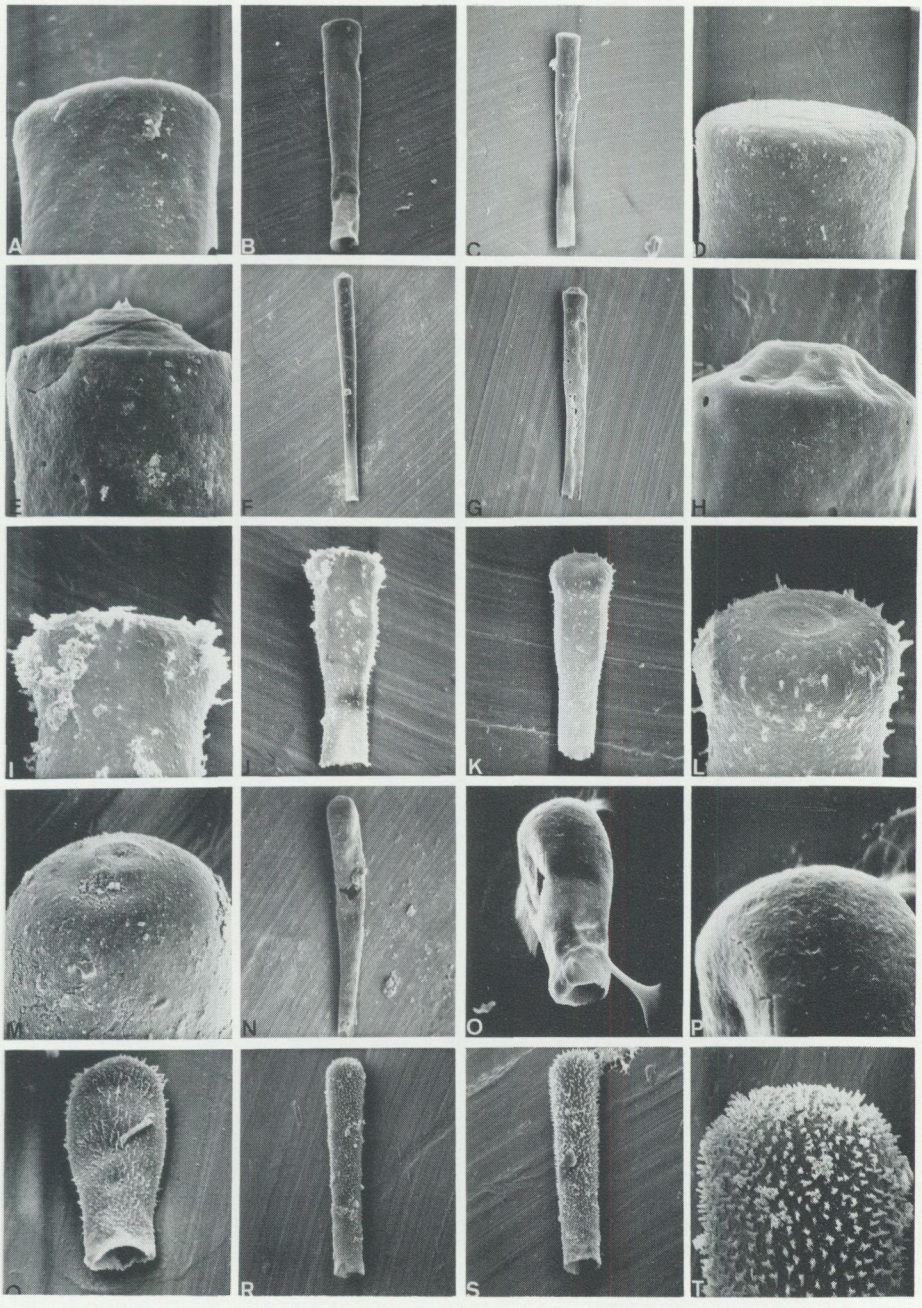
Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Upper Aluojan (Lower Llanvirn). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Volkhovian to Jõhvian (Upper Arenig–Upper Caradoc), Estonia (Eisenack 1934, 1962a). Hunderumian (uppermost Arenig–Lower Llanvirn), Dalarna, Sweden (Eisenack 1962a). Kundan (Upper Arenig–Lower Llanvirn), Moscow Syneclise, U.S.S.R. (Umnova 1969). *Calymene* Shale (Llanvirn), Normandie (Rauscher & Doubinger 1967a, 1967b) and Calvados (Rauscher 1970), France. Gullhögen Formation (Upper Llandeilo) to Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Llandeilo–Caradoc, Massif Armoricain, France (Paris 1980). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Henry et al. 1974). Herscheider Shale (Caradoc?), Westphalia, West Germany (Eisenack 1939).

Conochitina robusta Eisenack, 1959
Fig. 12 Q–T

1980 *Conochitina postrobusta* sp.n. – Nestor, pp. 101–102; Pl. 4:1–4
1981a *Conochitina robusta* – Grahn, pp. 26–27; Fig. 10 A–B (further references)
1981b *Conochitina robusta* – Grahn, p. 14; Fig. 4 M–P

Fig. 12. A–D. *Conochitina elegans* Eisenack, 1931. A–B. Gotska Sandöborrningen 1, Kukruse Stage (135.90 m). C–D. Gotska Sandöborrningen 1, Rakvere Stage (118.50–118.55 m). E–H. *Conochitina incerta* Eisenack, 1962. E–F. Gotska Sandöborrningen 1, Pirgu Stage (85.17–85.22 m). G–H. Gotska Sandöborrningen 1, Nabala Stage (116.40–116.46 m). I–L. *Conochitina micracantha* Eisenack, 1931. I–J. Gotska Sandöborrningen 1, Idavere Stage (135.20 m). K–L. Gotska Sandöborrningen 1, Rakvere Stage (119.09–119.14 m). M–N. *Conochitina minnesotensis* (Stauffer, 1933). M–N. Gotska Sandöborrningen 1, Oandu Stage (127.15–127.20 m). O–P. *Conochitina primitiva* Eisenack, 1939. O–P. Grötlingboborrningen 1, Kukruse Stage (435.00 m). Q–T. *Conochitina robusta* Eisenack, 1959. Q. Gotska Sandöborrningen 1, Skagen Limestone (127.50–127.55 m). R, T. Gotska Sandöborrningen 1, Idavere Stage (130.65 m). S. Gotska Sandöborrningen 1, Idavere Stage (135.20 m).

A–B. SGU Type 1306.A. Aboral part in lateral view, SEM ×370; B. Lateral view, SEM ×75. C–D. SGU Type 1309. C. Lateral view, SEM ×50; D. Aboral part in lateral view. Note the slightly convex base. SEM ×405. E–F. SGU Type 1311. E. Aboral part in lateral view, SEM ×355; F. Lateral view, SEM ×35. G–H. SGU Type 1310. G. Lateral view, SEM × 50; H. Aboral part in lateral view, SEM ×440. I–J. SGU Type 1316. I. Aboral part in lateral view, SEM ×365; J. Lateral view. Note the fringed aperture, SEM ×160. K–L. SGU Type 1284. K. Oblique lateral view, SEM ×140; L. Aboral part in oblique lateral view, SEM ×415. M–N. SGU Type 1318. M. Aboral part in lateral view, SEM ×300; N. Lateral view, SEM ×35. O–P. SGU Type 1340. O. Lateral view. SEM ×140; P. Aboral part in lateral view, SEM ×375. Q. SGU Type 1320. Lateral view, SEM ×150. R, T. SGU Type 1322. R. Lateral view, SEM ×60; T. Aboral part in lateral view, SEM ×310. S. SGU Type 1323. Lateral view, SEM ×80.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DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 177–495, width 75–99, width of aperture 49–67.

REMARKS – The Gotland specimens have an ornamentation that covers the whole vesicle, and the aperture is fringed.

OCCURRENCE – Gotland: Idaverean to Pirguan/Jonstorp.

Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Upper Dalby to Slandrom Limestones, Dalarna, Sweden (Laufeld 1967). Jõhvian (Middle Caradoc) and Oanduan to Pirguan, Estonia (Eisenack 1959, 1972). Lower Viola Limestone (Upper Caradoc), Oklahoma, U.S.A. (Jenkins 1969). Laggan Burn Limestone (Caradoc), Scotland (Jansonius 1964). Trenton Group to Utica Formation (Caradoc), Canada (Martin 1975). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Paris 1979). Upper Caradoc to Lower Llandovery, Belgium (Martin 1973). *Dalmanitina* Beds to the Zone of *Monograptus convolutus* (Middle Llandovery), Skåne, Sweden (Grahn 1978, unpub. mat.). Baltic erratics of Lower *Macrourus* Siltstone and of undifferentiated late Caradocian age (Grahn 1981a).

Conochitina suecica Laufeld, 1967
Fig. 13 A–D

1967 *Conochitina suecica* n.sp. – Laufeld, pp. 309–311; Fig. 15 A–E
1981a *Conochitina suecica* – Grahn, p. 27; Fig. 10 C–F

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 107–239, width 58–96, width of aperture 34–53.

OCCURRENCE – Gotland: Upper Kukrusean to Nabalan.

Upper Dalby Limestone, Dalarna, Sweden (Laufeld 1967). Baltic erratics of Lower *Macrourus* Siltstone (Grahn 1981a).

Conochitina synclinalis Eisenack, 1965
Fig. 13 E–H

1965 *Conochitina micracantha* subsp. *synclinalis* n. subsp. – Eisenack, pp. 124–125; Pl. 10:4

DESCRIPTION – *Conochitina* species with a subconical body and a subcylindrical neck that slightly widens towards the finely fringed aperture. The base is convex and the basal edge gently rounded. The flanks are somewhat convex and the vesicle wall is almost smooth or covered by simple spines.

DIMENSIONS – Total length 164–342, width 58–93, width of aperture 37–51.

REMARKS – *Conochitina synclinalis* has a superficial similarity to *Conochitina wesenbergensis* from which it differs in having a more convex body and a more rounded basal edge. Eisenack (1965:124) remarked that the greatest width of the vesicle is about 1/4 of the total length from the base towards the aperture.

OCCURRENCE – Gotland: Upper Kukrusean to Idaverean, Slandrom and Nabalan to Vormsian.

Conochitina villosa n.sp.
Fig. 13 I–L

ETYMOLOGY – Latin, *villosus,* woolly, referring to the characteristic arrangement of the ornamentation.

HOLOTYPE – SGU Type 1334.

TYPE STRATUM – Oandu Siltstone.

TYPE LOCALITY – Gotska Sandöborrningen 1 (126.55 m), Gotland.

DESCRIPTION – *Conochitina* species with a conical body and a subcylindrical neck with a fringed aperture. The base is slightly concave and the basal edge is rounded. The flexure is distinct. The vesicle wall is covered by long simple spines which are best developed on the body.

DIMENSIONS – Total length 133–219, width 65–85, width of aperture 36–42, max. height of ornamentation 19.

REMARKS – *Conochitina villosa* is distinguished from *Conochitina hirsuta* in having only simple spines and from *Conochitina micracantha* in not having a constriction orally of the basal edge and in having considerably longer spines.

OCCURRENCE – Gotland: Oanduan to Nabalan.

Conochitina wesenbergensis Eisenack, 1959
Fig. 13 M–P

1981a *Conochitina wesenbergensis* – Grahn, p. 29; Fig. 10 G–L (further references)
1981b *Conochitina wesenbergensis* – Grahn, p. 14; Fig. 4 Q–T

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 147–263, width 63–84, width of aperture 35–56.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan.

Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Rakverean to Pirguan, Estonia (Eisenack 1959, 1968b). Lower Viola Limestone (Upper Caradoc), Oklahoma, U.S.A. (Jenkins 1969). Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Baltic erratics of Lower *Macrourus* Siltstone (Grahn 1981a).

Genus *Coronochitina* Eisenack, 1965, emend.

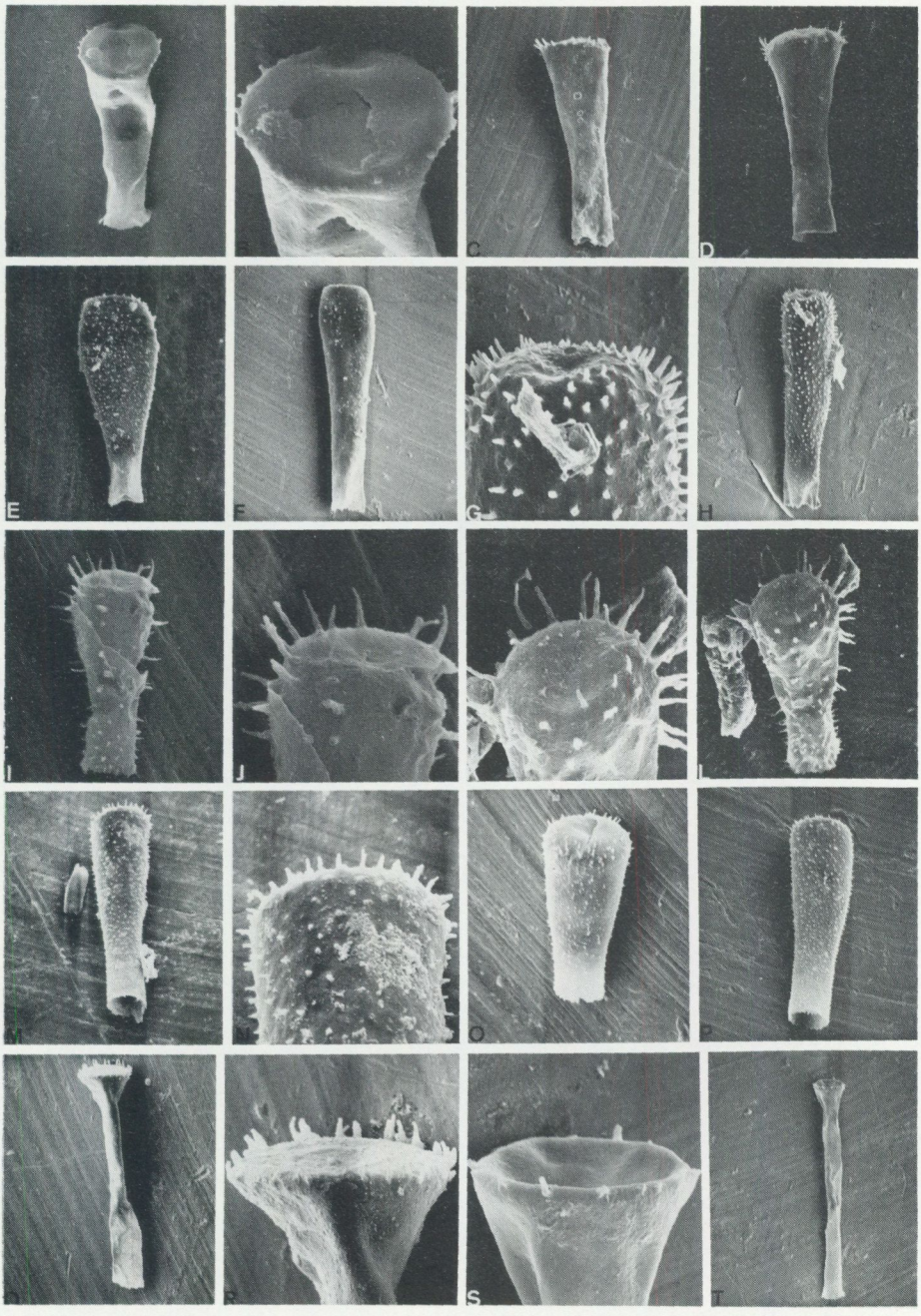
DIAGNOSE – Chitinozoans with a cylindrical to subcylindrical neck and conical to subconical body. The neck is comparatively long and may widen towards the aperture which is fringed or provided with simple spines. In general the flexure is distinct. The basal edge is sharp and provided with a row of spines. Oralward of the basal edge a constriction may be present. The base is flat or convex and always smooth. The vesicle wall may have simple spines orally of the basal edge.

REMARKS – *Coronochitina* differs from *Spinachitina* in having a more slender shape and a comparatively longer neck. It is distinguished from *Pogonochitina* Taugourdeau 1961 in having a much longer neck and a more distinct flexure. *Conochitina taugourdeaui* Eisenack 1968 is referred to *Coronochitina* due to its shape and lack of ornamentation on its base.

TYPE SPECIES – *Coronochitina coronata* (Eisenack, 1931).

Fig. 13. A–D. *Conochitina suecica* Laufeld, 1967. A–B. File Haidarborrningen 1, Idavere Stage (319.19–319.25 m). C. File Haidarborrningen 1, Nabala Stage (305.90 m). D. Gotska Sandöborrningen 1, Idavere Stage (134.20 m). E–H. *Conochitina synclinalis* Eisenack, 1965. E. Gotska Sandöborrningen 1, Vormsi Stage (97.85–97.90 m). F. Gotska Sandöborrningen 1, Nabala Stage (101.30–101.37 m). G–H. Gotska Sandöborrningen 1, Nabala Stage (103.62–103.70 m). I–L. *Conochitina villosa* n.sp. I–J Grötlingboborrningen 1, Slandrom Formation (423.25 m). K–L. Gotska Sandöborrningen 1, Oandu Stage (126.55 m). M–P. *Conochitina wesenbergensis* Eisenack, 1959. M–N. Gotska Sandöborrningen 1, Idavere Stage (135.20 m). O. Gotska Sandöborrningen 1, Idavere Stage (130.30 m). P. Gotska Sandöborrningen 1, Rakvere Stage (118.88–118.95 m). Q–T. *Coronochitina coronata* (Eisenack, 1931). Q–R. Gotska Sandöborrningen 1, Skagen Limestone (127.50–127.55 m). S–T. File Haidarborrningen 1, Pirgu Stage (260.30 m).

A–B. SGU Type 1326. A. Oblique lateral view, SEM ×165; B. Aboral part in oblique lateral view, SEM ×400. C. SGU Type 1328. Lateral view, SEM ×160. D. SGU Type 1312. Lateral view, SEM ×160. E. SGU Type 1285. Lateral view, SEM ×120. F. SGU Type 1319. Lateral view, SEM ×100. G–H. SGU Type 1329. G. Aboral part in lateral view, SEM ×365; H. Lateral view, SEM ×100. I–J. SGU Type 1336. I. Lateral view, SEM ×180; J. Aboral part in lateral view, SEM ×360. K–L. SGU Holotype 1334. K. Aboral part in lateral view, SEM ×350; L. Lateral view, SEM ×175. M–N. SGU Type 1286. M. Lateral view, SEM ×100; N. Aboral part in lateral view. SEM ×345. O. SGU Type 1341. Lateral view, SEM ×160. P. SGU Type 1300. Lateral view, SEM ×125. Q–R. SGU Type 1321. Q. Lateral view, SEM ×110; R. Aboral part in lateral view, SEM ×425. S–T. SGU Type 1272. S. Aboral part in lateral view, SEM ×370; T. Lateral view, SEM ×60.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Coronochitina coronata (Eisenack, 1931)
Fig. 13 Q–T

1931 *Conochitina coronata* n.sp. – Eisenack, pp. 87–88; Pl. 2:5
1962a *Conochitina coronata* – Eisenack, p. 295; Pl. 15:3–4
1965 *Coronochitina coronata* – Eisenack, pp. 127–128
1980 *Coronochitina coronata* – Nõlvak; Pl. 30:1 A–B

DESCRIPTION – *Coronochitina* species with a conical to subconical body and a long cylindrical to subcylindrical neck. The length of the neck varies from half to 8/9–6/7 of the total length. The aperture is provided with minor simple spines. The base is flat to somewhat convex and smooth, and the basal edge is sharp and provided with a row of simple spines. The flexure is distinct but may be rounded.

DIMENSIONS – Total length 263–344, width 65–81, width of aperture 20–43, max. height of ornamentation 8.

REMARKS – The specimen figured by Eisenack 1931 (Pl. 2:5) has a neck that seems to widen towards the aperture. This is probably due to flattening of the neck (cf. Fig. 13 Q).

OCCURRENCE – Gotland: Idaverean to Skagen and Rakverean to Pirguan.

Vormsian to Pirguan, Estonia (Nõlvak 1980:256). Baltic erratics of undifferentiated late Caradocian and Ashgillian age (Eisenack 1962a).

Genus *Cyathochitina* Eisenack, 1955

Cyathochitina calix (Eisenack, 1931)
Fig. 14 A–D

1980 *Cyathochitina calix* – Grahn, pp. 23–25; Fig. 14 A–G (further references)
1981a *Cyathochitina calix* – Grahn, p. 30; Fig. 11 A, D
1981b *Cyathochitina calix* – Grahn, p. 15; Fig. 5 A–D

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 300–419, width 128–179, width of aperture 64–71.

OCCURRENCE – Gotland: Upper Kukrusean to Skagen and Rakverean.

Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Upper Aluojan (Lower Llanvirn). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Gullhögen Formation (Lower Llandeilo) to Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Volkhovian to Aserian (Upper Arenig–Upper Llanvirn), Estonia (Eisenack 1958, 1962a, 1968b). Hunderumian (uppermost Arenig–Lower Llanvirn), Dalarna, Sweden (Eisenack 1962a). Hope Shales (Lower

Llanvirn), Welsh Borderland (Jenkins 1967). Herscheider Shale (Caradoc?), Westphalia, West Germany (Eisenack 1939).

Cyathochitina campanulaeformis (Eisenack, 1931)
Fig. 14 E–F

1980 *Cyathochitina* cf. *campanulaeformis* – Grahn, pp. 25–27; Fig. 15 A–D (further references)
1980 *Cyathochitina campanulaeformis* – Nõlvak; Pl. 29:8
1980 *Cyathochitina campanulaeformis* – Wrona; Pl. 26:3 A–B
1980 *Cyathochitina campanulaeformis* – Paris, pp. 290–293; Pl. 8:2–3; Pl. 10:5, 8; Pl. 11:13
1981a *Cyathochitina campanulaeformis* – Grahn, pp. 30–32; Fig. 11 B–C, E
1981b *Cyathochitina campanulaeformis* – Grahn, pp. 15–17; Fig. 5 E–H

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 160–383, width 87–203, width of aperture 33–73, max. width of carina 20.

REMARKS – The width of carina is very variable and many specimens have a diminutive carina.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan/Jonstorp. Baltic erratics of Late Ashgillian age.

Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Kundan to Porkunian (Upper Arenig–Upper Ashgill), Estonia (Eisenack 1962a, 1968a, 1968b; Nõlvak 1980). Hope Shales to Meadowtown Beds (Lower Llanvirn–Lower Llandeilo), Welsh Borderland (Jenkins 1967). Llanvirn–Llandeilo, Massif Armoricain, France (Paris 1980). Skövde to Bestorp Limestones (uppermost Llanvirn–Lower Ashgill), Västergötland, Sweden (Grahn 1981b). Base of *Didymograptus murchisoni* Zone to *Monograptus triangulatus* Subzone (Upper Llanvirn–Middle Llandovery), Sweden (Laufeld 1971). Dalby to Slandrom Limestones, Dalarna, Sweden (Laufeld 1967). Herscheider Shale (Caradoc?), Westphalia, West Germany (Eisenack 1939). Middle Ordovician in Bohemia (Eisenack 1948). Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). *Dalmanitina* Beds to the Zone of *Monograptus revolutus* (Lower Llandovery), Skåne, Sweden (Grahn 1978). Baltic erratics of Middle Ordovician age (Kozłowski 1963). Baltic erratics of Lower *Macrourus* Siltstone and of undifferentiated late Caradocian age (Grahn 1981a).

Cyathochitina costata n.sp.
Fig. 14 G

1980 *Cyathochitina* cf. *dispar* – Nõlvak; Pl. 29:2

ETYMOLOGY – Latin, *costatus,* provided with ridges, referring to the characteristic arrangement of the ornamentation.

HOLOTYPE – SGU Type 1277.

TYPE STRATUM – Fjäcka Formation.

TYPE LOCALITY – Grötlingboborrningen 1 (420.65 m), Gotland.

DESCRIPTION – *Cyathochitina* species with a subconical body and a cylindrical or conical neck tapering towards the straight aperture. The flexure is distinct and the flanks convex. The base is flat and the basal edge is provided with a short carina. The vesicle wall is covered with long distinct ridges from the aperture to the basal edge.

DIMENSIONS – Total length 337–357, width 150–183, width of apertue 61–75.

REMARKS – *Cyathochitina dispar* Benoit & Taugourdeau 1961 has an overall morphology similar to *Cyathochitina costata* but has faintly concentric striations instead of longitudinal ridges.

OCCURRENCE – Gotland: Nabalan to Fjäcka.
Nabalan, Estonia (Nõlvak 1980).

Cyathochitina kuckersiana (Eisenack, 1934)
Fig. 14 H–I

1980 *Cyathochitina kuckersiana* – Nõlvak; Pl. 29:7
1980 *Cyathochitina kuckersiana* – Wrona; Pl. 25:1 A–C; Pl. 26:4
1981a *Cyathochitina kuckersiana* – Grahn, p. 32; Fig. 11 F–H (further references)
1981b *Cyathochitina kuckersiana* – Grahn, p. 18; Fig. 5 I–L

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 173–400, width 117–211, width of aperture 43–83, max. width of carina 39.

REMARKS – The morphological variation is the same as that among the Västergötland specimens.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan/Jonstorp.
Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). *Calymene* Shale (Llanvirn), Normandie, France (Rauscher & Doubinger 1967a, 1967b). Upper Dalby Limestone, Dalarna, Sweden (Laufeld 1967). Upper Dalby to Bestorp (Lower Ashgill) Limestones, Västergötland, Sweden (Grahn 1981b). Kukrusean to Oanduan, Estonia (Eisenack 1962a). Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Baltic erratics of Lower *Macrourus* Siltstone (Grahn 1981a).

Cyathochitina latipatagium (Jenkins, 1969)
Fig. 14 J–K

1981a *Cyathochitina latipatagium* – Grahn, pp. 32–33; Fig. 11 I (further references)

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 143–215, width 143–179, width of aperture 48–72, max. width of carina 29.

OCCURRENCE – Gotland: Idaverean to Vormsian.

Calymene Shale (Llanvirn), Normandie, France (Rauscher & Doubinger 1967a, 1967b). Folkeslunda (Upper Llanvirn–Lower Llandeilo) and Dalby Limestones, Öland, Sweden (Grahn 1981a). Jõhvian (Middle Caradoc) to Oanduan, Estonia (Eisenack 1962a). Coston Beds to *Onnia* Beds (Caradoc), Welsh Borderland (Jenkins 1967). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Paris 1979). Viola Limestone (Caradoc), Oklahoma, U.S.A. (Jenkins 1969). Trenton Group to Utica Formation (Caradoc), Canada (Martin 1975). Macasty Formation (Upper Caradoc) to Ellis Bay Formation (Upper Ashgill), Anticosti Island, Canada (Achab 1977b, 1978, 1979).

Cyathochitina reticulifera Grahn, 1981
Fig. 14 L–N

1981a *Cyathochitina reticulifera* n.sp. – Grahn, pp. 33–34; Fig. 12 A–C (further references)
1981b *Cyathochitina reticulifera* – Grahn, p. 18; Fig. 5 M–P

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 164–375, width 87–182, width of aperture 33–101.

OCCURRENCE – Gotland: Idaverean and Rakverean to Fjäcka.

Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Baltic erratics of undifferentiated late Caradocian age (Grahn 1981a).

Cyathochitina stentor (Eisenack, 1937)
Fig. 14 O–P

1981a *Cyathochitina stentor* – Grahn, pp. 34–36; Fig. 12 H-J (further references)
1981b *Cyathochitina stentor* – Grahn, p. 19; Fig. 6 A–B, D–E

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – The specimens encountered have similar dimensions to those described by Grahn 1981a.

REMARKS – All investigated specimens of *Cyathochitina stentor* were fragmentary.

OCCURRENCE – Gotland: Upper Kukrusean.

Uppermost Ryd (Upper Llandeilo) to Lower Dalby Limestones, Västergötland, Sweden (Grahn 1981b). Kukrusean, Estonia (Eisenack 1962a). Dalby Limestone, Dalarna (Laufeld 1967) and Öland (Grahn 1981a), Sweden.

Genus *Desmochitina* Eisenack, 1931

Desmochitina amphorea Eisenack, 1931
Fig. 14 Q–R

1981a *Desmochitina amphorea* – Grahn, p. 38; Fig. 13 E–F (further references)
1981b *Desmochitina amphorea* – Grahn, pp. 19–21; Fig. 6 I–K

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 87–126, width 71–89, width of aperture 32–44.

OCCURRENCE – Gotland: Upper Kukrusean to Skagen and Rakverean to Nabalan.

Folkeslunda (uppermost Llanvirn) and Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Lower Dalby Limestone, Västergötland, Sweden

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Fig. 14. A–D. *Cyathochitina calix* (Eisenack, 1931). A–B. File Haidarborrningen 1, Idavere Stage (319.19–319.25 m). C–D. Grötlingboborrningen 1, Kukruse Stage (433.60 m). E–F. *Cyathochitina campanulaeformis* (Eisenack, 1931). E. Gotska Sandöborrningen 1, Idavere Stage (129.60 m). F. Gotska Sandöborrningen 1, Nabala Stage (117.18–117.23 m). G. *Cyathochitina costata* n.sp. G. Grötlingboborrningen 1, Fjäcka Formation (420.65 m). H–I. *Cyathochitina kuckersiana* (Eisenack, 1934). H. Gotska Sandöborrningen 1, Oandu Stage (127.15–127.20 m). I. Gotska Sandöborrningen 1, Nabala Stage (115.19–115.23 m). J–K. *Cyathochitina latipatagium* (Jenkins, 1969). J. Gotska Sandöborrningen 1, Vormsi Stage (96.34–96.40 m). K. File Haidarborrningen 1, Idavere Stage (319.19–319.25 m). L–N. *Cyathochitina reticulifera* Grahn 1981. L. File Haidarborrningen 1, Nabala Stage (305.90 m). M–N. Gotska Sandöborrningen 1, Rakvere Stage (120.80 m). O–P. *Cyathochitina stentor* (Eisenack, 1937). O–P. Grötlingboborrningen 1, Kukruse Stage (435.00 m). Q–R. *Desmochitina amphorea* Eisenack, 1931. Q. Gotska Sandöborrningen 1, Idavere Stage (132.00 m). R. Gotska Sandöborrningen 1, Idavere Stage (135.20 m). S–T. *Desmochitina cocca* Eisenack, 1931. S–T. Gotska Sandöborrningen 1, Idavere Stage (132.55 m).

A–B. SGU Type 1342. A. Lateral view, SEM ×70; B. Aboral part in lateral view, SEM ×180. C–D. SGU Type 1337. C. Aboral part in lateral view, SEM ×180; D. Lateral view, SEM ×70. E. SGU Type 1313. Oblique lateral view. Note the longitudinal thickenings at the flexure, SEM ×155. F. SGU Type 1314. Oblique lateral view, SEM ×100. G. SGU Holotype 1277. Lateral view, SEM ×85. H. SGU Type 1330. Oblique lateral view, SEM ×80. I. SGU Type 1301. Oblique lateral view, SEM ×100. J. SGU Type 1269. Lateral view, SEM ×110. K. SGU Type 1343. Lateral view, SEM ×135. L. SGU Type 1317. Oblique lateral view, SEM ×110. M–N. SGU Type 1282. M. Oblique lateral view, SEM ×115; N. Aboral part in oblique lateral view, SEM ×275. O–P. SGU Type 1338. O. Aboral part in oblique lateral view. Note the longitudinal ribs on the vesicle wall, SEM ×170; P. Lateral view, SEM ×40. Q. SGU Type 1292. Lateral view, SEM ×230. R. SGU Type 1290. Lateral view, SEM × 315. S–T. SGU Type 1324. S. Clusters of vesicles, SEM ×70; T. Detail of S, SEM ×280.


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(Grahn 1981b). Acton Scott Beds (Upper Caradoc), Welsh Borderland (Jenkins 1967). Baltic erratics of undifferentiated late Llanvirnian to Llandeilian age (Eisenack 1959).

Desmochitina cocca Eisenack, 1931
Fig. 14 S–T

1980 *Desmochitina cocca* – Grahn, p. 29; Fig. 16 A–C (further references)
1981 *Pseudodesmochitina minor* f. *cocca* – Paris, p. 120; Pl. 15:11
1981a *Desmochitina cocca* – Grahn, p. 38; Fig. 13 G–H

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 91–98, width 73–88, width of aperture 31–45.

REMARKS – As shown in Fig. 14 S, *Desmochitina cocca* originally occurred as tightly packed clusters where the vesicles are not in aboral-oral contact. Probably the vesicles of this species once were enclosed in a cocoon. The spongy surface on some of the vesicles might be remains of fluids or mucus from the cocoon.

OCCURRENCE – Gotland: Upper Kukrusean to Nabalan.

Upper Langevojan (Upper Arenig) to Lower Valastean (Lower Llanvirn) and Upper Aluojan (Lower Llanvirn). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Aserian (Upper Llanvirn) to Kukrusean, Estonia (Eisenack 1962a). Glenburrell Beds (Lower Caradoc), Welsh Borderland (Jenkins 1967). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Henry et al. 1974; Paris 1981). Baltic erratics of Lower *Macrourus* Siltstone and undifferentiated late Caradocian age (Grahn 1981a).

Desmochitina complanata Eisenack, 1932
Fig. 15 A–B

1981a *Desmochitina complanata* – Grahn, pp. 38–39; Fig. 14 A–D (further references)
1981b *Desmochitina complanata* – Grahn, p. 21; Fig. 6 L–M

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 51–98, width 79–112, width of aperture 34–50.

REMARKS – Several Gotland specimens show an ornamentation consisting of minute, simple spines (Fig. 15 A).

OCCURRENCE – Gotland: Upper Kukrusean to Vormsian/Fjäcka.

Folkeslunda (Upper Llanvirn–Lower Llandeilo) and Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Acton Scott Beds (Upper Caradoc),

Welsh Borderland (Jenkins 1967). Baltic erratics of undifferentiated late Llanvirnian to Llandeilian age (Eisenack 1959).

Desmochitina minor Eisenack, 1931
Fig. 15 C–D

1980 *Desmochitina minor* – Grahn, p. 30; Fig. 18 A–D (further references)
1980 *Desmochitina minor* – Nõlvak; Pl. 29:5
1981a *Desmochitina minor* – Grahn, p. 39; Fig. 14 E–F
1981b *Desmochitina minor* – Grahn, pp. 21–22; Fig. 6 N

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 75–129, width 56–86, width of aperture 35–59.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan.

Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Upper Aluojan (Lower Llanvirn). Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Volkhovian to Porkunian (Upper Arenig–Upper Ashgill), Estonia (Eisenack 1958, 1962a, 1965, 1968b; Nõlvak 1980). Hunderumian (uppermost Arenig–Lower Llanvirn) (Eisenack 1962a) and Upper Dalby to Slandrom Limestones, Dalarna, Sweden (Laufeld 1967). Gullhögen Formation (Lower Llandeilo) to Skagen Limestone, Västergötland, Sweden (Grahn 1981b). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Paris 1979). Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Viola Limestone (Upper Caradoc–Lower Ashgill), Oklahoma, U.S.A. (Jenkins 1969). Baltic erratics of Lower *Macrourus* Siltstone and undifferentiated late Caradocian age (Grahn 1981a).

Desmochitina nodosa Eisenack, 1931
Fig. 15 E–F

1981a *Desmochitina nodosa* – Grahn, pp. 39–41; Fig. 14 G (further references)
1981b *Desmochitina nodosa* – Grahn, p. 22; Fig. 7 A–B

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 78–119, width 53–94, width of aperture 35–59.

OCCURRENCE – Gotland: Idaverean to Rakverean.

Upper Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Keilan (Middle Caradoc), Estonia (Eisenack 1962a). Skagen Limestone, Dalarna, Sweden (Laufeld 1967). Zone of *Diplograptus multidens* (Middle Caradoc), Skåne, Sweden (Bergström et al. 1967). Baltic erratics of Middle Ordovician age (Kozłowski 1963), and of undifferentiated late Caradocian age (Schallreuter 1963; Grahn 1981a).

Desmochitina aff. *nodosa* Eisenack, 1931
Fig. 15 G–H

DESCRIPTION – *Desmochitina* species with a subspherical vesicle. The longitudinal axis is gently curved and the conical collar is attached at an oblique angle to the body. The vesicle wall is covered by verrucate thickenings.

DIMENSIONS – Total length 85–91, width 76–85, width of aperture 51–74.

REMARKS – *Desmochitina* aff. *nodosa* differs from *Desmochitina nodosa* in having its collar attached at an oblique angle to the body. Furthermore, the vesicles are not attached to each other through the operculum. The species has an overall similarity to *Desmochitina amphorea,* but the latter does not occur in chains (cf. Grahn 1981b:21; Fig. 6 I).

OCCURRENCE – Gotland: Idaverean, Rakverean and Fjäcka.

Desmochitina rugosa Eisenack, 1962
Fig. 15 I–J

1980 *Desmochitina rugosa* –Wrona; Pl. 27:2
1981a *Desmochitina rugosa* – Grahn, pp. 41–42; Fig. 15 A–C (further references)
1981b *Desmochitina rugosa* – Grahn, p. 24; Fig. 7 C–D

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 107–144, width 85–96, width of aperture 48–67.

OCCURRENCE – Gotland: Upper Kukrusean to Idaverean and Oanduan/"*Macrourus*" to Rakverean.

Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1981a). Lower Gullhögen Formation (Lower Llandeilo) and Dalby Limestone, Västergötland, Sweden (Grahn 1981b). Aserian to Kukrusean (Upper Llanvirn–Lower Caradoc), Estonia (Eisenack 1962a, 1968b). Dalby Limestone, Dalarna, Sweden (Laufeld 1967).

Genus *Eisenackitina* Jansonius, 1964

Eisenackitina cf. *oelandica* (Eisenack, 1955)
Fig. 15 K–M

DESCRIPTION – *Eisenackitina* species with a short, subconical to discoidal body that tapers into a short cylindrical neck. The neck widens at the straight aperture. The base is flat and the basal edge broadly rounded. The vesicle wall is covered by minute, simple spines or spinose thickenings.

DIMENSIONS – Total length 68–91, width 71–117, width of aperture 43–72.

REMARKS – *Eisenackitina* cf. *oelandica* differs from *Eisenackitina oelandica* in having an ornamentation.

OCCURRENCE – Gotland: Upper Kukrusean to Idaverean and Rakverean.

Genus *Eremochitina* Taugourdeau & Jekhowsky, 1960, emend. Laufeld 1967

Eremochitina dalbyensis Laufeld, 1967
Fig. 15 N–Q

1967 *Eremochitina dalbyensis* n.sp. – Laufeld, pp. 335–337; Fig. 29 A–F
1974 *Lagenochitina dalbyensis* – Henry, Nion, Paris & Thadeau, pp. 320–321; Pl. 1:7, 10, 14; Pl. 2:7–8; Pl. 3:7; Pl. 5:3, 6.

DESCRIPTION – *Eremochitina* species with a fusiform body and a neck that widens at the straight aperture. The base has a short and broad mucro. Some specimens have annular thickenings on the base. The basal edge is inconspicuous. The vesicle wall is perfectly smooth and the vesicle is often curved.

DIMENSIONS – Total length 167–270, width 44–63, width of aperture 29–51.

REMARKS – Henry et al. (1974:321) interpreted that the basal part was a pointed arch extension and not a mucro. They also claimed that many specimens lack this kind of extension. All Gotland specimens have this kind of basal process. According to Taugourdeau & Jekhowsky 1960 *Eremochitina* differs from *Lagenochitina* in having a mucro. This is, however, a poor character for the genus *Eremochitina,* since many *Lagenochitina* species may have a mucro (e.g. *Lagenochitina esthonica* and *Lagenochitina tumida*). *Eremochitina dalbyensis* is predictably distinguished from the genus *Lagenochitina* in not having a convex to somewhat flattened base, and in having a much more slender vesicle. Furthermore, *Eremochitina dalbyensis* lack ornamentation. Hence, this species is included in *Eremochitina.*

OCCURRENCE – Gotland: Idaverean and Rakverean.

Upper Dalby Limestone, Dalarna, Sweden (Laufeld 1967). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Henry et al. 1974). Kermeur Formation (Caradoc), Massif Armoricain, France (Henry et al. 1974).

Genus *Fungochitina* Taugourdeau, 1966

Fungochitina fungiformis (Eisenack, 1931)
Fig. 15 R–T

1931 *Conochitina fungiformis* n.sp. – Eisenack, p. 8; Pl. 2:17
1962a *Conochitina fungiformis* subsp. *spinifera* – Eisenack, p. 310; Pl. 14:15
1966 *Fungochitina fungiformis* – Taugourdeau, p. 39

DESCRIPTION – *Fungochitina* species with a subconical body and a cylindrical neck that widens at the straight aperture. The length of the neck is about 2/3 of the total length. The flexure is distinct. The base is convex and the basal edge gently rounded, smooth or provided with minute, spinose thickenings. In an oral direction from the basal edge, the vesicle wall is smooth or covered with spinose thickenings.

DIMENSIONS – Total length 145–168, width 82–94, width of aperture 38–46.

REMARKS – Eisenack (1968b:179) subdivided *Fungochitina fungiformis* into two subspecies, viz. *Fungochitina fungiformis* subsp. *fungiformis* and *Fungochitina fungiformis* subsp. *spinifera*. The former is defined as a smooth form and the latter as a form with minute spines on the basal edge and along the flanks. According to Eisenack the two subspecies occur

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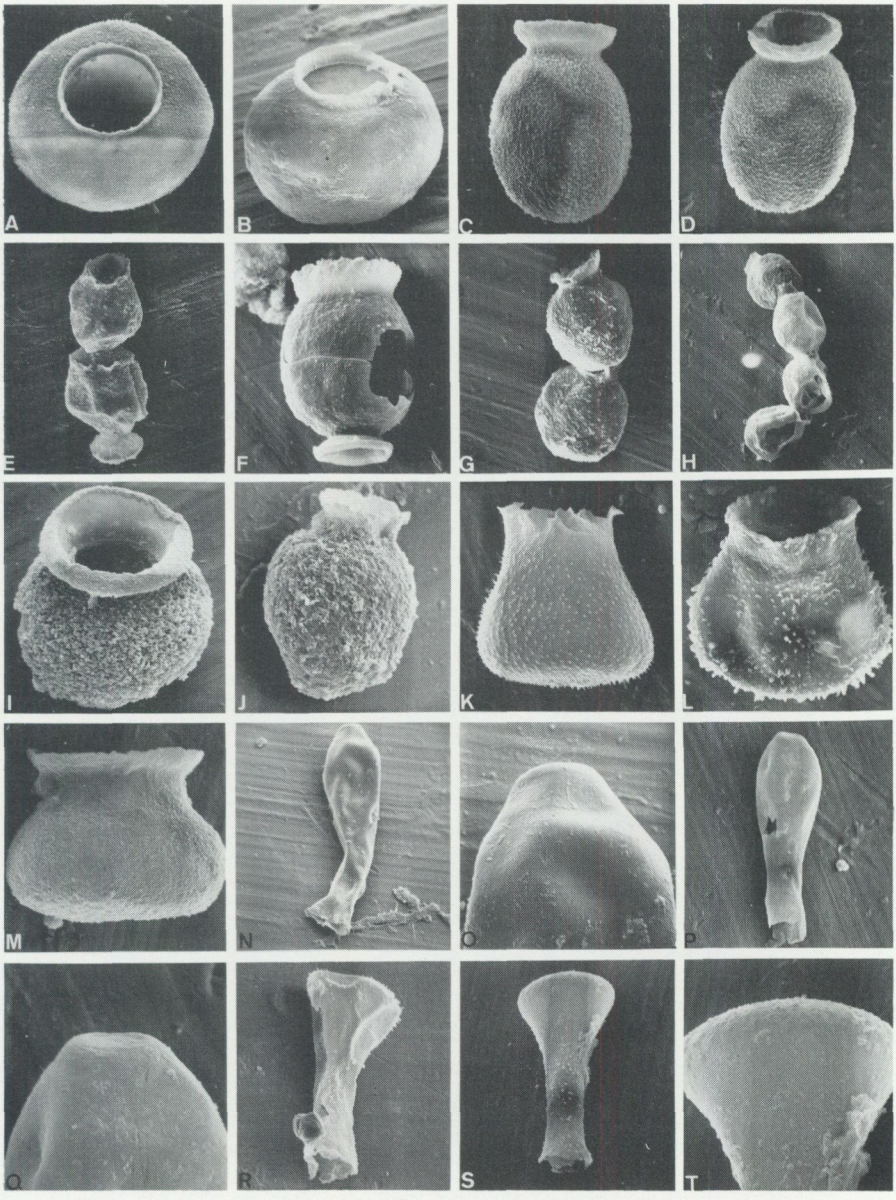
Fig. 15. A–B. *Desmochitina complanata* Eisenack, 1932. A. Gotska Sandöborrningen 1, Rakvere Stage (117.95–118.00 m). B. Gotska Sandöborrningen 1, Idavere Stage (135.55 m). C–D. *Desmochitina minor* Eisenack, 1931. C. Gotska Sandöborrningen 1, Rakvere Stage (123.15 m). D. Gotska Sandöborrningen 1, Rakvere Stage (120.80 m). E–F. *Desmochitina nodosa* Eisenack, 1931. E. Gotska Sandöborrningen 1, Skagen Limestone (127.50–127.55 m). F. Grötlingboborrningen 1, Skagen Limestone (424.90 m). G–H. *Desmochitina* aff. *nodosa* Eisenack, 1931. G–H. Grötlingboborrningen 1, Fjäcka Formation (420.65 m). I–J. *Desmochitina rugosa* Eisenack, 1962. I. Gotska Sandöborrningen 1, Idavere Stage (135.20 m). J. Gotska Sandöborrningen 1, Oandu Stage (125.50 m). K–M. *Eisenackitina* cf. *oelandica* (Eisenack, 1955). K. Grötlingboborrningen 1, Kukruse Stage (436.00 m). L. Grötlingboborrningen 1, Kukruse Stage (435.65 m). M. File Haidarborrningen 1, Kukruse Stage (321.75–321.80 m). N–Q. *Eremochitina dalbyensis* Laufeld, 1967. N–O. Gotska Sandöborrningen 1, Idavere Stage (132.30 m). P–Q. File Haidarborrningen 1, Idavere Stage (319.60–319.65 m). R. Grötlingboborrningen 1, Slandrom Formation (421.85 m). S–T. Gotska Sandöborrningen 1, Rakvere Stage (118.17–118.26 m).

A. SGU Type 1293. Oblique oral view. Note the ornamentation, SEM ×250. B. SGU Type 1294. Oblique lateral view, SEM ×295. C. SGU Type 1344. Lateral view, SEM ×310. D. SGU Type 1302. Oblique lateral view, SEM ×320. E. SGU Type 1331. Chain with two specimens, SEM ×155. F. SGU Type 1345. Lateral view, SEM ×275. G. SGU Type 1278. Chain with two specimens, SEM ×165. H. SGU Type 1279. Chain with four specimens, SEM ×95. I. SGU Type 1332. Oblique oral view, SEM ×315. J. SGU Type 1333. Lateral view, SEM ×250. K. SGU Type 1347. Lateral view. Note the ornamentation, SEM ×360. L. SGU Type 1348. Oblique lateral view, SEM ×345. M. SGU Type 1273. Lateral view, SEM ×345. N–O. SGU Type 1325. N. Lateral view, SEM ×130; O. Aboral part in lateral view. Note the mucro, SEM ×165. P–Q. SGU Type 1280. P. Lateral view, SEM ×165; Q. Aboral part in lateral view. Note the annular thickenings on the base, SEM ×515. R. SGU Type 1339. Lateral view. Note the spinose ornamentation, SEM ×170. S–T. SGU Type 1270. S. Lateral view, SEM ×160; T. Aboral part in lateral view, SEM ×390.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together in the "Wesenberger Stufe", which is approximately equivalent to the Rakvere Stage (Upper Caradoc). The Gotland specimens occur at the same stratigraphical level. In judging from the Gotland populations it is of no use to divide *Fungochitina fungiformis* into further species or subspecies.

OCCURRENCE – Gotland: Rakverean and Slandrom.
Rakverean, Estonia (Eisenack 1962a).

Genus *Lagenochitina* Eisenack, 1931

Lagenochitina baltica Eisenack, 1931
Fig. 16 A–D

1931 *Lagenochitina baltica* n.sp. – Eisenack, pp. 80–81; Pl. 1:1–3
1959 *Lagenochitina baltica* – Eisenack, p. 2; Pl. 3:6–7
1965 *Lagenochitina baltica* – Eisenack, p. 121; Pl. 9:1
1967 *Lagenochitina baltica* – Jenkins, pp. 462–463; Pl. 73:7
1967 *Lagenochitina baltica* – Laufeld, pp. 337–339; Fig. 30 A–E
1968b *Lagenochitina baltica* – Eisenack, p. 156; Pl. 24:8
1976a *Lagenochitina baltica* – Eisenack, Fig. 8 A–B
1977a *Lagenochitina baltica* – Achab, pp. 422–424; Pl. 5:1–2, 5, 7
1979 *Lagenochitina baltica* – Paris, pp. 40–41; Pl. 1:9
1980 *Lagenochitina baltica* – Nõlvak; Pl. 30:5

DESCRIPTION – *Lagenochitina* species with an ovoid body and a cylindrical to subcylindrical neck comprising about 1/3 of the total length. The base is convex. The basal edge and the flanks are broadly rounded. The flexure is distinct. The vesicle wall consists of delicate granules (Fig. 16 D).

DIMENSIONS – Total length 160–346, width 90–172, width of aperture 46–94.

REMARKS – One specimen similar to *Lagenochitina cylindrica* Eisenack 1931 was found in the Nabala Stage (Fig. 16 B). It is probably a deformed specimen of *Lagenochitina baltica.*

OCCURRENCE – Gotland: Rakverean to Pirguan/Jonstorp.

Nabalan to Pirguan, Estonia (Eisenack 1959, 1965; Nõlvak 1980). Mossen Shale (Middle Caradoc), Västergötland, Sweden (Grahn 1981b). Upper Slandrom to Fjäcka Shale, Dalarna, Sweden (Laufeld 1967). Coston to Alternata and *Onnia* Beds (Caradoc), Welsh Borderland (Jenkins 1967). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Paris 1979). Vauréal Formation (Lower Ashgill), Anticosti Island, Canada (Achab 1977a).

Lagenochitina prussica Eisenack, 1931
Fig. 16 E–F

1981b *Lagenochitina* cf. *prussica* – Grahn, p. 24; Fig. 7 E (further references).

DESCRIPTION – *Lagenochitina* species with a subspherical body and a subcylindrical neck that widens conically towards the straight aperture. The flexure is distinct. The vesicle wall has the same ornamentation as *Lagenochitina baltica*, but is comparatively less conspicuous.

DIMENSIONS – Total length 141–270, width 73–143, width of aperture 58–87.

OCCURRENCE – Gotland: Rakverean to Pirguan/Jonstorp.

Molodova Beds (Upper Caradoc–Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Fjäcka Shale, Dalarna, Sweden (Laufeld 1967). Vormsian, Estonia (Nõlvak 1980).

Genus *Rhabdochitina* Eisenack, 1931

Rhabdochitina gracilis Eisenack, 1962
Fig. 16 G–I

1980 *Rhabdochitina gracilis* – Grahn, pp. 35–36; Fig. 20 A–B, D (further references)
1981a *Rhabdochitina gracilis* – Grahn, p. 44; Fig. 15 G–J
1981b *Rhabdochitina gracilis* – Grahn, pp. 24–25; Fig. 7 F–G

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Max. length 960, width 54–85.

OCCURRENCE – Gotland: Upper Kukrusean to Pirguan. Baltic erratics of late Ashgillian age (cf. also Eisenack 1968a).

Upper Langevojan to Lower Valastean (Upper Arenig–Lower Llanvirn) and Seby (Upper Llanvirn) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Hunderumian (uppermost Arenig–lowermost Llanvirn), Dalarna, Sweden (Eisenack 1962a). Aluojan (Lower Llanvirn) to Kukrusean, Estonia (Eisenack 1962a). Gullhögen Formation (Lower Llandeilo); Dalby and Bestorp (Lower Ashgill) Limestones, Västergötland, Sweden (Grahn 1981b). *Dalmanitina* Beds (Upper Ashgill), Skåne, Sweden (Grahn 1978) and Baltic erratics of the same age (Eisenack 1968a). Baltic erratics of undifferentiated late Caradocian age (Grahn 1981a).

Rhabdochitina magna Eisenack, 1931
Fig. 16 J–L

1980 *Rhabdochitina magna* – Grahn, p. 36; Fig. 20 C, E (further references)
1981a *Rhabdochitina magna* – Grahn, pp. 45–46; Fig. 16 A–B

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Max. length 1879, width 86–127.

OCCURRENCE – Gotland: Upper Kukrusean to Idaverean and Rakverean to Pirguan/Jonstorp.

Upper Langevojan (Upper Arenig) to Lower Valastean (Lower Llanvirn) and Upper Aluojan (Lower Llanvirn); Källa (Llandeilo) to Lower Dalby Limestones, Öland, Sweden (Grahn 1980, 1981a). Aluojan (Lower Llanvirn) to Aserian (Upper Llanvirn) and Nabalan to Porkunian (Upper Ashgill), Estonia (Eisenack 1962a, 1965, 1968a, 1968b). Meadowtown Beds (Lower Llandeilo), Welsh Borderland (Jenkins 1967). Vauréal Formation (Lower Ashgill), Anticosti Island, Canada (Achab 1977a, 1978).

Genus *Spinachitina* Schallreuter, 1963, emend. Laufeld 1967

Spinachitina cervicornis (Eisenack, 1931)
Fig. 16 M–N

1931 *Conochitina cervicornis* n.sp. – Eisenack, p. 89; Pl. 2:12–13; Pl. 4:5
1963 *Spinachitina cervicornis* – Schallreuter, pp. 396–397
1967 *Spinachitina cervicornis* – Laufeld, pp. 340–341; Fig. 32 A–F

DESCRIPTION – *Spinachitina* species with a conical to subconical body and a subcylindrical neck that widens towards the fringed aperture. The

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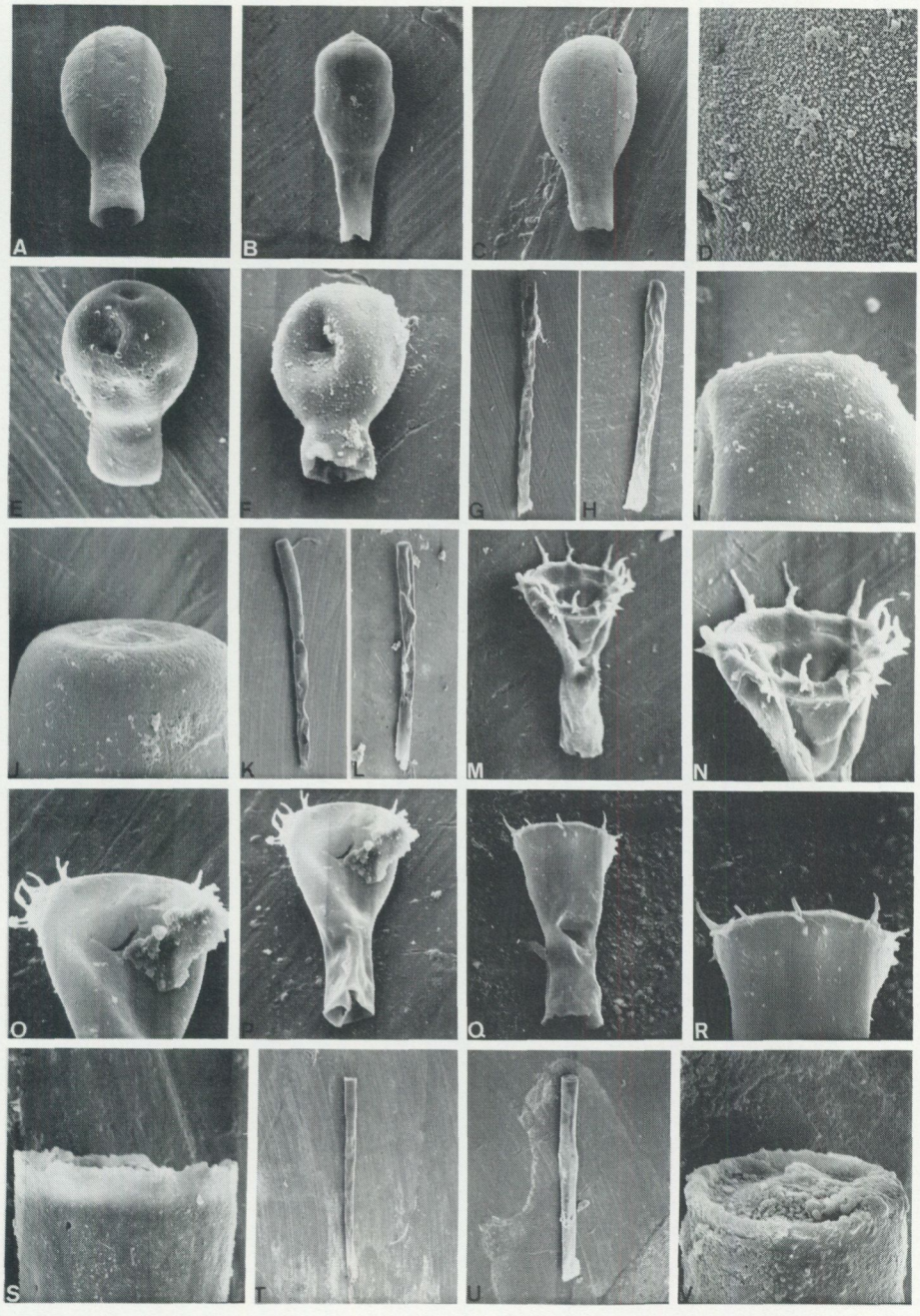
Fig. 16. A–D. *Lagenochitina baltica* Eisenack, 1931. A. Gotska Sandöborrningen 1, Rakvere Stage (119.09–119.14 m). B. Gotska Sandöborrningen 1, Nabala Stage (117.18–117.23 m). C–D. Gotska Sandöborrningen 1, Pirgu Stage (85.17–85.22 m). E–F. *Lagenochitina prussica* Eisenack, 1931. E. Gotska Sandöborrningen 1, Vormsi Stage (96.34–96.40 m). F. Gotska Sandöborrningen 1, Vormsi Stage (93.30–93.35 m). G–I. *Rhabdochitina gracilis* Eisenack, 1962. G. Grötlingboborrningen 1, Slandrom Formation (421.85 m). H–I. Gotska Sandöborrningen 1, Idavere Stage (133.20 m). J–L. *Rhabdochitina magna* Eisenack, 1931. J–K. Gotska Sandöborrningen 1, Vormsi Stage (97.57–97.68 m). L. File Haidarborrningen 1, Pirgu Stage (279.95–280.00 m). M–N. *Spinachitina cervicornis* (Eisenack, 1931). M–N. Grötlingboborrningen 1, *"Macrourus"* (424.35 m). O–R. *Spinachitina multiradiata* (Eisenack, 1959). O–P. File Haidarborrningen 1, Skagen Limestone (313.72–313.75 m). Q–R. Gotska Sandöborrningen 1, Nabala Stage (116.40–116.46 m). S–V. *Tanuchitina bergstroemi* Laufeld, 1967. S–T. Gotska Sandöborrningen 1, Pirgu Stage (82.17–82.24 m). U–V. Gotska Sandöborrningen 1, Pirgu Stage (90.19–90.23 m).

A. SGU Type 1303. Lateral view, SEM ×170. B. SGU Type 1307. Deformed specimen in lateral view, SEM ×85. C–D. SGU Type 1349. C. Lateral view, SEM ×115; D. Detail of C. Note the delicate granules, SEM ×575. E. SGU Type 1350. Oblique lateral view, SEM ×180. F. SGU Type 1351. Lateral view, SEM ×165. G. SGU Type 1327. Lateral view, SEM ×40. H–I. SGU Type 1315. H. Lateral view, SEM ×50; I. Aboral part in lateral view, SEM ×680. J–K. SGU Type 1296. J. Aboral part in lateral view, SEM ×285; K. Lateral view, SEM ×20. L. SGU Type 1274. Lateral view, SEM ×25. M–N. SGU Type 1346. M. Oblique lateral view, SEM ×170; N. Aboral part in oblique lateral view. Note the spinose thickenings on the branches, SEM ×275. O–P. SGU Type 1335. O. Aboral part in lateral view, SEM ×355; P. Lateral view, SEM ×225; Q–R. SGU Type 1321. Q. Lateral view, SEM ×205; R. Aboral part in lateral view, SEM ×350. S–T. SGU Type 1297. S. Aboral part in lateral view, SEM ×185; T. Lateral view, SEM ×25. U–V. SGU Type 1298. U. Lateral view, SEM ×35; V. Aboral part in oblique lateral view, SEM ×455.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length of the neck is about half of the total length. The flexure is distinct. The basal edge is sharp and provided with a row of complex spines. In general the spines branch distally. The branches are provided with spinose thickenings. There is a constriction oralward of the basal edge. The ornamentation decreases in size towards the aperture.

DIMENSIONS – Total length 136–165, width (excl. ornamentation) 75–80, width of aperture 34–45, max. height of ornamentation 25.

OCCURRENCE – Gotland: "*Macrourus*" and Nabalan.
Skagen to "*Macrourus*", Dalarna, Sweden (Laufeld 1967).

Spinachitina multiradiata (Eisenack, 1959)
Fig. 16 O–R

1959 *Ancyrochitina multiradiata* n.sp. – Eisenack, p. 14; Pl. 1:1–2
1962b *Ancyrochitina multiradiata* – Eisenack, p. 357; Pl. 44:17
1967 *Spinachitina multiradiata* – Laufeld, pp. 342–343; Fig. 33 A–D

DESCRIPTION – *Spinachitina* species with a conical body and a subcylindrical neck that widens at the fringed or straight aperture. The basal edge is sharp and provided with a row of simple spines that tapers distally. The length of the neck is about half the total length. The base is slightly convex and the flexure is rounded but distinct. The vesicle wall is smooth oralward of the basal edge.

DIMENSIONS – Total length 123–179, width (excl. ornamentation) 64–97, width of aperture 29–50, max. height of ornamentation 15.

OCCURRENCE – Gotland: Idaverean and Oanduan/"*Macrourus*" to Nabalan.

Skagen Limestone, Dalarna, Sweden (Laufeld 1967). Jõhvian (Middle Caradoc), Estonia (Eisenack 1959, 1962b).

Genus *Tanuchitina* Jansonius, 1964

Tanuchitina bergstroemi Laufeld, 1967
Fig. 16 S–V

1967 *Tanuchitina bergstroemi* n.sp. – Laufeld, pp. 343–345; Fig. 34 A–F
1968b *Tanuchitina bergstroemi* – Eisenack, p. 169; Pl. 29:23–24
1980 *Tanuchitina bergstroemi* – Nõlvak; Pl. 30:2 A–B
1981a *Tanuchitina bergstroemi* – Grahn, p. 46; Fig. 16 C–F

DESCRIPTION – See Grahn 1981a.

DIMENSIONS – Total length 485–1196, width 66–100, width of aperture 25–75, max. width of carina 13.

REMARKS – The Gotland specimens are similar to those described from Öland (Grahn 1981a).

OCCURRENCE – Gotland: Vormsian to Pirguan.

Fjäcka Shale, Dalarna, Sweden (Laufeld 1967). Baltic erratics of undifferentiated late Caradocian age (Grahn 1981a).

CHITINOZOAN BIOSTRATIGRAPHY AND CORRELATION

The stratigraphical ranges of the chitinozoan species are shown in Fig. 17. In this study the Caradocian and Ashgillian Chitinozoa from the subsurface of Gotland are compared with those from the Swedish mainland and Estonia. The age of the erratic boulders at Oil Myr is also discussed.

Published information about Caradocian and Ashgillian Chitinozoa from Estonia is too scanty for detailed comparisons, and equivalent beds in Sweden have only partly been treated from Dalarna (Laufeld 1967), Skåne (Grahn 1978) and Västergötland (Grahn 1981b). However, Caradocian and Ashgillian Chitinozoa from the subsurface of Gotland show a little more similarity to those of Estonia (39 species of 43 in common) than to those of other parts of Sweden (35 species of 43 in common). This is not surprising, since the Gotska Sandön and File Haidar borings are situated in the same North Estonian confacies belt (*sensu* Jaanusson 1976) as north Estonia. The Grötlingbo boring is situated within a transitional belt to the central Baltoscandian confacies belt. Männil (1972) compared early Caradocian chitinozoans from the central Baltoscandian confacies belt (the Livonian Tongue) in Estonia and Latvia with Dalarna in Sweden and found similarities. Except for Skagen and Oanduan/"*Macrourus*" it is possible to correlate Swedish strata with those in Estonia.

IDAVEREAN – The Kukrusean-Idaverean boundary and the stratigraphical use of chitinozoans at this level in the Baltic area has been discussed earlier (Grahn 1981b:29–30). *Angochitina communis, Cyathochitina reticulifera (Cyathochitina* aff. *stentor* in Estonian literature) and *Eremochitina dalbyensis* are three good indicators for Idaverean Beds in Baltoscandia. *Angochitina communis* can easily be confused with *Conochitina hirsuta,* especially since both species are restricted to the Idaverean. *Cyathochitina reticulifera* makes its debut in the Idaverean, except in Dalarna, where it is absent. Isolated occurrences of this species is also known from Rakverean to Vormsian/Fjäcka on Gotland and in Estonia. *Eremochitina dalbyensis* is restricted to the Idaverean with the exception of an isolated occurrence within Upper Rakverean in the Gotska Sandön boring. Furthermore, this species is not reported from Västergötland. Three other species, *Cono-*

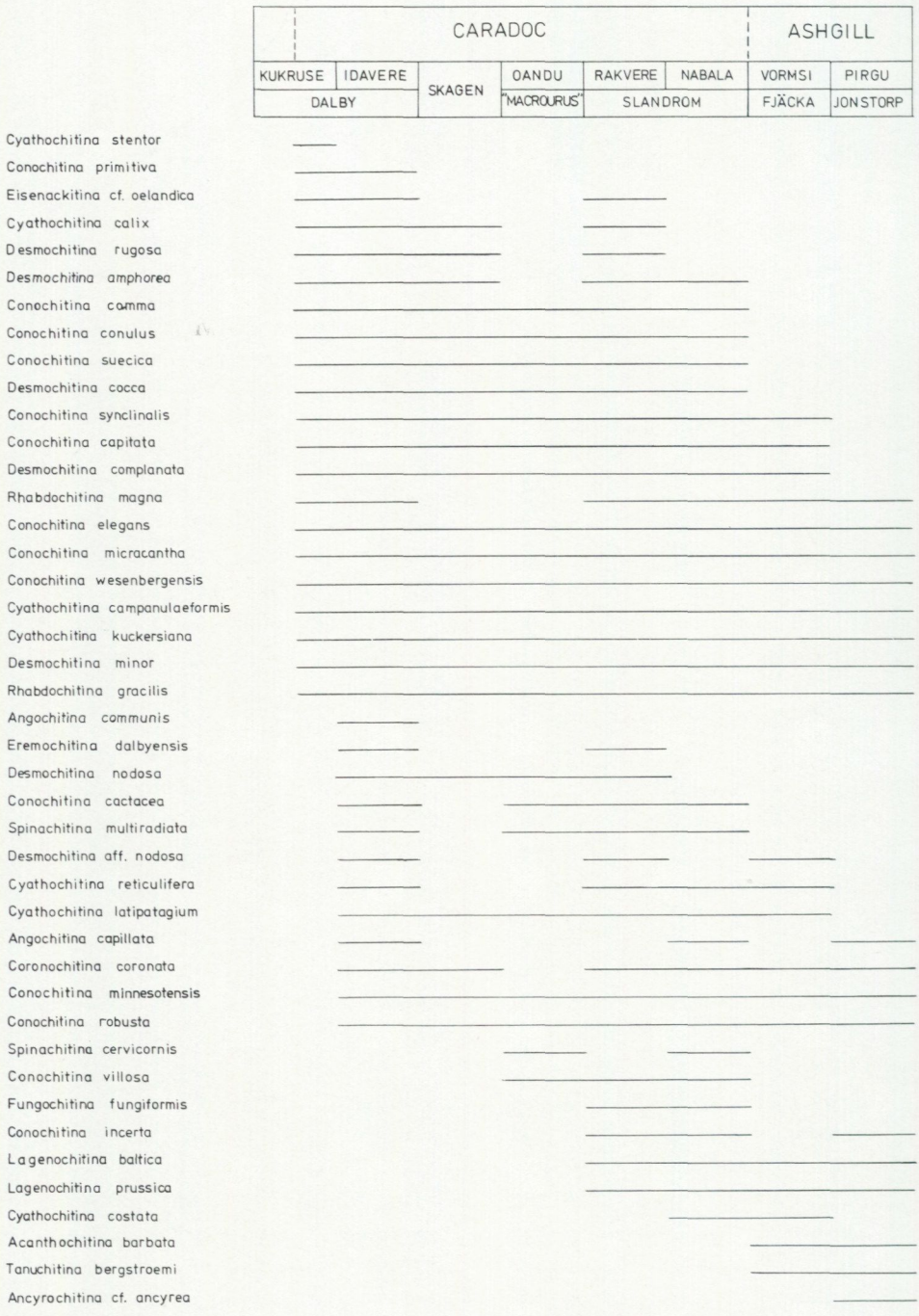

Fig. 17. Occurrence of Caradocian and Ashgillian chitinozoans on Gotland.

chitina robusta, Desmochitina nodosa and *Spinachitina multiradiata* appear for the first time in Baltoscandia within Idaverean.

In general the abundance of Idaverean chitinozoans on Gotland is below 6 specimens per gram of rock, with a maximum of 98.8 specimens in the File Haidar boring and 28.6 specimens in the Grötlingbo boring.

SKAGEN AND OANDUAN/"*MACROURUS*" – No chitinozoans are restricted to or characteristic of these two units on Gotland. However, the first known occurrence of *Conochitina villosa* appears in the Oanduan. It is also worthy of note that this stage is devoid of chitinozoans in the File Haidar boring (cf. Fig. 5).

The abundance of chitinozoans in Skagen and Oanduan/"*Macrourus*" on Gotland in general is below 4 specimens per gram of rock.

RAKVEREAN AND NABALAN/SLANDROM – The last known occurrence of *Cyathochitina calix* in Baltoscandia is in the Rakvere Stage. Within this stage *Fungochitina fungiformis* occurs on Gotland, where it has a restricted range and disappears at the end of Nabalan. *Fungochitina fungiformis* is known already in Keilan (approximately comprising the hiatus between Skagen and Oanduan on Gotland) from Estonia. *Cyathochitina costata (Cyathochitina* cf. *dispar* or *C. dispar* in Estonian literature) is restricted to Lower Nabalan in Estonia (Nõlvak 1980:256), but appears also in the Fjäcka equivalents on Gotland. *Conochitina villosa* has its last known occurrence in Upper Nabalan. As mentioned earlier the Slandrom Formation is recognized in the Grötlingbo boring, where it is possibly synchronous with the Rakvere and Nabala Stages. The Slandrom Formation has a less diverse chitinozoan fauna than the Rakvere and Nabala Stages, and there are no new species above those that occur in equivalent parts in the Gotska Sandön and File Haidar borings. On Gotland the abundance of chitinozoans in the Rakvere and Nabala Stages on Gotland is generally below 5 specimens per gram of rock, whereas at most only 0.9 specimens in the Slandrom Formation.

VORMSIAN/FJÄCKA – Two species of stratigraphical value, *Acanthochitina barbata* and *Tanuchitina bergstroemi,* have their first occurrence within these beds in Sweden and Estonia (Nõlvak 1981, pers. comm.), and they are good indicators for Ashgillian beds as interpreted here. *Acanthochitina barbata* has previously not been reported in younger beds, but on Gotland it is present also in Lower Pirguan. Two other species, *Conochitina capitata* and *Desmochitina complanata* have their last known occurrence in Baltoscandia within Vormsian/Fjäcka.

The abundance of Vormsian/Fjäcka chitinozoans on Gotland in general is below 6 specimens per gram of rock, with a maximum of 19.6 specimens.

PIRGUAN/JONSTORP – In north Estonia the *Lagenochitina* species disappear before the first *Ancyrochitina* specimens occur (Nõlvak 1981, pers. comm.). This is also true in the Gotland area (Fig. 9). In Estonia *Ancyrochitina ancyrea* appears for the first time in Lower Pirguan and *Tanuchitina bergstroemi* disappears somewhat later (Nõlvak 1981, pers. comm.). In the Grötlingbo boring *Ancyrochitina* cf. *ancyrea* occurs somewhat later in the Upper Jonstorp, and *Tanuchitina bergstroemi* is not known from younger beds than approximately middle Pirguan in the Gotland area, which seems to be in agreement with its range in Estonia.

In general the abundance of Pirguan/Jonstorp chitinozoans on Gotland is below 3 specimens per gram of rock, with a maximum of 14.5 specimens in the File Haidar boring and 60.2 specimens in the Grötlingbo boring.

DALMANITINA – The *Dalmanitina* Beds on Gotland are only present in the south. No chitinozoans were recorded from these beds.

ERRATICS OF LATE ASHGILLIAN AGE – Eisenack (1968a) described *Coronochitina (Conochitina) taugourdeaui* in erratic boulders from Oil Myr. In Estonia this species is known from the uppermost Pirgu and probably also Porkuni Stages (Nõlvak 1980:256). The absence of *Coronochitina (Conochitina) taugourdeaui* and the presence of *Ancyrochitina* cf. *ancyrea* in one of the investigated boulders suggests a late (but not latest) Pirguan age. In Estonia the Porkunian Beds generally have a less diverse chitinozoan fauna than that described from the erratic boulders by Eisenack (1968a), and it is possible that most erratic boulders found at Oil Myr are from Upper Pirguan beds.

The abundance of chitinozoans is about 2 specimens per gram of rock.

PALAEOECOLOGY

The Gotska Sandön boring displays the greatest abundance and diversity of chitinozoans of the three cores. For this reason this discussion of the chitinozoophoran (*sensu* Grahn 1981b:30) ecology is concentrated to the Gotska Sandön boring. Before such a discussion, it is useful to reconstruct the environmental conditions in the Gotland area during the Caradoc and Ashgill.

The closest land area at this time was situated in the northeast, probably covering most of Finland (Männil 1966; cf. Jaanusson 1973:17). At the beginning of Caradoc time the Gotland area was covered by skeletal sand bottoms mixed with carbonate mud. These bottom deposits indicate a comparatively high water energy. In late Idaverean and early Skagen times airborne ash particles, probably from volcanic activity in the Caledonides

(cf. Snäll 1977), were deposited on the seabed in the Gotland area. At about the same time a decrease in water energy changed the sedimentation to carbonate mud mixed with skeletal sand.

After a period of non-deposition in the lower part of *Dicranograptus clingani* chronozone (see Fig. 2) silt bottoms appear on Gotska Sandön and in north Gotland, while more argillaceous bottoms were present in south Gotland. The carbonate mud bottoms spread northwards after a period of non-deposition at different occasions in Rakverean time.

From the end of Nabalan to the beginning of Pirguan times the prevailing environmental conditions in south Gotland favoured formation of glauconite in the sediments. On Gotska Sandön and in north Gotland sedimentation changed dramatically in Vormsian time to more argillaceous deposits with a comparatively high content of pyrite. These beds were probably deposited in a restricted environment with a very low water energy (cf. Grahn 1981b:37).

A regression from north towards south probably started in early Pirguan time. Calcareous algae were abundant on the northern carbonate mud bottoms. Further towards the south terrigenous mud bottoms were present. At the end of Pirguan time the sea withdrew from the North Estonian confacies belt in the Gotland area. Sedimentation continued in south Gotland with deposition of calcium carbonate ooids. These ooids are of the Bahamitic type and are probably indicators of a subtropical to tropical shallow-water environment. During the early Hirnantian the Ordovician sea regressed from the Gotland area.

Not all chitinozoophorans show a conspicuous response to changing environmental conditions, but those that do will be discussed here. Different chitinozoan species reach their maximum relative frequencies in different types of rocks.

The volcanic ash falls in the Caradocian and Ashgillian of Gotland had, however, an equivocal effect on the chitinozoophorans. This is in agreement with the results from a similar study across some bentonites in Västergötland (Grahn 1981b:34).

Strata barren of all kinds of organic-walled microfossils occur. This might be explained by the oxidizing conditions in the sediment which prevent their preservation (Grahn 1981b:31).

The Caradoc and Ashgill sea in the Gotland area was never deep, and the differences in depth might have been comparatively small in the area.

It is convenient to subdivide the chitinozoophorans in three ecological categories: (1) Chitinozoophorans with preference for shallow water (calcarenites, calcareous siltstones with calcareous algae (*Cyclocrinus* sp.), calcilutites abundant in calcareous algae (*Palaeoporella variabilis* and others), and calcareous mudstones in the Upper Jonstorp Formation). (2)

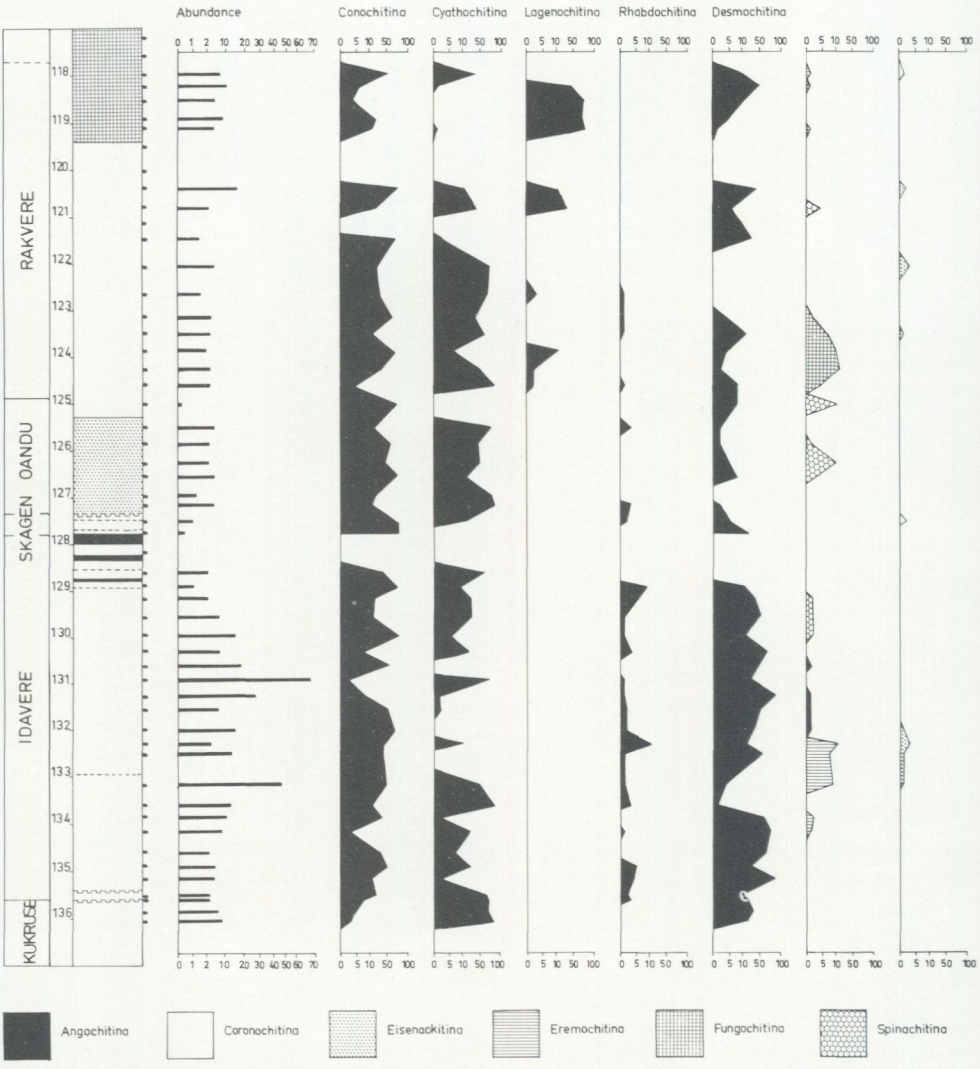

Fig. 18. Gotska Sandöborrningen 1, abundance (chitinozoan specimens per gram of rock) and relative frequencies of specimens within each genus in the Upper Kukrusean to Rakverean part of the core. For lithology, see Fig. 3.

Chitinozoophorans with preference for a restricted and probably reducing environment. (3) Chitinozoophorans with preference for carbonate mud bottoms in general.

CHITINOZOOPHORANS WITH PREFERENCE FOR SHALLOW WATER – Two chitinozoophorans, *Angochitina communis* and *Cyathochitina stentor*, are restricted to skeletal sand bottoms (cf. Fig. 18). Six others reached their maximum frequencies on these bottoms, viz. *Conochitina*

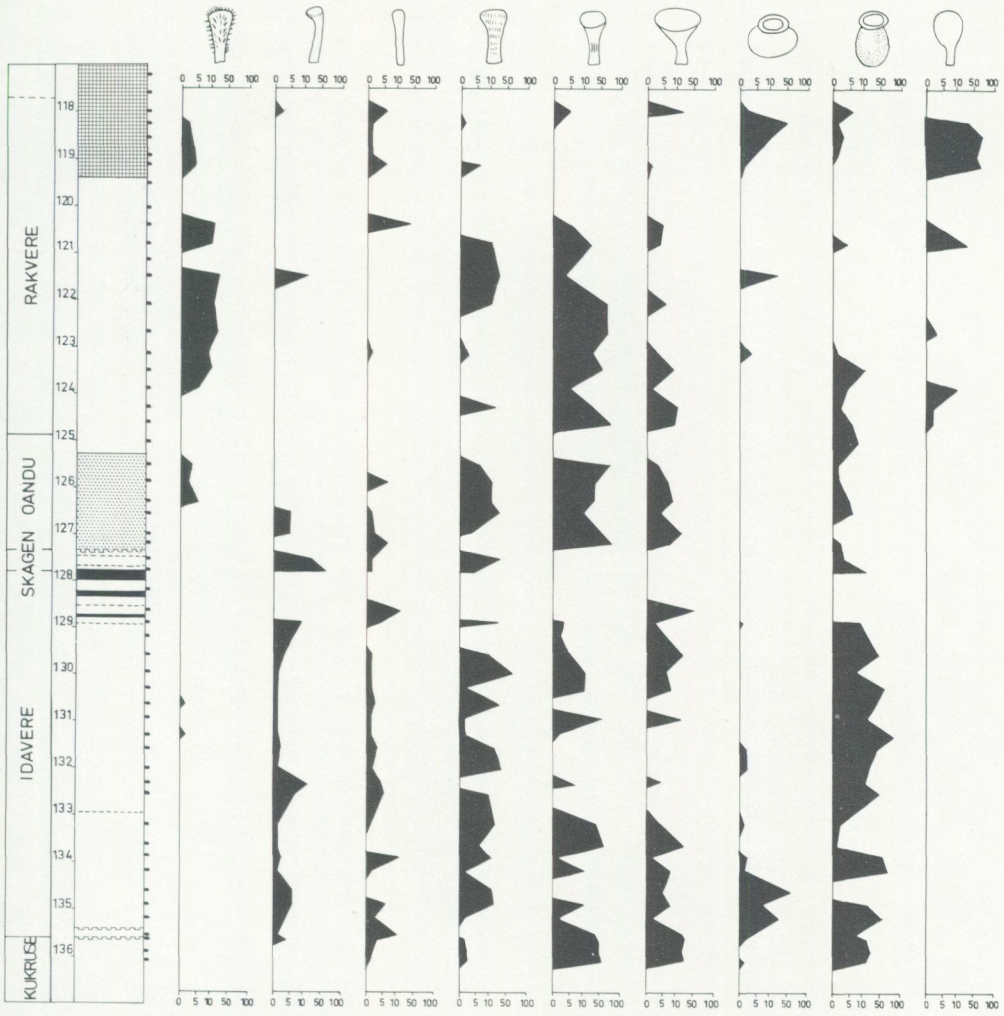

Fig. 19. Gotska Sandöborrningen 1, relative frequencies of specimens within selected species compared to the whole population in the Upper Kukrusean to Rakverean part of the core. From left to right: *Conochitina cactacea, Conochitina capitata, Conochitina elegans, Conochitina micracantha, Cyathochitina campanulaeformis, Cyathochitina kuckersiana, Desmochitina complanata, Desmochitina minor* and *Lagenochitina baltica.* For lithology, see Fig. 3.

primitiva, Desmochitina minor (Fig. 19), *Desmochitina* aff. *nodosa, Desmochitina rugosa, Eisenackitina* cf. *oelandica* (Fig. 18), and *Eremochitina dalbyensis* (Fig. 18). *Desmochitina minor* is the most common of the *Desmochitina* species, and this species contributes heavily to the maximum chitinozoan abundances on skeletal sand bottoms (Fig. 19).

Spinachitina multiradiata has a maximum frequency on silt bottoms during Oanduan time (Fig. 18).

In Pirguan time *Conochitina incerta, Conochitina wesenbergensis, Rhab-*

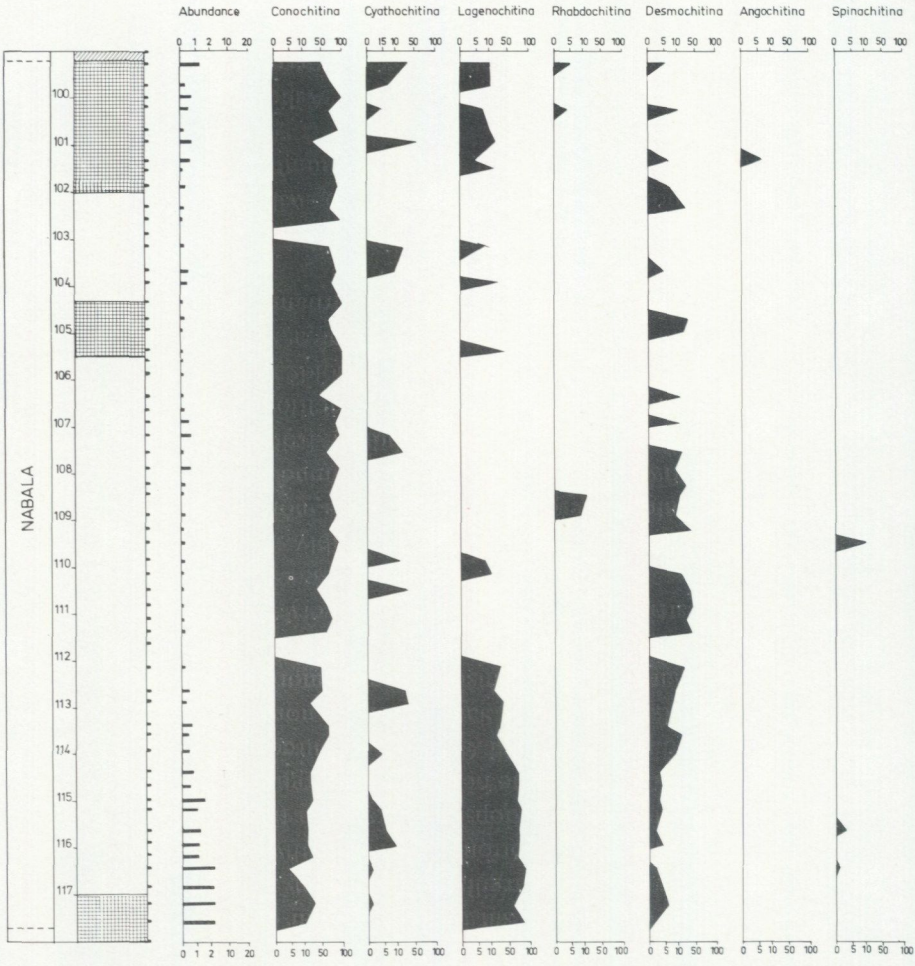

Fig 20. Gotska Sandöborrningen 1, abundance (chitinozoan specimens per gram of rock) and relative frequencies within each genus in the Nabalan part of the core. For lithology, see Fig. 3.

dochitina gracilis, Rhabdochitina magna, and *Tanuchitina bergstroemi* reached their maximum frequencies on carbonate mud bottoms with abundant calcareous algae (Figs. 18, 20, 22). *Conochitina wesenbergensis* dominates the chitinozoan fauna together with *Tanuchitina bergstroemi* in those peaks of chitinozoan abundance which occur in these bottoms.

Ancyrochitina cf. *ancyrea* occurs in the Upper Jonstorp Formation within a mudstone sequence rich in shelly fossils. This species was probably planktic (cf. Grahn 1978:10–13; 1981b:37), and the specimens were brought to the shore by currents. *Cyathochitina* is the only other genus present in these beds.

Another four chitinozoophorans, viz. *Conochitina micracantha, Cyatho-*

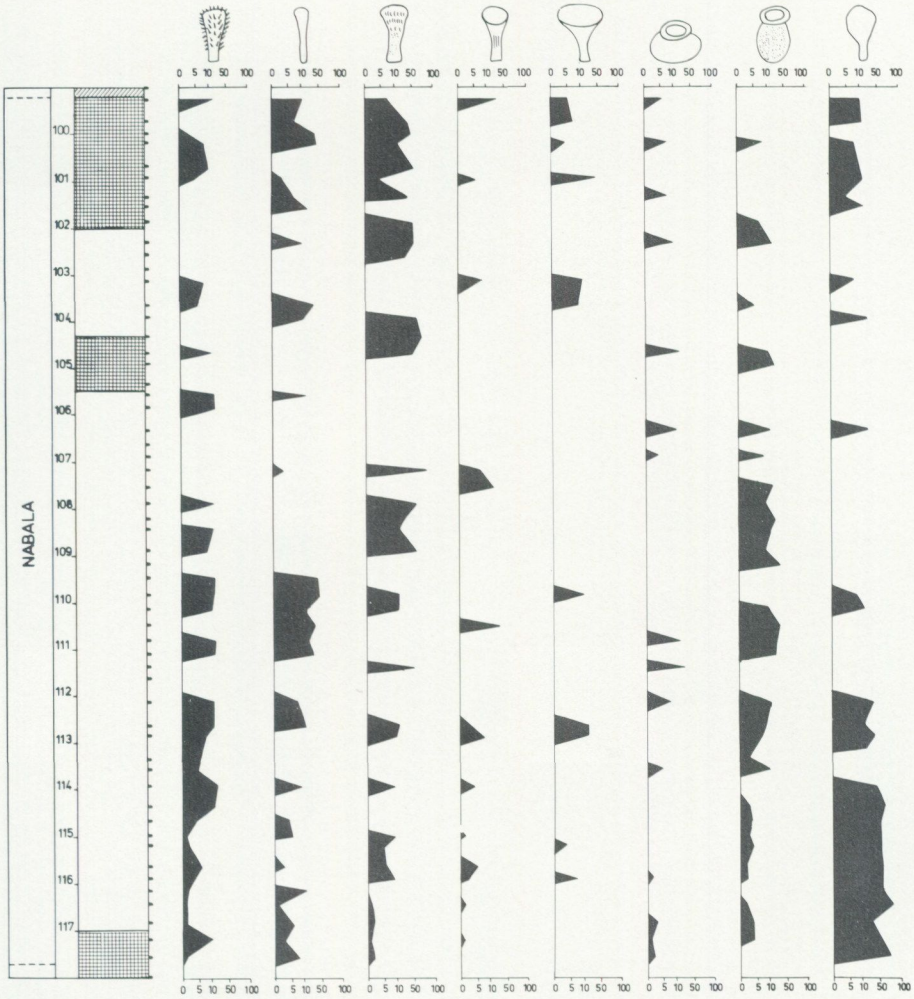

Fig 21. Gotska Sandöborrningen 1, relative frequencies of specimens within selected species compared to the whole population in the Nabalan part of the core. From left to right: *Conochitina cactacea, Conochitina elegans, Conochitina micracantha, Cyathochitina campanulaeformis, Cyathochitina kuckersiana, Desmochitina complanata, Desmochitina minor* and *Lagenochitina baltica.* For lithology, see Fig. 3.

chitina campanulaeformis, Cyathochitina kuckersiana, and *Desmochitina amphorea,* are of interest in this discussion of shallow marine environments although they do not show a pronounced preference for a specific type of bottom.

Conochitina micracantha is common on all types of bottoms (Figs. 19, 21, 23). Sudden increases in the chitinozoan abundance on the skeletal sand bottoms are often related to *Conochitina micracantha* (Fig. 19). This species is common also in the Skagen–Oanduan and Pirguan seas. In Upper Jonstorp *Conochitina micracantha* is the only *Conochitina* species present.

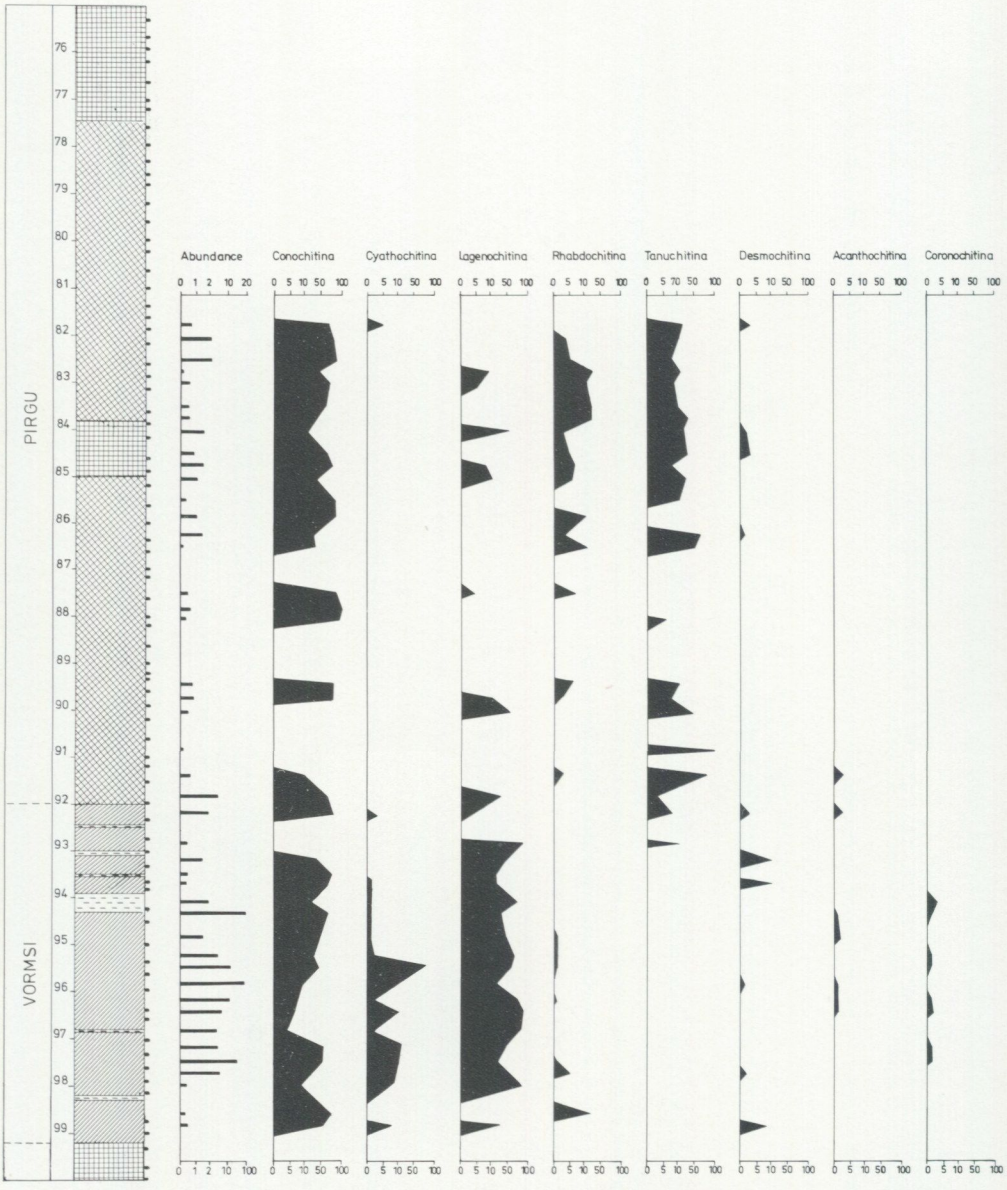

Fig. 22. Gotska Sandöborrningen 1, abundance (chitinozoan specimens per gram of rock) and relative frequencies of specimens within each genus in the Vormsian to Pirguan part of the core. For lithology, see Fig. 3.

Cyathochitina campanulaeformis is common throughout the sequence (Figs. 19, 21). Peaks in chitinozoan abundance on the skeletal sand bottoms, and in the Upper Jonstorp mud bottoms coincide with *Cyathochitina campanulaeformis*. In the latter environment *Cyathochitina campanulaefor-*

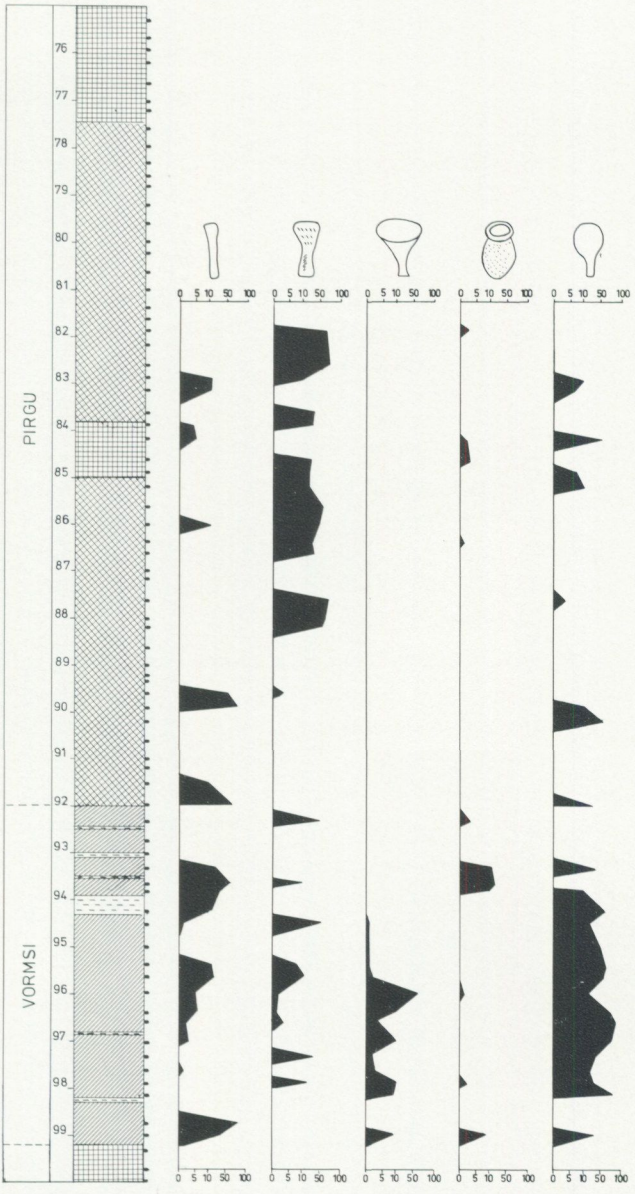

Fig. 23. Gotska Sandöborrningen 1, relative frequencies of specimens within selected species compared to the whole population in the Vormsian to Pirguan part of the core. From left to right: *Conochitina elegans, Conochitina micracantha, Cyathochitina kuckersiana, Desmochitina minor,* and *Lagenochitina baltica.* For lithology, see Fig. 3.

mis dominate together with *Ancyrochitina* cf. *ancyrea.* In Västergötland *Cyathochitina campanulaeformis* and *Conochitina capitata* have a tendency to be mutually exclusive (Grahn 1981b:34) this pattern also occurs in Gotland.

The occurrence of *Cyathochitina kuckersiana* (Figs. 19, 21, 23) is more difficult to explain. This species reached its maximum frequency on skeletal sand and silt bottoms (Fig. 19). These bottom environments have comparatively high water energies. Hence, it is confusing that *Cyathochitina kuckersiana* also has a frequency maximum on the Vormsian mud bottoms (Fig. 23), where water energies were very low. Obviously factors other than the type of bottoms were important for the distribution of *Cyathochitina kuckersiana.*

This interpretation probably also applies to *Desmochitina amphorea* which has maximum frequencies both on skeletal sand bottoms and on carbonate mud bottoms with glauconite.

CHITINOZOOPHORANS WITH PREFERENCE FOR A RESTRICTED AND PROBABLY REDUCING ENVIRONMENT – No chitinozoophorans have a pronounced preference for this environment, but two species, *Conochitina elegans* and *Lagenochitina baltica,* reach their maximum frequencies on these bottoms. In contrast *Conochitina robusta* markedly decreases.

Conochitina elegans and *Lagenochitina baltica* (Figs. 19, 21, 23) reached their maximum frequencies in the restricted environments during Vormsian (Fig. 23). Peaks in chitinozoan abundance in these beds and in the Lower Jonstorp are related to *Lagenochitina baltica.* Since these peaks occur within apparently uniform lithologies, other factors such as temperature and salinity were probably involved (cf. Grahn 1981b:36). Except in the Gotska Sandön area, *Lagenochitina baltica* is absent or very rare in the Upper Jonstorp mudstones and the algae-rich Pirguan calcilutites. This may indicate that this chitinozoophoran did not prefer too shallow waters.

Conochitina robusta is comparatively low in abundance on the Vormsian mud bottoms which have a high content of pyrite, presumedly reducing conditions prevailed within these sediments. One explanation for the low abundance of *Conochitina robusta* may be that comparatively low oxygen levels existed near the bottom which were unfavourable for this benthic chitinozoophoran (cf. Grahn 1978:10–13).

CHITINOZOOPHORANS WITH PREFERENCE FOR CARBONATE MUD BOTTOMS IN GENERAL – In addition to the chitinozoophorans already discussed eleven species are of interest, viz. *Acanthochitina barbata* (Fig. 22), *Conochitina cactacea* (Figs. 19, 21), *Conochitina capitata, Conochitina minnesotensis, Conochitina suecica, Cyathochitina costata, Cyathochitina reticulifera, Desmochitina complanata, Fungochitina fungiformis* (Fig. 18), *Lagenochitina prussica,* and *Spinachitina cervicornis.* All of them are

restricted to or have maximum frequencies on mud bottoms in general. Three of eleven species, viz. *Conochitina capitata, Cyathochitina reticulifera* and *Desmochitina complanata,* show preference for particular bottom types. *Conochitina capitata* has a maximum frequency in calcarenitic calcilutites (Fig. 19) and, as mentioned earlier, it also tends to be mutually exclusive in relation to *Cyathochitina campanulaeformis. Cyathochitina reticulifera* and *Desmochitina complanata* (Figs. 19, 21) reached their maximum frequencies in glauconite environments. Specimens of the other species are scarce, and no conclusions can be drawn about their ecology. *Cyathochitina reticulifera* can be used to demonstrate how a chitinozoophoran may spread geographically with time. This species first occurs on skeletal sand bottoms in the Gotska Sandön area and disappears in a calcilutitic sequence in Rakverean time when no deposition took place in the File Haidar area. Environmental conditions became more favourable for the chitinozoophoran in mid Nabalan time and *Cyathochitina reticulifera* "invaded" the carbonate mud bottoms at File Haidar. It disappeared somewhat later in a glauconitic calcilutite. Within these beds *Cyathochitina reticulifera* occurs in the Fjäcka equivalents at Grötlingbo for the last time in the Gotland area.

This distributional pattern indicates that the chitinozoophoran was benthic and its migration towards the south was favoured by factors other than bottom type. The rate of sedimentation is important for the distribution pattern of chitinozoans, but it was not a determining factor (Grahn 1981b:31).

In summary, the type of sea-bottom seems to have some importance for chitinozoan distribution, but it was certainly not the major factor influencing their distribution. The more general picture, which emerges from this study is that individual chitinozoan species tend to be found in a variety of depositional environments which indicates that the chitinozoans were planktic. However, there is strong evidence that the chitinozoans were propagation bodies of a chitinozoophoran animal (cf. Grahn 1981b:30), it is equally probable that the chitinozoans were planktic, pseudoplanktic, or just movable enough to be more or less easily dispersed by water movements to environments quite different from the biotope of the chitinozoophoran. This interpretation would also explain the patterns obtained in this investigation, particularly if different chitinozoophorans released chitinozoans with varying chances of drifting away. The durations of the egg and larval stages are important in this connection. In addition, factors such as general or unusual current conditions, temperature and salinity must have played an important role in the distribution of the chitinozoans. It should be observed that recent benthic organisms, as well as extinct ones, as a rule do not have the same worldwide distribution as many chitinozoans.

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