SVERIGES GEOLOGISKA UNDERSÖKNING

Serie C NR 787 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 75 NR 8

YNGVE GRAHN

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Address:
Yngve Grahn
Geological Survey of Sweden
Box 670
S-751 28 Uppsala

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ABSTRACT

Grahn, Yngve, 1981-03-21: Ordovician Chitinozoa from the Stora Åsbotorp boring in Västergötland, south-central Sweden. Sveriges geologiska undersökning, Ser. C, No. 787, pp 1–40, Uppsala 1981.

Ordovician Chitinozoa have not been described previously from Västergötland. In the Stora Åsbotorp boring, situated in the northeast part of the Billingen Plateau, 24 species from 6 genera have been recorded from Ordovician strata. The Chitinozoa are compared with those from Öland and Dalarna (Dalecarlia) and show great similarity with the chitinozoans from Öland. *Angochitina communis* is reported from the Baltoscandian area for the first time. Chitinozoan palaeoecology is briefly discussed.

INTRODUCTION

The Cambro-Silurian of Västergötland is classical in Swedish palaeontology since Linnaeus' (1747) description and Linnarsson's work at the end of the 19th Century (i.e. 1866, 1868, 1869, 1871). In three main areas, viz. Halleberg-Hunneberg, Kinnekulle and Billingen-Falbygden, there are terraced plateau hills covered by a cap of dolerite. Originally, the dolerite on Halleberg-Hunneberg consisted of sills within the Arenigan shales or lower levels, and in the two latter areas within the Llandoverian shales. The plateau hills have been preserved because they were downfaulted, and the area in its entirety constantly has had a low relief close to the erosion base. The dolerite cover has prevented a retrogressive erosion (cf. Martinsson 1974:198). The Palaeozoic beds are almost horizontal but local variations with dips of up to 25° occur in Billingen-Falbygden (Munthe 1905).

The purpose of this study is to investigate the occurrence of Ordovician chitinozoans in a suitable sequence in Västergötland and to try to correlate them with those of Öland (cf. Grahn 1980, 1981) and Dalarna (Dalecarlia) (cf. Laufeld 1967). The Ordovician of Västergötland is not exposed in its entirety and therefore it was desirable to choose a well-described core with sampling potential. The Stora Åsbotorp boring (see Fig. 1 and Appendix), situated in the northeast part of Billingen, fulfilled these requirements, although there are several stratigraphical gaps in the sequence (Fig. 2). The Upper Ordovician (Harjuan) part, except for the Hirnantian has been described by Skoglund (1963) and the Middle Ordovician (Viruan) part by Jaanusson (1965).

The Lower Ordovician (Oelandian) sequence is still undescribed. For a general review of the Harjuan and Viruan beds in Billingen reference is made to Jaanusson 1963 and 1965, respectively. The lowermost Ordovician (Tremadoc and Latorp Stage) has been described by Tjernvik (1956). Unfortunately, our knowledge about the Volkhovian (Upper Arenig) and

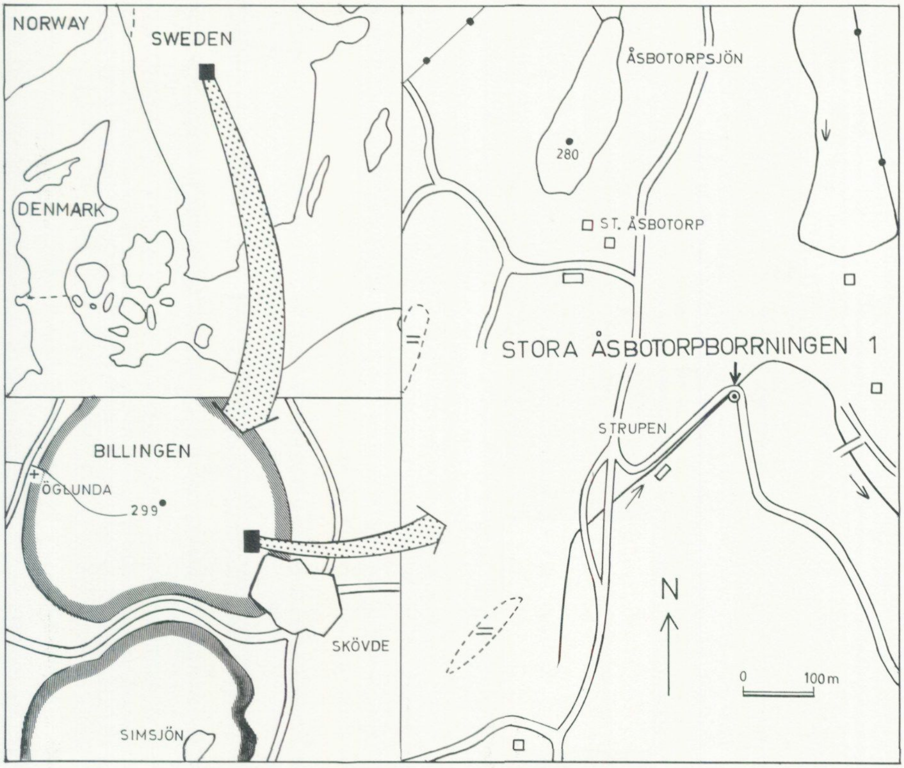


Fig. 1. Map showing the drilling site of the Stora Åsbotorp boring.

Kundan (Uppermost Arenig – Lower Llanvirn) beds is scanty. For this part of the sequence and for the Hirnantian beds reference is made to the descriptions of the geological map sheets by Westergård (1928, 1931).

Information about chitinozoans from Västergötland has not been published earlier.

SAMPLES AND METHODS

In all, 230 samples from the Ordovician of the Stora Åsbotorp boring have been examined. The Ordovician sequence, exclusive of the Hirnantian beds, is 81.01 m thick. In the lowermost Silurian and in the Hirnantian there are core losses, but the Hirnantian can be estimated to be at least 3.43 m. Altogether about 12 000 specimens of Chitinozoa were recovered. Only about a third of the samples yielded chitinozoans, of which 91% were restricted to Viruan strata and the rest to the Harjuan Bestorp Limestone. The laboratory methods used have been described earlier (Grahn 1980).

Formational units in the core	Baltoscandian stages	Graptolite zones	Conodont zones	Baltoscandian series	British series
Dalmanitina	Hirnantian	?	Amorphognathus ordovicicus	Harju	Ashgill
Ulunda	Jerrestadian				
Jonstorp		Dicellograptus complanatus			
Fjäcka	Vasagaardian	Pleurograptus linearis			
Bestorp			Amorphognathus superbus		
					Caradoc
Skagen	Not yet defined	Dicranograptus clingani		Viru	
Dalby		Diplograptus multidens	Amorphognathus tvaerensis		
		Nemagraptus gracilis	Pygodus anserinus		Llandeilo
Ryd	Uhakuan	Glyptograptus teretiusculus			
Gullhögen					
Skövde	Lasnamägian	Didymograptus murchisoni	Pygodus serra		Llanvirn
Vikarby	Aserian		?		
"Gigas"	Kundan	Didymograptus " bifidus"	Amorphognathus variabilis	Oeland	
"Obtusicauda"					
"Raniceps"					
"Expansus"					
" Lepidurus"	Volkhovian	Didymograptus hirundo	Microzarkodina parva	Ontika Subseries	Arenig
"Limbata"			Paroistodus originalis		
		Didymograptus extensus	Baltoniodus navis		
			Baltoniodus triangularis		
Billingian	Latorpian		Prioniodus evae		
			Prioniodus elegans		
		(Tetragraptus approximatus)	Paroistodus proteus		

Fig. 2. Diagram showing correlation of Ordovician rocks in the Stora Åsbotorp boring. Based mainly on Jaanusson (1965, pers. comm. 1981) and Skoglund (1963).

SYSTEMATICS

The taxonomic principles, terminology and methods of measurements and photography have been described earlier (Grahn 1980). The dimensions given in the descriptions are in microns.

Genus *Angochitina* Eisenack, 1931, emend. 1968

Angochitina communis Jenkins, 1967
Fig. 3 A–D

1967 *Angochitina communis* sp. nov. – Jenkins, pp. 450–451; Pl. 69:14–17; Text fig. 7.

DESCRIPTION – *Angochitina* species with a subconical to ovoid body and a cylindrical distinct neck, that can be widened at the fringed aperture. The width of the neck is about half of that of the body, and the length about 1/3 of the total length. The base is convex. The body is covered by long coalescent and simple spines and the neck with short simple spines.

DIMENSIONS – Total length 135–152, width 87–93, width of aperture 37–50, max. height of ornamentation 24.

REMARKS – The Västergötland specimens have a longer neck than the specimens described by Jenkins (1967).

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.
Onnia Beds (Upper Caradoc), Welsh Borderland (Jenkins 1967).

Genus *Conochitina* Eisenack, 1931, restricted 1955

Conochitina capitata Eisenack, 1962
Fig. 3 E–H

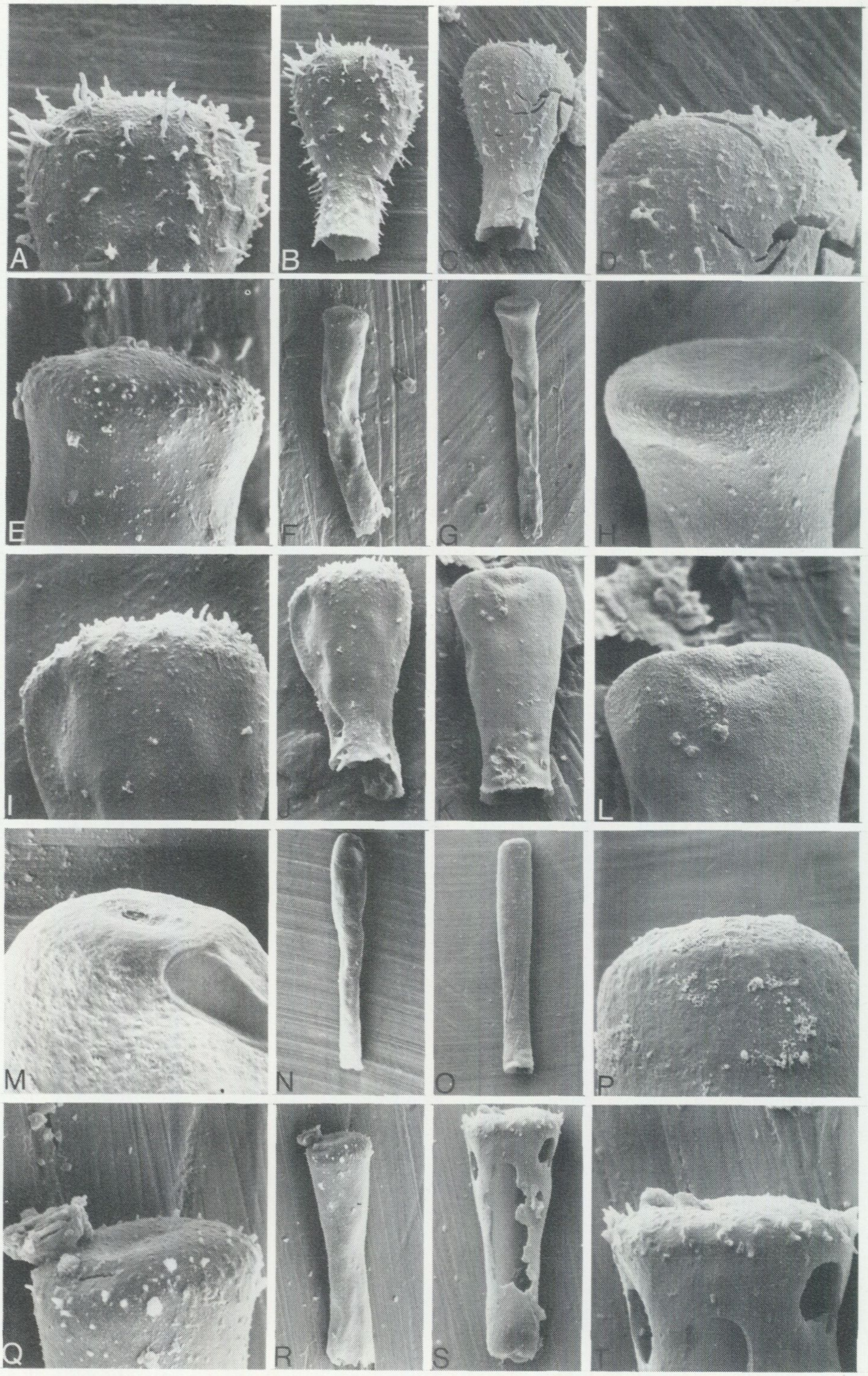
1981 *Conochitina capitata* – Grahn, p. 19; Figs. 8 I–L (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 293–805, width 48–87, width of aperture 29–61.

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

OCCURRENCE – Stora Åsbotorp boring: Lower Gullhögen Formation and Upper Dalby Limestone to Bestorp Limestone.
Aseri to Uhaku (Upper Llanvirn – Llandeilo) through Jõhvi (Middle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Caradoc), Estonia (Eisenack 1962a). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). Dalby to Lower Skagen Limestones (Lower Caradoc), Dalarna, Sweden (Laufeld 1967). Baltic erratics of Lower *Macrourus* Siltstone (Upper Caradoc) and undifferentiated late Caradocian age (Grahn 1981).

Conochitina conulus Eisenack, 1955
Fig. 3 I–L

1981 *Conochitina conulus* – Grahn, p. 21; Fig. 8 A–D (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 102–171, width 48–92, width of aperture 29–47.

REMARKS – Specimens with a smooth vesicle as well as specimens with minute, simple spines occur.

OCCURRENCE – Stora Åsbotorp boring: Middle Gullhögen Formation to Skagen Limestone.

Aseri to Uhaku (Upper Llanvirn – Llandeilo), Estonia (Eisenack 1955). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). *Calymene* Shale (Llanvirn), Normandie, France (Rauscher & Doubinger 1967a, 1967b). Baltic erratics of Lower *Macrourus* Siltstone (Upper Caradoc) (Grahn 1981).

Fig. 3. A–D. *Angochitina communis*. A–B. Upper Dalby Limestone (45.90 m). C–D. Upper Dalby Limestone (44.90 m). E–H. *Conochitina capitata*. E–F. Skagen Limestone (40.50 m). G–H. Gullhögen Formation (69.31 m). I–L. *Conochitina conulus*. I–J. Gullhögen Formation (69.62 m). K–L. Lower Dalby Limestone (51.86 m). M–P. *Conochitina* aff. *elegans*. M–N. Upper Dalby Limestone (43.95 m). O–P. Gullhögen Formation (69.31 m). Q–T. *Conochitina micracantha*. Q–R. Lower Dalby Limestone (51.86 m). S–T. Ryd Limestone (61.72 m).

A–B. SGU Type 795. A. Aboral part in lateral view, SEM x350; B. Lateral view. Note the fringed aperture, SEM x200. C–D. SGU Type 799. C. Lateral view, SEM x170; D. Aboral part in lateral view, SEM x360. E–F. SGU Type 804. E. Aboral part in lateral view. Note the simple spines at the basal edge, SEM x410; F. Lateral view, SEM x80. G–H. SGU Type 805. G. Lateral view, SEM x75; H. Aboral part in lateral view. Note the smooth basal edge, SEM x420. I–J. SGU Type 796. I. Aboral part in lateral view. Note the simple spines on the basal part, SEM x420; J. Lateral view, SEM x200. K–L. SGU Type 809. K. Lateral view. Note the smooth vesicle wall and the fringed aperture, SEM x200; L. Aboral part in lateral view, SEM x440. M–N. SGU Type 813. M. Aboral part in lateral view. Note the concave base, SEM x460; N. Lateral view, SEM x40. O–P. SGU Type 816. O. Lateral view, SEM x40; P. Aboral part in lateral view, SEM x320. Q–R. SGU Type 819. Q. Aboral part in lateral view, SEM x500; R. Lateral view, SEM x160. S–T. SGU Type 820. S. Lateral view, SEM x180; T. Aboral part in lateral view, SEM x460.

Conochitina aff. *elegans* Eisenack, 1931
Fig. 3 M–P

1976b *Conochitina elegans* – Eisenack, p. 188; Pl. 2:6–7.
1980 *Conochitina* aff. *elegans* – Grahn, p. 18; Figs. 10 A–D.
1981 *Conochitina* aff. *elegans* – Grahn, p. 23; Figs. 8 E–H.

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 756–904, width 89–125, width of aperture 67–95.

REMARKS – There is no difference in morphology between the Västergötland specimens and those from Öland (Grahn 1980, 1981). No specimens conspecific with *Conochitina elegans* Eisenack, 1931 have been found.

OCCURRENCE – Stora Åsbotorp boring: Middle Gullhögen Formation and Upper Dalby Limestone.

The Hunderum to Lower Valaste (Uppermost Arenig – Lower Llanvirn) and Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Baltic erratics of undifferentiated Late Caradocian age (Grahn 1981).

Conochitina micracantha Eisenack, 1931
Fig. 3 Q–T

1980 *Conochitina micracantha* – Grahn, pp. 18–20; Figs. 10 E–H (further references).
1980 *Conochitina micracantha* – Nõlvak; Pl. 29:6.
1981 *Conochitina micracantha* – Grahn, p. 23; Figs. 8 I–L.

DESCRIPTION – Total length 168–470, width 48–85, width of aperture 27–50.

REMARKS – Grahn (1980, 1981) remarked that Viruan and younger specimens of *Conochitina micracantha* from different geographical areas have their spinose ornamentation concentrated on the basal part. This is also true of the specimens from Västergötland. A specimen from the Nabala Stage (Upper Caradoc) in Estonia figured by Nõlvak (1980; Pl. 29:6) has a fringed aperture in contrast to the Swedish specimens. Furthermore, it has a vesicle wall covered by simple spines, although concentrated on the basal part. It is difficult to say whether or not this is typical for all *Conochitina micracantha* specimens of this age in Estonia.

OCCURRENCE – Stora Åsbotorp boring: Skövde to Bestorp Limestones.

Upper Langevoja (Eisenack 1976b) to the Hunderum (Uppermost Arenig – Lower Llanvirn) and Upper Aluoja (Lower Llanvirn). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Aseri to Nabala (Upper Llanvirn – Upper Caradoc), Estonia (Eisenack 1959, 1965, 1968b; Nõlvak 1980). 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 (Upper Caradoc) and of undifferentiated late Caradocian age (Grahn 1981).

Conochitina minnesotensis (Stauffer, 1933)
Fig. 4 A–D

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

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Max. length 1450, width 98–140.

OCCURRENCE – Stora Åsbotorp boring: Lower Dalby Limestone to Bestorp Limestone.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Persnäs to Lower Dalby Limestones (Llandeilo), Öland, Sweden (Grahn 1980, 1981). Volkhov to Porkuni (Upper Arenig – Upper Ashgill), Estonia (Eisenack 1962b, 1965; Nõlvak 1980). Decorah Formation (Lower Caradoc), Minnesota, U.S.A. (Stauffer 1933). Upper Dalby and Skagen Limestones (Lower Caradoc), 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 (Upper Caradoc) (Grahn 1981).

Conochitina pellifera Eisenack, 1959
Fig. 4 E–H

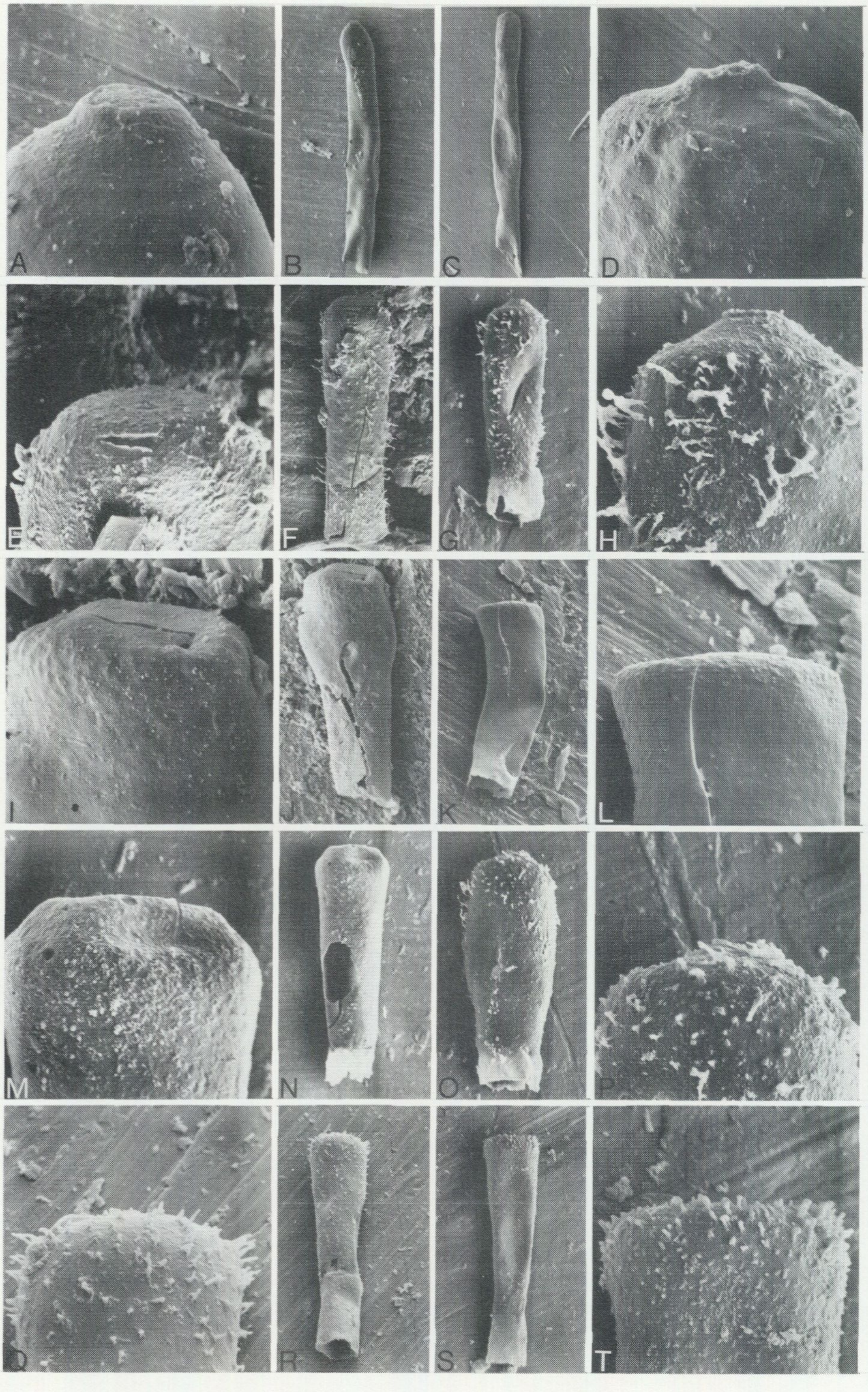
1981 *Conochitina pellifera* – Grahn, p. 25; Figs. 9 B–E (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 252–321, width 76–89, width of aperture 48–86.

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

Aseri to Uhaku (Upper Llanvirn – Llandeilo), Estonia (Eisenack 1959, 1976a). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981).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Conochitina primitiva Eisenack, 1939
Fig. 4 I–L

1980 *Conochitina primitiva* – Grahn, pp. 22–23; Figs. 12 E–H (further references).
1980 *Conochitina primitiva* – Paris, p. 184; Pl. 15:6.
1981 *Conochitina primitiva* – Grahn, p. 26; Figs. 9 F–H.

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 110–200, width 56–98, width of aperture 29–48.

REMARKS – The Viruan specimens of *Conochitina primitiva* show the same variation as those of similar age on Öland (Grahn 1981).

OCCURRENCE – Stora Åsbotorp boring: Gullhögen Formation to Upper Dalby Limestone.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Upper Aluoja (Lower Llanvirn). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Volkhov to Jõhvi (Upper Arenig – Upper Caradoc), Estonia (Eisenack 1934, 1962a). The Hunderum (Uppermost Arenig – Lower Llanvirn), Dalarna, Sweden (Eisenack 1962a). Kunda (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. 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).

Fig. 4. A–D. *Conochitina minnesotensis*. A–B. Upper Dalby Limestone (47.01 m). C–D. Bestorp Limestone (38.42 m). E–H. *Conochitina pellifera*. E–H. Upper Dalby Limestone (44.90 m). I–L. *Conochitina primitiva*. I–J. Upper Dalby Limestone (46.48 m). K–L. Lower Dalby Limestone (49.02 m). M–P. *Conochitina robusta*. M–N. Upper Dalby Limestone (45.90 m). O–P. Upper Dalby Limestone (44.90 m). Q–T. *Conochitina wesenbergensis*. Q–R. Upper Dalby Limestone (44.90 m). S–T. Upper Dalby Limestone (47.01 m).

A–B. SGU Type 828. A. Aboral part in lateral view, SEM x370; B. Incomplete specimen in lateral view, SEM x40. C–D. SGU Type 821. C. Incomplete specimen in lateral view, SEM x25; D. Aboral part in lateral view, SEM x300. E–F. SGU Type 810. E. Aboral part in lateral view, SEM x380; F. Lateral view, SEM x110. G–H. SGU Type 833. G. Lateral view. Note the tapering basal process, SEM x100; H. Aboral part in lateral view, SEM x360. I–J. SGU Type 800. I. Aboral part in lateral view, SEM x460; J. Lateral view, SEM x170. K–L. SGU Type 840. K. Lateral view, SEM x140; L. Aboral part in lateral view, SEM x430. M–N. SGU Type 834. M. Aboral part in lateral view, SEM x390; N. Lateral view. Note the smooth vesicle, SEM x110. O–P. SGU Type 797. O. Lateral view, SEM x130; P. Aboral part in lateral view, SEM x370. Q–R. SGU Type 829. Q. Aboral part in lateral view, SEM x430; R. Lateral view. Note the fringed aperture, SEM x120. S–T. SGU Type 801. S. Lateral view, SEM x110; T. Aboral part in lateral view, SEM x470.

Conochitina robusta Eisenack, 1959
Fig. 4 M–P

1981 *Conochitina robusta* – Grahn, p. 26; Figs. 10 A–B (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 218–318, width 80–100, width of aperture 55–65.

REMARKS – The Västergötland specimens have their ornamentation concentrated on the basal part of the vesicle, but specimens with a smooth vesicle occur.

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

Upper Dalby to Slandrom Limestones (Caradoc), Dalarna, Sweden (Laufeld 1967). Jõhvi and Oandu to Pirgu (Middle Caradoc – Lower Ashgill), 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 (Upper Ashgill) to the Zone of *Monograptus convolutus* (Middle Llandovery), Skåne, Sweden (Grahn 1978, unpub. mat.). Baltic erratics of Lower *Macrourus* Siltstone (Upper Caradoc) and of undifferentiated late Caradocian age (Grahn 1981).

Conochitina wesenbergensis Eisenack, 1959
Fig. 4 Q–T

1981 *Conochitina wesenbergensis* – Grahn, p. 29; Fig. 10 G–L (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – The few specimens encountered have the same dimensions as those described by Grahn (1981).

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). Rakvere to Pirgu (Upper Caradoc – Lower Ashgill), 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 (Upper Caradoc) (Grahn 1981).

Genus *Cyathochitina* Eisenack, 1955

Cyathochitina calix (Eisenack, 1931)
Fig. 5 A–D

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

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 218–420, width 70–212, width of aperture 39–66.

OCCURRENCE – Stora Åsbotorp boring: Gullhögen Formation to Upper Dalby Limestone.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Upper Aluoja (Lower Llanvirn). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Volkhov to Aseri (Upper Arenig – Upper Llanvirn), Estonia (Eisenack 1958, 1962a, 1968b). The Hunderum (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. 5 E–H

1980 *Cyathochitina* cf. *campanulaeformis* – Grahn, pp. 25–27; Figs. 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.
1981 *Cyathochitina campanulaeformis* – Grahn, p. 30; Figs. 11 B–C, E.

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Total length 146–378, width 73–198, width of aperture 37–98.

REMARKS – *Cyathochitina campanulaeformis* is morphologically very variable. Forms transitional to *Cyathochitina calix* (Grahn 1980) and *Cyathochitina kuckersiana* (cf. Figs. 5 G and 5 K) occur. *Cyathochitina campanulaeformis* is distinguished from *Cyathochitina kuckersiana* by the different development of base and carina. Criteria for separating *Cyathochitina campanulaeformis* from *Cyathochitina calix* have been discussed by Grahn (1980:25). As pointed out earlier (Grahn 1981:30), Caradocian and younger Baltoscandian specimens of *Cyathochitina campanuleformis* have longitudinal thickenings at the flexure. This is also


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true of the specimens from Västergötland. Nõlvak (1980; Pl. 29:8) figured a *Cyathochitina campanulaeformis* specimen from the Nabala Stage (Upper Caradoc) in Estonia. In agreement with the specimens from Sweden, this specimen has longitudinal thickenings at the flexure. It is not clear if this structure is typical for specimens of *Cyathochitina campanulaeformis* of this age in Estonia.

OCCURRENCE – Stora Åsbotorp boring: Skövde to Bestorp Limestones.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Kunda to Porkuni (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). Base of *Didymograptus murchisoni* Zone to *Monograptus triangulatus* Subzone (Upper Llanvirn – Middle Llandovery), Sweden (Laufeld 1971). Dalby to Slandrom Limestones (Upper Llandeilo – Caradoc), 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 (Upper Ashgill) 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 (Upper Caradoc) and of undifferentiated late Caradocian age (Grahn 1981).

Fig. 5. A–D. *Cyathochitina calix*. A–B. Lower Dalby Limestone (49.51 m). C–D. Upper Dalby Limestone (45.90 m). E–H. *Cyathochitina campanulaeformis*. E. Skagen Limestone (38.96 m). F. Upper Dalby Limestone (43.95 m). G. Upper Dalby Limestone (44.10 m). H. Gullhögen Formation (68.11 m). I–L. *Cyathochitina kuckersiana*. I. Skagen Limestone (38.96 m). J. Bestorp Limestone (36.90 m). K. Upper Dalby Limestone (46.48 m). L. Upper Dalby Limestone (47.01 m). M-P. *Cyathochitina reticulifera*. M–P. Upper Dalby Limestone (47.01 m).
Q–T. *Cyathochitina sebyensis*. Q–T. Gullhögen Formation (74.53 m).

A–B. SGU Type 830. A. Aboral part in lateral view, SEM x260; B. Lateral view, SEM x100. C–D. SGU Type 837. C. Lateral view, SEM x75; D. Aboral part in lateral view, SEM x210. E. SGU Type 822. Lateral view. Note the longitudinal thickenings at the flexure, SEM x85. F. SGU Type 838. Lateral view, SEM x120. G. SGU Type 798. Lateral view, SEM x170. H. SGU Type 817. Oblique lateral view. Note the smooth vesicle wall at the flexure, SEM x85. I. SGU Type 823. Lateral view, SEM x70. J. SGU Type 824. Lateral view, SEM x90. K. SGU Type 814. Lateral view, SEM x130. L. SGU Type 818. Oblique lateral view, SEM x95. M–N. SGU Type 835. M. Aboral part in lateral view, SEM x300; N. Lateral view, SEM x130. O–P. SGU Type 802. O. Oblique lateral view, SEM x140; P. Aboral part in oblique lateral view, SEM x300; Q–R. SGU Type 826. Q. Aboral part in lateral view, SEM x200; R. Lateral view, SEM x90. S–T. SGU Type 827. S. Lateral view, SEM x75; T. Aboral part in lateral view, SEM x200.

Cyathochitina kuckersiana (Eisenack, 1934)
Fig. 5 I–L

1980 *Cyathochitina kuckersiana* – Nõlvak; Pl. 29:7.
1980 *Cyathochitina kuckersiana* – Wrona; Pl. 25:1 A–C; Pl. 26:4.
1981 *Cyathochitina kuckersiana* – Grahn, p. 32; Figs. 11 F–H. (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 204–510, width (excluding carina) 138–260, width of aperture 37–95, max. width of carina 22.

REMARKS – The Västergötland specimens of *Cyathochitina kuckersiana* show a greater morphological variation than those described from Öland (cf. Grahn 1981).

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby to Bestorp Limestones.

Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). *Calymene* Shale (Llanvirn), Normandie, France (Rauscher & Doubinger 1967a, 1967b). Upper Dalby Limestone (Lower Caradoc), Dalarna, Sweden (Laufeld 1967). Kukruse to Oandu (Upper Llandeilo – Upper Caradoc), Estonia (Eisenack 1962a). Molodova Beds (Upper Caradoc – Lower Ashgill), Podolia, U.S.S.R. (Laufeld 1971). Baltic erratics of Lower *Macrourus* Siltstone (Upper Caradoc) (Grahn 1981).

Cyathochitina reticulifera Grahn, 1981
Fig. 5 M–P

1981 *Cyathochitina reticulifera* n. sp. – Grahn, p. 33; Figs. 12 A–C.

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 182–244, width 98–189, width of aperture 65–85.

REMARKS – The Västergötland specimens have a less pronounced ornamentation than the specimens described originally.

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

Baltic erratics of undifferentiated late Caradocian age (Grahn 1981).

Cyathochitina sebyensis Grahn, 1981
Fig. 5 Q–T

1981 *Cyathochitina sebyensis* n. sp. – Grahn, p. 34; Figs. 12 D–G.

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 240–442, width 98–196, width of aperture 37–75.

OCCURRENCE – Stora Åsbotorp boring: Lowermost Gullhögen Formation.

Seby Limestone (Uppermost Llanvirn), Öland, Sweden (Grahn 1981).

Cyathochitina stentor (Eisenack, 1937)
Fig. 6 A–B, D–E

1981 *Cyathochitina stentor* – Grahn, p. 34; Figs. 12 H–J (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 573–1486, width 122–177, width of aperture 61–108.

OCCURRENCE – Stora Åsbotorp boring: Uppermost Ryd Limestone to Lower Dalby Limestone.

Kukruse (Upper Llandeilo – Lower Caradoc), Estonia (Eisenack 1962a). Dalby Limestone (Upper Llandeilo – Lower Caradoc), Dalarna, (Laufeld 1967) and Öland (Grahn 1981) Sweden.

Cyathochitina striata (Eisenack, 1937)
Fig. 6 C, F–H

1980 *Cyathochitina* aff. *stentor* – Wrona; Pl. 38:4–5.
1981 *Cyathochitina striata* – Grahn, p. 36; Figs. 12 H–J (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 622–1318, width 73–122, width of aperture 44–73.

OCCURRENCE – Stora Åsbotorp boring: Gullhögen Formation to Lower Ryd Limestone.

Seby to Lowermost Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). Aseri to Uhaku (Upper Llanvirn – Llandeilo), Estonia (Eisenack 1968b).

Genus *Desmochitina* Eisenack, 1931

Desmochitina amphorea Eisenack, 1931
Fig. 6 I–K

1981 *Desmochitina amphorea* – Grahn, p. 38; Figs. 13 E–F (further references).

DESCRIPTION – See Grahn 1981.

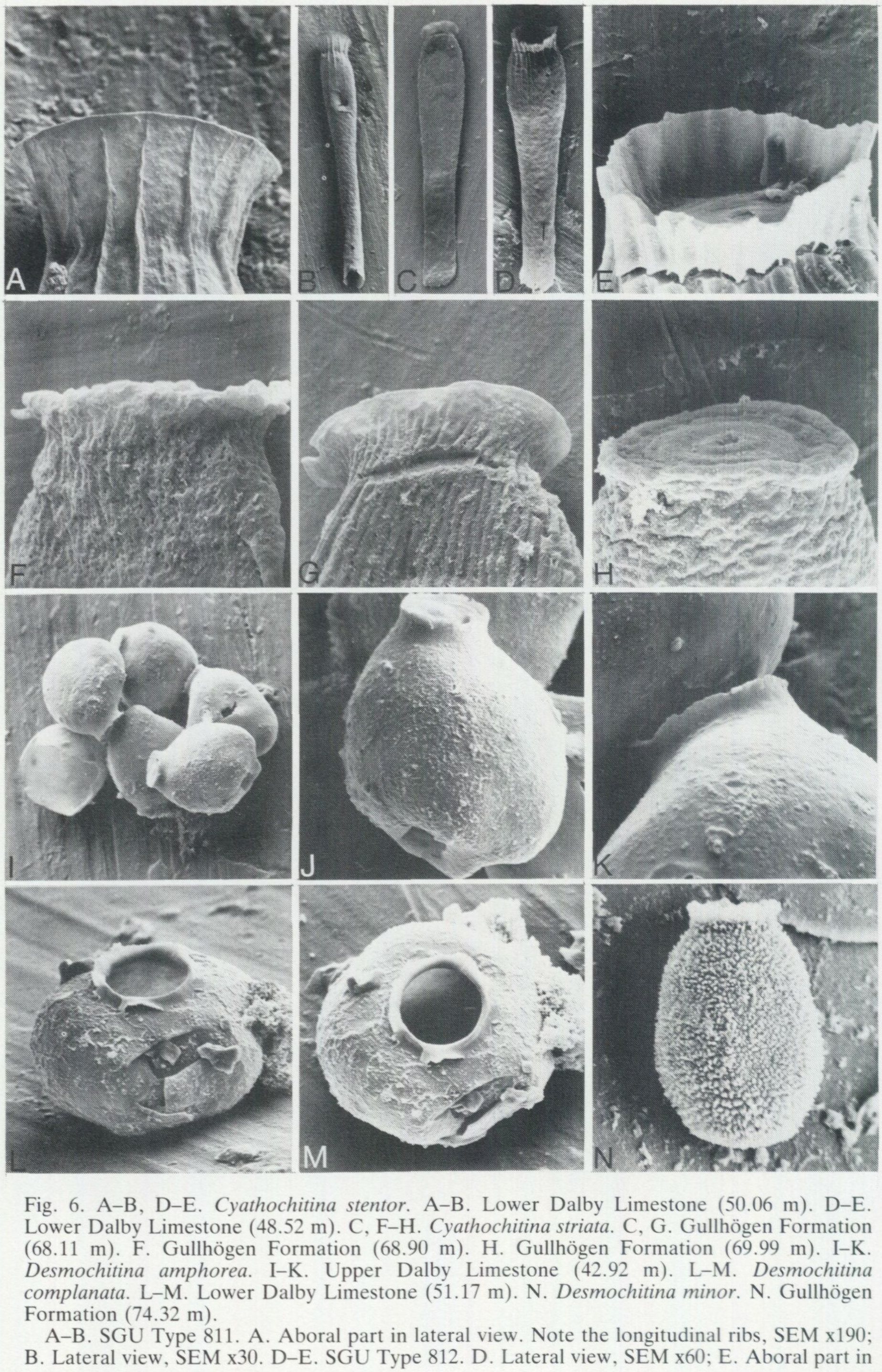

Fig. 6. A–B, D–E. *Cyathochitina stentor*. A–B. Lower Dalby Limestone (50.06 m). D–E. Lower Dalby Limestone (48.52 m). C, F–H. *Cyathochitina striata*. C, G. Gullhögen Formation (68.11 m). F. Gullhögen Formation (68.90 m). H. Gullhögen Formation (69.99 m). I–K. *Desmochitina amphorea*. I–K. Upper Dalby Limestone (42.92 m). L–M. *Desmochitina complanata*. L–M. Lower Dalby Limestone (51.17 m). N. *Desmochitina minor*. N. Gullhögen Formation (74.32 m).

A–B. SGU Type 811. A. Aboral part in lateral view. Note the longitudinal ribs, SEM x190; B. Lateral view, SEM x30. D–E. SGU Type 812. D. Lateral view, SEM x60; E. Aboral part in

DIMENSIONS – Total length 93–129, width 78–99, width of aperture 31–40.

REMARKS – As shown in Fig. 6 I, *Desmochitina amphorea* originally occurred as tightly packed clusters where the vesicles are arranged in a ring but not in aboral-oral contact. This suggests that the vesicles of this species once were enclosed in a cocoon (cf. Jenkins 1970).

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

Aseri to Uhaku (Upper Llanvirn – Llandeilo) and Jõhvi through Oandu (Caradoc), Estonia (Eisenack 1962a, 1965). Folkeslunda to Lower Dalby Limestones (Uppermost Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). Dalby Limestone (Upper Llandeilo – Lower Caradoc), Dalarna, Sweden (Laufeld 1967). Louredo Formation (Caradoc), Serra de Buçaco, Portugal (Henry et al. 1974).

Desmochitina complanata Eisenack, 1932
Fig. 6 L–M

1981 *Desmochitina complanata* – Grahn, p. 38; Figs. 14 A–D (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – The few specimens encountered have the same dimensions as those described by Grahn (1981).

OCCURRENCE – Stora Åsbotorp boring: Lower Dalby Limestone.

Folkeslunda (Uppermost Llanvirn) and Lower Dalby Limestones (Upper Llandeilo), Öland, Sweden (Grahn 1981). Acton Scott Beds (Caradoc), Welsh Borderland (Jenkins 1967). Baltic erratics of undifferentiated late Llanvirnian to Llandeilian age (Eisenack 1959).

Desmochitina minor Eisenack, 1931
Fig. 6 N

1980 *Desmochitina minor* – Grahn, p. 30; Figs. 18 A–D (further references).
1980 *Desmochitina minor* – Nõlvak; Pl. 29:5.
1981 *Desmochitina minor* – Grahn, p. 39; Figs. 14 E–F.

DESCRIPTION – See Grahn 1980.

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lateral view. Note the basal part, SEM x350. C, G. SGU Type 806. C. Lateral view, SEM x50. G. Aboral part in lateral view, SEM x330. F. SGU Type 807. Aboral part in lateral view, SEM x420. H. SGU Type 808. Aboral part in lateral view, SEM x380. I–K. SGU Type 839. I. Clusters of vesicles, SEM x130; J. Lateral view, SEM x310; K. Contact between two specimens, SEM x610. L–M. SGU Type 836. L. Oblique lateral view, SEM x290; M. Oblique oral view, SEM x280. N. SGU Type 841. Lateral view. Note the coalescent spines, SEM x280.

DIMENSIONS – Total length 111–135, width 77–103, width of aperture 42–62.

OCCURRENCE – Stora Åsbotorp boring: Gullhögen Formation to Skagen Limestone.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Upper Aluoja (Lower Llanvirn). Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). Volkhov to Porkuni (Upper Arenig – Upper Ashgill), Estonia (Eisenack 1958, 1962a, 1965, 1968b; Nõlvak 1980). The Hunderum (Uppermost Arenig – Lower Llanvirn) (Eisenack 1962a) and Dalby to Slandrom Limestones (Upper Llandeilo – Upper Caradoc), Dalarna, Sweden (Laufeld 1967). 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 (Upper Caradoc) and undifferentiated late Caradocian age (Grahn 1981).

Desmochitina nodosa Eisenack, 1931
Fig. 7 A–B

1981 *Desmochitina nodosa* – Grahn, p. 39; Fig. 14 G (further references).

DESCRIPTION – See Grahn 1981.

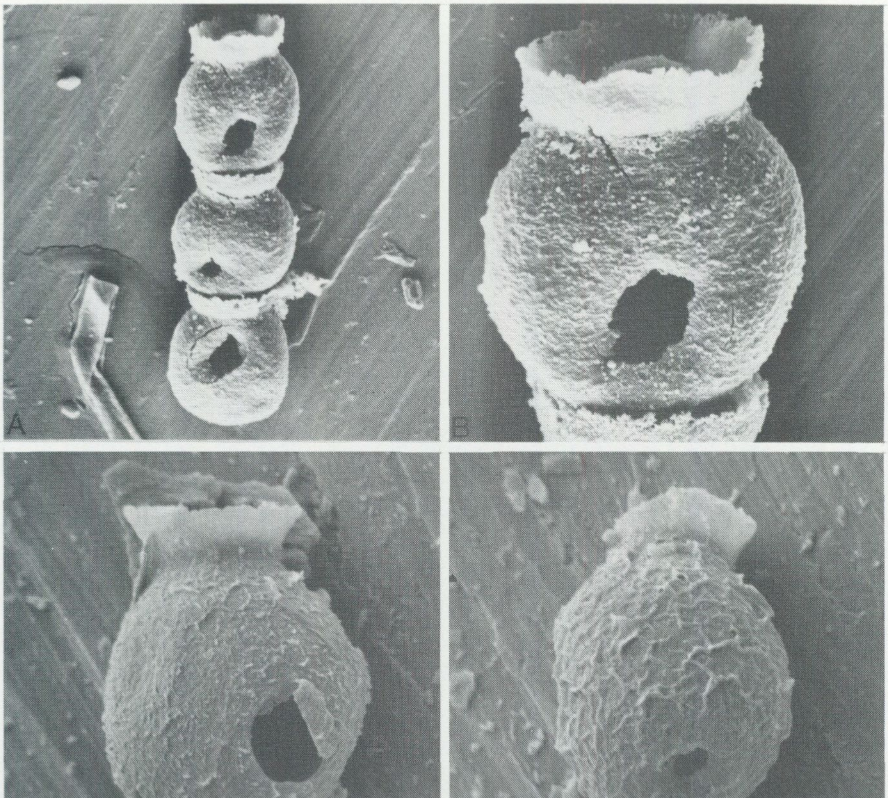
DIMENSIONS – Total length 94–103, width 74–92, width of aperture 55–69.

REMARKS – In the Västergötland populations of *Desmochitina nodosa* forms with a subcylindrical collar occur, as well as those with a conical collar.

OCCURRENCE – Stora Åsbotorp boring: Upper Dalby Limestone.

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

Fig. 7. A–B. *Desmochitina nodosa*. A–B. Upper Dalby Limestone (43.95 m).
C–D. *Desmochitina rugosa*. C. Upper Dalby Limestone (44.90 m). D. Lower Dalby Limestone (48.52 m). E. *Lagenochitina* cf. *prussica*. E. Bestorp Limestone (37.85 m).
F–G. *Rhabdochitina gracilis*. F–G. Upper Dalby Limestone (44.10 m).
A–B. SGU Type 815. A. Chain with three specimens, SEM x200; B. Lateral view, SEM x490. C. SGU Type 831. Lateral view, SEM x400. D. SGU Type 832. Lateral view, SEM x380. E. SGU Type 825. Lateral view, SEM x230. F–G. SGU Type 803. F. Lateral view, SEM x35; G. Aboral part in lateral view, SEM x570.


A
B
C
D
E
F
G

Desmochitina rugosa Eisenack, 1962
Fig. 7 C–D

1980 *Desmochitina rugosa* – Wrona; Pl. 27:2.
1981 *Desmochitina rugosa* – Grahn, p. 41; Figs. 15 A–C. (further references).

DESCRIPTION – See Grahn 1981.

DIMENSIONS – Total length 93–136, width 73–102, width of aperture 37–68.

OCCURRENCE – Stora Åsbotorp boring: Lower Gullhögen formation and Dalby Limestone.

Aseri to Kukruse (Upper Llanvirn – Lower Caradoc), Estonia (Eisenack 1962a, 1968b). Seby to Lower Dalby Limestone (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1981). Upper Dalby Limestone (Lower Caradoc), Dalarna, Sweden (Laufeld 1967). Baltic erratics of Lower *Macrourus* Siltstone (Upper Caradoc) and undifferentiated late Caradocian age (Grahn 1981).

Genus *Lagenochitina* Eisenack, 1931

Lagenochitina cf. *prussica* Eisenack, 1931
Fig. 7 E

1931 *Lagenochitina prussica* n. sp. – Eisenack, p. 81; Pl. 1:4–5.
1965 *Lagenochitina prussica* – Eisenack, pp. 121–122; Pl. 9:2–3.
1967 *Lagenochitina prussica* – Laufeld, p. 339; Figs. 31 A–C.
1968b *Lagenochitina prussica* – Eisenack; Pl. 31:24; Pl. 32:6 A–B.
1971 *Lagenochitina prussica* – Laufeld, p. 294; Pl. 2L.
1980 *Lagenochitina prussica* – Nõlvak: Pl. 29:3.

REMARKS – Only two specimens of *Lagenochitina* cf. *prussica* were found in the present material. They occur at 36.52 m and 37.85 m within the Bestorp Limestone, and they are of the same size as those described from Dalarna by Laufeld (1967:339).

OCCURRENCE – Stora Åsbotorp boring: Bestorp Limestone.

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

Genus *Rhabdochitina* Eisenack, 1931

Rhabdochitina gracilis Eisenack, 1962
Fig. 7 F–G

1980 *Rhabdochitina gracilis* – Grahn, pp. 35–36; Figs. 20 A–B, D (further references).
1981 *Rhabdochitina gracilis* – Grahn, p. 44; Figs. 15 G–J.

DESCRIPTION – See Grahn 1980.

DIMENSIONS – Max. length 1473, width 48–107.

OCCURRENCE – Stora Åsbotorp boring: Gullhögen Formation. Dalby and Bestorp Limestones.

Upper Langevoja to Lower Valaste (Upper Arenig – Lower Llanvirn) and Seby to Lower Dalby Limestones (Upper Llanvirn – Upper Llandeilo), Öland, Sweden (Grahn 1980, 1981). The Hunderum (Uppermost Arenig – Lowermost Llanvirn), Dalarna, Sweden (Eisenack 1962a). Aluoja to Kukruse (Lower Llanvirn – Lower Caradoc), Estonia (Eisenack 1962a). *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 1981).

CHITINOZOAN BIOSTRATIGRAPHY

The occurrence of Ordovician Chitinozoa in the Stora Åsbotorp boring is confined to the Viruan and Early Harjuan. A striking feature is the obvious change in chitinozoan diversity in the middle part of the Dalby Limestone. It is possible that this change in the chitinozoan fauna is a consequence of the environmental change represented by the Kukruse – Idavere boundary. If so, the boundary should be drawn somewhere in the interval between 47.96 m and 48.52 m. According to Männil (1966; Pl. 57) the boundary is marked by a lithological change at the former level.

In the Stora Åsbotorp core the chitinozoans appear in the Skövde Limestone (uppermost Llanvirn) and disappear in the Bestorp Limestone (Lower Ashgill). The stratigraphical ranges of the chitinozoan species are shown in Figs. 8–9.

OELANDIAN

In all, 57 samples from the Oelandian of the Stora Åsbotorp boring have been examined. None of them yielded chitinozoans. However, flattened chitinozoans occur in the Billingen Substage at Stora Stolan, about 13 km north of the boring. They are *Conochitina* cf. *decipiens, Conochitina* cf. *simplex, Lagenochitina* n. sp,. *Rhabdochitina?* cf. *granata,* and *Rhabdochitina* cf. *magna* (Rydberg 1970:16).

VIRUAN

VIKARBY AND SKÖVDE LIMESTONES – There was no recovery of Vikarby and Skövde Limestones in the core. Hence, samples were collected in the Gullhögen quarry, about 2 km south of the boring (Thorslund &

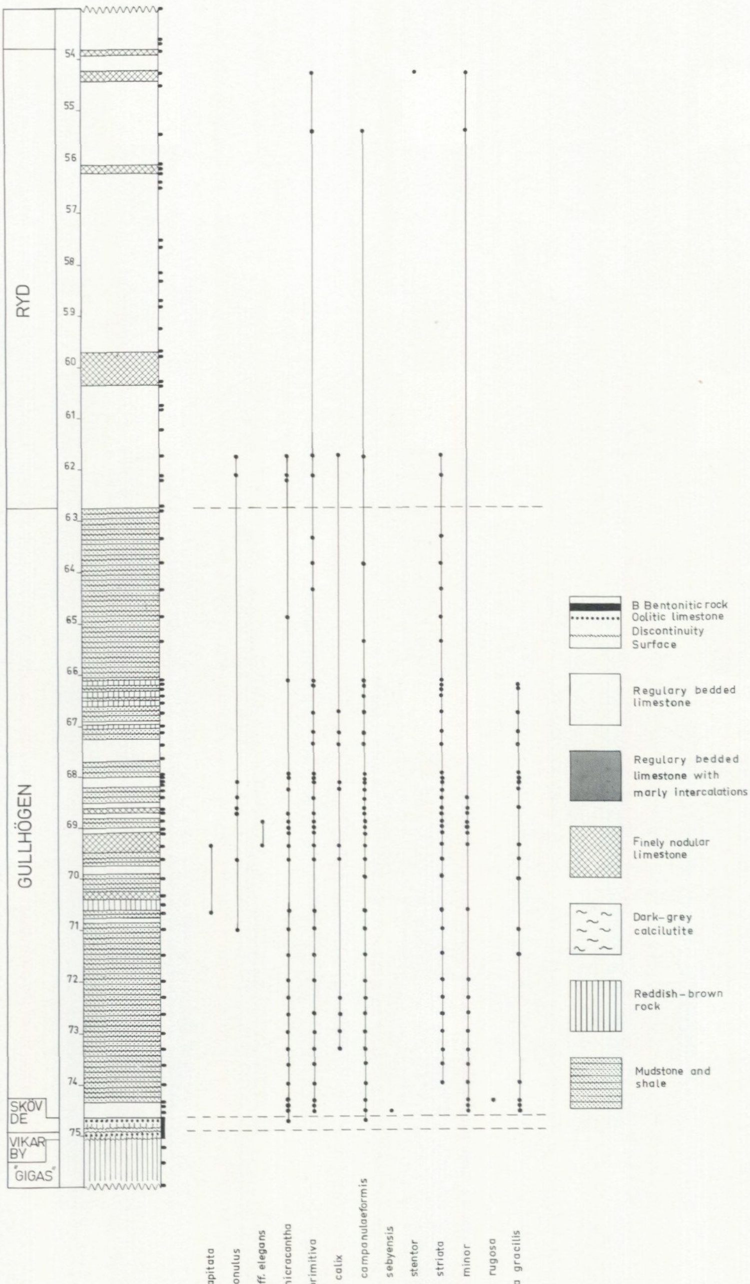


Fig. 8. Stora Åsbotorpborrningen 1, lithology, sample levels and chitinozoan occurrences in the pre-Kukrusean part of the core. Based on Jaanusson (1965).

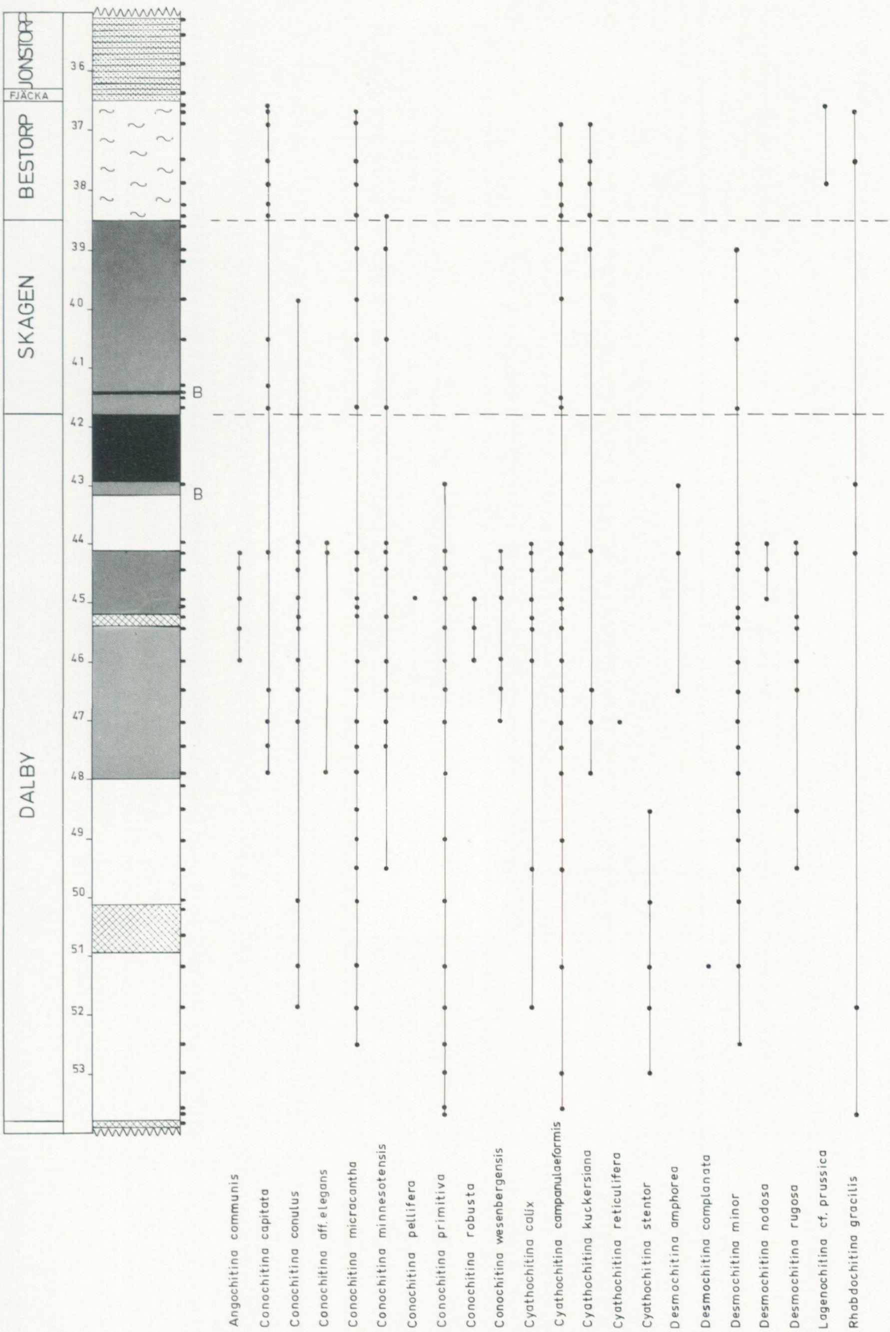


Fig. 9. Stora Åsbotorpborrningen 1, lithology, sample levels and chitinozoan occurrences in the post-Uhakuan part of the core. Based on Jaanusson (1965) and Skoglund (1963). For legend, see Fig. 8.

Jaanusson 1960:17). Only one sample yielded chitinozoans. A grey mudstone within the Skövde Limestone (corresponding to level 74.67–74.74 in the core) yielded *Conochitina micracantha* and *Cyathochitina campanulaeformis*.

GULLHÖGEN FORMATION – Only one species, *Cyathochitina sebyensis*, is restricted to this unit.

RYD LIMESTONE – In the Ryd Limestone only the upper and lower parts yielded chitinozoans. In the lower part *Cyathochitina striata* disappears, and in the upper part *Cyathochitina stentor* makes its debut in the sequence. *Cyathochitina striata* is restricted to the Uhakuan part of the core.

DALBY LIMESTONE – According to the chitinozoan fauna the Dalby Limestone can be divided into two parts. In this paper the lower part is considered as approximately equivalent to the Kukruse Stage, and the upper part to the Idavere Stage. One species, *Desmochitina complanata,* is restricted to the lower part of the Dalby Limestone, and another, *Cyathochitina stentor* disappears at the top of the same part. Seven species, *Angochitina communis, Conochitina pellifera, Conochitina robusta, Conochitina wesenbergensis, Cyathochitina reticulifera, Desmochitina amphorea,* and *Desmochitina nodosa* are restricted to the upper part of the Dalby Limestone. Previously, *Angochitina communis* has been reported from the *Onnia* Beds (Upper Caradoc) in the Welsh Borderland (Jenkins 1967) and its occurrence in Västergötland is the first outside Britain.

SKAGEN LIMESTONE – No chitinozoans are restricted to this unit.

The Skagen Limestone is not developed in its entirety in Västergötland, and in the Stora Åsbotorp boring there is a hiatus in late Caradoc (i.e. the upper part of the Skagen Limestone to the Bestorp Limestone). However, on Kinnekulle and in the Billingen-Falbygden area there is an Upper Caradocian unit, the Mossen Formation, which corresponds to the upper part of the Zone of *Dicranograptus clingani.* A sample from the Kullatorp boring on Kinnekulle (Jaanusson 1965:11) at 63.20 m in the Mossen Shale yielded the following chitinozoans: *Conochitina micracantha, Conochitina robusta, Cyathochitina campanulaeformis,* and *Lagenochitina baltica.*

HARJUAN

BESTORP LIMESTONE – One species, *Lagenochitina* cf. *prussica,* is restricted to this unit.

In all, 52 samples from beds younger than the Bestorp Limestone were examined in the Stora Åsbotorp boring, but none of them yielded chitinozoans. However, chitinozoans from these beds are known from

Västergötland. A sample from the Öglunda Limestone, collected in a ravine at the Öglunda cave about 7.5 km northwest of the boring (Jaanusson 1963:126–127; Westergård 1928:49) yielded the following chitinozoans: *Conochitina micracantha, Desmochitina minor* and *Rhabdochitina gracilis*. The Öglunda Limestone is a dark, dense, mostly finely nodular limestone between the upper and lower parts of the Jonstorp Formation (cf. Fig. 2).

COMPARISON WITH THE CHITINOZOANS FROM ÖLAND AND DALARNA

Ordovician Chitinozoa from Sweden are known in some detail from Öland (Grahn 1980, 1981) and the Caradocian of Dalarna (Laufeld 1967). During most of Ordovician time Öland, Dalarna and Billingen was situated within the same depositional area, the central Baltoscandian confacies belt (sensu Jaanusson 1976) in the epicontinental Baltoscandian sea. This is also reflected in the chitinozoan fauna that shows a great similarity in different parts of this depositional area. Comparable strata in the Stora Åsbotorp boring have 22 of 23 species in common with Öland and 11 of 22 with Dalarna. However, with the exceptions mentioned below there is a dissimilarity in the ranges of many species between the different geographical areas. This might depend on small differences in the environmental conditions within various parts of the area. The best fit of chitinozoan ranges is in the Upper Llandeilian to Lower Ashgillian (i.e. Dalby Limestone to Bestorp Limestone and Fjäcka Shale).

The lower part of the Dalby Limestone is characterized by the presence of *Cyathochitina stentor*. In the Stora Åsbotorp boring *Cyathochitina stentor* succeeds the closely related *Cyathochitina striata* above a sequence of strata devoid of chitinozoans. On Öland (Grahn 1981) the ranges of these species show a minor overlap. *Cyathochitina striata* has not been reported from Dalarna. The Dalby Limestone on Öland is exclusively of Kukruse age and *Cyathochitina stentor* ranges through the entire unit. In Dalarna *Cyathochitina stentor* disappears c. 9 m below the top of the Dalby Limestone, and is succeeded by *Cyathochitina kuckersiana* with a minor overlap. In the Stora Åsbotorp boring *Cyathochitina kuckersiana* succeeds *Cyathochitina stentor* without overlap.

Laufeld (1967:293) remarked that the Kukruse – Idavere boundary in Dalarna is situated probably 8–10 m below the top of the Dalby Limestone. According to Jaanusson (1976:317) and Bergström (1971), the Kukruse – Idavere boundary should be drawn 12–12.5 m below the top. The lower part of the Idavere Stage in Estonia (Männil 1971; Nõlvak 1972) is characterized by the presence of *Eremochitina dalbyensis*. This species first appears about

8 m below the top of the Dalby Limestone in Dalarna. Furthermore, because *Cyathochitina stentor* is a characteristic species for the upper parts of the Kukruse Stage in Estonia (Männil 1971:310), and is unknown in post-Kukrusean beds in those parts of Baltoscandia where the Kukruse and Idavere Stages can be separated, the disappearance of *Cyathochitina stentor* might be used for drawing the boundary between the two stages. If so, the Kukruse – Idavere boundary should be drawn about 8.5 m below the top of the Dalby Limestone in Dalarna, which is in agreement with Männil (1972), and in the interval between 47.96 m and 48.52 m in the Stora Åsbotorp boring as I earlier suggested. It may be added that the change in the chitinozoan fauna at the Kukruse – Idavere boundary is less pronounced in Estonia (cf. Nõlvak 1972) than in Sweden.

In Dalarna *Desmochitina amphorea* is restricted to the Dalby Limestone which agrees with its range in the Stora Åsbotorp boring. *Desmochitina rugosa* disappears and *Conochitina robusta* appears in the Idavere Stage both in Dalarna and the Stora Åsbotorp boring. The latter species appears for the first time in Baltoscandia at this level. Another species of stratigraphical significance, *Desmochitina nodosa,* appears for the first time in the Idavere Stage and disappears in the Skagen Limestone (approximately Jõhvi – Lower Keila). In the Stora Åsbotorp boring *Desmochitina nodosa* is restricted to the Idavere Stage, and in Dalarna to the Skagen Limestone. According to Skoglund (1963), the Bestorp Limestone is contemporaneous with the lower part of the Fjäcka Shale. The presence of *Lagenochitina* cf. *prussica* in the former unit in Västergötland and *Lagenochitina prussica* in the latter unit in Dalarna˙ support his correlation.

REMARKS ON PALAEOECOLOGY

"Chitinozoan palaeoecology" is not a very logical concept, considering the fact that the chitinozoans are interpreted as the reproductive parts of yet unidentified invertebrates (Grahn & Afzelius 1980). It is often necessary to refer to these organisms. For briefness, I introduce the term "chitinozoophorans" for these animals, to be used in this vernacular form only, without taxonomic implications.

The first chitinozoans in Västergötland appear in the Billingen Substage which also constitutes the basal part of the Ordovician in the Stora Åsbotorp boring. The barren Ontikan strata in the core may be explained by poor supply of organic material in the sea (cf. Jaanusson 1973:25). On Öland, Ontikan chitinozoans are restricted to glauconitic strata, except for those in the Upper Aluoja (equivalent of the "Gigas" Limestone). The formation of glauconite, as well as pyrite, is favoured by the presence of organic matter in the sediments. The metabolic activities of bacteria on decaying organic matter will reduce ferric compounds to pyrite (Jaanusson 1973:25) or/and glauconite (McRae 1972:416). Reduction to pyrite is common in grey carbonate sediments in Baltoscandia (Jaanusson 1973:25). Very low supply of organic matter is not sufficient for reduction of ferric compounds, except locally (Jaanusson 1973:25). In such diagenetic environments the oxidizing conditions probably prevented preservation of the chitinozoans. This might be one reason for the lack of chitinozoans in reddish-brown limestones. One explanation for low production of organic matter is low production of nutrients in the sea water. Such conditions also have consequences in the food chain and for the chitinozoophorans. It seems possible that this mechanism may explain the absence of chitinozoans in some non-oxidizing or weakly oxidizing diagenetic environments.

Generally calcilutites display greater abundance of chitinozoans than calcarenites. In the present material it cannot be determined whether this is due to a slower rate of sedimentation or reflects optimum life conditions for the chitinozoophorans. A slow rate of sedimentation must play an important role, but studies of Silurian Chitinozoa from Gotland (Laufeld 1974:121) indicate that mud buttoms were the most favourable environment for most chitinozoophorans. The rate of sedimentation does not effect the balance in the abundance between the different species. In the present material, 8 species (i.e. *Angochitina communis, Conochitina pellifera, Conochitina robusta, Conochitina wesenbergensis, Cyathochitina kuckersiana, Cyathochitina reticulifera, Desmochitina amphorea,* and *Lagenochitina* cf. *prussica*) are restricted to calcilutites, 2 species (i.e. *Conochitina capitata* and *Cyathochitina striata*) to muds in general, and 2 species (i.e. *Cyathochitina sebyensis* and *Desmochitina complanata*) to calcarenites. The two latter species have not been reported from other lithologies. Some of the species (e.g., *Conochitina capitata, Desmochitina minor, Desmochitina rugosa* and others) reach their maximum relative frequencies in different types of rocks suggesting preference for certain sediments. The fact that this kind of differentiation is present suggests a benthic mode of life of the respective chitinozoophorans, but their wide geographical distribution and the fact that most of them also occur on other types of bottoms indicate that other factors, difficult to define, were involved.

The relative frequencies of specimens within each genus (Figs. 10–11) also gives a rough idea about the palaeoecology of the species within each genus. The most important species from a palaeoecological point of view have been studied with reference to the relative frequencies of specimens within each species compared to the whole population (Figs. 12–13), and they will be commented on below.

In the Early Uhakuan an influx of terrigenous mud and a decrease in

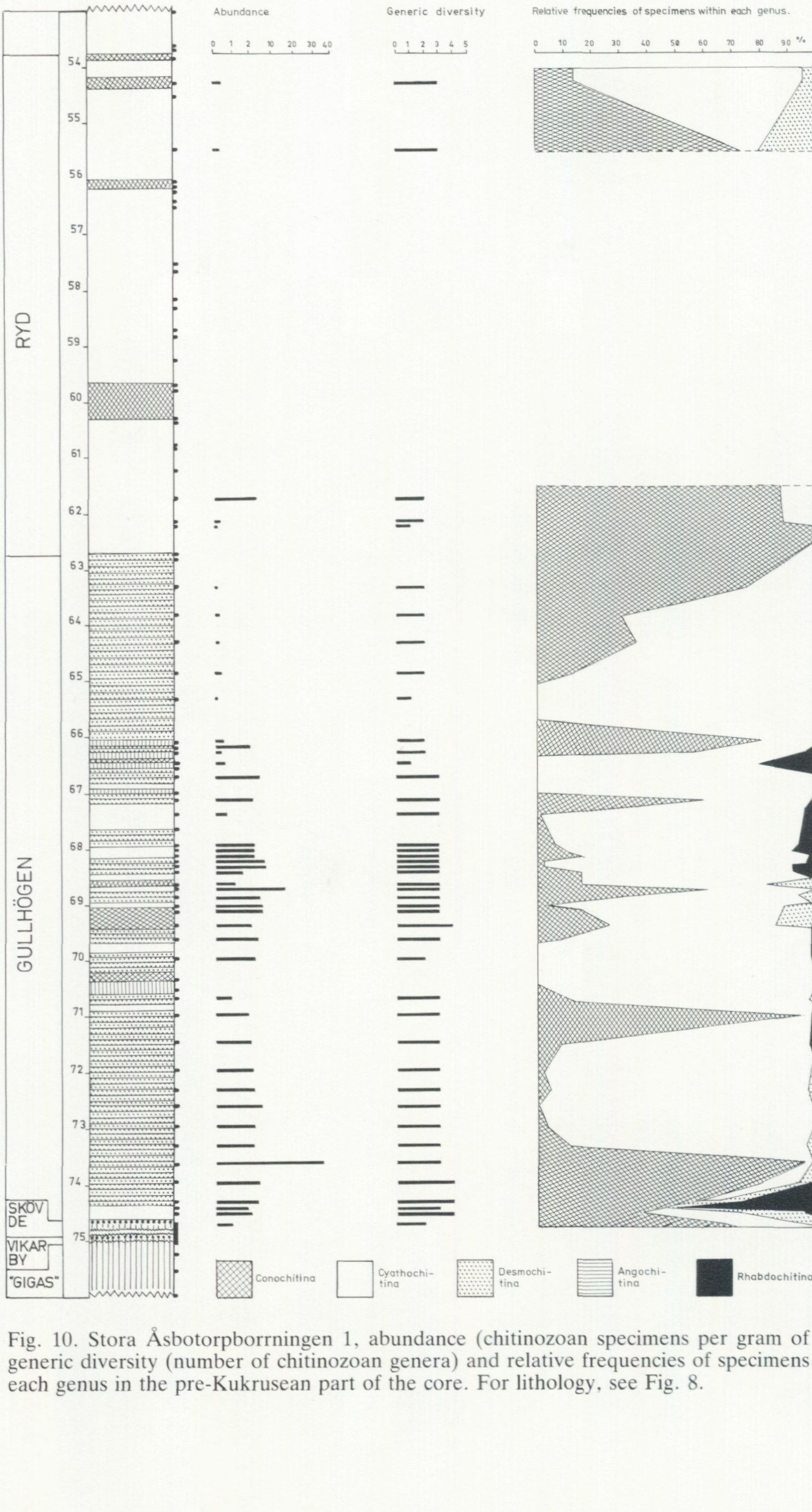


Fig. 10. Stora Åsbotorpborrningen 1, abundance (chitinozoan specimens per gram of rock), generic diversity (number of chitinozoan genera) and relative frequencies of specimens within each genus in the pre-Kukrusean part of the core. For lithology, see Fig. 8.

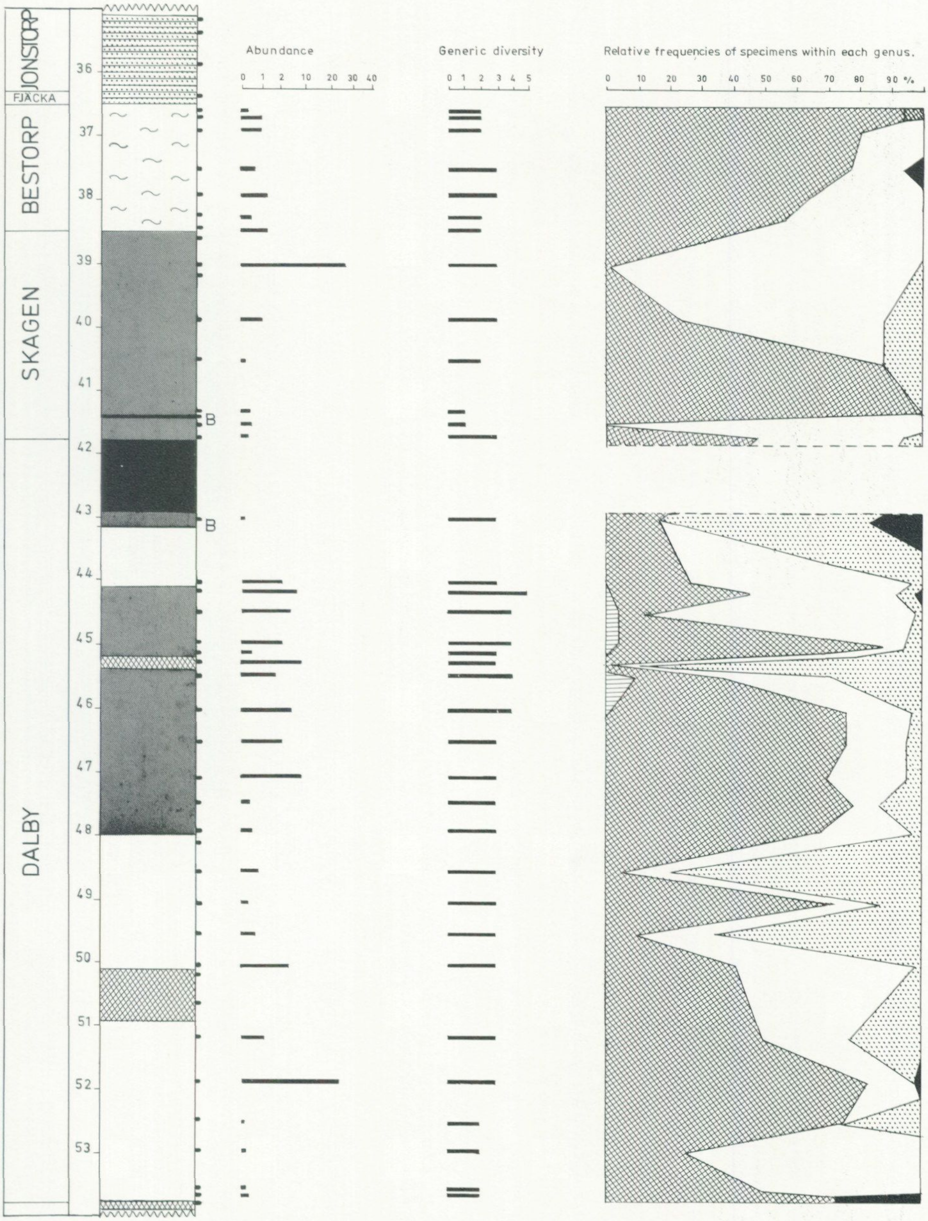


Fig. 11. Stora Åsbotorpborrningen 1, abundance (chitinozoan specimens per gram of rock), generic diversity (number of chitinozoan genera) and relative frequencies of specimens within each genus in the post-Uhakuan part of the core. For legend, see Fig. 10. The two specimens of *Lagenochitina* are not considered. For lithology, see Fig. 8.

water energy changed the sediments from skeletal sands to muds poor in macrofossils. The soft terrigenous mud bottom probably favoured *Cyathochitina campanulaeformis* and *Cyathochitina striata,* because these species dominate the chitinozoan fauna. Abrupt increases in chitinozoan abundance occur at horizons which show influxes of carbonate mud. These peaks of chitinozoan abundance reflect a change in the rate of sedimentation, and they are commonly connected with an increase in the frequency of *Conochitina micracantha* and *Conochitina primitiva* (Fig. 12). These two species dominate the genus *Conochitina* except for intervals in beds of post-Kukrusean age where *Conochitina capitata* occurs (Fig. 13).

The middle part of the Ryd Limestone is devoid of chitinozoans and generally poor in fossils. The absence of chitinozoans can be explained by the brown and reddish-brown lithologies and oxidizing conditions within the sediment. In the late Uhakuan sedimentation changed to grey carbonate muds, a condition that persisted to the middle Kukrusean. Recolonisation started, and one chitinozoan species, *Cyathochitina stentor,* immigrated. An increase of chitinozoan abundance and diversity at the end of the Kukrusean is coupled with a change from carbonate muds to skeletal sands. On the skeletal sand bottoms, with a comparatively high water energy, *Desmochitina* species reach their maximum relative frequency (Fig. 10). *Desmochitina minor* dominates (Fig. 13), but the *Desmochitina* peaks are connected with an increase of *Desmochitina rugosa* specimens (Fig. 13). *Cyathochitina* has its minimum abundance and relative frequency in these intervals. In uppermost Idaverean *Desmochitina amphorea* is the only *Desmochitina* species present (Fig. 13). Just above or at the supposed Idavere – Kukruse boundary the sediments once again changed back to carbonate muds, which led to a remarkable expansion of chitinozoan diversity.

The volcanic ash fall of the lower bentonite bed in the Late Idaverean had a marked effect on the chitinozoophorans. Above the bentonite a dramatic reduction of the chitinozoan abundance and diversity (from 20 to 3 species) takes place. This is not a general rule, however, because above the thick bentonite bed in the uppermost Dalby Limestone the diversity and abundance of chitinozoans is twice as high as below the bentonite, and there is no difference below and above the lower bentonite in the Skagen Limestone in this respect. The change from a chitinozoan fauna completely dominated by *Cyathochitina campanulaeformis* below the latter bentonite to one completely dominated by *Conochitina capitata* above is difficult to explain. These two species also have a tendency to be mutually exclusive in post-Kukrusean beds (Fig. 13). In any case, the volcanic ash favoured *Conochitina capitata* and temporarily exterminated *Cyathochitina campanulaeformis*.

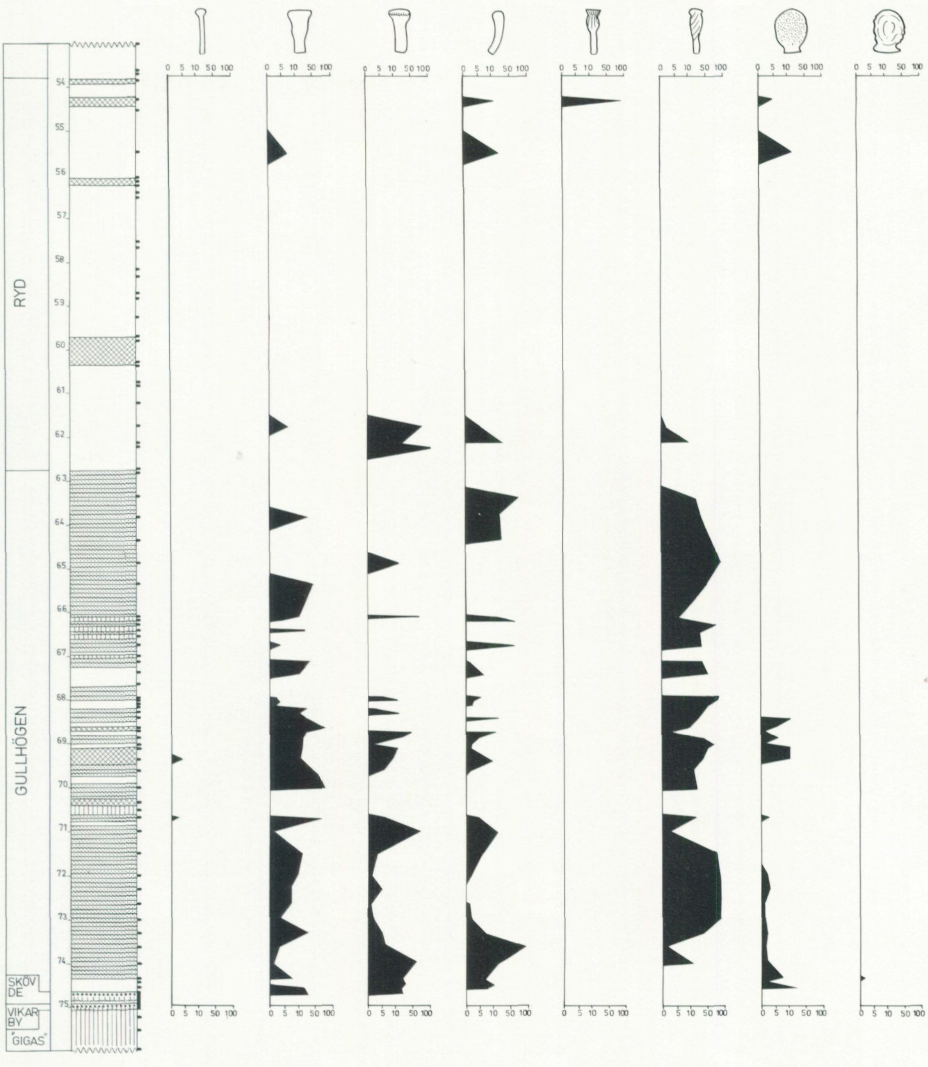


Fig. 12. Stora Åsbotorpborrningen 1. Relative frequencies of specimens within selected Chitinozoa species compared to the whole population. From left to right: *Conochitina capitata, Cyathochitina campanulaeformis, Conochitina micracantha, Conochitina primitiva, Cyathochitina stentor, Cyathochitina striata, Desmochitina minor,* and *Desmochitina rugosa*. For lithology, see Fig. 8.

The Skagen Limestone sea-bottom was probably too soft for larger sedentary organism, because the fauna is dominated by vagile organisms (Jaanusson 1965:56). The chitinozoan fauna consists of long-ranging species with low abundance, except in the uppermost part. Half a metre below the top of the Skagen Limestone the abundance suddenly increases almost 30

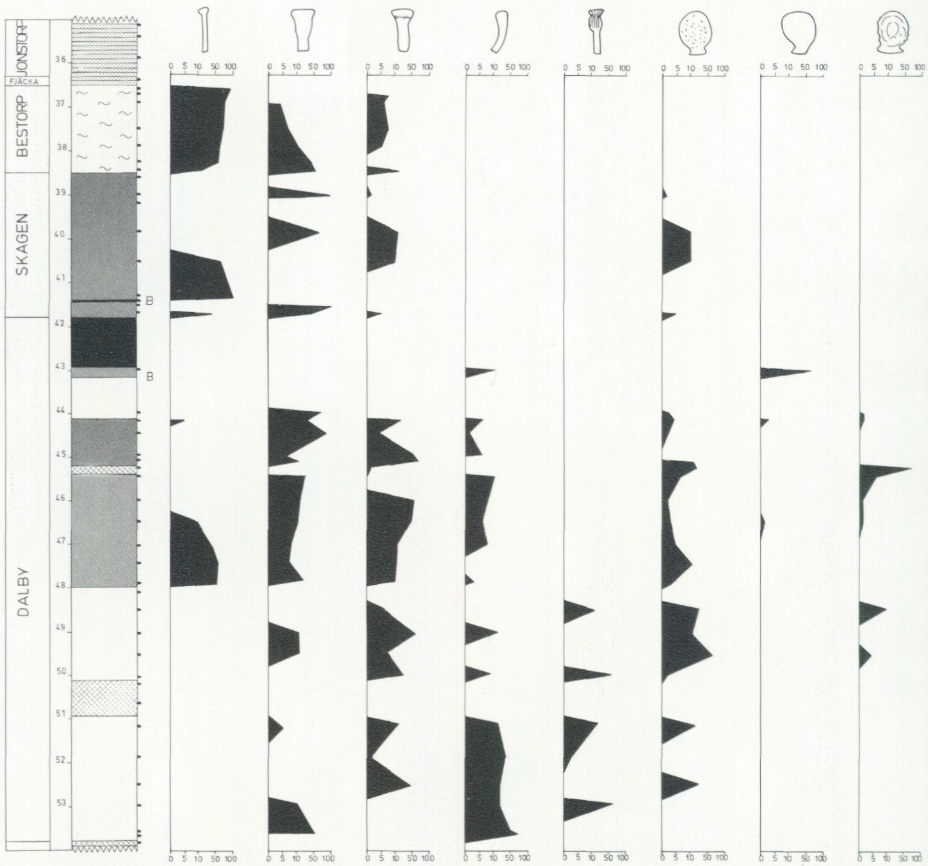


Fig. 13. Stora Åsbotorpborrningen 1. Relative frequencies of specimens within selected Chitinozoa species compared to the whole population. From left to right: *Conochitina capitata, Cyathochitina campanulaeformis, Conochitina micracantha, Conochitina primitiva, Cyathochitina stentor, Desmochitina minor, Desmochitina amphorea,* and *Desmochitina rugosa.* For lithology, see Fig. 8.

times. No lithological change takes place. The chitinozoan fauna is almost completely dominated by *Cyathochitina campanulaeformis*. Paris (1980:91) found it unlikely that benthic organisms suddenly could increase within a bed, without any perceptible change in the lithology. A lithological change is, however, not necessary to explain this phenomenon. Factors like temperature and salinity are not always reflected in the lithology, and they may have the same effects on the fauna as a change in the type of sediment (cf. Jaanusson & Bergström 1980).

Above the level which indicates the "blooming" of *Cyathochitina campanulaeformis* the chitinozoans disappear from the Skagen Limestone. After a period of non-deposition lasting from late Caradocian (i.e. the upper part of the Skagen Limestone) to early Ashgillian, the chitinozoans temporarily return in the Bestorp Limestone, which probably was deposited in a restricted environment with a very low water energy. Chitinozoan abundance is consistently low. One species, *Lagenochitina* cf. *prussica,* is restricted to the unit, and is known from the Fjäcka Shale and Vormsi Beds of the same age and representing similar water energy conditions in the epicontinental Baltoscandian sea.

No chitinozoans were present in younger Ordovician beds in the Stora Åsbotorp boring. Except for the Hirnantian, these strata are predominantly terrigenous mudstones. The content of macrofossils is generally low.

During the Hirnantian the sea was shallowing. Small changes in the water level could change the life conditions at the bottom dramatically. The Hirnantian sediments in Västergötland are of the Bahamian type (Jaanusson 1973; Stridsberg 1980), which indicates a subtropical to tropical shallow-water environment. The sea was probably too shallow and agitated for benthic chitinozoophorans. It is possible that planktic chitinozoans were carried to the shore by currents, and then deposited on bottoms not suitable for benthic chitinozoophorans. Such conditions were present in the Hirnantian sea in Skåne (Scania) where planktic and benthic chitinozoans were almost mutually exclusive (Grahn 1978). Similar environments as those in the Hirnantian in Västergötland are also known from the upper Högklint Beds (Lower Wenlock) on Gotland (Jaanusson 1979:37). The chitinozoans there show the same pattern as in the Hirnantian Beds in Skåne (cf. Laufeld 1979:72, 74; Figs. 22–23). However, it is obvious that the environments in the Hirnantian sea in Västergötland were unfavourable for the preservation of the chitinozoans.

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APPENDIX

STORA ÅSBOTORPBORRNINGEN 1, VE 7468 3135, c. 2400 m NW of Skövde church.

Topographical map sheet 8 D Skara NO. Geological map sheet Aa 121 Sköfde.

Core drilling (T.D. 96.80 m) made by the Geological Survey of Sweden in cooperation with the Gullhögen Kalkbruk AB in 1945, c. 375 m SE the south end of Lake Åsbotorpsjön. The diameter of the core is 7 cm.

Upper Cambrian – Llandovery.

References: Thorslund 1958, Fig. 3, Bill.; Skoglund 1963, pp. 12–13; Jaanusson 1965, pp. 30–41.

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