

CHITINOZOAN BIOFACIES OF LATE EARLY LLANDOVERY (*CORONOGRAPTUS CYPHUS*) AGE IN THE EAST BALTIC

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Abstract. Four lateral chitinozoan biofacies, mainly defined by the distribution of *Cyathochitina* species, are recognized from the uppermost lower Llandovery strata (*Coronograptus cyphus* age) in 18 eastern Baltic sections. *Cyathochitina kuckersiana* (Eisenack, 1934) seems to have preferred shallow-water near-shore conditions and *C. calix* (Eisenack, 1931) deeper parts of the shelf, whereas *C. campanulaeformis* (Eisenack, 1931) is more widespread. Representatives of the genus *Cyathochitina* appear to be absent in most of the near-shore environment. However, these chitinozoan biofacies are probably of only regional significance and occur where calcareous muds (which formed calcilutites) were deposited.

Key words: Chitinozoa, Llandovery, biofacies, East Baltic.

INTRODUCTION

Calcareous muds were deposited over an extensive area of the northern and central-eastern Baltic at the end of early Llandovery (*Coronograptus cyphus*) time. The calcilutites which formed of these muds are currently included in the Slitere Member of the Saarde Formation (Gailite et al., 1987) and partly in the Nurmekund Formation of the Raikküla Regional Stage (Nestor, 1995). The presence of skeletal detritus in limestones determines the Raikküla Formation (Fig. 1). The more argillaceous basal strata of the Raikküla Stage are, in some sections, considered to be a separate member, the Pusku Member (Heldur Nestor, pers. comm.). Within the wide deposition area of these limy sediments, mineralogical and palaeontological differences and structural features indicate various sedimentary environments (Jürgenson, 1966; Kaljo & Jürgenson, 1977;

Series	Stage	Regional stage	Graptol. zone	LOCAL STRATIGRAPHICAL UNITS		
				Central Estonia	South Estonia	West Latvia
LLANDOVERY	Aeronian	Raikküla	C. gregarius		Ikla Member	Dobele Formation
	Rhuddanian		C. cyphus		Raikküla Formation	Kolka Member
		Juuru	D. confertus	Nurmekund Formation	Slitere Member	
				Pusku Member	Pusku Member	
			Tamsalu Formation	Õhne Formation		

Fig. 1. Stratigraphic correlations and generalized nomenclature of the uppermost lower Llandovery units of the East Baltic (after Nestor, 1995).

Einasto, 1986). Organic remains are rare in the calcilutites, and palaeontological information comes mainly from specific fossiliferous beds. The intercalation of graptolitic mudstones in the limestones indicates more offshore conditions, and the presence of algal structures suggests shallower conditions of sedimentation. The content of fine terrigenous material decreases shoreward – to the north and east of Estonia where coarse-grained limestones, dolomicrites, and dolomites occur. In addition, the distribution of brachiopod communities in the Raikküla Stage, studied by Kaljo & Rubel (1982), shows their distinct connection to lithofacies belts. Thus, in the northernmost core sections (e.g. Kirikuküla), the *Linoporella* and *Borealis* communities occur, and in central Estonian cores (e.g. Varbla and Sulustvere) the *Pentamerus* and *Stricklandia* communities are represented. In southwest Estonian and north Latvian core sections (e.g. Ohesaare, Ikla, and Kolka), the *Clorinda* community is present.

Kaljo & Vingisaar (1969), Kaljo (1970), and Ulst (1973) correlated limestones of the Slitere (earlier Sturi) Member with strata of the lower and middle parts of the *Coronograptus cyphus* Zone. The thickness of the Slitere Member ranges from 6 to 36 m in central and southern Estonia and northern Latvia. During *cyphus* time, deeper-water argillaceous sediments of the Remte Formation deposited in western Latvia.

In southern Estonian and northern Latvian sections (Fig. 1), the Slitere Member is overlain by argillaceous limestones and marls of the Kolka Member. In central Estonia this part of the sequence (included in the Raikküla Formation) comprises shallow-water near-shore deposits (facies belts I and II of Nestor & Einasto, 1977) which are barren of chitinozoans. This upper part of the sequence which is of late *C. cyphus* age is not considered in the present paper.

CHITINOZOAN DISTRIBUTION

The presence of the late early Llandovery *Conochitina electa* chitinozoan Biozone has been established in nearly all Estonian and Latvian sections studied (Nestor, 1994). Graptolite data from the Ikla, Kolka, and Ventpils core sections (Kaljo, 1970; Ulst, 1973; Gailite et al., 1987) indicate that the *Conochitina electa* Zone is correlative with the *Coronograptus cyphus* Zone.

This paper discusses the chitinozoan biofacies in the lower half of the *Conochitina electa* Zone which is characterized by the appearance of numerous specimens of *Conochitina electa* Nestor, 1980 in the lowermost part of the Raikküla Stage, up to a small "interregnum" within the *Conochitina electa* Zone, indicated by the scarcity or absence of chitinozoans (Nestor, 1994). The lower boundary of this zone is defined, apart from abundant appearance of *Conochitina electa*, also by the disappearance of *Belonechitina postrobusta* (Nestor, 1980) and *Cyathochitina kuckersiana* (Eisenack, 1934). The last mentioned species are common in the uppermost beds of the Juuru Stage (Fig. 1), which are correlated, using graptolites, with the *Dimorphograptus confertus* Zone (Kaljo et al., 1984). However, *Cyathochitina kuckersiana* may also occur above the chitinozoan small interregnum within the upper part of the Kolka Member whereafter this species disappears.

The distribution of chitinozoan species, except *Ancyrochitina ancyrea* (Eisenack, 1931), is shown in Fig. 2 for selected sections which have different facies character. Figure 3 displays the regional distribution of certain, more abundant, chitinozoan species occurring in the lower part of the Raikküla Stage. Each bar represents the approximate range of the species in the interval studied in the corresponding section. *Conochitina electa* (Pl. I, figs. 1–3) is present in all sections (Fig. 3), whereas other species occur irregularly. The distribution of *Ancyrochitina* species is not shown in Fig. 3, but *A. ancyrea* (Pl. II, fig. 6) is found in all sections; *A. bifurcaspina* Nestor, 1994 (Pl. II, fig. 3) occurs mostly in the lower part of the studied interval, but sometimes sporadically throughout the section; *Plectochitina* cf. *P. spongiosa* (Achab, 1977) (Pl. II, fig. 4) is distributed in the Viki, Kolka, and Asuküla cores; *Ancyrochitina ramosaspina* Nestor, 1994 (Pl. II, fig. 5) occurs in the uppermost part of the studied interval in the Ohesaare, Ruhnu, Ikla, Varbla, and Viki cores; and sparse *Belonechitina aspera* (Nestor, 1980) are identified in the Ruhnu, Sulustvere, Asuküla, and Raikküla cores.

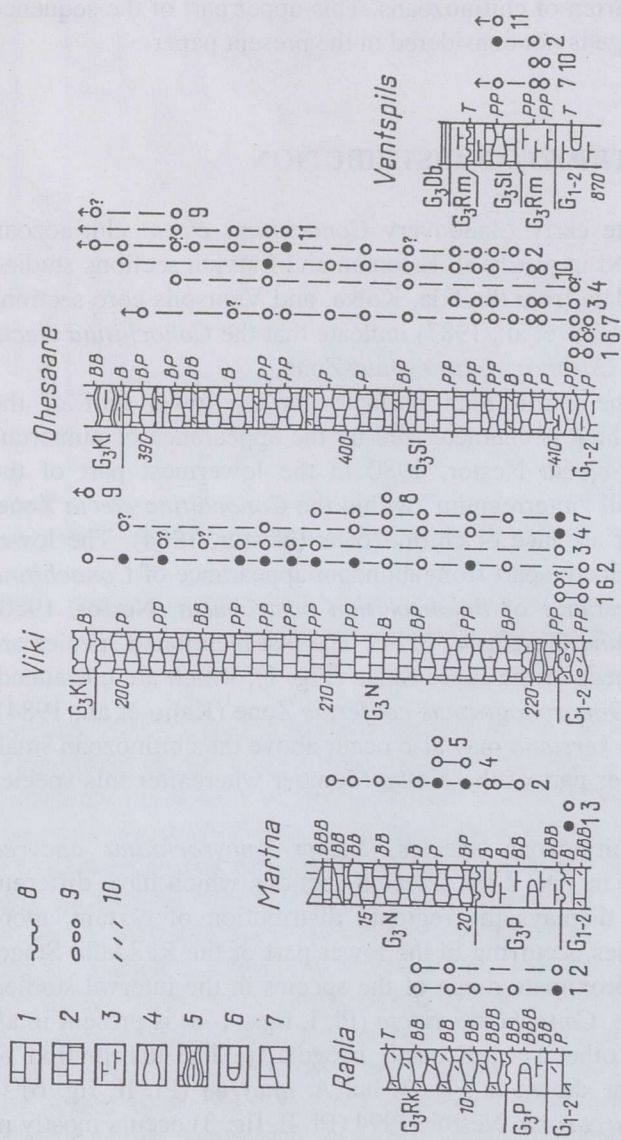


Fig. 2. Distribution of chitinozoan species in the lower part of the Raikküla Stage in some East Baltic core sections. Chitinozoan species: 1, *Cyathochitina kuckerstana* (Eisenack, 1934); 2, *Conochitina electa* Nestor, 1980; 3, *Cyathochitina campanulaeformis* (Eisenack, 1931); 4, *Ancyrochitina bifurcaspina* Nestor, 1994; 5, *Belonechitina aspera* (Nestor, 1980); 6, *Belonechitina postrobusta* (Nestor, 1980); 7, *Conochitina iklensis* Nestor, 1980; 8, *Plectochitina* cf. *P. spongiosa* (Achab, 1977); 9, *Ancyrochitina ramosaspina* Nestor, 1994; 10, *Cyathochitina calix* (Eisenack, 1931); 11, *Spinachitina maennili* (Nestor, 1980). Legend to the lithological columns: 1, limestone; 2, calcilutite; 3, calcareous mudstone and marl; 4, nodular structure of limestone and calcilutite; 5, nodular limestone with thin (dash) and thick interlayers of marl; 6, marls with limestone nodules; 7, cross-bedded limestones; 8, discontinuity surface; 9, conglomerate; 10, skeletal detritus. Organic-walled microfossil associations in the samples: B, BB, benthic elements (mainly scolecodonts) prevail (the number of letters stands for the stage of prevalence); BBB, absence of planktic elements; P, PP, planktic elements (mainly chitinozoans) prevailing; T, samples containing no organic-walled microfossils. The black dots indicate an abundant occurrence, and the white dots an average or uncommon occurrence of chitinozoans. Indices: G₁₋₂, Juuru Stage; G₃, Raikküla Stage; G_{3N}, Nurmekund Member; G_{3P}, Pusku Member; G_{3Rk}, Raikküla Formation; G_{3Sl}, Slitere Member; G_{3M}, Kolka Member; G_{3Db}, Dobele Formation.

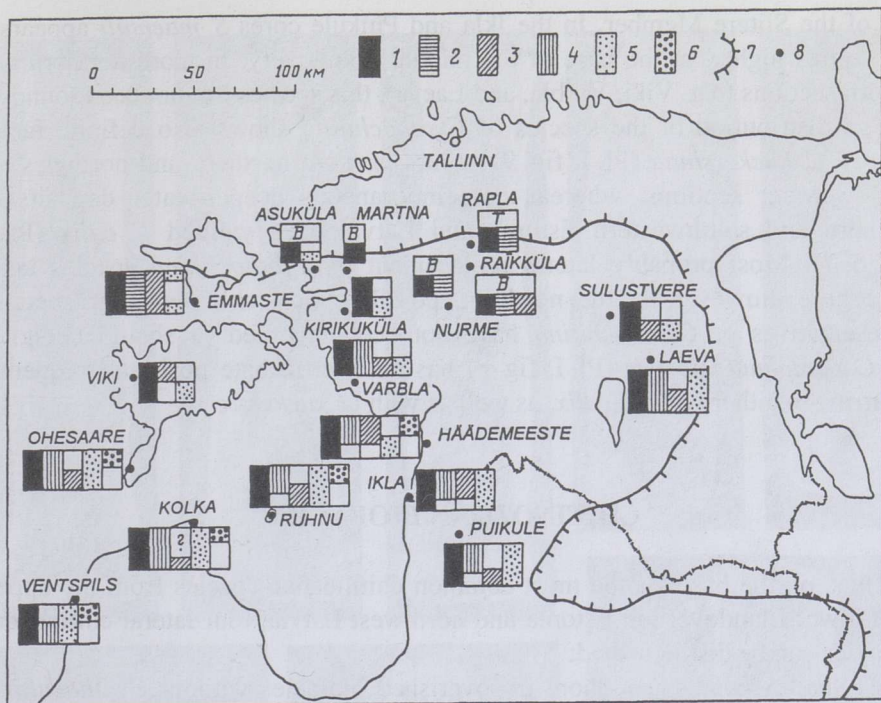


Fig. 3. Distribution pattern of selected chitinozoan species in the lower part of the Raikküla Stage in the sections studied. White blocks indicate the interval of the section where a particular species does not occur. 1, *Conochitina electa* Nestor, 1980; 2, *Cyathochitina kuckersiana* (Eisenack, 1934); 3, *Cyathochitina campanulaeformis* (Eisenack, 1931); 4, *Cyathochitina calix* (Eisenack, 1931); 5, *Conochitina iklaensis* Nestor, 1980; 6, *Spinachitina maennili* (Nestor, 1980); 7, limit of the present distribution of the lower Llandovery deposits; 8, location of the core sections. T, part of the section containing no organic-walled microfossils; B, part of the section containing only benthic microfossils (mainly scolecodonts).

These forms do not appear to show any environmental control, except for the extreme rarity of specimens of *Ancyrochitina* in the deepest-water sediments of the Ventspils section.

The dominant species in all studied sections is *Conochitina electa*, suggesting a broad tolerance to different environmental conditions.

Conochitina iklaensis Nestor, 1980 (Pl. I, figs. 4, 5) is common in the southern and southwestern cores, but in central Estonia it is missing or occurs only in the lowermost part of the interval considered (Fig. 3).

Spinachitina maennili (Nestor, 1980) (Pl. II, figs. 1, 2) is present only in the sections of southwest Estonia. This species is characteristic of the middle Llandovery (Nestor, 1976, 1980, 1994), but appears already in the uppermost

part of the Slitere Member. In the Ikla and Puikule cores *S. maennili* appears a few metres higher, at the base of the middle Llandoverý. In more northern and eastern sections (e.g. Viki, Varbla, and Laeva), this species has not been found.

The distribution of the species of *Cyathochitina* shows also definite facies control. *C. kuckersiana* (Pl. I, fig. 9) occurs in more northern and northwestern shallow-water sections, whereas contemporaneous deeper-water deposits of southern and southwestern Estonia and Latvia have yielded *C. calix* (Pl. I, figs. 6, 7). Most probably lateral replacement of *Cyathochitina* species takes place here, however, in the northern, possibly most shallow-water sections representatives of *Cyathochitina* have not been recorded. It should be noted that *C. campanulaeformis* (Pl. I, fig. 8) has an intermediate position, frequently occurring together with *C. calix*, as well as with *C. kuckersiana*.

CHITINOZOAN BIOFACIES

Thus, on the basis of the most common chitinozoan species from the uppermost lower Llandoverý in Estonia and northwest Latvia, four lateral chitinozoan biofacies can be distinguished:

(1) Shallow-water near-shore impoverished biofacies without *Cyathochitina*. It occurs in the northwesternmost part of Estonia (Kirikuküla, Asuküla, and Martna cores; see Fig. 3).

(2) Shallow-water biofacies with *Cyathochitina kuckersiana*. *Conochitina iklaensis* is usually missing. This biofacies occurs in the northern, central part of Estonia (Nurme, Rapla, and Raikküla cores).

(3) Biofacies with *Cyathochitina campanulaeformis*. In the lower part of the studied interval *Conochitina iklaensis* is also present. The biofacies is distributed in the western and eastern parts of central Estonia (Sulustvere, Viki, and Emmaste? cores).

PLATE I

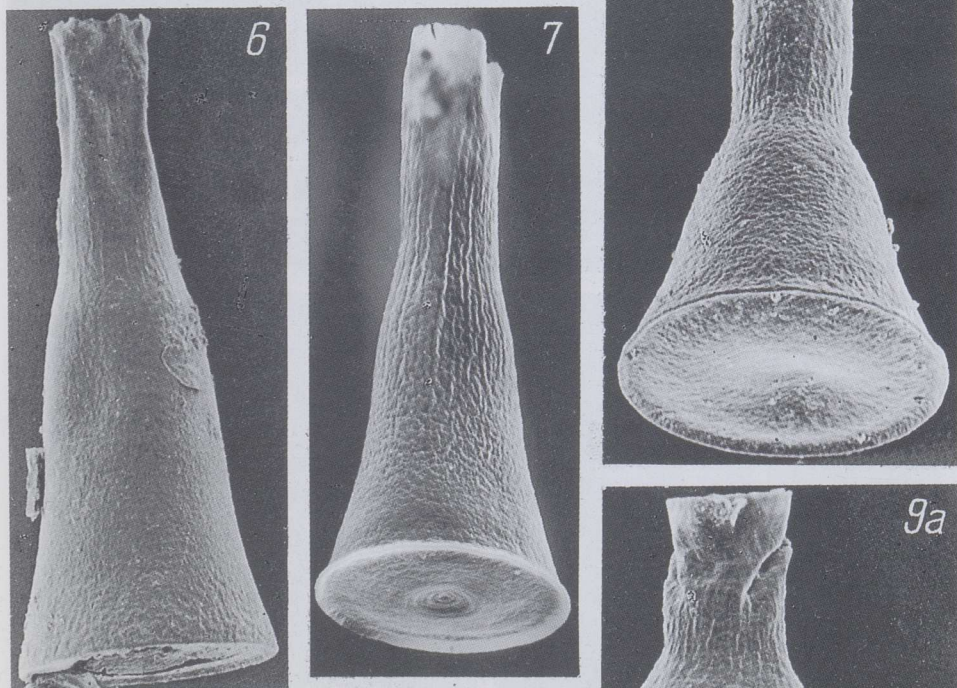
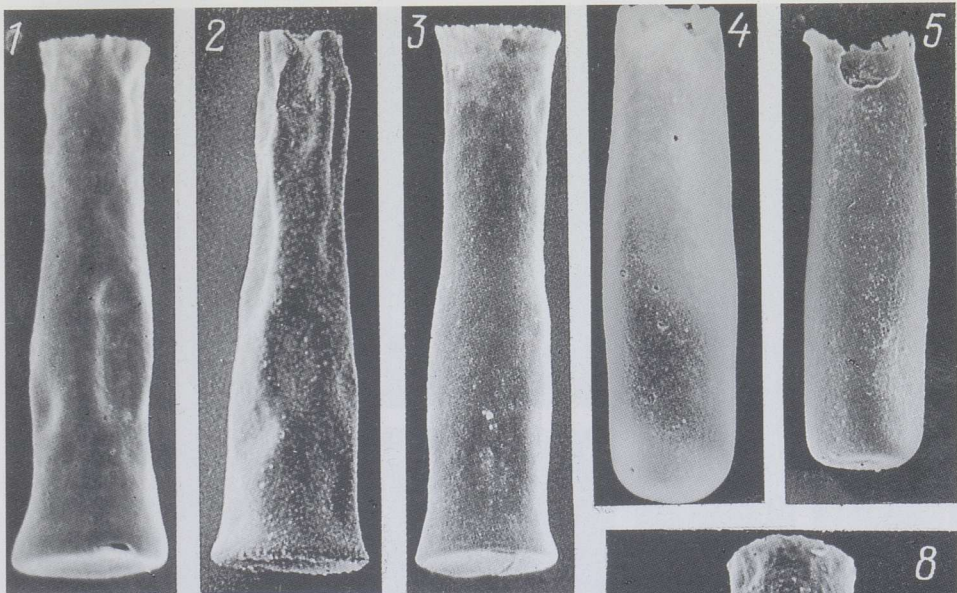
Figs. 1–3. *Conochitina electa* Nestor, 1980; Raikküla Stage. 1, Ch 30/1220, Emmaste core, depth 41.3 m, SEM × 250. 2, Ch 36/9388, Ventspils core, depth 867 m, SEM × 250. 3, Ch 28/1220, Emmaste core, depth 41.3 m, SEM × 250.

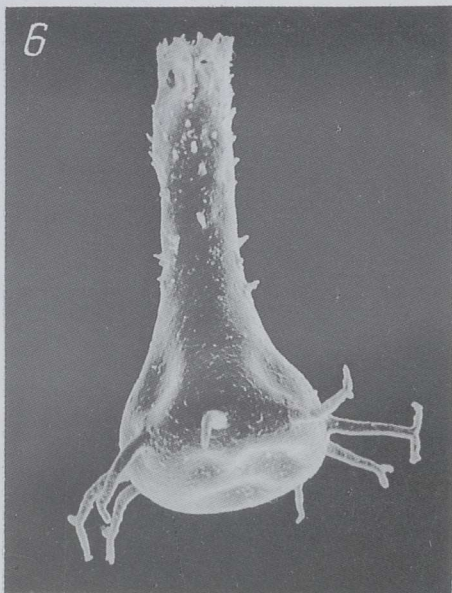
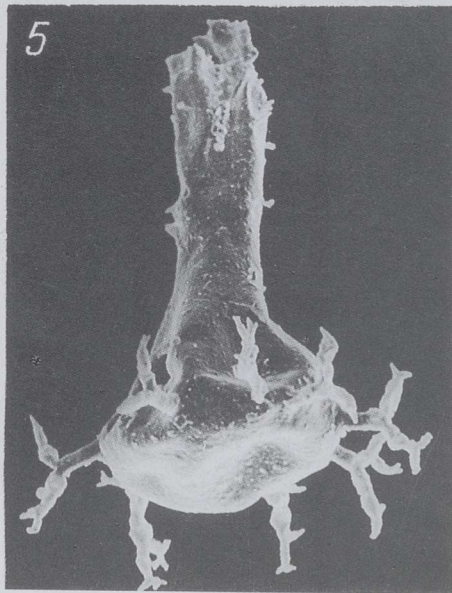
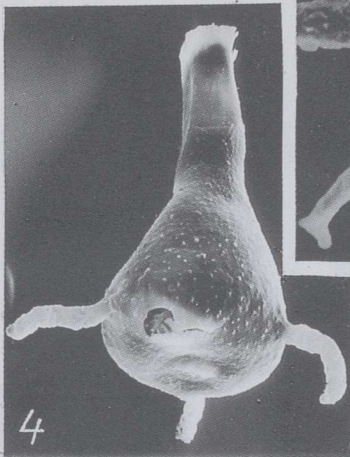
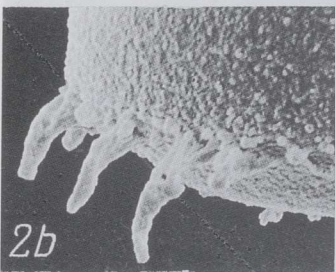
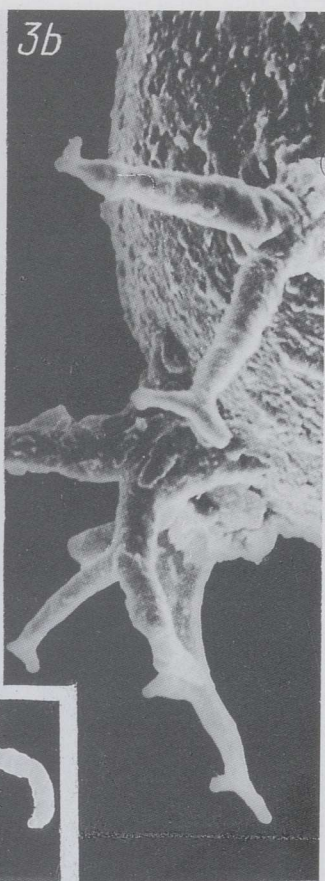
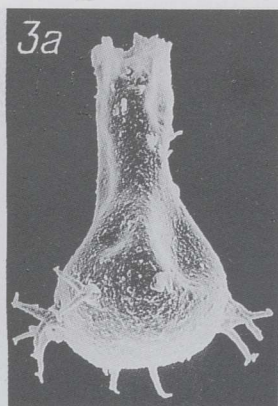
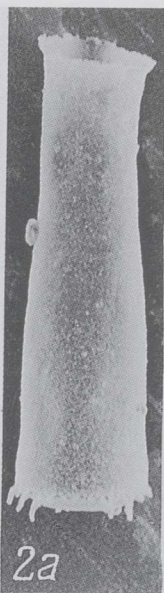
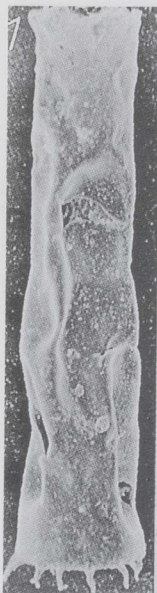
Figs. 4, 5. *Conochitina iklaensis* Nestor, 1980; Raikküla Stage, Ruhnu core, depth 584 m, SEM × 250. 4, Ch 37/1682; 5, Ch 40/1682.

Figs. 6, 7. *Cyathochitina calix* (Eisenack, 1931); Raikküla Stage. 6, Ch 429/1685, Ruhnu core, depth 576.2 m, SEM × 250. 7, Ch 42/611, Ohesaare core, depth 399 m, SEM × 250.

Fig. 8. *Cyathochitina campanulaeformis* (Eisenack, 1931). Ch 43/9540, Juuru Stage, Seliste core, depth 340.3 m, SEM × 250.

Fig. 9. *Cyathochitina kuckersiana* (Eisenack, 1934). Ch 431/1367, Raikküla Stage, Varbla core, depth 189.85 m. 9a: SEM × 250; 9b: detail (carina), SEM × 250.





(4) Deep-water offshore biofacies with *Cyathochitina calix*. Numerous specimens of *Conochitina iklaensis* and rare *Cyathochitina campanulaeformis* are recorded as well. This biofacies is restricted to the southern and southwestern parts of Estonia and northwest Latvia.

Considering the presence or absence of *Spinachitina maennili* in the latter biofacies, the following depth controlled variations as subdivisions can be distinguished:

(a) *Spinachitina maennili* is missing, also in the middle Llandovery (Varbla and Laeva cores; see Nestor, 1994).

(b) *Spinachitina maennili* is missing, but appears higher in the section in the lowermost middle Llandovery (Ikla and Puikule cores).

(c) *Spinachitina maennili* appears already in the upper part of the lower Llandovery – in the middle of the Slitere Member (Ohesaare, Ruhnu, Häädemeeste, Kolka, and Ventspils cores).

In deeper-water settings *Cyathochitina* is rare or disappears, suggesting some environmental control. In the Ventspils core, *C. calix* occurs only in the lowermost part of the condensed sequence.

According to the facies model for the East Baltic Silurian (Nestor & Einasto, 1977, 1982), the first three chitinozoan biofacies (1–3) are of shelf origin, whereas 1–2 are characteristic of the inner (shallow) shelf, and 3 of the middle (deeper) part of the shelf. The deepest biofacies with *C. calix* (4) is mainly restricted to the outer shelf (transition facies belt).

This distribution model of chitinozoans in different facies belts is now considered valid only in case of sedimentation of very fine-grained calcareous muds which form calcilutites. In the underlying, topmost part of the Juuru Stage, as well as in the overlying, topmost part of the Kolka Member, in the argillaceous nodular limestones and marls, no differences were observed in the distribution pattern of *Cyathochitina* species. *Cyathochitina kuckersiana* occurs in large numbers in shallow-water sections of the Tamsalu Formation in central Estonia, as well as in the deeper-water Õhne Formation and Kolka Member of the Saarde Formation in southern Estonia.

PLATE II

Figs. 1, 2. *Spinachitina maennili* (Nestor, 1980); Raikküla Stage. 1, Ch 2/1462, Ikla core, depth 462.9 m, SEM \times 250. 2, Ch 1/1686, Ruhnu core, depth 573.3 m. 2a: SEM \times 250; 2b: SEM \times 1360.

Fig. 3. *Ancyrochitina bifurcaspina* Nestor, 1994. Ch 541/1919, Raikküla Stage, Ohesaare core, depth 391.35 m. 3a: SEM \times 525; 3b: SEM \times 1630.

Fig. 4. *Plectochitina* cf. *P. spongiosa* (Achab, 1977). Ch 46/9798, Raikküla Stage, Kolka core, depth 640.8 m, SEM \times 350.

Fig. 5. *Ancyrochitina ramosaspina* Nestor, 1994. Ch 252/1452, Raikküla Stage, Ikla core, depth 480.4 m, SEM \times 320.

Fig. 6. *Ancyrochitina ancyrea* (Eisenack, 1931). Ch 241/1919, Raikküla Stage, Ohesaare core, depth 391.35 m, SEM \times 350.

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KITINOSOADE BIOFAATSIESED IDA-BALTI VARA-LLANDOVERY LÕPUS (*CORONOGRAPTUS CYPHUS*'E EAL)

Viiu NESTOR

Kitinosaade, põhiliselt *Cyathochitina* liikide leviku alusel saab Ida-Balti Alam-Llandovery läbilõigetes eristada nelja lateraalset biofaatsiest. *C. kuckersiana* (Eisenack, 1934) näib eelistavat rannalähedasi madalaveelisi olusid ja *C. calix* (Eisenack, 1931) šelfi sügavaimat osa, kuna *C. campanulaeformis* (Eisenack, 1931) on laiema levikuga. Perekond *Cyathochitina* esindajate puudumine kõige põhjapoolsemates läbilõigetes tähistab omaette, vaesustunud biofaatsiest. Need biofaatsiesed on tõenäoliselt siiski vaid regionaalse tähtsusega ja on seotud põhiliselt puhaste lubimudade (neist on hiljem kujunenud afaniitsed lubjakivid) settimisega.

БИОФАЦИИ ХИТИНОЗОЙ В ВОСТОЧНОЙ ПРИБАЛТИКЕ В КОНЦЕ РАННЕГО ЛЛАНДОВЕРИ (ВРЕМЯ *CORONOGRAPTUS CYPHUS*)

Вийу НЕСТОР

По распространению хитинозой, в основном видов *Cyathochitina*, в ряде разрезов нижнего лландовери Восточной Прибалтики выделены четыре латеральные биофации. *C. kuckersiana* (Eisenack, 1934) встречается в северных и северо-западных разрезах, предпочитая более мелководные прибрежные условия, *C. calix* (Eisenack, 1931) – в разрезах Южной и Юго-Западной Эстонии и Латвии, выбирая средой своего обитания более глубоководные участки шельфа, и *C. campanulaeformis* (Eisenack, 1931) занимает промежуточное между ними положение. Отсутствие представителей семейства *Cyathochitina* в самых северных разрезах позволяет выделить отдельную, четвертую биофацию. Все эти биофации имеют, по всей вероятности, лишь региональное значение и связаны только с отложениями чистых известковых илов (из которых позднее сформировались афанитовые известняки).