

REFLECTION OF WENLOCK OCEANIC EPISODES AND EVENTS ON THE CHITINOZOAN SUCCESSION OF ESTONIA

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Abstract. During this study the model of oceanic and climatic cyclicity by Jeppsson (*J. Geol. Soc.*, 1990, 147) was applied in the Wenlock sequence of Saaremaa on the basis of chitinozoan succession. The boundaries of some Wenlock episodes and events, established in the reference sections of Ireviken 3 and Vattenfallet outcrops, and Slitebrottet quarries of Gotland, were traced by chitinozoans in the Ohesaare section. In the paper the main changes in the chitinozoan assemblage during primo and secundo episodes and events are discussed. Diversity variations in primo and secundo episodes are expressed also in the monotonous marlstones of the Ohesaare core. The severest extinctions of the chitinozoan assemblage occurred during the Ireviken and Mulde events. The Boge and Valleviken events probably corresponded to an extensive stratigraphic gap in the sections of northern Saaremaa.

Key words: chitinozoans, Wenlock, oceanic episodes and events.

INTRODUCTION

A model for oceanic and climatic cyclicity, linked to the sedimentological and biotic fluctuations, was worked out by Jeppsson (1990). His main idea was to show alternation of primo and secundo episodes in oceanic state. Primo episodes were characterized by humid climate, cold bottom waters, reduction of carbonate deposition, and an increase in the clay content in sediments, related to the increased abundance and diversity of marine microplankton. Secundo episodes, on the contrary, were characterized by arid climate, salinity-dense oceanic bottom waters, sedimentation of pure carbonates in shallow waters, and rich and diverse benthic fauna. More or less abrupt changes between episodes, often leading to faunal extinctions, were termed as “events”. Thirteen primo and secundo episodes and events are distinguished in the Wenlock sequence of Gotland, adopted as a reference sequence (Jeppsson et al., 1995; see Fig. 1).

TIME	EPISODES & EVENTS	GOTLAND		NORTHERN SAAREMAA	OHESAARE	STAGE	STANDARD GRAPTOLITE ZONATION
		LIMEST.	MARL				
W	G L E E D O N					R O O T S I K Ū L A	<i>M. vulgaris</i> / <i>M. gerhardi</i> <i>M. deubeli</i> <i>M. praedeubeli</i> <i>G. nassa</i> <i>M. d. parvus</i>
	Klinte Secundo Episode	Klinterberg (part of)	70 —	Rootsi-kūla 25-33	Rootsi-kūla 36		
E	Mulde S.-S. Event	Mulde Halla	15 25			J A A G A R A H U	<i>C. lundgreni</i>
	Hellvi Secundo Episode	Slite	35 5?		Sörve 50		
N	Valleviken E.		— 7	Hiatus		J A A G A R A H U	<i>C. perneri</i>
	Allekvia Primo Episode		2? 31				
L	Lansa S.		>15 x			J A A G A R A H U	<i>C. rigidus</i>
	Boge E.		— 4,5(?)		Jamaja 95		
O	Sanda P.		1? ≥(21)	Tagavere 9-15		J A A G A R A H U	<i>M. belophorus</i>
	S. E.		8 —				
C	P.		0-2 8	Maasi 5-16		J A A G A R A H U	<i>M. belophorus</i>
	Vatten-fallet	Slite	8-26 —	Vilsandi 0-25			
K	Secundo Episode	Tofla	0-8 —	Paramaja 0-15	Paramaja 20	J A A G A R A H U	<i>M. antennularius</i>
	Högklint		30 x	Ninase 5-25	Tölla 25		
N	Ireviken E.	Upper Visby	— 8-11	Mustjala 8-37		J A A G A R A H U	<i>M. riccartonensis</i> <i>C. murchisoni</i> <i>C. centrifugus</i>
	Snipklint Primo Episode	Lower Visby	— 4,5				
LLAN-DO-VERY			Sealevel				

Fig. 1. Correlation of the Wenlock oceanic episodes and events of the Gotland reference sequence (from Jeppsson et al., 1995) with the regional stratigraphic units of Estonia. Stratigraphic thicknesses on Gotland are from Hede (1960) (cited in Jeppsson et al., 1995) and new measurements by Jeppsson: x, presence proven but unmeasured; —, lack of strata, exposures or collections; S, Secundo Episode; P, Primo Episode; E, event. Figures given are the maxima for strata of each episode. Lithologies are indicated conventionally (i.e., blocks for limestone and dashes for argillaceous limestones). Stippling at the top of the Slite Beds represents the Slite siltstone. Graptolite biozones are from Jeppsson (1996). For northern Saaremaa the thickness range of stratigraphic units is shown.

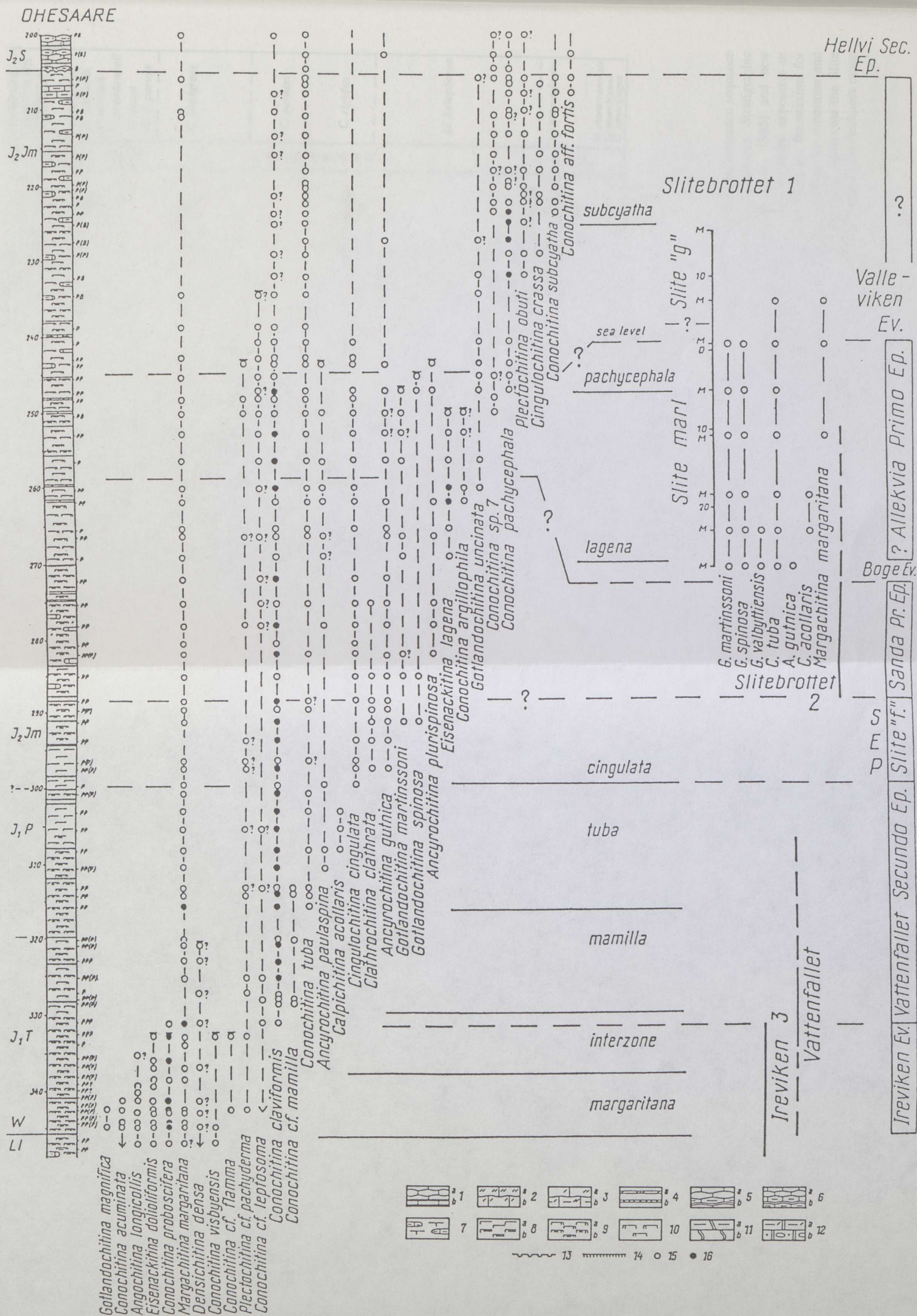


Fig. 2. Lithological log, ranges of selected chitinozoan species, succession of chitinozoan biozones, and span of the lower and middle Wenlock oceanic episodes and events in the section of the Ohesaare core. Stratigraphic position of the reference sections of the Ireviken 3 and Vattenfallet outcrops, and Slitebrottet quarries. Chitinozoan ranges in Slitebrottet 1 according to Laufeld (1974). Stratigraphic indices: J₁T, Tölla Beds of the Jaani Stage; J₁P, Paramaja Member of the Jaani Stage; J₂Jm, Jamaja Formation of the Jaagarahu Stage; J₂S, Sörve Formation of the Jaagarahu Stage. Abbreviations: S = Sec. Ep., Secundo Episode; P = Pr. Ep., Primo Episode; E = Ev., Event. Key to the lithological log: 1, limestone: a, pure, b, limestone with marlstone interbeds; 2, skeletal grainstone: a, coarse-grained, b, fine-grained; 3, wackestone: a, pure, b, argillaceous; 4, interbeds: a, skeletal grainstone, b, pelletal grainstone; 5, nodular limestone: a, pure, b, argillaceous with marlstone interbeds; 6, fine nodular limestone: a, pure, b, argillaceous with marlstone interbeds; 7, marlstone with limestone nodules; 8, marlstone: a, calcareous, b, argillaceous; 9, dolomitic marlstone: a, pure, b, argillaceous; 10, calcitic dolomitic marl; 11, dolomite: a, argillaceous skeletal, b, bioclastic pelletal; 12, dolomite: a, argillaceous skeletal, b, bioclastic pelletal; 13, hardground; 14, metabentonite layer; 15, occurrence of species; 16, abundant occurrence of species. Organic-walled microfossil association (the number of letters indicates the stage of prevalence): P, planktic elements (mainly chitinozoans) prevailing; B, benthic elements prevailing.

The boundaries of some Wenlock episodes and events were identified in the sections of Ireviken 3 and Vattenfallet outcrops, and Slitebrottet quarries (Jeppsson et al., 1995). As a result of recent investigation of these outcrops by a group of Estonian geologists, the corresponding intervals were established also in Estonian sections, including Ohesaare (Figs. 2, 3). The results will be published in a forthcoming paper by V. Nestor and R. Einasto. The correlation of the sections is based on chitinozoans only to show how different events and episodes reflect on the assemblage of chitinozoans. In the present paper they are not related to the conodont succession.

RECOGNITION OF THE EPISODES AND EVENTS BY CHITINOZOANS

The basal beds of the Wenlock are characterized by a rich assemblage of chitinozoans, dominated by *Conochitina proboscifera*. The **Ireviken Event** (Fig. 1) is expressed by a drastic decline of the chitinozoan species diversity in all studied early Wenlock sections of Estonia (Nestor, 1992, 1994). In the Ireviken reference section nine chitinozoan taxa disappeared finally from the Silurian sequence, whereas some taxa appeared in this interval. Ten chitinozoan datum levels have been established in the Ireviken 3 section. Stratigraphically the eighth level is the most important. It marks the extinction of *Angochitina longicollis*, which occurs in abundance throughout the upper Llandovery and basal Wenlock all over the world (Verniers et al., 1995). The Ireviken Event is represented in the lower part of the Mustjala Member and Tõlla Beds of the Jaani Regional Stage (Figs. 1, 2).

The reference section of the **Vattenfallet Secundo Episode**, succeeding the Ireviken Event, was fully studied by Laufeld (1979), we investigated only its lower part. According to Jeppsson et al. (1995), the Vattenfallet Secundo Episode began at the final extinction datum of the Ireviken Event below the boundary of the Högklint Beds at Vattenfallet. The interval of this secundo episode is characterized by a moderate species diversity in the reference section as well as in the Estonian sections studied (Nestor, 1994). This episode includes mainly transitional species of chitinozoans, dominated by *Conochitina claviformis* and *Margachitina margaritana*, together with *Conochitina tuba* and *Calpichitina acollaris*, which appear in the upper part of the interval (Fig. 2). In Estonian sections the Vattenfallet Secundo Episode embraces the uppermost part of the Mustjala Member and Tõlla Beds, also the Ninase and Paramaja members of the Jaani Stage (Figs. 1, 2). Jeppsson included in this episode also the lower units of the Slite Beds (units a, b, c, d, e), but correlation of this part of the sequence with Estonian sections is still uncertain. According to Laufeld (1974), Slite "a" and "b" contain only transitional species, in Slite "c" *Conochitina tuba* and *Ancyrochitina gutnica* make their appearance, in Slite "d" *Clathrochitina clathrata* appears. In Estonian sections *Conochitina tuba* occurs already in the

upper part of the Jaani Stage, other species appear in the basal beds of the Jamaja Formation (Fig. 2), but *Clathrochitina clathrata* is present also in the Maasi Beds of the Jaagarahu Stage (Nestor & Nestor, 1991). Therefore the lower units of the Slite Beds may partly be correlated with the Vilsandi(?) and Maasi beds of the Jaagarahu Stage, partly maybe with a stratigraphic gap, as was supposed by Jeppsson et al. (1994).

According to Jeppsson et al. (1995), the **Sanda Primo Episode** has not yet a precise lower boundary. Taking into consideration chitinozoan data, it would be better to include also Slite "f" in this episode. Slite "f" is characterized by a diverse assemblage of chitinozoans, including six species which appear in this interval for the first time (Laufeld, 1974). We have studied the Sanda Primo Episode in the lowermost 15 m of the reference section of Slitebrottet 2 quarry. The occurrence of *Gotlandochitina martinssoni* and *G. spinosa*, and the appearance of *Eisenackitina lagena* and *Conochitina argillophila* allows us to correlate this part of the section with the lower-middle part of the Jamaja Formation in the Ohesaare core (Fig. 2). During the Sanda Primo Episode, the most favourable conditions for chitinozoans existed in the area of the Sörve Peninsula, where marly and argillaceous sediments of the Jamaja Formation deposited. In the northern part of Saaremaa, however, the coeval sediments are mostly represented by the dolomites and biomicritic limestones of the Tagavere Beds (Nestor & Nestor, 1991) containing very few chitinozoans.

The part of the sequence corresponding to the **Boge Event** has not been investigated on chitinozoans at Slitebrottet, as it remains between the intervals studied by Laufeld (1974) in the Slitebrottet 1, and by us in the Slitebrottet 2 section. Possibly the disappearance of *Eisenackitina lagena* and *Conochitina argillophila*, not identified by Laufeld in the Slitebrottet 1 quarry, is connected with this event. The Boge Event is probably related to the beginning of an extensive stratigraphic gap between the Tagavere Beds of the Jaagarahu Stage and the Viita Beds of the Rootsiküla Stage in West Estonian sections (Nestor & Nestor, 1991). In the Ohesaare section this level approximately coincides with the middle of the Jamaja Formation (Fig. 1).

The level of the next, **Lansa Secundo Episode** is still not determined by chitinozoans. According to Jeppsson et al. (1995) this interval is represented by pure limestones and it occurs also in the Slitebrottet 2 quarry, but evidently higher than the part of the section studied by us.

The reference section of the **Allekvia Primo Episode** is the Slitebrottet 1 quarry, from where chitinozoans were studied by Laufeld (1974). The similar assemblage of chitinozoans (see Fig. 2) and the disappearance of *Gotlandochitina* species (*martinssoni*, *spinosa*, *valbyttiensis*) in the topmost part of the section allow for rough correlation of this level with the corresponding level in the Ohesaare core. However, the interval of this episode is considerably smaller at Ohesaare than at Slitebrottet 1 (Fig. 2).

The interval of the **Valleviken Event** terminates the Wenlock sequence in the Slitebrottet 1 quarry (Fig. 2). According to Laufeld (1974), this interval of the reef formation is not characterized by chitinozoans. Yet, they are present in the layer with *Pentamerus gotlandicus*, which was formed at the beginning of this event in other areas (Jeppsson et al., 1995). *Conochitina pachycephala* appears and five species of chitinozoans disappear during the Valleviken Event on Gotland as well as in the Ohesaare core (Fig. 2), approximately in the middle–upper part of the Jamaja Formation of the Jaagarahu Stage. In some West Estonian sections (Kihnu and Häädemeeste) only the lower part of this interval is represented, followed by a stratigraphic gap (Nestor & Nestor, 1991). The uppermost portion of about 40 m of the Jamaja Formation is characterized by a rich assemblage of chitinozoans (*Plectochitina obuti*, *Cingulochitina crassa*, *Conochitina subcyatha*, etc., see Fig. 2), not recorded from Gotland. Therefore, it is not excluded that on Gotland there exists an hiatus between the Valleviken Event and the Hellvi Secundo Episode (Fig. 2).

The beginning of the **Hellvi Secundo Episode** is characterized by a sudden decrease in the clay content in limestones. According to Jeppsson et al. (1995), this level coincides approximately with the lower boundary of the *testis* graptolite Biozone. These characteristics fit well with the beginning of the Sörve Formation of the Jaagarahu Stage in the Ohesaare section (Kaljo, 1990). The episode shows a moderate occurrence of chitinozoans, dominated by *Conochitina tuba* and *Conochitina cribrosa*, the last species appearing in the upper part of the interval. The Hellvi Secundo Episode is represented in the lower part of the Sörve Formation.

The beginning of the **Mulde Event** coincides with the uppermost part of the *lundgreni* graptolite Biozone (Jeppsson, 1996) and also with the end of the deposition of the Sörve Formation (Fig. 3). The exact position of the boundary between the Hellvi Secundo Episode and the Mulde Event in the Ohesaare section is still unclear. There is one finding of *Gothograptus nassa* at a depth of 166.4 m, which has conventionally been treated as the base of the *nassa* Biozone (Kaljo, 1990). A gradual extinction of most of the chitinozoan species, characteristic of the Wenlock, began already about 20 m below this level. Nine species disappear in the Mulde and Halla beds on Gotland (Laufeld, 1974) and 15 in the upper part of the Sörve Formation. Besides, there appear six species, including *Sphaerochitina indecora*, the index species of the highest chitinozoan biozone of the Wenlock.

The topmost, **Klinte Secundo Episode**, is not studied in the Ohesaare section as chitinozoans are very scarce in the skeletal pack- and wackestones of the lowermost part of the Rootsiküla Formation and totally missing in pelletal limestones and lagoonal dolomites of the rest of the same formation. According to Jeppsson et al. (1995), the lower boundary of the Klinte Secundo Episode is defined at the base of the Klinteberg Beds. To recognize this boundary in the Ohesaare section, conodont data should be used. *Ozarkodina confluens densidentata*

OHESAARE

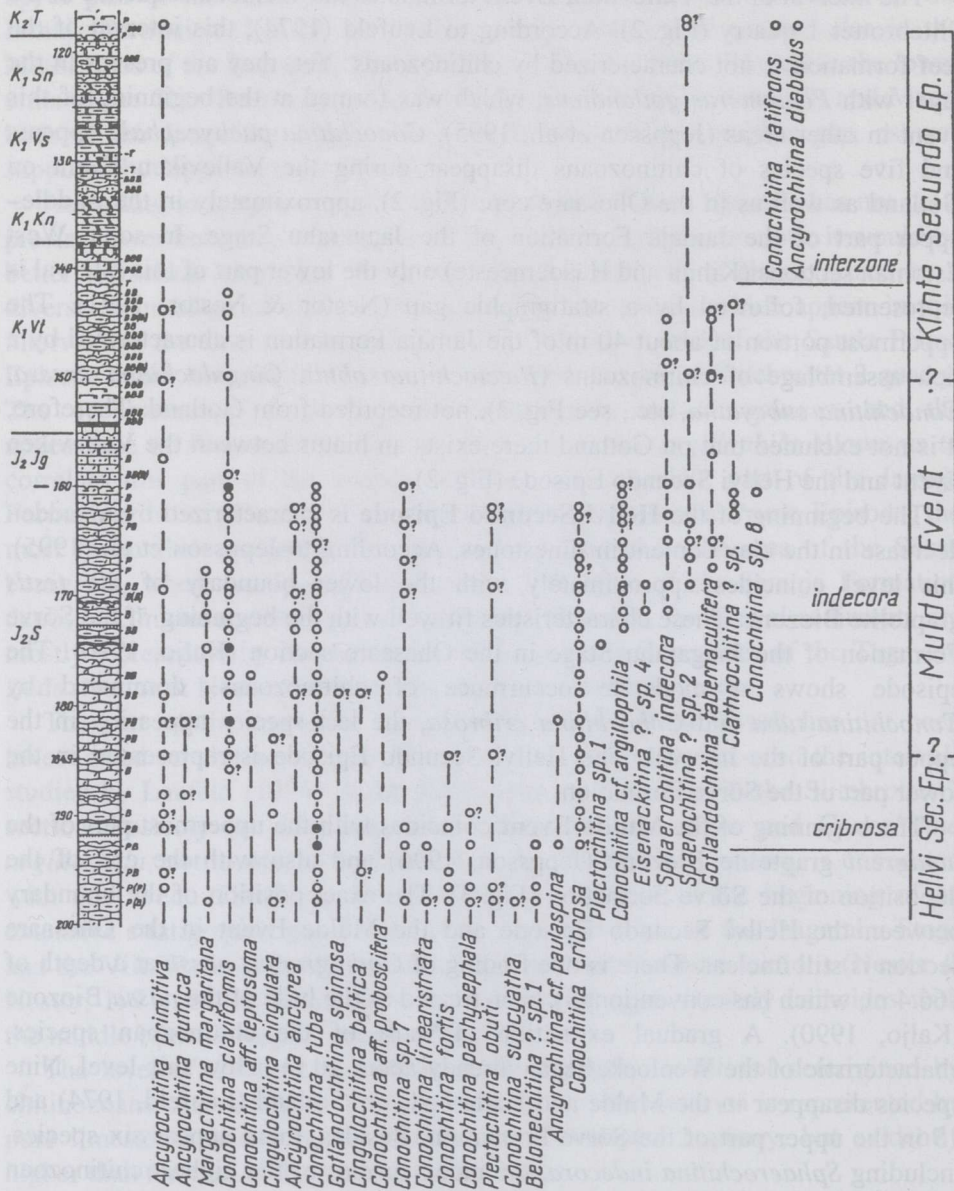


Fig. 3. Lithological log, ranges of chitinozoan species, succession of chitinozoan biozones, and span of the upper Wenlock oceanic episodes and events in the section of the Ohesaare core. Stratigraphic indices: $J_2 S$, Sörve Formation of the Jaagarahu Stage; $J_2 Jg$, Jaagarahu Formation of the same stage; $K_1 Vt$, Viita Beds of the Rootsiküla Stage; $K_1 Kn$, Kuusnõmme Beds of the Rootsiküla Stage; $K_1 Vs$, Vesiku Beds of the Rootsiküla Stage; $K_1 Sn$, Soeginina Beds of the Rootsiküla Stage; $K_2 T$, Torgu Formation of the Paadla Stage. Sec. Ep., Secundo Episode. Organic-walled microfossil association (the number of letters indicates the stage of prevalence): P, planktic elements (mainly chitinozoans) prevailing; B, benthic elements prevailing; T, samples not containing organic-walled microfossils. Key to lithology see Fig. 2.

Viira appears for the first time at the base of the Klinteberg Beds as well as in the Ohesaare section, at a depth of 149.8 m (Jeppsson et al., 1994). Therefore we may correlate the lower boundary of the Klinte Secundo Episode with the lowermost part of the Rootsiküla Stage (Fig. 3).

CONCLUSIONS

Jeppsson's model of primo and secundo oceanic episodes fits well with the diversity cycles of chitinozoans in the Wenlock succession of Estonia. The diversity and abundance of chitinozoans were higher during primo episodes, on average 9–10 species per sample, and lower during secundo episodes, 3–5 species per sample. Such diversity variations are observed also in deeper-water monotonous marlstones. Each event is characterized by a more or less abrupt decrease in chitinozoan diversity. The severest extinctions in the chitinozoan assemblage occurred during the Ireviken and Mulde events. The Boge and Valleviken events were probably coeval with the formation of extensive stratigraphic gaps in the upper part of the Jaagarahu Stage in the sections of northern Saaremaa.

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WENLOCKI OOKEANI EPISOODIDE JA SÜNDMUSTE PEEGELDUMINE KITINOSOADE SUKTSESSIOONIS EESTIS

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Kitinosoade järgnevuse alusel on võimalik rakendada Wenlocki ookeani ja kliima tsüklilisuse mudelit Saaremaa läbilõigete puhul. On määratud ligikaudsed tsüklitevahelised piirid ning analüüsitud muutusi kitinosoade kooslustes "primo" ja "secundo" episoodide ja sündmuste vältel. Liigilise mitmekesisuse tsüklilised muutused on täheldatavad ka Ohesaare Wenlocki läbilõike monotoonsetes merglites. Liikide suurim väljasuremine on seotud Irevikeni ja Mulde sündmusega Wenlocki alguses ja lõpus. Boge ja Vallevikeni sündmusele vastab tõenäoliselt ulatuslik stratigraafiline lünk Saaremaa kesk- ja põhjaosa läbilõigetel.

ОТРАЖЕНИЕ ВЕНЛОКСКИХ ОКЕАНИЧЕСКИХ ЭПИЗОДОВ И СОБЫТИЙ НА СУКЦЕССИИ ХИТИНОЗОЙ В ЭСТОНИИ

Вийу НЕСТОР

Использована модель океанической и климатической цикличности в венлоке о-ва Сааремаа, основанная на сукцессии хитинозой. По изменению ассоциаций хитинозой приблизительно определены границы между "примо" и "секундо" эпизодами и событиями. Выяснилось, что хитинозои более многочисленны и разнообразны в течение "примо" эпизодов. Различия видового разнообразия заметны и в толще монотонных мергелей венлока скв. Охесааре. Уровни максимального исчезновения видов связаны с Иревикским и Мульдеским событиями в начале и конце венлока. События Бoge и Валлевикен совпадают, вероятно, с образованием значительного стратиграфического перерыва в разрезах северной и средней частей о-ва Сааремаа.