

LATE SILURIAN SHALLOW AND DEEP WATER CONODONTS  
OF THE EAST BALTIC

V. Viira

The present paper deals with the zonation of the East Baltic Upper Silurian conodonts and their facies dependence. A large number of samples were studied for to characterize all facies belts from near-shore up to basin one. They come from 7 borings of Saaremaa (Ohesaare, Kaugatuma, Kingissepa, Sakla) and North-West Latvia (Kolka-54, Ventpils, Pavilosta) and also from more than 30 localities of Saaremaa (Fig. 1). Published information is available only on conodonts from Kolka-4 (Гайлите, Ульст, 1974) and Ohesaare boring (Ви́йра, 1977), on the Upper Silurian spathognathodians (Ви́йра, 1982 a), and the apparatus *Ctenognathodus purchisoni* (Ви́йра 1982 б).

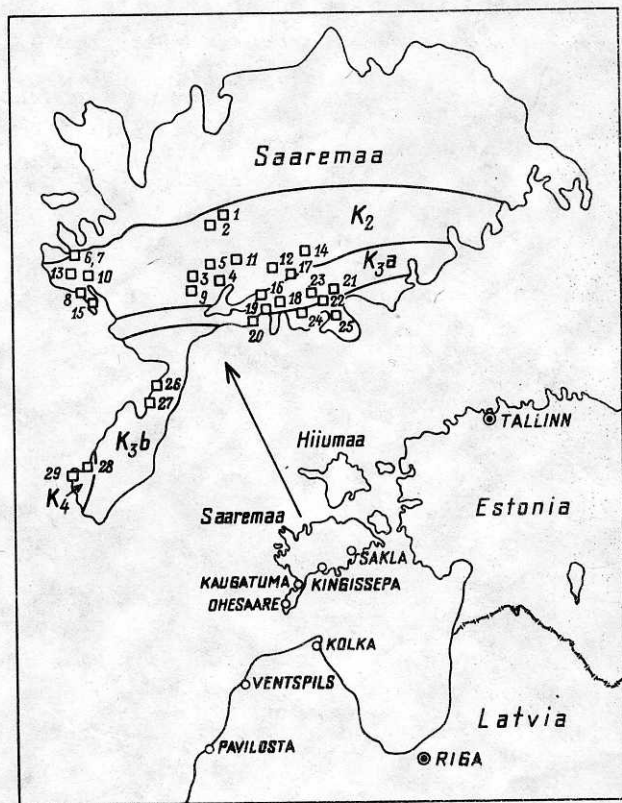


Fig. 1

Location map of outcrops (quadrangles) and borings (circles). Explanation of locality numbers see in Fig. 3.

General distribution

Ludlow and Downton conodont faunas show high abundances and rather low diversity. They are characterized by bar and blade elements, whereas platform elements appear to be of very limited distribution. Carbonate deposits of the shelf area contain the richest fauna where the prevalence of multielement genera *Ozarkodina* and *Oulodus* is typical of the given region. The Ludlow part of the section is rich in the longranging apparatus

tuses *Ozarkodina confluens*, *O. e. excavata*, *Oulodus siluricus*. In the East Baltic they appear gradually beginning with the Lower Wenlock but the largest gatherings occur just in the Ludlow. The Downton contains besides *O. confluens* also abundant *O. s. eosteinhornensis* and *Oul. elegans*. On Gotland different *Ozarkodina* and *Oulodus* (= *Hindeodella* and *Ligonodina*) also occur nearly in the same quantity as in Estonia (Jeppson, 1969, 1972, 1974).

Two distinct changes are observable in stratigraphic range of the Upper Silurian conodonts of the northern East Baltic. The first is expressed by replacement of the Upper Wenlock shallow water *Ctenognathodus murchisoni* association with a rich Ludlow fauna containing *O. confluens*, *O. e. excavata* and *Oul. siluricus*. These apparatuses are known already from the underlying Wenlock deposits but in specific condition of the Rootsiküla time they were rare or lacking. The second change is more distinct. It is defined by the appearance of conodonts of the *eosteinhornensis* Zone. Besides the index-species *O. s. eosteinhornensis*, *Oul. elegans* makes its first appearance on this level. The named two taxa in association with *O. confluens* form the rich Downton fauna. All three apparatuses occur up to the uppermost beds of the Silurian.

#### Taxonomic notes

In the northern East Baltic at the present stage of study the following apparatuses and their component elements have been identified.

1. *Ozarkodina excavata excavata* (Branson et Mehl):

*Spathognathodus inclinatus inclinatus* (Rhodes),  
*Ozarkodina media* Walliser,  
*Neoprioniodus excavatus* (Branson et Mehl),  
*Hindeodella equidentata* Rhodes,  
*Plectospathodus extensus* Rhodes,  
*Trichonodella excavata* (Branson et Mehl).

The apparatus ranges from the Jaani Stage (Lower Wenlock) into the Kuressaare Stage (uppermost Ludlow).

2. *Ozarkodina confluens* (Branson et Mehl):

*Spathognathodus primus* (Branson et Mehl),  
*Ozarkodina typica* Branson et Mehl,  
*Neoprioniodus bicurvatus* (Branson et Mehl),  
*Hindeodella confluens* (Branson et Mehl),  
*Plectospathodus flexuosus* Branson et Mehl,  
*Trichonodella symmetrica* (Branson et Mehl).

Most characteristic part of the apparatus is its spathognathodontan element *S. primus*. On the basis of morphological differences in *S. primus* 5 morphotypes (Klapper, Murphy, 1974) and three subspecies (Helfrich, 1975) have been established. In the northern East Baltic 6 chronological subspecies: *S. primus bucerus* (Wenlock), *S. primus densidentatus* (Uppermost Wenlock), *S. primus retroversus* (Uppermost Wenlock), *S. primus cornidentatus* (Ludlow), *S. primus ambiguus* (uppermost Ludlow) and *S. primus nasutus* (Downton) have been proposed (Виһра, 1982 a). *O. confluens* makes its first appearance in the lowermost beds of the Jaagarahu Stage (Wenlock) and is present up to the end of the Silurian.

3. *Ozarkodina steinhornensis eosteinhornensis* (Walliser):

*Spathognathodus steinhornensis eosteinhornensis* Walliser,  
*Ozarkodina typica denckmanni* Ziegler,  
*Neoprioniodus arisaigensis* Legault,  
*Hindeodella priscilla* Stauffer,

*Plectospathodus alternatus* Walliser,  
*Trichonodella symmetrica* (Branson et Mehl).

The characteristic element is *S. s. eosteinhornensis* in which 4 varieties are distinguished (Ви́йра, 1982 a). The apparatus occurs in the Kuressaare, Kaugatuma and Ohesaare Stages.

4. *Ozarkodina* sp. S :

*Neoprioniodus* ? sp. S Viira, 1977,  
*Ligonodina* sp. S Viira, 1977,  
*Trichonodella* sp. S Viira, 1977.

Undescribed apparatus, evidently containing six robust elements. The apparatus is restricted to the lower half of the Paadla Stage.

5. *Oulodus siluricus* (Branson et Mehl):

*Lonchodina walliseri* Ziegler,  
*Lonchodina greilingi* Walliser,  
*Neoprioniodus multiformis* Walliser,  
*Ligonodina silurica* Branson et Mehl,  
*Trichonodella inconstans* Walliser.

The complete apparatus is illustrated by Chlupač, Křiž und Schönlaub (1980, Table 17, Fig. 20). In the East Baltic Silurian it ranges from the Jaagarahu Stage up to the uppermost beds of the Paadla Stage.

6. *Oulodus elegans* (Walliser):

*Lonchodina detorta* Walliser,  
*Ozarkodina ortuformis* Walliser,  
*Neoprioniodus williamsi* Legault,  
*Ligonodina elegans* Walliser,  
*Trichonodella inconstans* Walliser.

The apparatus occurs in the Kuressaare, Kaugatuma and Ohesaare Stages.

7. *Ctenognathodus murchisoni* (Pander):

*Spathognathodus murchisoni* (Pander),  
*Ligonodina* sp. n. L Viira, 1977,  
*Lonchodina* ? sp. n. N Viira, 1977,  
*Trichonodella* sp. n. V Viira, 1977.

The apparatus is described and illustrated in the paper on the Upper Wenlock shallow water conodonts (Ви́йра, 1982 б). *C. murchisoni* is a guide fossil for the Rootsiküla Formation.

Besides the above named ones elements of the following apparatuses have been found:

*Distomodus dubius* (Rhodes),  
*Pelekysgnathus dubius* Jeppsson,  
*Kockelella variabilis* Walliser,  
*Polygnathoides siluricus* Branson et Mehl.

Names of conodonts interpreted by formal taxonomy are given in inverted commas.

#### Associations

In the East Baltic Wenlock and Upper Silurian the environmental types of conodonts are distinguished: lagoonal, shoal-shelf and slope ones. Terms come from facies belts of the Silurian Paleobaltic Basin (Нестор, Эйнасто, 1977). From the shallow inshore towards the continental slope the associations are as follows: (1) *Ctenognathodus*, (2) *Ozarkodina* and *Oulodus*, (3) *Kockelella* and *Polygnathoides*.

Lagoonal type is represented by *Ctenognathodus* association known from the Upper Wenlock so far. Besides lagoon it occurs also in the transitional area to the shoal

belt (Вийра, 1982 б). Typical representative of this association is *Ctenognathodus murchisoni*, other conodonts are rare. *O. confluens* with a spathognathodontan element "*S.*" *primus retroversus* occurs sometimes.

Shoal-shelf type of conodonts is mostly represented by *Ozarkodina* and *Oulodus*. These two multielement genera are distributed in the whole mentioned area. The shoal belt is rich in *O. confluens* association, which is rather common in the open shelf as well. It occurs in detritic, nodular and clayey limestones. The *O. e. excavata* association is more characteristic of the open shelf belt of Ludlow age but it is found also in the shoal belt. However, *O. e. excavata* does not occur in Downton and its ecological niche is occupied by the *O. s. eosteinhornensis* association. These two associations are characterized by a wider facies affiliation as compared with the *O. confluens* association and they may occur also in clays and marls of the slope belt.

Conodonts of the multielement genus *Oulodus*, being frequent in the shoal and open shelf belts, are mostly represented by species *Oul. siluricus* (Ludlow) and *Oul. elegans* (Downton). *Oul. siluricus* has nearly the same ecological position as *O. confluens*. *Oul. elegans* is more connected with the *O. s. eosteinhornensis* association.

Offshore part of the basin (slope facies belt) was inhabited by the association of *Kockelella variabilis* and *Polygnathoides siluricus* in Ludlow.

#### Zonation

The abundance of conodonts decreases from the shallow part of the basin towards the open sea. Such a situation is especially characteristic of Ludlow conodonts. Simultaneously with decreasing of their number a taxonomic change takes place: in offshore facies platform conodonts appear. Therefore we have presented two zonal schemes: one for shallow and the other for deeper water sediments (Table).

Table  
Northern East Baltic Upper Silurian conodont zones

SERIES	Regional stratigraphic scheme		SHELF AREA		BASIN AREA
			Zone	Subzone	Zone
DOWNTON	DHESAARE		eosteinhornensis	remscheidensis	eosteinhornensis
	KAUGATUMA	LÕO		canadensis	
		ÄIGU		eosteinhornensis s. str.	
KURESSAARE	KUDJAPE	aff. scanica			
	TAHULA				
LUDLOW	PAADLA	UDUVERE	D. dubius - „Belodus” sp.		siluricus
		HIMMISTE	Ozarkodina sp. S-		
		SAUVERE	D. confluens cornidentatus		
WENLOCK	ROOTSIKÜLA	SOEGININA	Ctenognathodus murchisoni		sagitta
		VESIKU			
		KUUSNÕMME			
		VIITA			

Zones with *sagitta*, *eosteinhornensis* and *siluricus* were established in the Carnic Alps by O. Walliser (1964), later on they are recognized in many parts of the world. Other Upper Silurian zones of the northern East Baltic are local. They are assemblage zones presumably. Subzones of the *eosteinhornensis* Zone are based on the replacement of different "*Spathognathodus*" s. *eosteinhornensis* morphotypes.

An important guide fossil is "*Spathognathodus*" aff. *snajdri*. Among conodonts identified as "S." aff. *snajdri* two morphological types similar to "S." *snajdri* and "S." *crispus* are established. In literature both they are interpreted as zonal ones whereas "S." *crispus* is considered stratigraphically younger than "S." *snajdri* (Walliser, 1964; Helfrich, 1975; Chlupač, Kříž, Schönlaub, 1980). In our material there is no clear succession of the above species. E.g. in 15 kg of sample dissolved from Karala locality among hundred specimens of "S." aff. *snajdri* both element types occurred. Thus for ascertaining the position of "S." *snajdri* and "S." *crispus* we mark our forms in the open nomenclature.

"S." aff. *snajdri* ranges from the lower part of the Paadla Stage up to lowermost Kaugatuma Stage. It has been identified in all studied sections of northern East Baltic, including more offshore ones, but also in a number of localities of the Saaremaa (Fig. 2, 3). The lower limit of the "S." aff. *snajdri* range is recognized in the studied borings on the following levels: Sakla 33.2 m, Kingissepa 39.2 m, Ohesaare 113.3 m, Kolka 289.8 m, Ventspils 464.2 m, Pavilosta 622.7 m. Relative to the lower boundary of the Paadla Stage in above sections the species appears step by step higher towards the central part of the basin. The upper limit of the "S." aff. *snajdri* range is more uniform. The latest specimens occur in the lowermost part of the Äigu Beds: Kaugatuma 28.9 m, Ohesaare 61.2 m, Kolka 253.6 m, Ventspils 406.0 m, Pavilosta 604.0 m.

#### Shelf zones

##### *Ctenognathodus murchisoni* Zone

The base of the *murchisoni* Zone (Ви́пра, 1982 6) is defined by the appearance of *C. murchisoni*. The fauna of the zone is dominated by index-species. *O. confluens* is represented by subspecies with a spathognathodontan element "S." *primus retroversus*. *O. sagitta bohemica* and *O. e. excavata* are rare.

The zone corresponds to the Rootsiküla Formation (excl. lowermost part).

The stratotype for the zone is Vesiku outcrop.

##### *Ozarkodina* sp. S - *O. confluens cornidentatus* Zone

The zone is defined primarily on the ranges of the *Ozarkodina* sp. S apparatus. The base of the zone is determined by the first appearance of *Ozarkodina* sp. S or *O. confluens cornidentatus*. The latter subspecies appears in Fig. 2 given borings on levels: Ohesaare 118.0 m, Kaugatuma 81.2 m, Kingissepa 43.3 m, Sakla 34.1 m, Kolka 304.2 m.

The zone is rich in two nominate species. *O. e. excavata* and *Oul. siluricus* are frequent. "S." aff. *snajdri* first appears in this zone.

The zone covers the Sauvere and Himmiste Beds and the lower part of the Torgu Formation. It may be distinguished in the near-shore and shelf areas only. The stratotype of the zone is Roopa cliff.

##### *Distomodus dubius* - "Belodus" sp. Zone

The zone is characterized by the occurrence of *Distomodus dubius*, *Pelekysgnathus dubius* and "Belodus" sp. Its lower boundary is marked by the first appearance of *D. dubius* or "Belodus" sp., in case the former is lacking. The base of the zone lies in borings (Fig. 2) as follows: Ohesaare 106.5 m, Kaugatuma 57.5 m, Kingissepa 35.0 m, Sakla 19.9 m, Kolka 294.6 m.

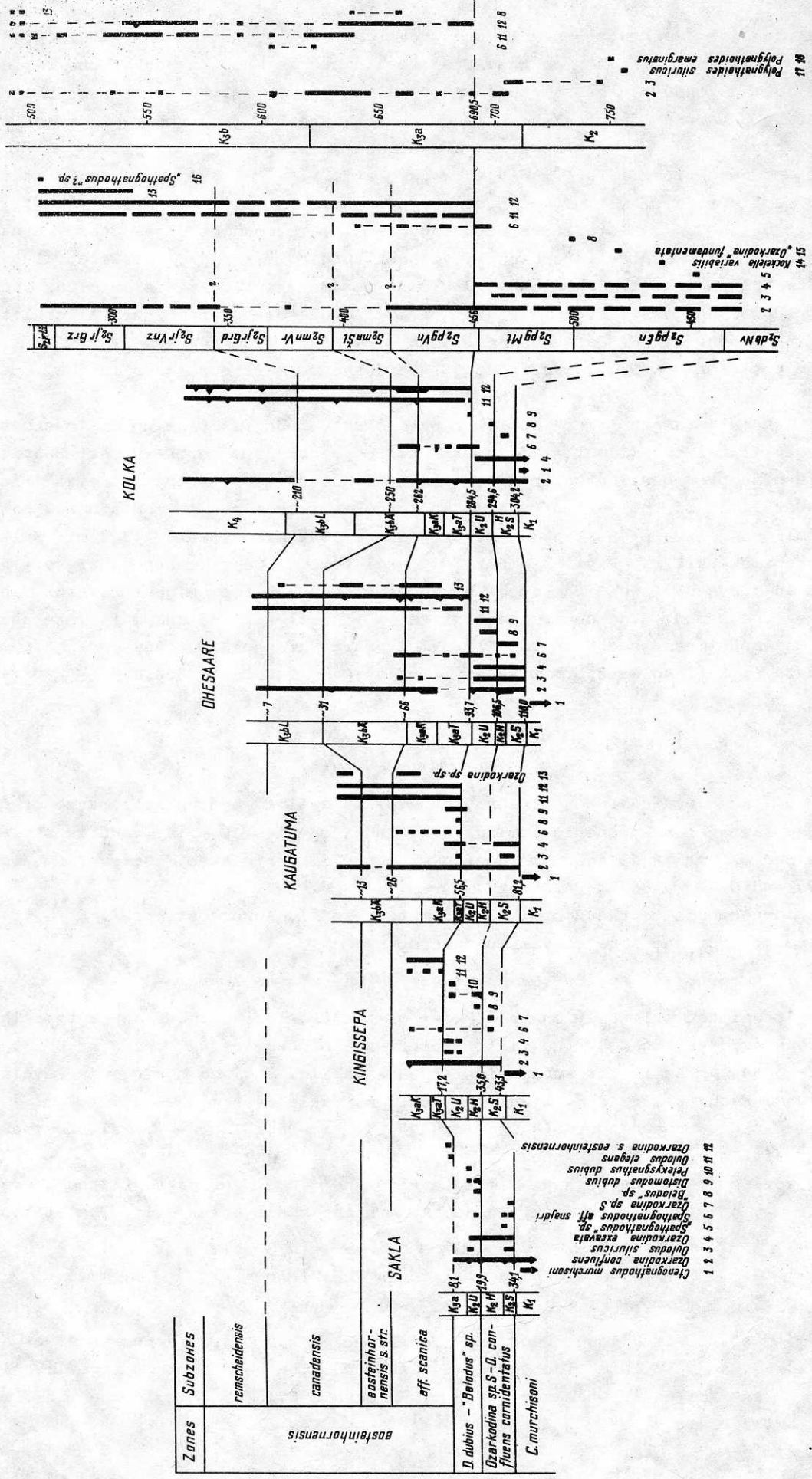


Fig. 2. Correlation of the Upper Silurian boring sections in the northern East Baltic by conodonts. Stratigraphical subdivisions of the Ventspils boring sections in the northern East Baltic by conodonts. Stratigraphical subdivisions of the Ventspils core: S<sub>2</sub>dbNv - Nova Beds of the Dubysa Formation, S<sub>2</sub>pgEn - Engure Member, S<sub>2</sub>pgMt - Mituva Beds, S<sub>2</sub>pgVn - Ventspils Beds, all three the Pagaġiaġi Formation, S<sub>2</sub>mnŠ1 - Šilale Beds and S<sub>2</sub>mnVr - Varniai Beds of the Miniġa Formation, S<sub>2</sub>jrGrd - Girdġiai Beds, S<sub>2</sub>jrVnz - Venzova Beds and S<sub>2</sub>jrGrz - Garġde Beds of the Ķura Formation.

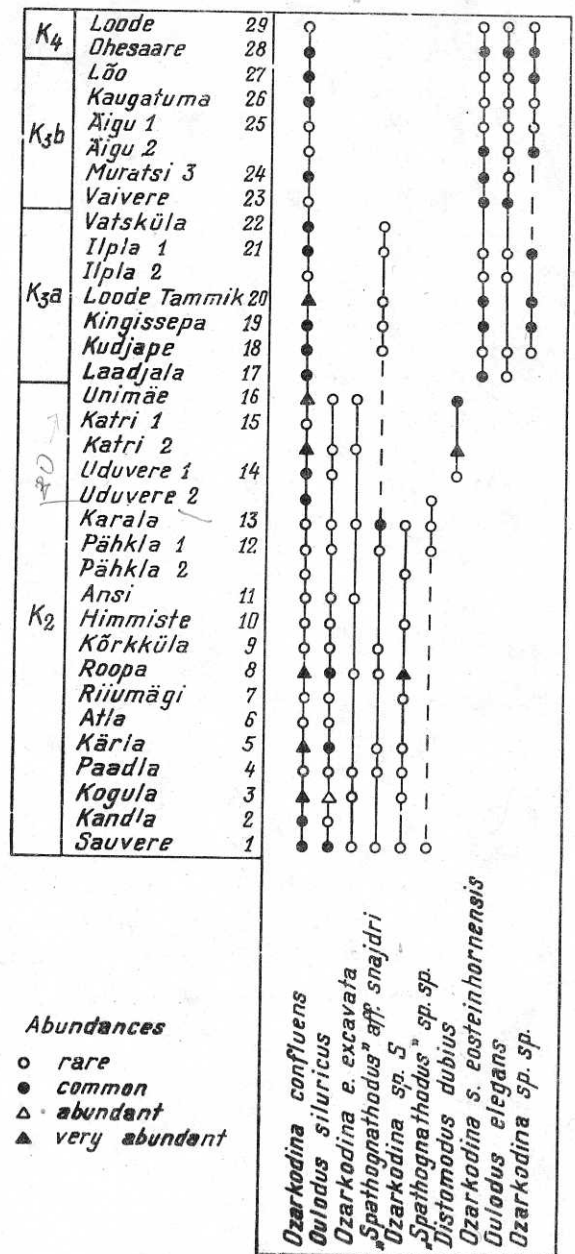


Fig. 3. Distribution of selected conodonts in the Upper Silurian localities of Saaremaa.

Besides the two index species the zone contains *P. dubius*, *O. confluens cornidentatus*, *O. e. excavata*, *Oul. siluricus*. All these conodonts disappear at the upper boundary.

*D. dubius* - "*Belodus*" sp. Zone occupies the Uduvere Beds and upper part of the Torgu Formation. The zone has been determined in the sections of the shelf area.

The stratotype of the zone is Unimäe abandoned quarry.

*Ozarkodina steinhornensis eosteinhornensis* Zone

In the East Baltic the lower boundary is well distinguished by the appearance of numerous specimens of all zonal apparatus elements and those of usually accompanying it *Oul. elegans*. The third, more frequent apparatus is *O. confluens* with two spathognathodontan elements on subspecies level "*S.*" *primus ambiguus* and "*S.*" *primus nasutus*. Besides them there occur "*S.*" aff. *snajdri* (in the lower subzone) and undescribed new apparatus of *Ozarkodina* (at least two taxa).

The *eosteinhornensis* Zone reaches the uppermost beds of the Silurian section of the northern East Baltic. In the East Baltic basin it has been identified in all the

studied sections. However, the investigations revealed a difference in the frequency of occurrence: while in relatively shallow water sections (Kaugatuma, Ohesaare, Kolka) it is common and found almost in all samples, in places even in great abundances, then in deeper water deposits (Pavilosta) it is rare and occurs, by no means, in all samples.

On the basis of the stratigraphical distribution of morphotypes of the "S." s. *eosteinhornensis* element subzones are distinguished in the shelf deposits (Ви́йра, 1982 a). However, as differences between morphotypes have transitional character the limits of subzones are not always clear.

*Ozarkodina s. eosteinhornensis* aff. *O. s. scanica* Subzone. The lower boundary coincides with that of the *eosteinhornensis* Zone. The subzone corresponds to the interval of the occurrence of the earliest morphotype. By its morphology the spathognathodontan element of *O. s. eosteinhornensis* aff. *O. s. scanica* is similar to that of *Hindodella steinhornensis scanica* apparatus described by L. Jeppsson (1974) from the Öved Ramsåsa Group at Bjäsjölagård, Klinta and Tullesbo in Skåne.

The subzonal association consists besides the index-species of *O. confluens ambiquus*, *Oul. elegans*, "S." aff. *snajdri*, *Ozarkodina* sp. Stratigraphically the subzone occupies nearly all of the Kuressaare Formation (except its uppermost part).

*Ozarkodina s. eosteinhornensis* s. str. Subzone. The lower boundary is determined by the appearance of specimens of the typical subspecies in the topmost part of the Kuressaare Formation. "S." aff. *snajdri* terminate within this subzone. The subzone corresponds to the Äigu Beds of the Kaugatuma Formation.

*Ozarkodina s. eosteinhornensis canadensis* Subzone. This subzone determined by *canadensis* morphotype, covers the Lõo Beds of the Kaugatuma Formation. The lower and upper boundaries are indistinct as the appearance of *canadensis* and *remscheidensis* morphotypes is gradual. Besides the index morphotype there can also be found the *remscheidensis* morphotype but in small numbers.

*Ozarkodina s. eosteinhornensis remscheidensis* Subzone. The subzone is distinguished by the predominance of the *remscheidensis* morphotype at which the *canadensis* morphotype continues their existence. A characteristic feature of this subzone is that *O. confluens* is represented by subspecies with a spathognathodontan element "S." *primus nasutus* appearing in the upper part of the *canadensis* Subzone.

## Basin zones

### *Polygnathoides siluricus* Zone

This zone is defined on the occurrences of the index-species in two sections: Pavilosta (Latvia), depth 756.0 m (2 specimens) and Vidukle (Lithuania), depth 1166.2 m (1 specimen). Besides the index-species "P." *emarginatus* (Pavilosta, depth 750.3 m) and *D. dubius*, *P. dubius* (Vidukle, depth 1166.2 m) have been identified. The last two give reason for correlation the *siluricus* Zone with the *D. dubius* Subzone of the shelf area, at least with a part of it.

### *Ozarkodina s. eosteinhornensis* Zone

The zone was described above in more detail. In general the conodont complex is analogous with that of the shelf area. However, offshore deposits finds of all conodonts, also of the index-species, are comparatively rare. Thus reliability of drawn zonal boundaries depends, first of all, on the frequency and sizes of samples.



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