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Late Silurian conodont biostratigraphy in the northern East Baltic

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ABSTRACT – *Conodont biostratigraphy of the late Silurian Paadla to Ohesaare stages of the northern East Baltic is described based on the conodont fauna collected over a long period from the rock samples of many outcrops and about 20 borehole sections. The conodont distribution from shallow shelf (Kolka borehole) through open shelf (Ohesaare and Ventspils boreholes) to deeper part (Pavilosta borehole) of the Palaeobaltic Basin is discussed. A stratigraphically rather sharp faunal change took place on the boundary of the Paadla and Kuressaare stages. The studied interval includes the snajdri, crispa and remscheidensis zones. The last zone is subdivided into four subzones: baccata, eosteinhornensis, canadensis and remscheidensis. The eosteinhornensis Subzone marks the beginning of the Pridoli. The detorta Zone occupies a short interval in the remscheidensis Subzone.*

RIASSUNTO – [Biostratigrafia a conodonti del Siluriano superiore nella parte settentrionale del Baltico orientale] – *La fauna a conodonti estratta da campioni di molti affioramenti e di circa venti perforazioni consente di tracciare un quadro biostratigrafico del Siluriano superiore della parte settentrionale del Baltico orientale. Viene discussa la distribuzione dei conodonti da ambienti costieri (pozzo Kolka), alla parte più profonda (pozzo Pavilosta) del bacino paleobaltico, passando per tutti gli ambienti intermedi (pozzi Ohesaare e Ventspils). Dal punto di vista stratigrafico, una netta variazione delle faune si riscontra al limite tra i piani Paadla e Kuressaare. L'intervallo studiato comprende le biozone a snajdri, crispa e remscheidensis; quest'ultima viene divisa in quattro sottozone: baccata, eosteinhornensis, canadensis e remscheidensis. La sottozona a eosteinhornensis segna la base del Pridoli; la Biozona a detorta è limitata a un breve intervallo nella Sottozona a remscheidensis.*

INTRODUCTION

Late Silurian conodont faunas, as all Lower Palaeozoic faunas, are abundant in the northern East Baltic. A brief review of the distribution and zonation of Ordovician and Silurian conodonts is found in the monograph *Geology and Mineral resources of Estonia* (Raukas & Teedumäe, 1997). The late Silurian conodont fauna has been studied since the 1970s, but the results have been partly published in Russian (Viira, 1970, 1982, 1983, 1994; Männik & Viira, 1993). For this reason the present research was initiated, with the intention of making the most important results of the cited papers accessible for a wider audience. Recently a paper on the latest Silurian (Ohesaare Stage) conodonts and the position of the *detorta* Zone was submitted for publication (Viira, in press). In the course of preparing the latter manuscript all Upper Silurian conodont collections, extant and newly obtained were examined. The aim of this paper is to summarize all conodont data and to give the survey of whole late Silurian conodont biostratigraphy. The present study deals with the Ludlow Paadla and Kuressaare stages and the Pridoli Kaugatuma and Ohesaare stages in the north-western Latvia and on Saaremaa Island of Estonia (Text-figs. 1, 2).

GEOLOGICAL SETTING

The Upper Silurian deposits of the East Baltic formed at the period of the general regression, during the last infilling stage of the development of the Palaeobaltic Basin (Nestor & Einasto, 1997). The infilling stage began with a brief transgressive event during the Kuressaare Stage and is represented by different marlstones and nodular argillaceous biomicritic limestones. This late Ludlow transgression reached its maximum at the beginning of the Pridoli (early Kaugatuma time). The deeper basin where calcareous-argillaceous muds deposited was very wide and extended from south-western Latvia to north-western Poland. In the onshore direction (northern Latvia, Saaremaa Island), it was gradually followed by open shelf biomicritic marlstones and bioclastic to crinoidal limestones of the shoal belt. During the late Kaugatuma and Ohesaare times, the general facies pattern remained unchanged but all facies belts migrated gradually south-westwards. Due to unstability of the bottom, the intercalation of deposits of neighbouring facies often took place.

The East Baltic area has some advantages for Upper Silurian conodont studies. Shelf deposits have yielded good fauna, including index species, especially the



Text-fig. 1 - Location map and facies belts (I-III) of the early Pridoli (after Bassett *et al.*, 1989). I - inshore lagoon/restricted shelf, II - shoal, III - open shelf. Borehole sections: 1) Ohesaare, 2) Kolka, 3) Ventspils, 4) Pavilosta. The dashed line: the boundary of present extension of rocks.

Ozarkodina remscheidensis group. Besides, many borehole sequences penetrate through Silurian sediments. All this allows us to establish vertical ranges and lateral distribution of conodonts from shallow shelf to deeper basin. In the present paper the facies concept by Nestor & Einasto (1977, 1997) is used. They distinguished five facies belts in the Palaeobaltic Silurian Basin, but here shoal, open shelf and transitional belts receive most attention.

MATERIAL

The conodonts discussed herein come from the borehole and outcrop samples collected over a long period. Some of the borehole sections (Pavilosta,

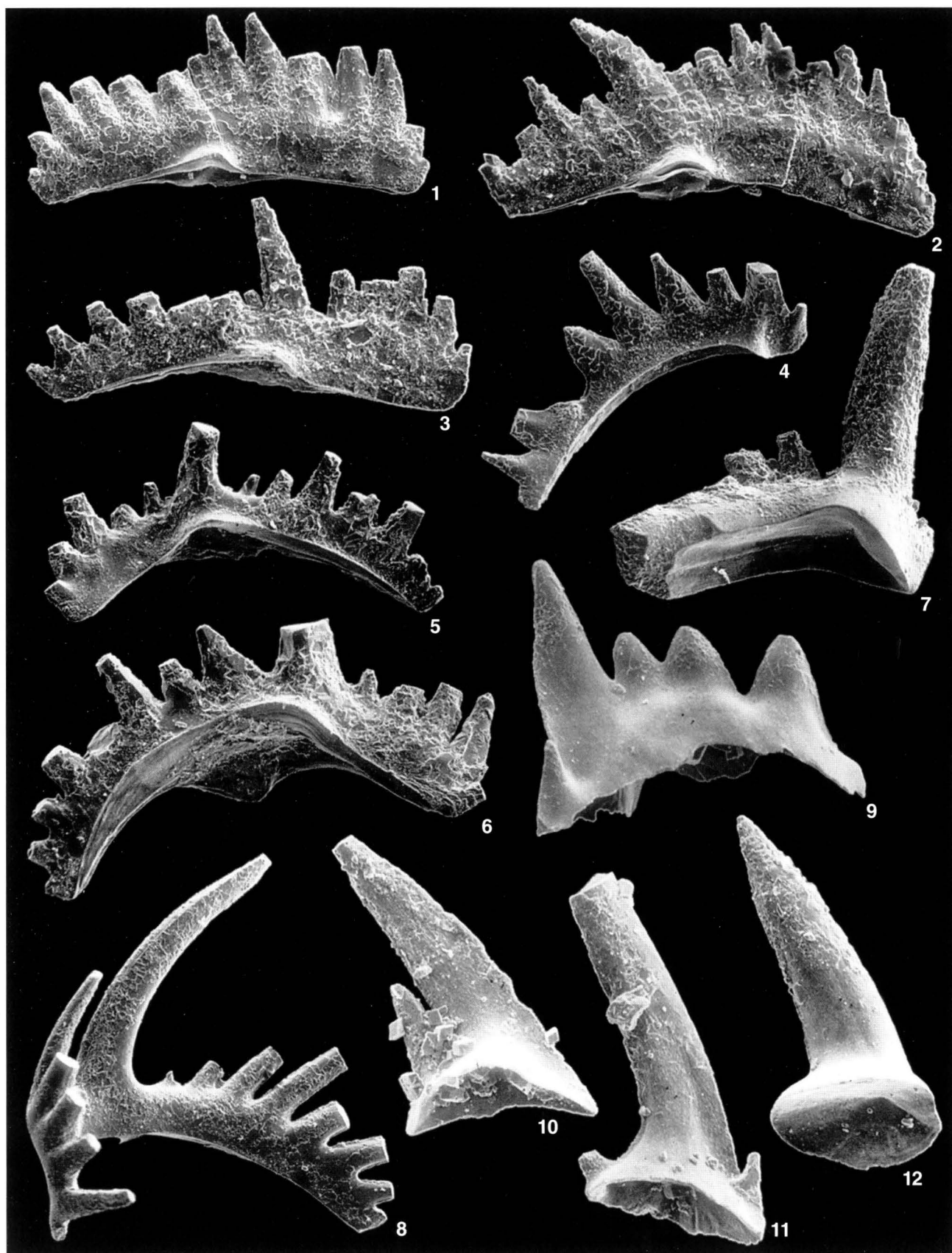
Ventspils) were sampled and prepared for conodonts and vertebrates together with T. Märss. As a result, thousands of specimens in hundreds of samples from numerous outcrops and boreholes were got. Barren samples were very rare - only a few small samples from boreholes. The samples from outcrop sections weighed on average 4-5 kg and those from the boreholes 500-1300 g. The index of colour alteration is about 1. For the present study four borehole sections chosen to demonstrate the late Silurian conodont distribution from shallow shelf (Kolka) through open shelf (Ohesaare, Ventspils) to deeper part (Pavilosta) of the Palaeobaltic Basin (Text-fig. 3).

BIOSTRATIGRAPHY

The distribution and evolution of the late Silurian conodonts in the northern East Baltic are closely correlated with the development and environmental conditions of this pericontinental sea. The diversity of conodont species is highest in the Ludlow Paadla Stage where a number of species of the genera *Ozarkodina*, *Oulodus* and *Ctenognathodus* are widely distributed or make their first appearance (Männik & Viira, 1993). This Ludlow radiation phase was in a way caused by wide-spread different environments of the shallow shelf giving rise to some specific near-shore biofacies and specific shallow-water conodonts, for example *Ozarkodina roopaensis* (Viira, 1994). Besides Saaremaa Island this species is in the northern East Baltic identified only in the Kolka section (Text-fig. 3). For the Paadla Stage, *Ozarkodina confluens* is most common. It appears first, according to the shallowing of the basin, in the middle Wenlock in the onshore part (Saaremaa Island) and gradually later towards the basin, until in the Pavilosta section it occurs already in the upper part of the Ludlovian Pagegiai Formation. Another facies-depending species in the Paadla Stage

EXPLANATION OF PLATE 1

- Figs. 1-4 - *Ozarkodina excavata* (Branson et Mehl).
 1) Pa element, section Karala, sample 1, Cn 1534, x 65;
 2) Pa element, section Karala, sample 1, Cn 1535, x 95;
 3) Pb element, section Karala, sample 2, Cn 1536, x 100;
 4) M element, section Karala, sample 2, Cn 1537, x 80.
- Figs. 5-8 - *Oulodus siluricus* (Branson et Mehl).
 5) Pb element, section Karala, sample 2, Cn 1538, x 80;
 6) Pa element, section Karala, sample 1, Cn 1539, x 65;
 7) M element, section Karala, sample 2, Cn 1540, x 60;
 8) Sc element, section Karala, sample 1, Cn 1541, x 50.
- Figs. 9-12 - *Coryssognathus dubius* (Rhodes)
 9) Pa element, section Unimäe, sample 2-74, Cn 1542, x 110;
 10) M element, section Unimäe, sample 2-74, Cn 1543, x 120;
 11) Pb element, section Unimäe, sample 2-74, Cn 1544, x 120;
 12) coniform element, section Unimäe, sample 2-74, Cn 1545, x 100.
- (Specimens shown in lateral view).



SERIES	REGIONAL STAGES	SAAREMAA NORTH LATVIA	NORTH-WEST LATVIA	WEST LATVIA	CONODONT ZONES
PRIDOLI	OHESAARE	KAIVI MB. OHESAARE FM.	TARGALE FM.	JURA FM.	detorta
	KAUGATUMA	KAUGATUMA FM.	MINIJA FM.	MINIJA FM.	remscheidensis canadensis easternhornensis
LUDLOW	KURESSAARE	KURESSAARE FM.	VENTSPILS FM.	PAGEGIAI FM.	baccata/snajdri parasnajdri
	PAADLA	TORGU FM. PAADLA FM.	MITUVA FM. ENGURE FM.	DUBYSIA FM.	crispa snajdri snajdri

Text-fig. 2 - Late Silurian stratigraphic units in the northern East Baltic.

is *Oulodus siluricus*. Analogically to *Ozarkodina confluens*, it is numerous in shoal and open shelf belts of the Ohesaare and Kolka sections but is absent in the transitional belt of the Pavilosta section. *Ozarkodina excavata*, however, is absent in the shallow-water Kolka section. In the upper part of the Paadla Stage the index species *Ozarkodina crispa* and *Coryssognathus dubius* appear. *Ozarkodina crispa* is represented by two specific alpha morphs in the Silurian shallow-water pericontinental sea of the northern East Baltic (Viira & Aldridge, 1998). These morphs are characterized by a small size and short blade, with fused or unfused posterior denticles. The basal cavity may not extend to the posterior tip. *Ozarkodina crispa* alpha morphs are succeeded by *Ozarkodina snajdri parasnajdri* which usually has a long blade and large posteriorly situated

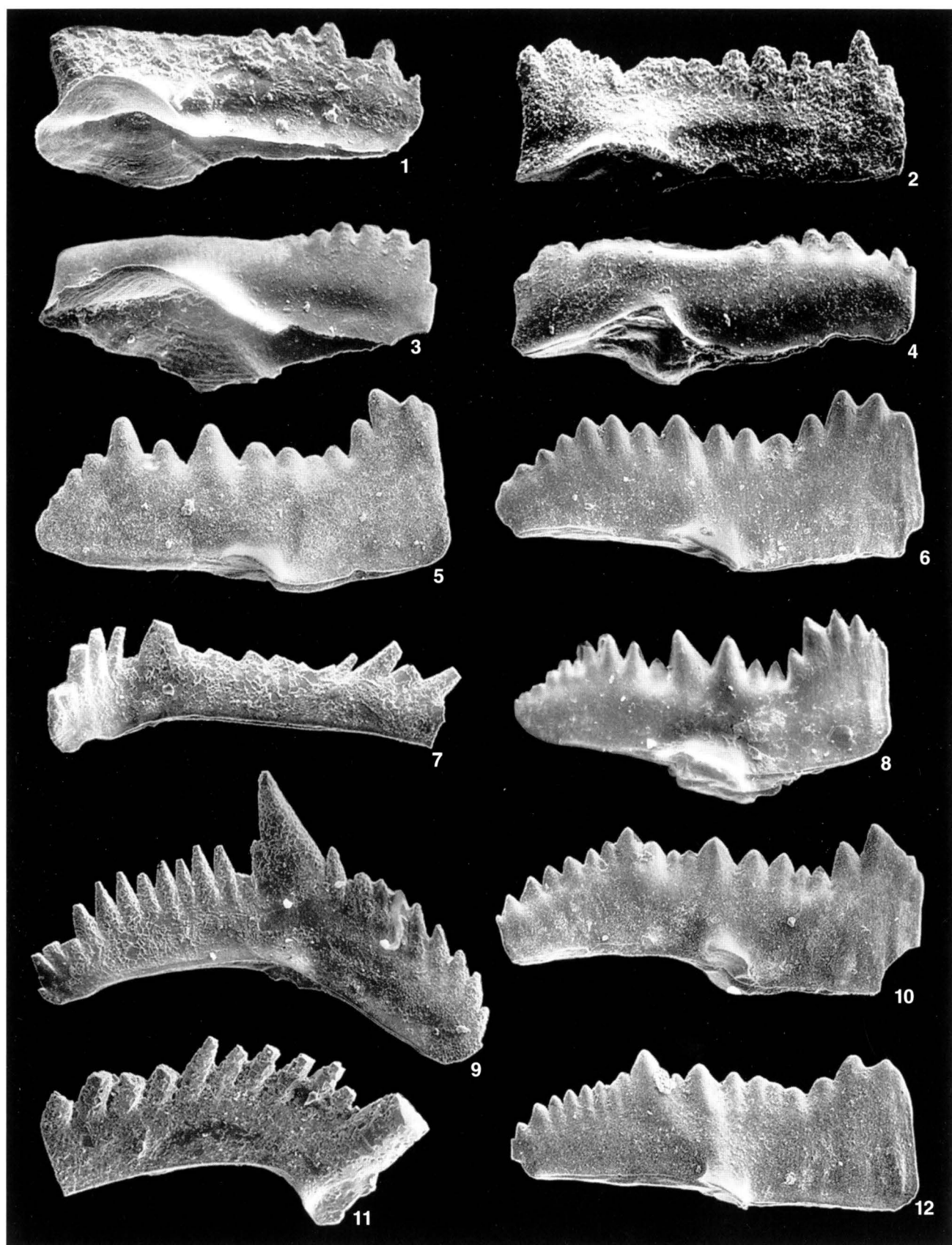
basal cavity. The distribution of the two latter species is somewhat different (Text-fig. 3). In the shallow shelf area (Kolka, Ohesaare) *Ozarkodina crispa* occurs in the upper part of the Paadla and Torgu formations and is replaced by *Ozarkodina s. parasnajdri* in the uppermost Ludlow Kuressaare Formation. In the Ventspils section *Ozarkodina crispa* makes its appearance in the Ventspils Formation and disappears in the lower part of the Miniija Formation which is supposed to be of Pridolian age. The range of *Ozarkodina s. parasnajdri* lies within the *Ozarkodina crispa* range in this section. In the deeper part of the basin (Pavilosta) *Ozarkodina crispa* alpha morphs are absent and both subspecies of *Ozarkodina snajdri* are likely to define together the Ludlow-Pridoli boundary beds. So it is possible to follow the gradual moving of the range of *Ozarkodina crispa* stratigraphically upward from middle Ludlow Sauvere Beds of the Paadla Stage on Saaremaa Island (Sakla, Riksu boreholes) to the uppermost Ludlow in the more southward borehole sections (Uduvere Beds of the Paadla Stage at Ohesaare, Kuressaare Stage at Kolka, and Ventspils Formation at Ventspils). At the boundary between the upper Ludlow Paadla and Kuressaare stages more than 75% of the species and 40% of the genera (*Ctenognathodus*, *Kockelella* etc.) disappear, expressed more distinctly in Saaremaa Island sections. At the lower boundary of the Kuressaare Stage appear *Ozarkodina remscheidensis* and *Oulodus elegans*, different subspecies of which in association with the *Ozarkodina confluens* form the prevalent and relatively uniform Pridoli fauna. Approximately at the same level *Ozarkodina excavata* and *Oulodus siluricus* disappear.

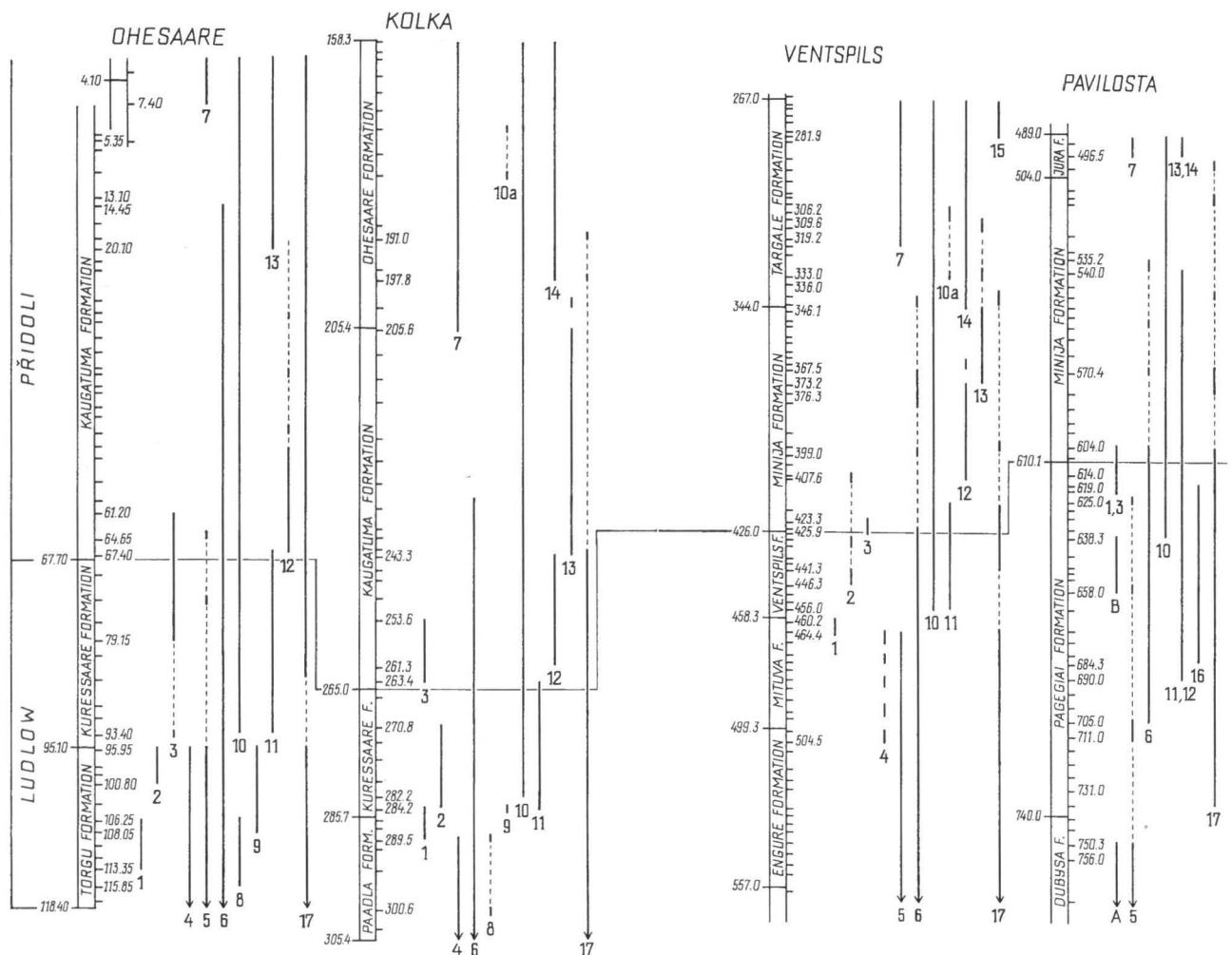
The abundance of specimens in all studied sections and outcrops has allowed us to examine the morphology and variability of these species and distinguish different subspecies of *Ozarkodina remscheidensis* and *Ozarkodina confluens* (Viira, 1983). For this purpose numerous

EXPLANATION OF PLATE 2

- Figs. 1-2 - *Ozarkodina crispa* (Walliser).
 1) alpha 2 morph, Pa element, Kaugatuma borehole, 58.5 m, Cn 1546, x 140;
 2) alpha 3 morph, Pa element, section Paadla, sample 3-73, Cn 1547, x 120.
- Fig. 3 - *Ozarkodina snajdri parasnajdri* Viira & Aldridge.
 Pa element, Kaugatuma borehole, 45.5 m, Cn 1548, x 135.
- Fig. 4 - *Ozarkodina cf. snajdri* (Walliser).
 Pa element, section Pähkla, sample 1-74, Cn 1549, x 90.
- Figs. 5-12 - *Ozarkodina confluens* (Branson & Mehl).
 5) Pa element, section Uduvere, sample 14-76, Cn 1550, x 45;
 6) Pa element, section Uduvere, sample 10-76, Cn 1551, x 45;
 7) Sc element, section Karala, sample 2, Cn 1552, x 85;
 8) Pa element, section Vatsküla, sample 1-74, Cn 1553, x 60;
 9) Pb element, section Karala, sample 2, Cn 1554, x 65;
 10) Pa element, section Uduvere, sample 14-76, Cn 1555, x 35;
 11) M element, section Karala, sample 2, Cn 1556, x 75;
 12) Pa element, section Uduvere, sample 9-76, Cn 1557, x 35.

(Specimens shown in lateral view)





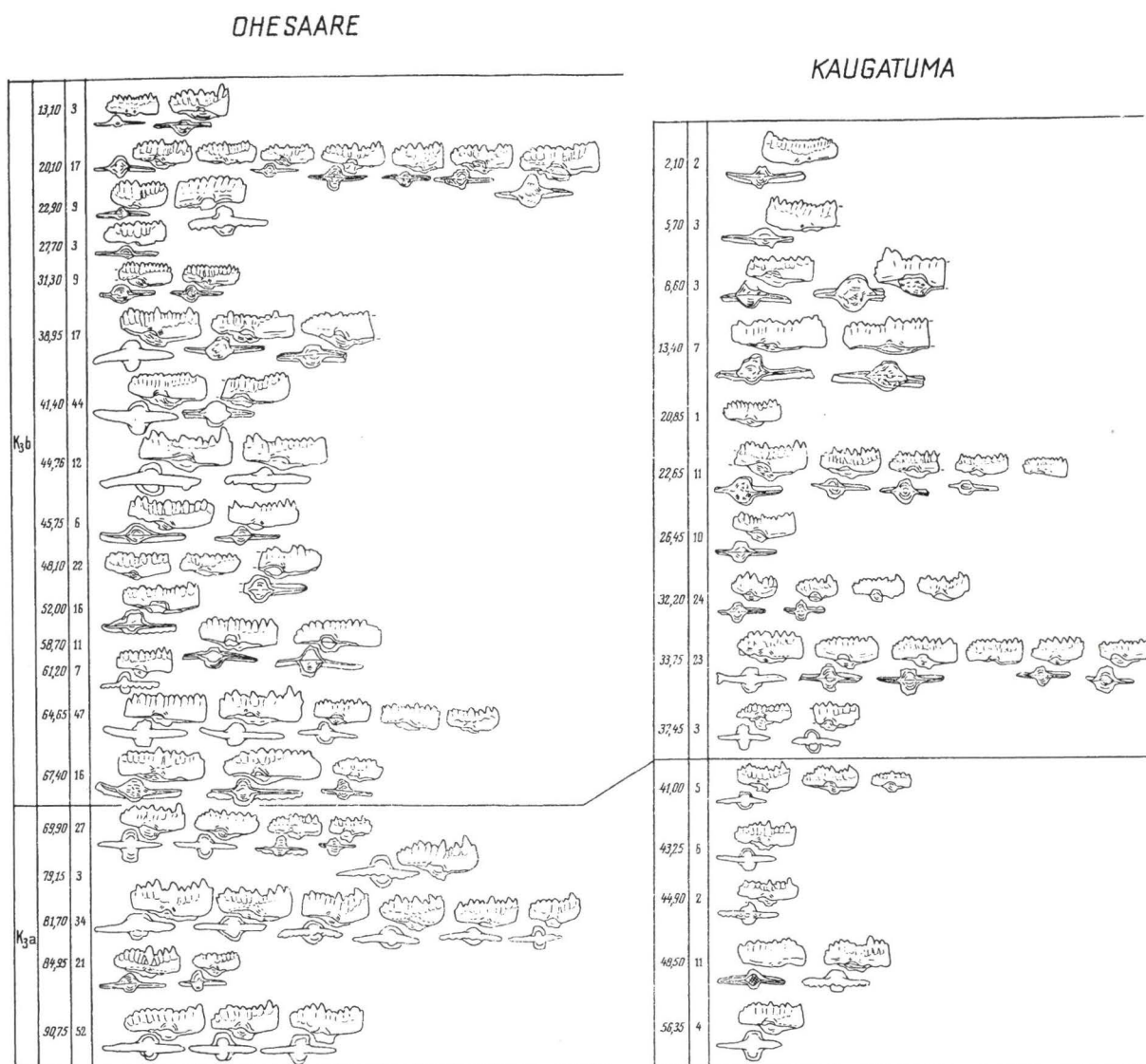
Text-fig. 3 - Ranges of the conodont species in the boreholes under discussion. A) *Polygnathoides siluricus* Branson & Mehl, B) *Belodella* sp., 1) *Ozarkodina snajdri snajdri* (Walliser), 2) *Ozarkodina crista* (Walliser), 3) *Ozarkodina snajdri parasnajdri* Viira et Aldridge, 4) *Oulodus siluricus* (Branson & Mehl), 5) *Ozarkodina excavata* (Branson & Mehl), 6) *Ozarkodina confluens* (Branson & Mehl), 7) *Ozarkodina nasuta* (Viira), 8) *Ozarkodina roopaensis* Viira, 9) *Corysognathus dubius* (Rhodes), 10) *Oulodus elegans* (Walliser), 10a) *Oulodus elegans detorta* (Walliser), 11) *Ozarkodina remscheidensis baccata* Miller & Aldridge, 12) *Ozarkodina remscheidensis eosteinhornensis* (Walliser), 13) *Ozarkodina remscheidensis canadensis* (Walliser), 14) *Ozarkodina remscheidensis remscheidensis* (Ziegler), 15) *Amydrotaxis ? praecox* Viira, 16) *Pseudooneotodus* sp., 17) *Panderodus* sp.

specimens from sample to sample in the stratigraphic succession were studied and 460 specimens illustrated (Viira, 1983, figs. 2-4, 9, 13-15). Fig. 4 from that paper with drawings of specimens of *Ozarkodina remscheidensis* from the Ohessaare and Kaugatuma borehole sections is reprinted in this paper (Text-fig. 4). On the basis of the morphologic changes of the *Ozarkodina remscheidensis* Pa elements four taxa were identified on four stratigraphic levels. The taxonomic revision of these taxa is given in the section "Taxonomic remarks". The stratigraphically first *Ozarkodina remscheidensis baccata* (in former papers as subspecies aff. *scanica*) has the Pa element which is characterized

by irregular denticles and asymmetrically flared cavity (Miller & Aldridge, 1997). This subspecies appears abruptly in the Kuressaare Formation in the sections on Saaremaa, partly as a result of the stratigraphic gap, and gradually in more basinal sections (Pavilosta). In the boundary beds of the Kuressaare and Kaugatuma stages *O. remscheidensis eosteinhornensis* makes its appearance. The Pa element of this subspecies is characterized by equal denticles and the absence of the node on the lobe. Similar specimens were described as alpha morph of this subspecies from Sardinia by Olivieri & Serpagli (1990). Our *O. r. eosteinhornensis* specimens belong supposedly to this alpha morphotype.

In the upper part of the Kaugatuma Stage the third member of the *O. remscheidensis* lineage, *O. r. canadensis*, prevails. This subspecies has a big denticle in the centre of the blade. *Ozarkodina canadensis* was described as a Pa element (*Spathognathodus*) from the Sutherland River Formation of Devon Island (Walliser, 1960). Later, Walliser (1964) put this taxon in the synonymy of *Spathognathodus steinhornensis remscheidensis*. In the present paper *O. r. canadensis* is regarded as a separate taxon occurring stratigraphically

between *O. r. eosteinhornensis* and *O. r. remscheidensis*. The latter subspecies from the Ohesaare Stage is the last member of this lineage and is similar but not identical with the *Ozarkodina remscheidensis* from the Lower Devonian Hüingshäuser Schichten of the Rheinisches Schiefergebirge (Ziegler, 1960). The Pa element of the late Silurian subspecies differs from the Lower Devonian one in a shorter blade and smaller denticles at the anterior end (Pl. 3, figs. 5-7). Still, the samples from the Kaavi Member (uppermost Ohesaare



Text-fig. 4 - Specimens of *Ozarkodina remscheidensis* in the Ohesaare and Kaugatuma boreholes (from Viira, 1983). On the left columns the depths of samples in meters and number of specimens are marked. The specimens in the Kuressaare Stage (K3a) are determined as *Ozarkodina remscheidensis baccata*, the specimens in the Kaugatuma Stage (K3b) in the interval 67.40 m up to 22.90 m of Ohesaare borehole and in the interval 33.75 m up to 2.10 m of Kaugatuma borehole as *Ozarkodina remscheidensis eosteinhornensis*. First specimens of *Ozarkodina remscheidensis canadensis* appear on the depth 20.10 m in the Ohesaare borehole.

Stage) contained specimens of the Pa element with a rather long blade and well-developed high anterior part of the blade, which showed strong resemblance to the type specimens from the Schiefergebirge (Viira, in press). The complete successive distribution of these four subspecies of *Ozarkodina remscheidensis* from late Ludlow up to the latest Silurian is observed in shelf facies sections Ohesaare, Kolka and Ventspils (Text-fig. 3). In the deeper basin area (Pavilosta), due to relative sparseness of specimens, all subspecies cannot be exactly defined. Another lineage in the late Silurian is the *Ozarkodina confluens* group of apparatuses. In the paper by Viira (1983), *Spathognathodus* (= *Ozarkodina*) *confluens cornidentatus* was described in the Paadla Stage and *Spathognathodus* (= *Ozarkodina*) *confluens ambiguus* in the Kuressaare Stage. The first subspecies has 2-3 big posteriorly inclined denticles in the central-posterior part of the blade (Pl. 2, figs. 5, 6, 10, 12); *O. confluens ambiguus* is characterized by a convex posterior part of the blade in the lateral view (Pl. 2, fig. 8). These two taxa are mostly distributed in the shoal and open shelf facies belts. The last member of the *Ozarkodina confluens* lineage is *Ozarkodina nasuta* (= *Spathognathodus confluens nasutus* Viira, 1983) from the Ohesaare Stage of the latest Silurian. *Ozarkodina nasuta* has a distinct very high anterior part of the blade (Pl. 4, figs. 7, 8). The stratigraphic range of the latter species is determined by the Ohesaare Stage and it is present in all studied sections and outcrops of latest Silurian age. The third most numerous Late Silurian species in the East Baltic is *Oulodus elegans*. It appears in the sections of Saaremaa Island after the gap, abruptly above the lower boundary of the Kuressaare Stage together with *Ozarkodina remscheidensis baccata*. Only in the Pavilosta section *Oulodus elegans* appears later due to the belated shallowing of the sea. The subspecies

Oulodus elegans detorta is recorded in the limits of the *Ozarkodina r. remscheidensis* range, not reaching the Silurian-Devonian boundary (Viira, in press). This is clearly observed in the Ventspils section where the boundary of the systems is defined by vertebrates (Märss, 1986). In the uppermost part of the Targale Formation at Ventspils, above the *Oulodus e. detorta* range, a species having the Pa element with a widely opened basal cavity is preliminarily supposed to belong to the genus *Amydrotaxis* (Viira, in press)

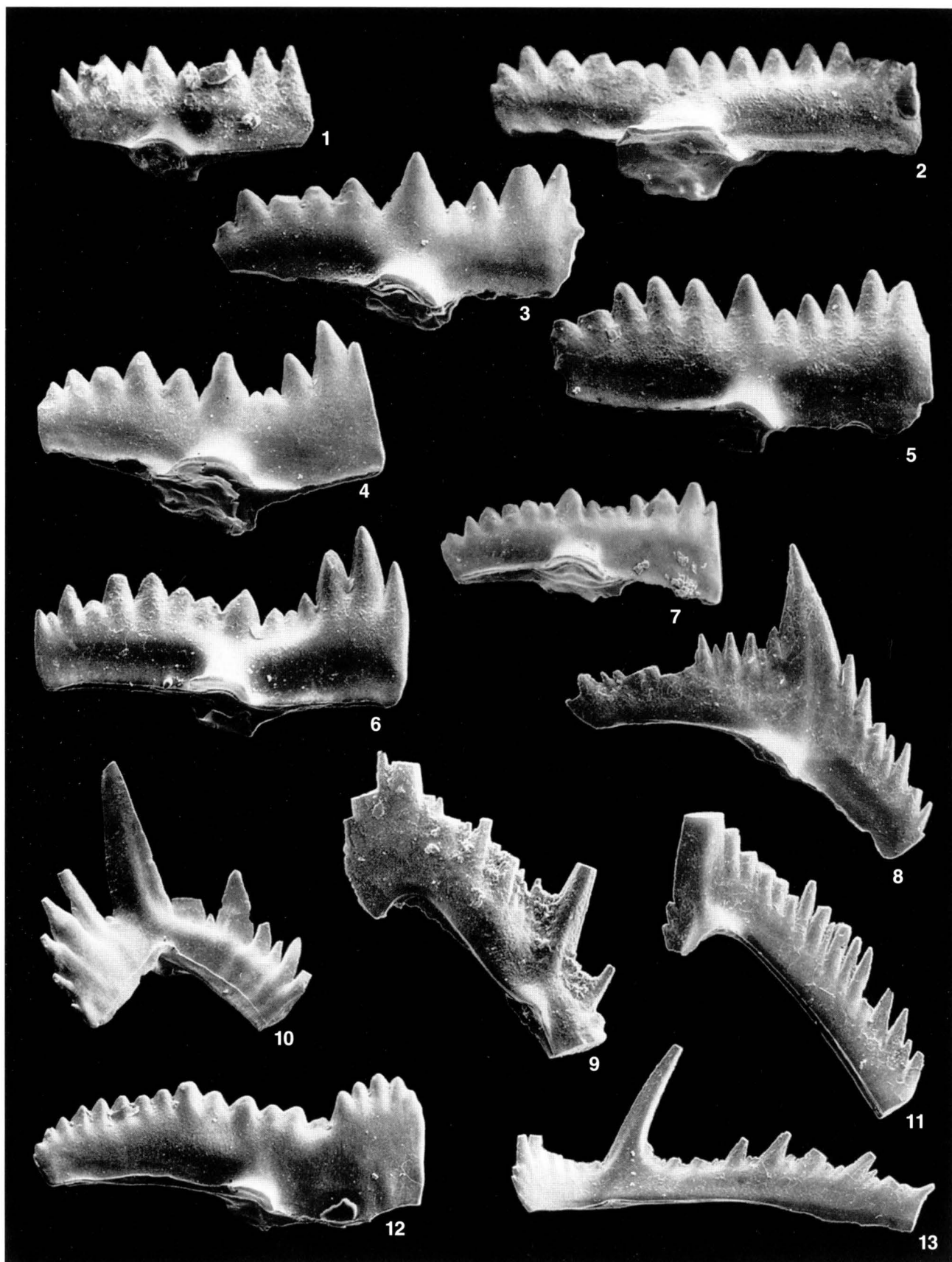
TAXONOMIC REMARKS

Klapper & Murphy (1975) changed the species name *steinhornensis* to *remscheidensis* because of the occurrence of different apparatus structures. Still, different points of view exist, concerning the name of this Pridolian species. Besides *Ozarkodina remscheidensis*, *Ozarkodina steinhornensis* (Jeppsson, 1975, 1988, 1989; Jeppsson *et al.*, 1994; Viira, 1982, 1983) have been used. Below, the *Ozarkodina remscheidensis* group is considered keeping in view from the holotype and original description. Historically the first described species was *Spathognathodus* (= *Ozarkodina*) *canadensis* with the following diagnosis: denticles of uneven size, basal cavity situated subcentrally, tongue-like lobes of different length (Walliser, 1960). *Spathognathodus* (= *Ozarkodina*) *remscheidensis* Ziegler has also uneven denticles but 1-2 anterior ones are higher, lobes are symmetrical and the blade is rather long (Ziegler, 1960). *Spathognathodus* (= *Ozarkodina*) *steinhornensis eosteinhornensis* was described as a subspecies and its diagnosis was given in comparison with the species *Spathognathodus* (= *Pandorellina*) *steinhornensis*: denticles of even size,

EXPLANATION OF PLATE 3

- Fig. 1 - *Ozarkodina remscheidensis baccata* Miller & Aldridge.
Pa element, section Ilpla, sample 1, Cn 1558, x 65.
- Fig. 2 - *Ozarkodina remscheidensis eosteinhornensis* (Walliser).
Pa element, section Vaivere, sample 1, Cn 1559, x 65.
- Figs. 3-4 - *Ozarkodina remscheidensis canadensis* (Walliser).
3) Pa element, section Looe, sample 4-75, Cn 1560, x 65;
4) Pa element, section Looe, sample 3-74, Cn 1561, x 70.
- Figs. 5-9, 13 - *Ozarkodina remscheidensis remscheidensis* (Ziegler)
5) Pa element, section Looe, sample 3-74, Cn 1562, x 80;
6) Pa element, section Looe, sample 4-75, Cn 1563, x 65;
7) Pa element, Kaavi 571 borehole, 11.60 m, Cn 1564, x 50;
8) Pb element, section Looe, sample 2-74, Cn 1565, x 80;
9) M element, with additional basal cavity, section Looe, sample 3-74, Cn 1566, x 70;
13) Sc element, section Looe, sample 4-75, Cn 1567, x 60.
- Figs. 10-12 - *Ozarkodina confluens* (Branson & Mehl).
10) Sb element, section Looe, sample 4-75, Cn 1568, x 35;
11) M element, section Looe, sample 2-74, Cn 1569, x 70;
12) Pa element, section Looe, sample 3-74, Cn 1570, x 40.

(Specimens shown in lateral view).



lobes are situated middle-posteriorly and less heart-like (Walliser, 1964). For *Ozarkodina remscheidensis baccata* characteristic features are irregular denticles, asymmetrically flared cavity, straight blade (Miller & Aldridge, 1997). All named species were based on the Pa element which joint characters are denticles and lobes or basal cavity. Barnett (1971, 1972) considers the basal cavity and shape of the lobes as important evolutionary features. The East Baltic material shows that in the course of evolution the asymmetrical basal cavity (*Ozarkodina remscheidensis baccata*) developed through "less heart-like" (*O. r. eosteinhornensis*) and tongue-like (*O. r. canadensis*) cavity to a rather large nearly heart-like basal cavity (*O. r. remscheidensis*). The basal cavity is centrally or posteriorly centrally located in all cases. Only the denticulation is variable. All taxa of the *Ozarkodina remscheidensis* group were described from different stratigraphic levels and geographically dispersed places. The above four taxa of *Ozarkodina remscheidensis* group are what we believe to form a lineage in the late Silurian. To establish the succession of species, we need also to know the variability of species. The most acceptable for us are the views expressed first in Walliser's monograph of 1964 and explained in more detail in the paper by Murphy *et al.* (1981, p. 748). "The species dealt with here (that is *Ozarkodina remscheidensis* – *Eognathus sulcatus* lineage, V.V.) are connected by intermediants. They show a shift of the range of variability from level to level. At each level, we can distinguish several varieties (which are described as morphs). All intergrading morphs occurring at a single horizon belong to the same species, and should have the name. Species boundaries are defined by the first occurrence of a new morph (variety)." The succession of the four *Ozarkodina remscheidensis* subspecies in the northern East Baltic is

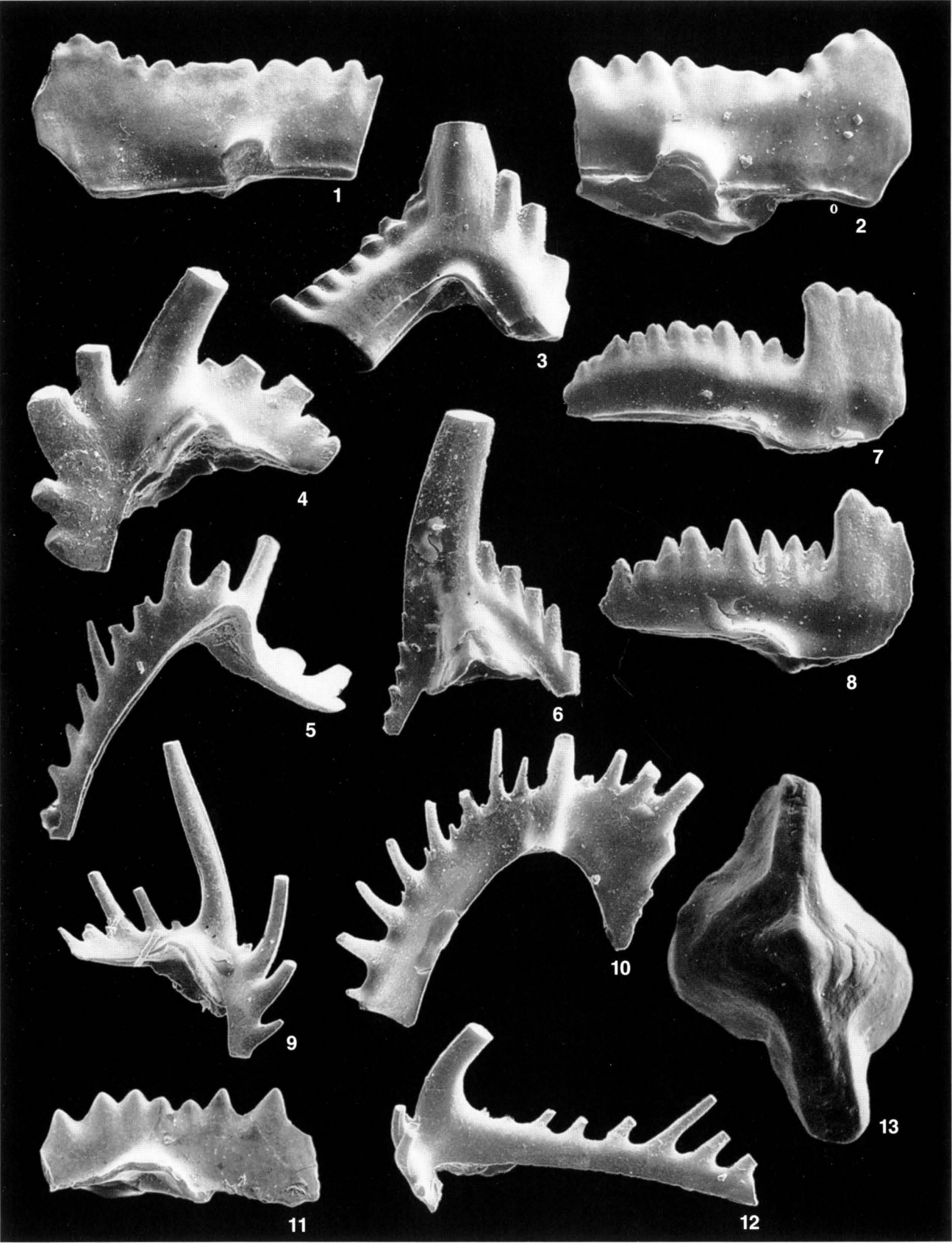
defined in the analogous way. When in the continuous range of *Ozarkodina remscheidensis* Pa specimens with even denticles appear then it is the appearance of *Ozarkodina r. eosteinhornensis* although the "baccata" specimens are still present (Text-fig. 4). In the same way the first appearances of *Ozarkodina r. canadensis* and *Ozarkodina r. remscheidensis* are specified. To establish the true stratigraphic order, it is worthy of note that in its monograph Walliser (1964) put *Spathognathodus canadensis* in the synonymy of *Spathognathodus steinhornensis remscheidensis*, thus stating that *S. canadensis* is younger than *S. s. eosteinhornensis*. In our opinion *Ozarkodina r. canadensis* should not be combined with *Ozarkodina r. remscheidensis* because there is a fixed level for the first taxon in the East Baltic. Even more, we guess that in the future it might be useful to rename the last subspecies and leave "remscheidensis" for the Devonian specimens. In the future it looks reasonable to give up using *remscheidensis* as species name and instead promote these subspecies to species rang such as *Ozarkodina baccata*, *O. eosteinhornensis*, *O. canadensis*, *O. n. sp.* From this point of view the future will lead to late Silurian zonation where instead *remscheidensis* the *baccata*, *eosteinhornensis*, *canadensis* and a new species zones occurs.

CONCLUSIONS

The late Silurian conodont zones in the interval under discussion are *Ozarkodina snajdri*, *Ozarkodina crispa*, *Ozarkodina remscheidensis*, and *Oulodus elegans detorta*. The species *Ozarkodina crispa* is represented by two alpha morphs (Viira & Aldridge, 1998). The species *Ozarkodina remscheidensis* is regarded in sensu

EXPLANATION OF PLATE 4

- Figs. 1-3 - *Ozarkodina* sp. A.
 1) Pa element, section Loode, sample 4-75, Cn 1571, x 35;
 2) Pa element, section Loode, sample 4-75, Cn 1572, x 35;
 3) M element, section Loode, sample 4-75, Cn 1573, x 45.
- Figs. 4-6, 9, 12 - *Oulodus elegans* (Walliser).
 4) Pb element, section Loode, sample 2-74, Cn 1574, x 75;
 5) Pa element, section Loode, sample 2-74, Cn 1575, x 75;
 6) M element, section Loode, sample 2-74, Cn 1576, x 75;
 9) Pb element, section Loode, sample 1-74, Cn 1577, x 60;
 12) Sc element, section Loode, sample 2-74, Cn 1578, x 65.
- Figs. 7-8 - *Ozarkodina nasuta* (Viira).
 7) Pa element, section Loode, sample 4-75, Cn 1579, x 50.
 8) Pa element, section Loode, sample 2-74, Cn 1580, x 95.
- Fig. 10 - *Oulodus elegans detorta* (Walliser).
 Sb element, section Loode, sample 2-74, Cn 1581, x 60.
- Fig. 11 - *Amydrotaxis ? praecox* Viira.
 Pa element, section Loode, sample 6-75, Cn 1582, x 50.
- Fig. 13 - Basal body of *Ozarkodina confluens* or *Ozarkodina nasuta*.
 Section Loode, sample 3-74, Cn 1583, x 120.
- (Specimens shown in lateral view except Fig. 13 which is in upper view).



lato; it comprises four stratigraphically determined subspecies with morphologically different Pa elements: *Ozarkodina remscheidensis baccata* (latest Ludlow), *O. r. eosteinhornensis* (lowermost Pridoli), *O. r. canadensis* (middle Pridoli), *O. r. remscheidensis* (upper Pridoli). The identification of these subspecies is easier if numerous specimens are available. The *Oulodus elegans detorta* Zone is a short interval in the range of *Ozarkodina r. remscheidensis* in the uppermost Silurian.

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