Early to early Middle Ordovician conodont biostratigraphy of the Tamsalu drill core, central Estonia

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Abstract: This investigation examines the distribution of conodont elements in the Early to early Middle Ordovician Latorpian, Volkhoverian, Kundan and Aserian stages of the Tamsalu drill core in central Estonia. Slightly more than 24, 600 conodont elements from 17 samples were examined, and the biostratigraphic results were compared to previous works on conodont biostratigraphy from localities in Estonia, Russia and Öland, Sweden. The samples are indicative of the Oepikodus evae Zone, the Baltoniodus navis Zone, the Paroistodus originalis Zone, the Baltoniodus norriandicus Zone, the Lenodus variabilis Zone, the Yangtzeplacognathus crassus Zone, the Eoplacognathus pseudoplanus Zone, (the latter including the Microzarkodina hagetiana and the Microzarkodina ozarkodella subzones) and finally the Eoplacognathus suecicus Zone. The thicknesses of the different stages (Latorpian, Volkhoverian, Kundan and Aserian) are compared between the following localities in Estonia: Tamsalu, Kaugatuma, Ohesaare, Rumba, Kullamaa, Mäekalda, Tartu, Taga-Roostoeja and Ontika. Two new species, Parapaludites n. sp. A and Texania n. sp. A, are described.

Keywords: Ordovician, Latorpian, Volkhoverian, Kundan, Aserian, conodonts, biostratigraphy, Parapaludites n. sp. A., Texania sp. A, Tamsalu, Estonia.

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Conodonts belong to the Conodontophorida (or Cono-
donta), a group of early chordates, and are provided with
small, phosphatic, tooth-like structures that are preserved
in some abundance (Sweet 1988). They are found in
marine rocks of late Cambrian to late Triassic age. The
conodonts have been the object for study for over 100
years and were first discovered by Pander (1856). Their
value for biostratigraphy continues to grow, because of
their rapid morphological evolution, small size, relative
abundance and wide distribution. They are also fairly
resistant to the rigours of diagenesis and tectonism, and
amenable to extraction from carbonaterocks by using
weak organic acid or by physical methods (Brasier 1980).

The main aim of this study is to investigate the cono-
dont fauna from the Tamsalu drill core, in central Esto-
nia (Fig. 1) biostratigraphically, and compare it to cono-
dont faunas of similar age from localities in Estonia:
Mäekalda (Viira et al. 2001), Tartu (Männik 1998), Taga-
Roostoa (Poldvere 1999), Ontika (Mägi 1990) and Kau-
gatuma and in Öland, Sweden: Gillberga (Löfgren 2000b)
and Horns Udde (Bagnoli & Stouge 1997). A general
comparison of thicknesses of Latorpian, Volkhovian,
Kundan and Aserian beds in different parts of Estonia:
Kaugatuma, Ohesaare (Viira 1967), Rumba (Kaljo &
Nestor 1990), Kullamaa (Kaljo & Nestor 1990), Mäeka-
lida (Viira et al. 2001), Tartu (Männik 1998), Taga-Roo-
stoja (Poldvere 1999), and Ontika (Mägi 1990) has also
been made (Figs. 2 and 3). Two new species, Parapal-
todus n. sp. A and Texania n. sp. A were discovered dur-
ing the investigation and are described here.

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**Fig. 1.** Map of Estonia, showing the location of the Tamsalu drill core and the localities discussed in the text: Kaugatuma, Ohesaare, Kullamaa, Rumba, Mäekalda, Tartu, Taga-Roostoa and Ontika. The inset map shows the localities on Öland, Sweden: Gillberga and Horns Udde and St Petersburg.
Fig. 2. Varying thicknesses of Latorpian, Volkovian, Kundan and Aserian beds in Estonia. Sections are generally arranged from W to E. For location, see Fig. 1.
Geological setting

In the early Ordovician, Baltoscandia was situated at 25–35°S and epicontinental seas with extensive distribution of carbonate sediments had a greater extent than during any other period. The marine flora and fauna changed markedly in this period and a number of major taxonomic groups appeared or became common: bryozoans, brachiopods, echiinoderms, planktic graptolites, conodonts, ostracods, chitinozoans and others (Stanley 1993). Estonia, on the Baltic plate, is among the areas in the world where this fauna is particularly well preserved and easily available for study (see Raukas & Teedumäe 1997).

The large-scale biogeographical and facies differentiation within the Ordovician Palaeobasin of Baltoscandia is expressed in the concept of facies belts (Jaanusson 1976; see also Raukas & Teedumäe 1997). The territory of Estonia is divided between the North Estonian and the Central Baltoscandian facies belts (see Raukas & Teedumäe 1997). Tamsalu is within the North Estonian belt.

The Tamsalu borehole was drilled through strata in central Estonia and includes beds from the Latorian, Volkovian, Kundan and Aserian stages. The Billingen Substage in Estonia comprises the upper part of the Latorian Stage and is characterised by the two zonal indicators, Prioniodus elegans and Oepikodus evae, respectively. This substage is mostly represented by glauconitic limestones in the North and by the reddish-brown, occasionally glauconitic dolomites in central Estonia (see Raukas & Teedumäe 1997).

The Volkovian Stage is represented by the first appearance of Baltoniodus triangulatus, followed by the successive zones of Baltoniodus navis, Paroistodus originalis, Baltoniodus norrlandicus (Raukas & Teedumäe 1997) and in the upper part Lenodus antivariabilis (see Zhang 1998). The term "Volkov Stage" was introduced by Rõõmusoks (1956) and this interval was thoroughly described by Orviku (1960), who also introduced a threefold subdivision of the Volkov Stage, which was thought to be consistent with the established eastern Baltic subtidal units, from the base: Saka, Viäna, and Langevoja substages (Dronov et al. 2000). The Volkov Stage is lithologically complex, as most of the beds consist of partly dolomitized glauconitic limestone or greenish-grey limestones and marls or grey argillaceous glauconitic limestones (see Raukas & Teedumäe 1997).

The Kundan Stage is divided into the Lenodus variabilis, Yangtzeplacognathan crassus and Eoplacognathan pseudoplanus zones. The last mentioned zone is subdivided into the Microzarkodina hagetiina and Microzarkodina ozarkodella subzones (Zhang 1998). The Kundan Stage is represented by oolitic, glauconitic and sandy limestone in northern Estonia, by yellowish-grey sandy limestones and calcareous sandstones in the W, and by up to 15 m red mottled oolitic limestone in central Estonia (see Raukas & Teedumäe 1997). The thickness of the Kundan Stage shows an obvious decrease from the central part towards northwestern Estonia. In northern and central Estonia it does not exceed 10 m, but may locally reach 20 m in southeastern Estonia (see Raukas & Teedumäe 1997).

In northern and central Estonia the Aserian Stage is 0.1–5 m thick and consists of bioclastic limestones with unevenly distributed ooids, predominantly brown iron (gothitic) ooids (see Raukas & Teedumäe 1997). The zonal indicator for the lower part of this stage is Eoplacognathan suecicus (Zhang 1998).

### Table: Thickness of Regional stages at Tamsalu and other selected localities in Estonia

<table>
<thead>
<tr>
<th>Locality</th>
<th>Aserian (m)</th>
<th>Kundan (m)</th>
<th>Volkovian (m)</th>
<th>Latorian (m)</th>
<th>Thickness (m)</th>
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<tr>
<td>Kaugatuma</td>
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<tr>
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<tr>
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<td>2.2</td>
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<tr>
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<td>7.2</td>
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<tr>
<td>Taga-Roostoja (25A)</td>
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<td>Ontika (section)</td>
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<td>2.6</td>
<td>1.9</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Fig. 3. Thickness of Regional stages at Tamsalu and other selected localities in Estonia. Numbers in parentheses after names denote the core's specific directory number of the Estonian Geological Survey.

Material and methods

The 17 conodont samples in this study were collected from the Tamsalu drill core, central Estonia (Fig. 1), and the extraction of the conodonts was performed in Uppsala, Sweden, by using a buffered acetic acid method similar to the one described by Jeppsson et al. (1985). A little more than 24,600 conodont elements were sorted and glued in microfossil slides, and species determined by Anita M. Löfgren. The preservation of the conodonts is generally good, with some minor variations between the samples and all conodont elements have a CAI value of less than 1.5 (for explanation of index; see Epstein et al. 1977). Each sample contains between 383 and 6052 elements. The samples have been referred to stages, zones and subzones, according to the conodont distribution with the help of literature and previously established biostratigraphy.

The Aserian Stage is 3.6 m thick and the samples EST 86-18 B and EST 86-19 belong to this, while samples EST 86-1 to EST 86-18A belong to the top of the Kundan Stage (183.2 m) and downwards (Lars Holmer, Uppsala, personal communication to Anita M. Löfgren, 1992). Samples EST-12 and EST 86-13 are missing and EST 86-5 did not contain enough elements to investigate further.
I have also correlated Tamsalu is with other localities in Estonia and Sweden and similarities as well as differences of the species composition and the thicknesses of the different stages are noted. Some specimens of biostratigraphically important species have been chosen for SEM photographing. These elements have been coated with gold and photographed, and the separate pictures then scanned from the negatives and digitally collected to “plates”. The elements of the two new species have been drawn with help of Camera Lucida equipment.

Repository of material. *The material is housed in the type collection of the Geological Institute, Technical University of Tallinn, Estonia.*

**Thickness**

A comparison is made between Tamsalu and other localities in Estonia (Fig. 1) with respect to thickness of the Latorian, Volkhovian, Kundan and Ascerian stages (Fig. 2). Possibly, the Latorian and Ascerian stages are thicker than described in the comparison between the various localities, because their tops and/or bases have not been encountered. In western Estonia, on the island of Saaremaa, there are two drillings, that include the four stages above, Ohesaare with about 13.9 m and Kaugatuma with about 10.9 m in thickness (Fig. 3). The successions of the localities Rumba and Kullamaa are about 14.5 m and 10.1 m thick, respectively (Fig. 3). Mäekalda is situated on the N coast of Estonia near Tallinn, and a little farther E is Ontika, with thicknesses of about 7.7 m and 13.9 m respectively (Fig. 3). The succession of Tagarostoja in northeastern Estonia, which did not include the Latorian Stage, is 14.4 m and that of Tartu in the southeastern part is 25.1 m (Fig. 3). Finally, the Tamsalu drill core central Estonia is 12.1 m.

The Latorian Stage is 0.8 - 2.0 m in Estonia (Fig. 3). Kullamaa in western Estonia has the highest value (2.0 m), and the lowest value (0.8 m) is from the island of Saaremaa on the west coast of Estonia. In Mäekalda and Ontika the Latorian Stage varies between 1.2 and 1.9 m. The samples from the Tamsalu drill core do not include the lower boundary of the Latorian Stage. Only 0.10 m of this stage is represented.

The Volkhovian Stage varies between 1.0 m and 7.2 m (Fig. 3). On the island of Saaremaa, there is a difference between the Ohesaare and Kaugatuma borings of 2.8 m although there is only c.10 km between these sites. The highest value of the Volkhovian Stage is from Tartu (7.2 m).

The Kundan Stage also has its greatest thickness in the Tartu drill core with 11.6 m and the lowest at Mäekalda with 2.1 m (Fig. 3). It looks as if the Kundan Stage decreases in thickness towards the NW and then increases to the SW, S and SE Estonia. If we compare Mäekalda and Ontika in the N there is a difference of 5.4 m.

The Ascerian Stage also shows a marked difference between the localities. The Tartu drill core has the highest value (6.3 m) and Mäekalda the lowest one (0.5 m) (Fig. 3).

**Description of the samples**

The conodont element distribution for each of the 17 samples from the Tamsalu drill core is shown in Fig. 4, together with the relative frequencies and their abundance in Fig. 5. Three samples, EST 86-5, EST 86-12 and EST 86-13, have not been included, because the residues were not available for EST 86-12 and -13 and in EST 86-5 there were too few conodont elements. The characteristics of the samples and descriptions of the different conodont zones to which they have been assigned, are described below.

**Latorian Stage**

**The Oepikodus evae Zone (191.7-190.7m)**

The *Oepikodus evae* Zone was first described by Lindström (1971), and *O. evae* (Lindström, 1955) was proposed as a zonal indicator. This zone is also characterized by the first appearance of *Oistodus lanceolatus* Pander, 1856, *Periodon flabellum* (Lindström, 1955) and *Stolodus stola* (Lindström, 1955) according to Slouge (1989). Several taxa have their last occurrences at Tamsalu in this zone: *Oepikodus evae*, *Stolodus stola*, *Parapalodus* n. sp. A, *Tripodus* cf. T. laevis, *Decoriconus peselephantis* and *Texania* n. sp. A.

EST 86-18 A (191.7 m)

The 1210 elements in this sample represent 20 different species, but two of these, *Priioniodus elegans* and *Tripodus* sp., are probably redeposited since their edges are worn. The most abundant species is *Drepanoidostodus forceps*, which is by far the most numerous, and then *Scolopodus striatus* Pander, 1856, *Oistodus lanceolatus*, *Drepanodus arcuatus* Pander, 1856, *Protopanderodus rectus* (Lindström, 1955) *Periodon flabellum* and *Oepikodus evae*. In the sample there is a new species, *Parapalodus* n. sp. A., which will be described below (see appendix).

EST 86-17 (191.3 m)

This sample is represented by 1950 conodont elements of 15 different species. No elements of *Oepikodus evae* were found, but instead some new species have been added, such as *Texania* n. sp. A and *Drepanoidostodus* cf. *basiovalis* (Sergeeva, 1963). *Drepanoidostodus forceps* is still dominant in numbers. Only three elements of *Paroistodus originalis* (Sergeeva, 1963) were found in this sample, but a lot of *Periodon flabellum*. This is typical of the
<table>
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<th>Species</th>
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<th>EST 86-17</th>
<th>EST 86-16</th>
<th>EST 86-14</th>
<th>EST 86-11</th>
<th>EST 86-10</th>
<th>EST 86-9</th>
<th>EST 86-8</th>
<th>EST 86-7</th>
<th>EST 86-6</th>
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<th>EST 86-2</th>
<th>EST 86-1</th>
<th>EST 86-1BB</th>
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<th>Total</th>
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<p>| Malakaldia                                   | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Tantia                                      | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Tagize-Rosebaj                             | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Orifiz                                   | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Kaupatum                                   | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Gillbergia                                  | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |
| Horns udde                                | x          | x         |           |           |           |           |           |           |           |           |           |           |           |            |         |        |</p>
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Legend:
- Oepik / Balt. Periodon
- Scolopodus
- Drepanost. (Drepanostomum)
- Semiaccontiodus
- Eoplacognathus
- Other taxa

1 m scale
upper O. evee Zone in Estonia (cf. Viira et al. 2001) and also of a few levels in the same interval in the St. Petersburg region (Tolmacheva 2001). In this sample the last elements of Parapalododus n. sp. A and Texania n. sp. A occur.

Volkhovian Stage

The Baltoniodus navis Zone (190.7-190.3 m)
The Baltoniodus navis Zone was first defined by Lindström (1971), and B. navis (Lindström, 1955) was proposed as a zonal indicator. The zonal definition was later revised by Lögren (1993) and Bagnoli & Stouge (1997). The base of the zone is currently defined by the first appearance of B. navis and its top by the abundant occurrence (> 0.3 %) of Triangularodus brevibasis (see Lögren 1995).

EST-86-16 (190.7 m)
This sample contains 6052 elements of 13 different species. The most common species is Microzarkodina flabellum (Lindström, 1955) and thereafter Drepanoistodus forcps, Baltoniodus navis, Drepanoistodus cf. basiovalis and Trapezognathus quadrangularum. (Lindström, 1955). No Paroistodus originalis elements were found in this sample.

The Paroistodus originalis Zone (190.3-189.7 m)
The Paroistodus originalis Zone was first defined by Lindström (1971), and it is characterized by the abundant occurrence of Paroistodus originalis. Its boundaries were discussed in detail by Lögren (1995). Here the base is drawn at the level where T. brevibasis exceeds 0.3% in abundance. The upper boundary is drawn just below the first appearance of B. norrlandicus (see Lögren 2000a)

EST 86-15 (190.2 m)
The 1093 elements in this sample represent 10 different species. Paroistodus originalis, which was found in an earlier sample (EST 86-17), reappears here in fair abundance (13%). The species Drepanoistodus forcps, Drepanoistodus cf. basiovalis and Microzarkodina flabellum have disappeared and have been replaced by Drepanoistodus basiovalis (Sergeeva, 1963) and Microzarkodina parva. Baltoniodus navis is still abundant but Trapezognathus quadrangularum is rare.

The Baltoniodus norrlandicus Zone (189.7-2 m), Trapezognathus quadrangularum Subzone
The Baltoniodus norrlandicus Zone was introduced by Bagnoli & Stouge (1997) and they defined the Zone as the interval between the first appearance of Baltoniodus norrlandicus (Lögren, 1978) to the first appearance of Lenodus variabilis (An, 1981). Lögren (2000a) extended the zone to also include beds up to the first appearance of Lenodus variabilis (Sergeeva, 1963), and distinguished a lower subzone (with T. quadrangularum) and an upper subzone (with L. variabilis). The lower boundary is easy to recognize in the East Baltic, across the different biocenoses belts in Sweden and in Norway (see Lögren 2000a). Only the lower subzone has been identified in the Tamsalu drill core.

EST 86-14 (189.7 m)
The total number of elements in this sample is 2769, representing 17 different species. The most abundant taxa are Baltoniodus norrlandicus and Drepanoistodus basiovalis with nearly equal numbers (~40%). The species indicating the Trapezognathus quadrangularum Subzone disappears with this sample with only few elements. Trapezognathus quadrangularum had its highest abundance in the P. originalis Zone. Since there were no Lenodus antivariabilis found in the sample, it could be assigned to the lower part of the zone. Other species in this sample are Paroistodus originalis, Scolopodus striatus, Periodon flabellum, Scalpelloides latus, Triangularodus brevibasis and Oistodus lanceolatus, all of which also disappear with this sample. One other species, Semicontiodus corniformis (Sergeeva, 1963) (cf. Lögren 1999) appears for the first time.

Kundan Stage

The Lenodus variabilis Zone [188.2 (188.5)-187.7 m]
The Lenodus variabilis Zone is equivalent to the early Amorphognathus variabilis Zone (sensu Lindström 1971). Lenodus variabilis first appears slightly above the lower boundary of the Kundan Stage (Lögren 2000a). The top of the zone is defined as the level of first appearance of Y. crassus (see Zhang 1998). Baltoniodus medius (Dzik, 1976) and Scalpelloides gracilis (Sergeeva, 1974) first appear in the lower part of this zone.

EST 86-11 (188.2 or 188.5 m)
The 383 elements in this sample represent 11 species. The most abundant species is Baltoniodus medius (Dzik, 1976). Some other new species also appear, such as Lenodus variabilis, Scalpelloides gracilis and Drepanoistodus venustus (Stauffer, 1935). Species with continued range are, e.g., Protopenoderus rectus and Drepanodus arcatus. They are lacking entirely from beds immediately above this, only to reappear again higher up in the sequence. There is still a lot of Semicontiodus corniformis.

The Yangzheplacognathus crassus Zone (187.7-186.8 m)
The base of the Yangzheplacognathus crassus Zone is indicated by the first appearance of the species Y. crassus (Chen & Zhang, 1992) and its top by the last appearance of this species (Zhang 1998).

EST 86-10 (187.7 m)
The total number of elements in this sample is 710, representing 12 species. Baltoniodus medius is still dominating and the less common species are the same as in
the preceding sample. One new species appears, *Yangtzeplacogynathus crassus*, which also has given the zone its name.

**EST 86-9 (187.2 m)**
The 620 elements in this sample represent 9 species. The sample is dominated by *Baltonioidus medius*. *Lenodus variabilis* is lacking, but a new species has appeared: *Dapsilodus viruensis* (Fährus, 1966). Both *Yangtzeplacogynathus crassus* and *Microzarkodina parva* disappear at the top of this zone.

**The Eoplacognathus pseudoequus Zone, Microzarkodina hagetenia Subzone (186.8-184.7 m) and Microzarkodina ozarkodella Subzone (184.7-183.2 m)**

The *Eoplacognathus pseudoequus* Zone is subdivided into two subzones, the lower one characterized by *Microzarkodina hagetenia* Stouge & Bagnoli, 1990, and the upper one by *M. ozarkodella* (Lindström, 1971) (see Löfgren 2000b). That *E. pseudoequus* (Viira, 1974) could be used as a zonal index of the upper part of the Kundan Stage was first proposed by Viira (1974) (Zhang 1998).

**EST 86-8 (186.8 m), M. hagetenia Subzone**
The total number of elements in this sample is 950, representing 11 species. *E. pseudoequus* indicates the zone and few elements of *M. hagetenia* the subzone. The dominating species are *B. medius* followed by *S. cornuformis* and *D. basiivalis*. Only a few elements of *C. longibasis* (Lindström, 1955), *D. venustus*, *S. gracilis* and *Dapsilodus viruensis* are represented in the sample.

**EST 86-7 (186.4 m), M. hagetenia Subzone**
The 1831 elements in this sample represent 11 species. The dominating species is *B. medius*. There are a lot of elements of *D. basiivalis*, *S. cornuformis*, and *E. pseudoequus*, but few of *D. venustus*, *S. gracilis*, *Dapsilodus viruensis* and *M. hagetenia*. *Drepanodus arcautus* reappears, but only with one element. *Semiacontiodus davidi* Löfgren, 1999 first appears in the middle of the zone. There are no elements of *Cernuodius longibasis*.

**EST 86-6 (185.7 m), M. hagetenia Subzone**
The total number of elements in this sample is 1471, representing 11 species. *B. medius* is still dominating in the sample, followed by *D. basiivalis*, *S. cornuformis* and *S. gracilis*. *Cernuodius longibasis* appears for the last time in the sample.

**EST 86-4 (184.7 m), M. ozarkodella Subzone**
The 573 elements in this sample represent 9 species. A new species, *Microzarkodina ozarkodella* appears. This could have happened already in sample number 5, which was not available to me. The extent of the subzone is thus unclear. *B. medius* is dominating in the sample. The same species are represented as in sample number 6 and *D. arcuatus* disappears again.

**EST 86-3 (184.3 m), M. ozarkodella Subzone**
The total number of elements in this sample is 999, representing 12 species. *Dapsilodus viruensis* and *Protopanderodus rectus* appear again. The remainder of the species are the same as in sample number 4. *B. medius* is the dominating species.

**EST 86-2 (183.7 m) M. ozarkodella Subzone**
The 638 elements in this sample represent 11 species. *D. venustus* reappears and disappears in the sample. Both *P. rectus* and *S. davidi* disappear. The same species are represented as in the preceding sample and *B. medius* is still dominating.

**EST 86-1 (183.2 m), M. ozarkodella Subzone**
The total number of elements in this sample is 1094, representing 11 species. The dominating species is *Baltonioidus medius*, and *Drepanodus arcautus* appears again. For the rest, the same species are represented as in sample number 2.

**Aserian Stage**

**The Eoplacognathus suetius Zone (183.2 m - )**

The *Eoplacognathus suetius* Zone is characterized by the nominal species, by a lot of *B. medius*, and in Estonia even by *S. cornuformis* (Viira et al. 2001).

**EST 86-18 B**
The 1134 elements in this sample represent 12 species. Two species *Eoplacognathus suetius* Bergström, 1971, and *Protopanderodus cf. graei* (Fährus, 1966), first appear. The most abundant species is still *B. medius*. *D. bosiivalis*, *S. gracilis* and *M. ozarkodella* occure more frequently (are more common).

**EST 86-19**
The total number of elements is 1206, representing 10 species. The species are the same as in the preceding sample, number 18 B, with increased numbers of elements for most of them.

**B. medius** still dominates.

**Comparisons with other sections**

Similarity and dissimilarity between Tamsalu and other previously studied localities in Estonia and in northern Öland, Sweden, will be discussed below. The localities I have compared to Tamsalu are Mäckalda (Viira et al. 2001), Tartu (Männik 1998), Taga-Roostoja (Poldvere 1999), Ontika (Mägi 1990) and Kaugatuma in Estonia, and Gillberga (Löfgren 2000b) and Horns Udde (Bagnoli & Stouge 1997) in Sweden (Fig. 1). The species, which are found in every locality (Fig. 4), are *Drepaniosistodus forcipes*, *Baltonioidus navis* (except possibly in Taga-Roostoja?), *Baltonioidus norriancus* and *Semiacontiodus cornuformis*. Texania n. sp. A occurs only in Tamsalu. *Pararapaloidus* n. sp. A occurs only in Tamsalu and possibly at Horns Udde. *Yangtzeplacognathus crassus*has only been reported from Tamsalu and Gillberga.

*Mäckalda.*—The Mäckalda section in North Estonia is about 12 m thick with well-preserved conodont elements. The section includes the Baltoscandian zones from the Tremadocian Varanguan *Paltodus deltifer* Zone up
to the Aserian *Yangtzeplacognathus foliaceus* Zone (Viira et al. 2001) (Fig. 6). The *Yangtzeplacognathus crassus* Zone has not been identified here. Tamsalu and Mäekalda yielded largely the same list of conodont species, except a few, such as *Parapaltoodus* n. sp. A, *Tetania* n. sp. A, *Lenodus variabilis*, *Yangtzeplacognathus crassus*, *Microzarkodina hagetiana*, *Semiaccentius davidii* and *Protopanderodus* cf. *graeai*, which occur at Tamsalu, but not at Mäekalda (Fig. 4).

In Mäekalda some species occur that are not found in Tamsalu. These species are: *Protopanderodus* cf. *gradius* in the *P. elegans* and *O. evae* zones, *Polonodus tabulepointensis* in the *E. pseudoplanus* Zone, *Parapaltoodus simplicissimus* and *Semiaccentius bulbosus* in the upper *E. pseudoplanus* Zone.

**Tartu.** — The investigated drill core from Tartu is about 72 m. It contains conodont elements from the Lower Ordovician to the upper Middle Ordovician, with the Latorpian, Volkovian, Kundan, Aserian, Lasnamägi, Uhlaku, Kukruse, Idavere, Jõhvi and Keila stages (see Männik 1998). The Tartu drill core, has mostly the same species as found at Tamsalu (Fig. 4). There are more differences, however, between Tartu and Tamsalu than between Tamsalu and Mäekalda. In the interval assigned to the *Oepikodus evae* Zone there are no elements found of the zonal indicator. *Stolodus stola* and *Periodon flabellum* are also missing, and only *Oistodus lanceolatus* represents the *O. evae* Zone. The *Baltoniodus navis* Zone, the *Paroistodus originalis* Zone and the *Baltoniodus norrlandicus* Zone are all represented at Tartu. A zone that seems to be lacking at Tartu is the *Yangtzeplacognathus crassus* Zone. Only the subzonal species *Microzarkodina hagetiana* and *Microzarkodina ozarkodella* represent the *E. pseudoplanus* Zone.

Species that are found in Tartu but not in Tamsalu are *Trapezognathus diprion* in the *O. evae* Zone, Balto-
niodus triangularis in the B. triangularis Zone, Drepanoistodus stougel in the L. variabilis Zone and Protopanderodus robustus in the B. norrlandicus Zone and the M. hagetiana Subzone.

Taga-Roostoa. – This is a drill core (14.4 m), from c.70 km E of Tamsalu and is comparable to Tamsalu and Mäeakla in the distribution of conodont species and zones (Fig. 4). The two zones that are not represented here are the Baltoniodus navis and the Yangtzeplacognathus crassus zones. Probably, the Baltoniodus navis Zone may occur within an unsampled area (1.2 m) of the drill core (Poldvere 1999). The Lenodus antivariabilis Subzone of the B. norrlandicus Zone was identified at Taga-Roostoa in contrast to Tamsalu where there is no record of this zone, although the uninvestigated samples, EST 86-12 and 13 may represent it. Consequently, one species that was found in Taga-Roostoa but not in Tamsalu is Lenodus cf. antivariabilis. Species that are not found in Taga-Roostoa are Stolodus stola, Tripodus cf. T. laevis, Cornuodus longibasis, Drepanoistodus cf. baiosialis, Trapezognathus quadrangularum, Scalpellodus latus (included in Scalpellodus gracilis, see Poldvere 1999), Triangulodus brevibasis, Microzarkodina parva, Drepanoistodus baiosialis, Yangtzeplacognathus crassus, Dapsilidos virusensis, Microzarkodina hagetiana and Semiactiniodus davidi (Fig. 4).

Ontika. – This is a section in northern Estonia. The section contains stages from the Latorpian to the base of the Aserian. The species are nearly all the same as in Tamsalu, Taga-Roostoa and Mäeakla (Fig. 4). One can identify the Oepikodus eave Zone with O. eave, S. stola and P. flabellum, the Baltoniodus navis Zone with B. navis and T. brevibasis, the Paroistodus originalis Zone with P. originalis and appearance of B. norrlandicus in the upper part of this zone (and thus including part of the B. norrlandicus Zone as well). The Lenodus variabilis Zone contains L. variabilis. The Y. crassus Zone has not been identified. The Eoplagognathus pseudoplanus Zone is only represented by the subzonal species M. ozarkodella in the upper part of this zone. The E. sucius Zone is characterized by the nominal species and by B. medius and S. cornformis. Other species that were found at Tamsalu, but have not been reported from Ontika are Paraparotodus n. sp. A, Tripodus cf. T. laevis, Decroiconus peselephantis, Texania n. sp. A, Drepanoistodus baiosialis, D. venustus, Scalpellodus gracilis, Dapsilidos virusensis, M. hagetiana, Semiactiniodus davidi and Ptopanoderous cf. graecii. In Ontika there are also species that are not found in Tamsalu. The species arc: Baltoniodus triangularis in the B. triangularis Zone, Scopalodus cf. bulbosus, Ansellia cf. jemtlandica and Polonodus (Dzikodus) clivosus.

Kaugatuma. – This is a drill core from the island Saaremaa in western Estonia, about 10.90 m long. In the Kaugatuma drill core all stages from the Latorpian Stage are represented with the O. eave Zone to the Aserian Stage with the E. sucius Zone. The species composition and the zonation is mostly the same as in Tamsalu. The zonal indicator of the E. pseudoplanus Zone is lacking and the zone only characterised by M. ozarkodella, the subzonal species indicator for the upper subzone. Species that were found in Tamsalu but not here are Paraparotodus n. sp. A, Tripodus cf. T. laevis, Decroiconus peselephantis, Texania n. sp. A, Drepanoistodus cf. baiosialis, Trapezognathus quadrangularum, Triangulodus brevibasis, Baltoniodus medius, D. venustus, Y. crassus, Dapsilidos virusensis, M. hagetiana, E. pseudoplanus, Semiactiniodus davidi and Ptopanoderous cf. graecii. Species that are not found in Tamsalu but in Kaugatuma are Polonodus (Dzikodus) clivosus and Drepanoistodus conulatus.

Gillberga. – The Gillberga quarry in northern Öland provides a c. 16 m thick sequence through middle Volkhovan to upper Kundan (mid-Arenig to early Llandovery) beds (Löfgren 2000b). The sequence ranges from the middle part of the Baltoniodus navis Zone to the middle or upper part of the Microzarkodina ozarkodella Subzone of the Eoplagognathus pseudoplanus Zone (Löfgren 2000b). Because zones below the Baltoniodus navis Zone have not been investigated and beds above the Eoplagognathus pseudoplanus Zone are unavailable in the area, the species from these intervals were not recorded. The Yangtzeplacognathus crassus Zone and the Trapezognathus quadrangularum Subzone are both represented here as they are in Tamsalu. Species that are found in Gillberga but not in Tamsalu are Lenodus antivariabilis, Paraparotodus similicissimus, Ansellia cf. jemtlandica, Parapanderodus quietus and Microzarkodina bella.

Horns Udde. – The faunal succession is from two representative sections: North of Horns Udde and Horns Udde quarry, Öland (Bagnoli & Stouge 1997). The sections contain beds from the Oepikodus eave Zone in the Latorpian Stage to the Lenodussp. A Zone (approx. equal to the L. variabilis Zone and the Y. crassus Zone) in the Kundan Stage. Here is the only additional place where the species Paraparotodus n. sp. A that was also found in Tamsalu may be present (Fig. 4). The species composition is similar to that of Tamsalu. Only a few species are lacking here; Tripodus cf. T. laevis, Texania n. sp. A, Drepanoistodus baiosialis and Baltoniodus medius. At Horns Udde there are some typical species from Öland that are not found at Tamsalu, nor at other localities in Estonia. These species are: Protopanderodus floridus, Protopanderodus sulcatus, Protopriornius aranda, Protopriornius costatus and Protopriornius papillosus. Other species that are present at Horns Udde but not found in Tamsalu are Trapezognathus diprinon and Drepanoistodus contractus.

Discussion

The conodont fauna at Tamsalu (Figs. 7 and 8) is in many respects similar to those from other investigated drill cores and sections in Estonia and Öland, Sweden. Comparisons were made between the faunas from the Tamsalu drill core and from the following Estonian and Swedish localities: Mäeakla (Viira et al. 2001) in northern Estonia, Tartu (Männik 1998) in southeastern Estonia, Taga-Roostoa (Poldvere 1999) in northeastern Estonia, Ontika (Mägi 1990) in northeastern Estonia, Kaugatuma (D.
Fig. 7. Conodont elements from the Tamsalu drill core. (A) *Oapikodus evae* (Lindström, 1955) from sample EST 86-18A, x90, (B-D) *Texania* n. sp. A from sample EST 86-17, Bx80, C:x50, D:x60, (E) *Oistodus lanceolatus* Pander, 1856, from sample EST 86-17, x30, (F) *Periodon flabellum* (Lindström, 1955) from sample EST 86-17, x90, (G-H) *Microzarkodina flabellum* (Lindström, 1955) from sample EST 86-16, x100, (I) *Microzarkodina hagetiana* Stouge & Bagnoli, 1990, from sample EST 86-6, I:x70, (J-K) *Microzarkodina ozarkodella* (Lindström, 1971) from sample EST 86-18B, x70, (L) *Triangulodus brevibasis* (Sergeeva, 1963) from sample EST 86-15, x50, (M) *Microzarkodina parva* (Lindström, 1971) from sample EST 86-14, x70, (N) *Baltiodus norrandicus* (Löfgren, 1978) from sample EST 86-14, x70, (O-Q) *Baltiodus navia* (Lindström, 1965) from sample EST 86-16, Ox80, P:x50, Q:x70, (R) *Scolopodus striatus* Pander, 1856, from sample EST 86-17, x60, (S-U) *Tripodus cf. laevis* from sample EST 86-18A, x60.
Fig. 8. Conodont elements from Tamsalu drill core. (A-B) Parapaludodus n. sp. A from sample EST 86-17, A: x70, B: x50. (C) Parapaludodus n. sp. A from samples EST 86-18A x60. (D) Scolopodus striatus Pander, 1856, from sample EST 86-17, x60, (E) Semiacontododus cornutiformis (Sergeeva, 1963) from sample EST 86-11, x100, (F) Paroistodus originalis (Sergeeva, 1963) from sample EST 86-15, x110, (G) Baltoniodus medius (Zak, 1976) Sb element from sample EST 86-7, x70, (H-L) Lenodus variabilis (Sergeeva, 1963) from sample EST 86-11, H: x120, L: x50, (J) Yangzijiacongnatus crassus (Chen & Zhang, 1992) from sample EST 86-9, x70, (K-L) Eoplacognathus suecicus (Bergström, 1971) from sample EST 86-19, K: x90, L: x70, (M-N) Eoplacognathus pseudoplanus (Mira, 1974) from sample EST 86-8, M: x80, N: x90.
Kaljo, pers. comm. 1984) on the island of Saaremaa on the west coast of Estonia, Gillberga (Löfgren 2000b) and Horns Udde (Bagnoli & Stouge 1997) sections on northern Öland, Sweden.

The two lowermost Tamsalu samples, EST 86-18A and EST 86-17, are referred to the upper part of the *O. evae* Zone (Fig. 4). The most abundant species is *D. forcepts* (55.1% and 59.6%) which together with *P. flabellum* (4.1% and 12.8%) is typical of the upper part of *O. evae* Zone in Estonia (cf. Viira et al. 2001) and also of a few levels in the same interval in the St. Petersburg region (Tolmacheva 2001). The *O. evae* Zone was identified also in the other, earlier investigated localities in my investigation except Tartu (missing the zonal indicator) and Gillberga (level not investigated). In samples EST 86-18A and EST 86-17 two new species were found: *Parapatidodus* n. sp. A in samples EST 86-18A and EST 86-17, and *Taxania* n. sp. A in sample EST 86-17. These species have not been found in any earlier investigated localities in Estonia or Sweden (a possibly conspecific element of *Parapatidodus* was found at Horns Udde, Sweden). Since the zonal indicator *B. triangularis* is missing in the sample immediately above the *O. evae* Zone from the Tamsalu drill core I have placed this sample, EST 86-16, in the *B. navis* Zone instead. In EST 86-16, the *B. navis* Zone is represented by the most abundant species *M. flabellum* (34.5%) together with *D. forcepts* (31.9%). This zone has been encountered in all localities except Taga-Roostaja (the zone could possibly have been found in an uninvestigated interval of the drill core here).

The next sample, EST 86-15 is indicative of the *Paroistodus originalis* Zone, because of the high abundance of the zonal indicator, *P. originalis* (12.9%) and because *T. brevibasis* exceeds 0.3% in abundance (in this case 12.8%). The upper boundary is delimited by the first appearance of *B. norrlandicus* (see Löfgren 2000a). The *E. originalis* Zone is not represented in many localities, both in Estonia and Sweden (Löfgren 1995). The *B. norrlandicus* Zone is represented by the zonal indicator *B. norrlandicus* (43.2%), and other species typical for the zone (see Tolmacheva 2001): *D. basiovalis* (39.9%) and *M. parva* (5.0%) in the sample EST 86-14. The presence of *Trapezognathus quadrangularis* in this sample denotes the lower subzone of the *B. norrlandicus* Zone. This zone could also be identified in other localities in Estonia and Sweden. The upper subzone of the *B. norrlandicus* Zone, the *Lenodus antivariabilis* Subzone, has not been found in the Tamsalu drill core, but may be represented by one or both of the missing samples EST 86-13 and EST 86-12.

The sample EST 86-11 indicates the *Lenodus variabilis* Zone with the most abundant species *B. medius* (49.9%) together with the zonal indicator *Lenodus variabilis* (9.7%) and some other species, which first appear here. This zone has been identified in all the localities investigated in Estonia and Sweden. The *Yangtzeplacognathus crassus* Zone has only been identified in Tamsalu, Estonia, and in Gillberga, Sweden. In Tamsalu the zone is represented by the samples EST 86-10 and EST 86-9. The base of the *Yangtzeplacognathus crassus* Zone is indicated by the first appearance of the zonal species *Y. crassus* (Chen & Zhang, 1992) and its top by the last appearance of this species (Zhang 1998) which is also the case here. The species *Y. crassus* has a relative abundance of 3.1% in EST 86-10 and 6.3% in EST 86-9.

The next zone in the Tamsalu drill core is the *Eoplacognathus pseudoplanus* Zone with the two subzones with *Microzarkodina hagetiana* and *Microzarkodina ozarkodella*, respectively. The samples EST 86-8, EST 86-7 and EST 86-6 represent the *Microzarkodina hagetiana* Subzone with the typical subzonal indicator, *M. hagetiana*, reaching a relative abundance of 1.1%, 0.8% and 1.6%, respectively in the three samples. The *Microzarkodina ozarkodella* Subzone is represented by EST 86-4, EST 86-3, EST 86-2 and EST 86-1. The relative abundance of the subzonal indicator, *M. ozarkodella*, is 0.9%, 4.5%, 0.5% and 3.2%. Sample EST 86-5, that did not contain enough elements, has been excluded. The fact that *E. pseudoplanus* (Viira, 1974) could be used as a zonal index of the upper part of the Kundan Stage was first proposed by Viira (1974) (Zhang 1998). This zone, the *E. pseudoplanus* Zone, has been identified in all investigated localities in Estonia (except Taga-Roostaja) and at Gillberga, Sweden. In some cases only the subzonal indicators are represented. In the Tartu drill core, the zone is only identified by the subzonal species *M. hagetiana* and *M. ozarkodella* and in Onitka and Kaugatuma the zone is only represented by *M. ozarkodella*.

The last two samples from the Tamsalu core, EST 86-18B and EST 86-19 contain the zonal indicator *Eo- placognathus suiceps* (1.1% and 3.2%, respect.). The *E. suiceps* Zone has also been recognized in Mäckalda.

The most abundant species in the Tamsalu drill core (Fig. 5) from the basal sample, EST 86-18A to the top one, EST 86-19, are *B. medius, B. norrlandicus, B. navis, D. forcepts, B. basiovalis* and *M. flabellum*.

The comparison between Tamsalu and the localities (Fig. 2): Kaugatuma, Ohesaare (Viira 1967), Rumba (Kaljo & Nestor 1990), Kullamaa (Kaljo & Nestor 1990), Mäckalda (Viira et al. 2001), Tartu (Männik 1998), Taga-Roostaja (Poldvere 1999) and Onitka (Mägi 1990) in Estonia shows a small difference in thickness, except for the Tartu area (see Raukas and Teedumäe 1997). Generally, the Volkhnovan, Kundan and Aserian Stages are thickest in the Tartu drill core in southeastern Estonia. The Latorian Stage did not exhibit such a big difference regarding the thickness between the localities. The maximum thickness of the Latorian Stage appears to be in western Estonia (Rumba and Kullamaa) and in northeastern Estonia (Onitka). The Latorian is only measured down to 466.4 m in Kaugatuma and to 191.7 m in Tamsalu, since the base was not encountered.

The Volkhnovan Stage exhibits more pronounced differences between the localities. The highest value of thickness is in southeastern Estonia (Tartu) and it thins out on the W mainland (Rumba and Kullamaa), increases in the central and northern Estonia and to the W on the island of Saaremaa. The Volkhnovan Stage is measured down to 120.4 m in Taga-Roostaja, without the base being reached.
The Kundan Stage increases thickness in northeastern and southeastern Estonia, decreases in northern and central Estonia, and increases again in the W. The highest value of thickness is in Tartu and the lowest one in Mäekalda. The base and the top of the Kundan Stage in the Tamsalu drill core were difficult to decide, because the lacking samples EST 86-13 and EST 86-12.

The Aserian Stage also varies between the localities in Estonia. The lowest value is in Mäekalda in the north and the highest value in Tartu in southeastern Estonia. In northeastern Estonia (Onitka) the Aserian Stage is thinner than in the southeast and central Estonia. Its thickness increases on the W mainland but decreases on the island of Saremaa.

Conclusions
The comparison of the Tamsalu drill core and the other previously investigated drill cores and sections in Estonia and Sweden points to similarities between them all, except for a few species and zones/subzones that occur in some localities but not in others. In some cases this could be explained by that level not having been investigated or by lack of the zonal indices. The investigated Tamsalu drill core represents a sequence deposited in a shallower part of the palaeobasin than represented by most of the other drill cores, but probably deeper than represented by the sections in the N. (e.g., Mäekalda). The species P. flabellum, in the O. evae Zone, that is represented in all localities except Tartu, indicates deep water and an open ocean. This taxon would increase only at the peak of transgression in the lower parts of the ramp zone. The species P. originalis is known to increase in intervals considered to represent transgressive events (Löfgren 1995). The regressive events are instead represented by shallow water species such as S. corniformis and possibly species of Microzarkodina which also occur in the Tamsalu drill core.

The thicknesses of the different stages (Latorian, Volkovian, Kundan and Aserian) and the localities (Tamsalu, Kaugatuma, Ohesaare, Rumba, Kullamaa, Mäekalda, Tartu, Tapa-Roostja and Onitka) show an increase in the western, middle and eastern parts of Estonia and a decrease in the North (see Raukas & Tedumäe 1997).

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References
Appendix

Description of two new taxa: *Parapalatodus* n. sp. A and *Texania* n. sp. A.

Genus *Parapalatodus* Stouge, 1984

*Type species.* — *Parapalatodus simplicissimus* Stouge, 1984, pl. 1, figs. 20, 21, 26-28A.

*Remarks.* — Stouge (1984) diagnosed *Parapalatodus* as having erect to proclined drepanodontiforms and twisted ostrodontiforms (scandodontiforms). The elements have a large laterally compressed cusp with sharp anterior and posterior keels and a triangular base. The basal cavity is also triangular.

*Parapalatodus* n. sp. A

Fig. 8: A-C, Fig. 9: A-D.

*Occurrence.* — From the *Oepikodus evae* Zone, samples EST 86-18A and EST 86-17, in the Tamsalu drill core. The *Parapalatodus* elements reported from the *O. evae* Zone at Horns Udde by Bagnoli & Stouge (1997) may possibly belong to the same species.

*Material.* — 4 drepanodontiform elements.

*Diagnosis.* — A species with drepanodontiform elements having a proclined to subrect, stout cusp with lenticular cross section and a small base with laterally compressed basal cavity with an extended tip (peak).

*Description.* — The drepanodontiforms have a proclined to subrect cusp with a broad, lenticular cross section. The lateral carinae are rounded, and become narrower at the anterior and posterior edges which gives the lenticular form of the cusp cross section. The basal cavity is

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*Fig. 9.* Camera lucida drawings of four different elements of *Parapalatodus* n. sp. A (A-D), from the Tamsalu drill core, Estonia and one of *Parapalatodus simplicissimus* (E), from the Gilberga quarry, Öland, Sweden. A. *Parapalatodus* n. sp. A from sample EST 86-18A, *O. evae* Zone. B-D. *Parapalatodus* n. sp. A from sample EST 86-17, *O. evae* Zone. E. *Parapalatodus simplicissimus* from sample ÖL 83-106, *Yangizeplacognathus crassus* Zone. The *Parapalatodus* n. sp. A elements are also shown as photos in Fig. 8, A-C.
moderately deep and triangular with concave sides in lateral view. The basal cavity apex is extended and close to the anterior edge. The aboral margin is convex, with rounded postero basal and anterobasal corners. The cusp lacks the anterior lateral furrow running along the length of the cusp, which is present in *Parapaltonodus simplicissimus*.

**Remarks.** – *Parapaltonodus* n. sp. A differs from *Parapaltonodus simplicissimus* Stouge, 1984 by its rounded carinae and its lenticular cross-section of the cusp and has no lateral furrow running along the length of the cusp. The basal cavity is less deep than in *P. simplicissimus* (Fig. 9 E) and with an extended apex close to the anterior edge (Fig. 9 A-D).

**Genus Texania** Pohler, 1994  
**Type species.** – *Texania heligna* Pohler, 1994, pl. 8, figs. 11-15; Text-figure 16.

**Description.** – “Genus includes albid seximembrate conodont apparatuses with ozarkodiniform (Pa, Pb), oistodontiform (M) and ramiform (Sa, Sb, Sc) elements in the apparatus. Ozarkodiniform and ramiform elements possess a single denticulated (posterior) process. Cusp is reclined and may be costate. Oistodontiform elements display a reclined cusp that is longer than the posterior process, and sharp edged. Base of most elements is dark brown; basal cavity is shallow” (Pohler 1994).

**Texania** n. sp. A  
Fig. 7:B-D, Fig. 10:A-F.  
**Occurrence.** – Oepikodus evae Zone, sample EST 86-17 in the Tamsalu drill core.  
**Material.** – 8 elements; 6 ramiform (Sa, Sb, Sc), 1 ozarkodiniform (P) and 1 oistodontiform element (M).  
**Diagnosis.** – A species of *Texania* with P, M, Sa, Sb and Sc elements, all of which are white with a dark basal cavity surrounded by a hyaline area. Ramiform and M elements typically show strong lateral flexion.

**Description.** – The oistodontiform and ramiform elements in this species of *Texania* are characterised by strong flexure of the posterior process. In accordance with the genus characterisation all elements are white in the upper part and the basal cavity is dark surrounded by a hyaline area. The cusp of the oistodontiform element is recurved and the curved posterior process is flexed towards the aboral margin. The margin is convex and the oral aboral margin is concave. The basal cavity is moderately deep and has faintly concave triangular sides.

The P element has a straight aboral margin that makes an almost right angle with the anterior margin of the cusp. There are five laterally compressed and confluent denticles on the posterior process. The denticles are suberect to erect, while the anterior process is rudimentary and adenate.

The ramiform elements have a fairly long, reclined to recurved cusp, which is laterally compressed. There may be up to two denticles on the anterior edge. Costate ramiform element has two edges of the cusp developed as keels. The posterior process possesses five to seven denticles and which are confluent and laterally compressed. The Sb element shows slightly curved denticles. The anterobasal corner is rounded. The ramiform elements are deflected in three different directions.

**Remarks.** – The ramiform elements in *Texania* n. sp. A differ from those of *T. heligna* because of the two denticles on the anterior edge of Sc elements and that the denticles on the posterior process are confluent. The anterior denticles are typical for elements of *Microzarkodina* and *Periodon*, but as a rule not *Texania*. In this case the denticles are very small and only two in number and *Microzarkodina* often seems to have more than one and often bigger anterior denticles than those found on elements of *Texania*. *Periodon* usually has more denticles on its elements. Consequently, *Texania* seems to be the best place for this new species, at least until more elements have been retrieved.

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Fig. 10. Camera lucida drawings of *Texania* n. sp. A from the Tamsalu drill core, Estonia. An elements are from sample EST 86-17, O. evae Zone. A. Ozarkodiniform element (Pa) of *Texania* n. sp. A.B. Ramiform element (Sa) of *Texania* n. sp. A. C. Ramiform element (Sc) of *Texania* n. sp. A. D-E. Ramiform element (Sb) of *Texania* n. sp. A. F. Oistodontiform element (M) of *Texania* n. sp. A. The *Texania* sp. A specimens are shown as photos in Fig. 7 B-D; there A corresponds with D, D corresponds with C and E corresponds with B on the photos.

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