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The Llandovery–Wenlock boundary interval in west-central continental Estonia: an example from the Suigu (S-3) core section

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Abstract. A gap corresponding to several conodont and chitinozoan zones occurs in the Llandovery–Wenlock boundary interval in some sections in the western coastal region of Estonia and on islands in the Muhu Strait. New data from the Suigu (S-3) core section demonstrate that the gap has geographically wider distribution in western continental Estonia. Detailed study of faunas from that section revealed that here the gap corresponds to at least four conodont zones (from below): the Lower and Upper *Pseudooneotodus bicornis* and Lower and Upper *Pterospathodus pennatus procerus* zones, but probably also the upper(most) Upper *Pt. amorphognathoides amorphognathoides* Subzone and the Lower *Kockelella ranuliformis* Zone (or part of it) are missing. In sense of chitinozoan biostratigraphy, the gap correlates with most of the *Margachitina margaritana* Zone. Only the uppermost part of this zone is represented in the section. However, although the gap in the Suigu (S-3) core section is distinct and well dated biostratigraphically, the $\delta^{13}C$ curve demonstrates no evidence of it. Causes of this controversy are still waiting to be revealed.

Our data indicate that changes in sedimentation in the Llandovery–Wenlock boundary interval occurred earlier in the distal graptolite-bearing and later in the proximal environments. Most probably, sedimentation in the Baltic Palaeobasin in the late Telychian and early Sheinwoodian was strongly affected by tectonic evolution of the Baltoscandian foreland basin.

Key words: conodonts, chitinozoans, lithology, geochemistry, stratigraphy, Silurian, Estonia.

INTRODUCTION

A gap correspondig to several conodont and chitinozoan zones in the Llandovery–Wenlock boundary interval has been reported from sections located on the western coast of Estonia and on islands in the Muhu Strait (Hints et al. 2006; Rubel et al. 2007). However, due to big sampling intervals (1 m or more) in the sections studied earlier and the limited size of samples, exact dating of the gap remained problematic. Also, the area of distribution of the gap is poorly known. An attempt to increase the precision of the dating of the gap is made in this paper, based on lithological, biostratigraphical and geochemical data from the recently acquired high-quality Suigu (S-3) core section but by considering also earlier data available. The core, 9 cm in diameter, originates from a well drilled in 2006 by the company Salveesia OÜ about 18 km NE of the town of Pärnu, close to Suigu village in west-central continental Estonia (Fig. 1). The interval studied in the section (6.2–40.0 m) corresponds to the upper Velise, Jaani and the lower Muhu formations, to the interval from the upper Adavere Stage below to the lowermost Jaagarahu? Stage above (= upper Telychian–lower Sheinwoodian). Lithologically, this interval consists of more or less argillaceous dolostones with interbeds of dolomitized marlstone. The uppermost 6.2 m of the section is represented by sandy clays of Quaternary age. Although the lithological features recognized in the Suigu (S-3) core section are characteristic of the Velise and Jaani formations, here these units are less argillaceous than in a 'typical' succession (e.g. in the Viki core section; Põldvere & Nestor 2010). The Silurian part of the core was described lithologically and sampled for detailed biostratigraphical and geochemical studies with the aim of dating the drilled strata, in particular the gap in the Llandovery–Wenlock boundary interval. The geographical distribution of the gap and its possible level in more complete sections (if present, its duration here is below the current biostratigraphical resolution) will also be discussed. In addition

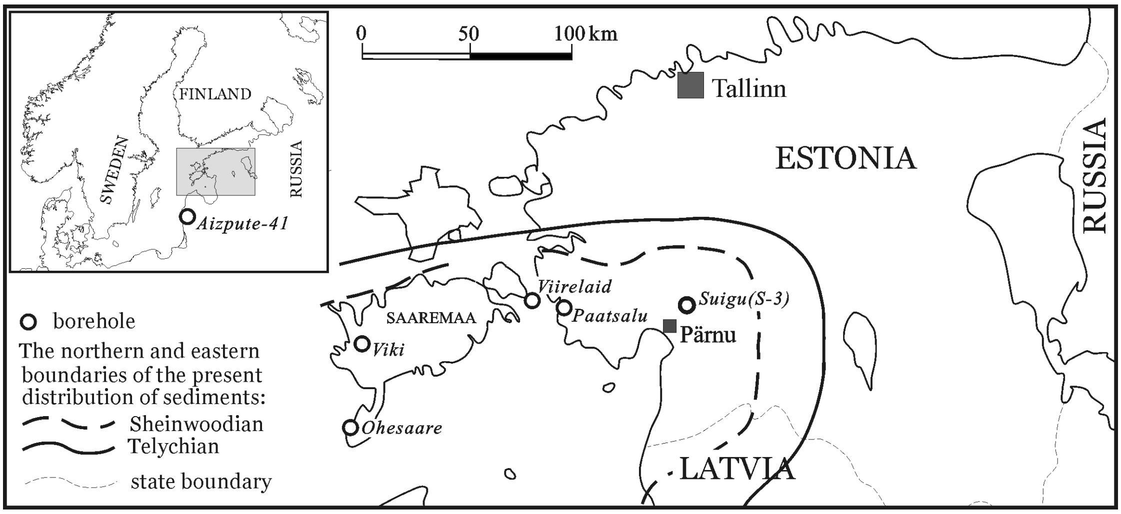

Fig. 1. Location of the sections referred to in the text.

to conodont- and chitinozoan-based biostratigraphy, tephrostratigraphical (correlation based on K-bentonites) and $\delta^{13}C$ analyses were applied to provide more criteria for the dating of strata. Lithological studies were aimed to reveal any possible facies (environmental) change which might be expected to be related to a gap of biostratigraphically recognizable duration.

MATERIAL AND METHODS

The section was described lithologically, and sampled for microfossil (conodonts and chitinozoans) and geochemical analyses (rock composition and $\delta^{13}C$). Detailed lithological study of 79 selected intervals under microscope included all samples processed later for microfossils. Additionally, 13 thin sections were prepared and 9 samples from the main types of rock were analysed for CaO, MgO, CO_2 and insoluble residue (IR) contents (Fig. 2). Study of the residues of microfossil samples provided more information about the mineralogical composition of IR but also about the occurrence and distribution of several groups of faunas in the section. However, as these residues did not contain the clay and finest silt fractions which were washed out during sample processing, we could not estimate the total content of IR in these intervals. Carbon isotopes were measured from 55 samples (including all microfossil samples) using the methods described in Kaljo et al. (1997). The analyses were performed with the GasBench II preparation line connected to the Thermo Scientific Delta V Advantage mass spectrometer. The results are given in the usual δ-notation, as per mil deviation from the VPDB standard. Reproducibility of duplicate analyses was generally better than ±0.1‰. All possible K-bentonites were analysed using a method of Kiipli et al. (2010). To identify a particular K-bentonite, the composition of magmatic sanidine phenocrysts was analysed using X-ray diffractometry (XRD). The dating of strata in the studied section is mainly based on the distribution of conodonts and chitinozoans but also the results of K-bentonite and $\delta^{13}C$ analyses were applied to provide more criteria. The stratigraphic nomenclature used corresponds to that in Nestor (1997, p. 90, table 8). The terms applied to indicate bed thickness in lithological descriptions follow the classification of Põlma (1982, p. 150): thickness < 0.2 cm = microbedded, 0.2–2.0 cm = thin-bedded, 2–10 cm = medium-bedded and 10–50 cm = thick-bedded.

Samples for microfossils were prepared using standard methods. All samples were dissolved in buffered acetic acid and thereafter processed with buffered formic acid to get rid of dolomite in residues (Jeppsson & Anehus 1995; Jeppsson et al. 1999). In total, 52 samples weighing between 0.48 and 1.78 kg (mostly about 1 kg each) were processed for microfauna. Conodonts and chitinozoans were both picked from the same residues. All samples yielded conodonts. Chitinozoans were continuously present in the lower and middle parts of the section but missing in its uppermost part, in the samples above 13.86 m. All samples studied are housed in the Institute of Geology at Tallinn University of Technology, the core (under the name Suigu, ID 1822) is stored in Keila core depository (town of Keila, Estonia; depository manager is the Estonian Land Board).

LITHOLOGY

The strata corresponding to the interval from the upper Adavere Stage to the lowermost Jaagarahu? Stage (= upper Telychian–lower Sheinwoodian) are exposed in the Suigu (S-3) core section. Due to dolomitization, primary structures and textures of the rock are often poorly preserved, particularly in the uppermost part of the section. Macrofossils, where present, are completely recrystallized or leached out and preserved as internal moulds. Most of the data about faunas other than conodonts and chitinozoans come also from the residues of biostratigraphical samples. These fossils, as a rule, are preserved in residues because of their (complete) pyritization or they consist of phosphate (e.g. conularids).

Adavere Stage, Velise Formation

The formation (interval 31.10–40.00 m; Fig. 2) is characterized by intercalation of indistinctly nodular (in the lower part of the interval; Fig. 3: 10) to irregularly thin- to medium-bedded (upper part of the interval; Fig. 3: 9) grey variously argillaceous dolostone and dark greenish-grey dolomitized marlstone. Dolomitized marlstone is dominating in the lowermost part of the formation; its content decreases gradually higher in the interval. Scattered fossil fragments are crushed, deformed, sometimes leached or recrystallized, and replaced by pyrite. Small ostracods, sponge spicules, agglutinated foraminifers, gastropods, bivalves, brachiopods, fragments of conularids and bryozoans occur in the residues. Bioturbation (burrows mainly horizontal) is more common in the upper part of the formation. The IR is dominated by clay. Angular to subrounded silt- to sand-size quartz grains are particularly common in the lower part of the formation. Six K-bentonites were recognized (Fig. 2, Table 1). Pyritized discontinuity surfaces occur at 31.3 and 31.1 m. The lower surface has stronger, the upper one weaker impregnation (Fig. 3: 8).

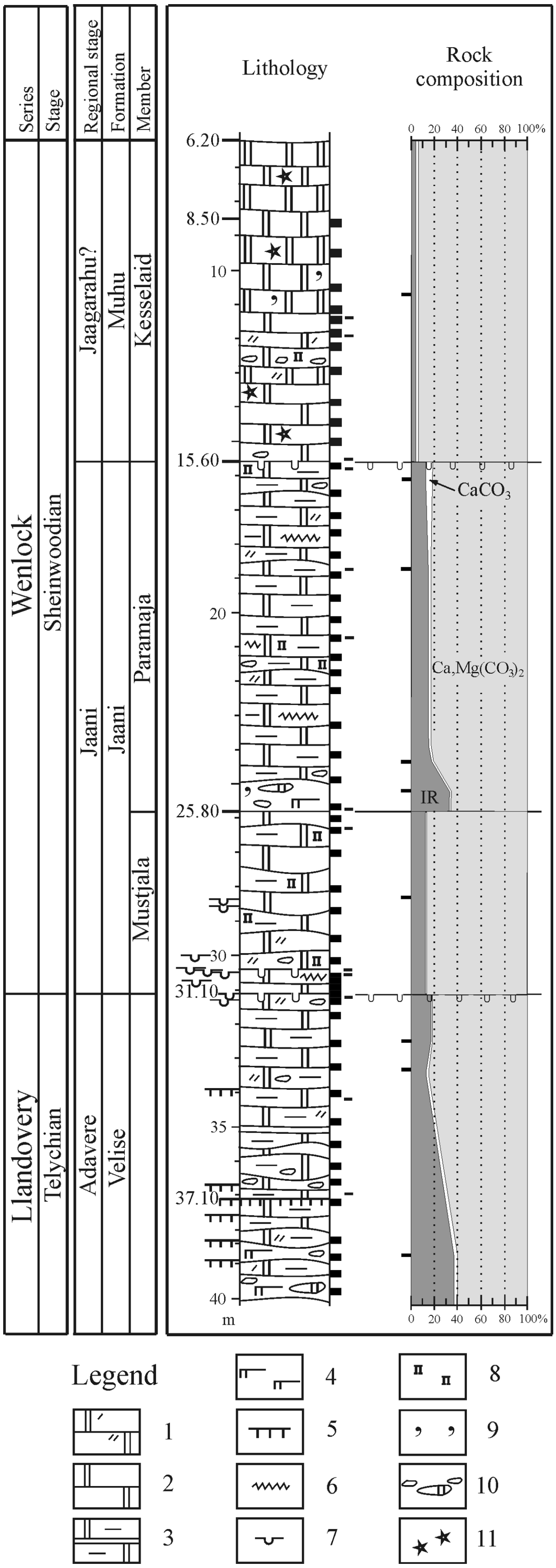

Fig. 2. Suigu (S-3) core section. From left to right: general stratigraphy, regional stratigraphy, lithological log of the section, location of micropalaeontological samples, location of thin sections, rock composition (positions of samples analysed are indicated on the left side). Legend: 1, dolostone (crystal size more than 0.01 mm) with fine and coarse bioclasts; 2, dolostone with crystal size less than 0.01 mm; 3, argillaceous dolostone with interbeds of dolomitic marlstone; 4, dolomitic marlstone; 5, K-bentonite; 6, bioturbation; 7, discontinuity surface; 8, pyritic mottles; 9, glauconite grains; 10, carbonate clasts; 11, vugs. IR, insoluble residue.

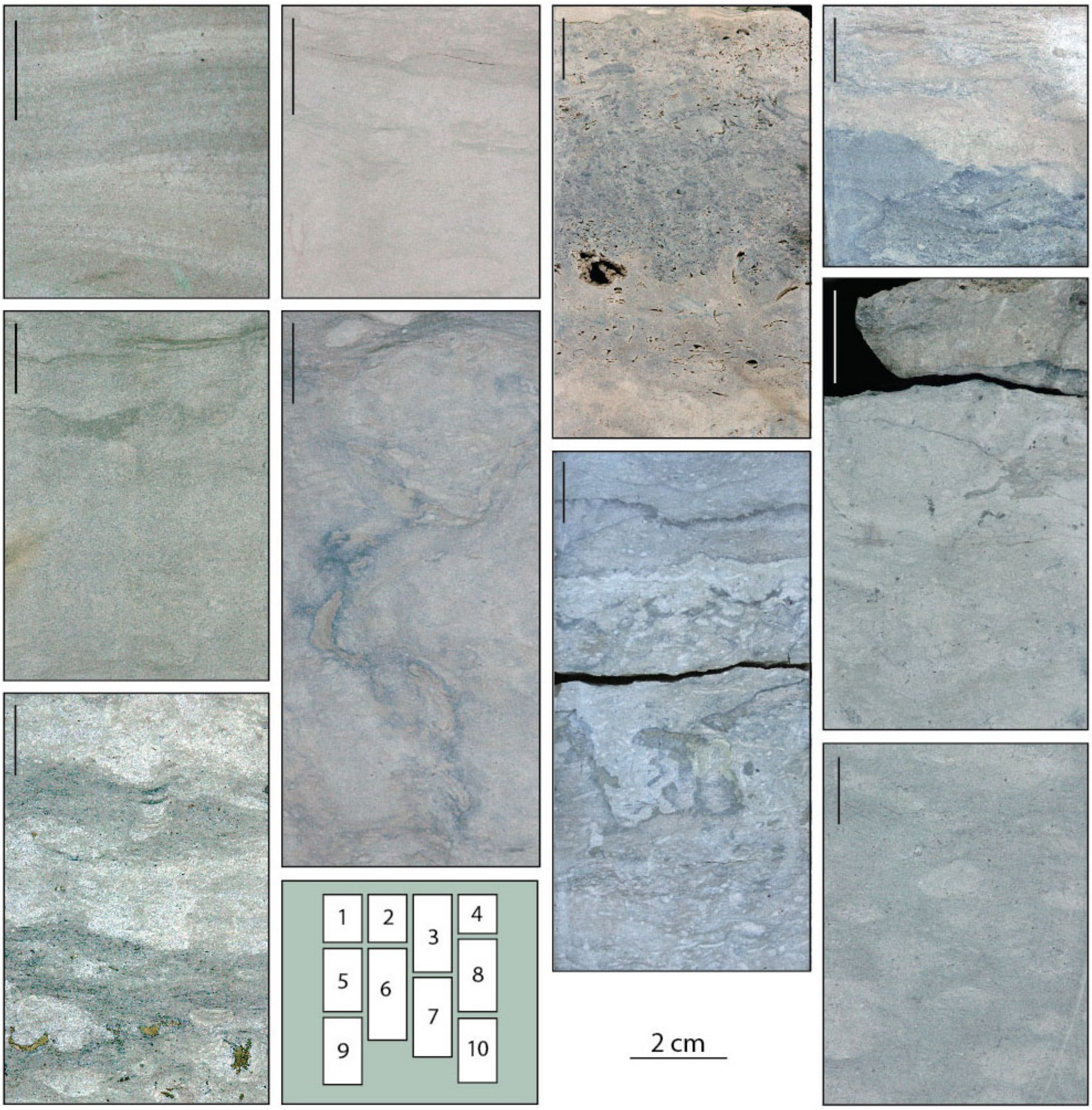

Fig. 3. Selected rock samples from the Suigu (S-3) core section. **1**. Low-angle inclined bedding in dolostone. Anhedral dolomite crystals are smaller in lighter beds. Green clay-grade material is concentrated in disjointed films and patches (burrows?), fractures and open vugs are observed. Interval 11.55–11.61 m. **2**. Dolostone with irregular interbeds of argillaceous dolostone. Interval 12.31–12.37 m. **3**. Deformed surface at 12.80 m is overlain by a 9 cm thick conglomeratic bed. Skeletal fragments and elongated carbonate clasts are more or less rounded and enriched with pyrite. Surfaces in open vugs (moldic porosity) are usually lined by crystals of calcite and dolomite. Interval 12.70–12.84 m. **4**. Pyritized discontinuity surface at 15.60 m, at the boundary between the Jaani and Muhu formations. Elongated carbonate clasts above the surface are oriented subparallel to bedding. Disjointed microstylolite seams (amplitude 0.05 mm) are found. Interval 15.55–15.63 m. **5**. Burrowed pyritized and slightly argillaceous dolostone with rare dolomitic marlstone interbeds. Interval 16.44–16.54 m. **6**. Thick-bedded dolostone with branching burrows. Interval 26.41–26.55 m. **7**. Complex of pyritized discontinuity surfaces. Dolostone with rare argillaceous patches and disjointed interbeds is rich in burrows and pyrite aggregates. Open vugs and fractures form in some places up to 10% of the rock. Intervals 30.38–30.46 and 30.49–30.59 m. **8**. Pyritized discontinuity surface at 31.10 m marking the Llandovery–Wenlock boundary in the section. Burrows related to the surface are mainly vertical. Interval 31.08–31.18 m. **9**. Intercalation of variously argillaceous dolostone and dolomitic marlstone. Pyrite aggregates have various shapes and often replace skeletal fragments. Interval 34.66–34.78 m. **10**. Nodules of variously argillaceous dolostone are packed within highly argillaceous dolostone and dolomitic marlstone. Interval 38.77–38.88 m.

Table 1. General characteristics and geochemical correlation of volcanic material from the Suigu (S-3) core section. The question mark shows that no information is available

Suigu (depth, m)	Description	Thickness, cm	$(Na+Ca)AlSi_3O_8$ in sanidine, mol%	Width of the sanidine XRD reflection, deg, 2 theta	ID of the ash bed	Correlation with Viki (depth, m)	Correlation with Viirelaid (depth, m)	Correlation with Paatsalu (depth, m)
33.90	Grey marlstone	0.5–2	?	Weak reflection	?	?	?	?
36.70	Grey marlstone	3.0	34–35	0.330	457	145.7	?	?
37.20	Yellowish bentonite	5.0–7.0	45.2	0.089	475	147.5	65.9	72.5
37.55	Grey marlstone	0.5	41.3	0.142	480	148.0	?	?
38.30	Yellow hard K-feldspar	0.3	?	?	?	?	?	?
38.90	Grey marlstone	0.3	45.5	0.103	494	149.4	66.6	?

Jaani Stage, Jaani Formation

The formation (interval 15.60–31.10 m) is represented by the Mustjala and Paramaja members (Fig. 2).

Mustjala Member

The member (interval 25.80–31.10 m) consists of medium- to thick-bedded, partly bioturbated, brownish-grey, slightly argillaceous dolostone with thin irregular wavy interbeds of dark grey dolomitic marlstone. Fossil fragments are rare, usually pyritized, deformed and sometimes selectively silicified. Agglutinated foraminifers, brachiopods, bivalves, sponge spicules, conularids and crinoids occur. Numerous burrows are mainly horizontal, but may also be inclined and vertical (Fig. 3: 6). The IR yields clay and subrounded to angular silt- and sand-size quartz grains. The content of quartz grains increases upwards in the member. At least ten uneven pyritized discontinuity surfaces are found (Fig. 3: 7). The lowermost 0.35–0.40 m thick interval just above the discontinuity surface at 31.10 m has yielded abundant unevenly distributed fine bioclastic material (wackestone). Fossil fragments are mostly leached and preserved as moulds. At the upper boundary of the Mustjala Member argillaceous dolostone is replaced by dolomitized marlstone.

Paramaja Member

The member (interval 15.60–25.80 m) is composed of thin- to thick-bedded bioturbated, grey, dolomitized marlstone (lowermost 1.30–1.50 m) to variously argillaceous dolostone (Fig. 3: 5). Wavy interbeds of dark grey dolomitic marlstone are common in the lower and become rare in the upper part of the member. Fossils are dominated by small crushed and deformed bivalves and brachiopods. Agglutinated foraminifers, conularids, bryozoans and sponge spicules are present. The morphology of dissolution moulds suggests that most of them originate from fragments of echinoderms and various shells. Burrows are horizontal in the lower part of the member and inclined or rarely vertical in its middle and upper parts. Original depositional structures are often completely destroyed by bioturbation. The IR consists of clay and angular to subrounded silt- and sand-size quartz grains (Fig. 2). The content and roundness of grains increases upwards in the section. The upper boundary of the Paramaja Member (= upper boundary of the Jaani Formation) is marked by a rugged pyritized discontinuity surface at 15.60 m (Fig. 2; Fig. 3: 4).

Jaagarahu? Stage, Muhu Formation

The formation is represented by the Kesselaid Member (interval 6.20–15.60 m; Fig. 2) consisting of indistinctly thin- to medium-bedded light grey microcrystalline dolostone (Fig. 3: 2). Horizontal and inclined microlamination (cross bedding?) characterizes some intervals (Fig. 3: 1). Rare wavy interbeds of greenish-grey dolomitic marlstone occur in the lower part of the member. Few microstylolites are found. Subrounded to rounded carbonate clasts are abundant just above the lower boundary of the member and above an irregular surface at 12.80 m, in the about 10 cm thick conglomerate (tempestite?). The conglomerate yields abundant unsorted fossil fragments. Vugs and moulds of shell valves are oriented parallel to the bedding (Fig. 3: 3). Crushed and deformed, sometimes pyritized fossils in the residues are dominated by bivalves and brachiopods, while ostracods, gastropods, sponge spicules, conularid and crinoid fragments are less common. Some intervals contain vertical (in the uppermost part of the member) and horizontal (in its lower part) indistinct burrows. The IR consits of clay, angular to subrounded silt- and sand-size quartz and rare angular feldspar grains. As is evident from the residues of microfossil samples, general content of quartz increases upwards in the succession.

BIOSTRATIGRAPHY

Chitinozoans

Chitinozoans are abundant in the lower and middle parts of the Suigu (S-3) core section, in the Adavere and Jaani stages, but are practically missing in samples from the Jaagarahu Stage. In total, 38 chitinozoan species have been identified and six chitinozoan zones (CtZ) and one interzone recognized (Fig. 4).

The Conochitina proboscifera *CtZ*

The lowermost part of the Suigu (S-3) core section, up to sample 34.84–35.00 m, is characterized by the association of chitinozoans typical of the upper part of the Adavere Stage (*Con. proboscifera*, *Eisenackitina dolioliformis*, *E. causiata*, *E. inanulifera*, *Calpichitina densa*, *Angochitina longicollis*). *Ramochitina ruhnuensis, Belonechitina meifodensis, Ancyrochitina vikiensis* and *Ancyrochitina* aff. *ancyrea* in this interval indicate the upper part of the *Con. proboscifera* CtZ (Nestor 1994, 2005).

The Conochitina acuminata *CtZ*

The zone is represented by a single sample (34.10–34.26 m) in the studied section. Its maximum possible thickness here is 1.42 m. Together with the index species, *Con. acuminata*, *Con. flamma* and *Con. visbyensis* appear. The *Con. acuminata* CtZ has small thickness also in the Paatsalu and Viirelaid core sections (Hints et al. 2006; Rubel et al. 2007) but further west, on SW Saaremaa (Ohesaare core section) and on Ruhnu Island (Ruhnu-500 core section), the zone is represented by 6–7 m thick strata (Nestor 2003, 2005).

The Margachitina banwyensis *CtZ*

Probable appearance of *M. banwyensis* in sample 33.30–33.42 m may mark the lower boundary of the *M. banwyensis* CtZ in the studied section (Fig. 4). *Margachitina banwyensis* was described by Mullins (2000) as a transitional form between *Calpichitina densa* and *M. margaritana*, all three probably forming an evolutionary (morphological) lineage. In most of the East Baltic sections *M. banwyensis* and *M. margaritana* are difficult to separate due to poor preservation of specimens and, as a result, the level of appearance of *Margachitina* has been indicated as the base of the *M. margaritana* CtZ. However, it should be remembered that although *M. banwyensis* has not been identified in these sections, the strata corresponding to the *M. banwyensis* CtZ elsewhere could still exist there. The strata corresponding to both the *M. banwyensis* and *M. margaritana* CtZs are, most probably, indicated as a single *M. margaritana* CtZ. In the studied section, as also in the Ohesaare core section (Nestor 2005), specimens of *Margachitina* are sufficiently well preserved for separating *M. banwyensis* from *M. margaritana* and identifying both CtZs. Ten chitinozoan species, including *Con. acuminata* and *Con. flamma*, disappear in the upper part of the *M. banwyensis* CtZ, some of them just below the discontinuity surface at 31.10 m in the section (Fig. 4).

The Margachitina margaritana *CtZ*

Chitinozoans characteristic of this zone are found in a single sample (31.00–31.07 m) only. The zone has small thickness also in the Viirelaid core section (Rubel et al. 2007) and has not been recognized in the Paatsalu core section (Hints et al. 2006). The upper boundary of the *M. margaritana* CtZ corresponds to the level of disappearance of *Angochitina longicollis* (Nestor 1994).

Interzone

No taxa distinctive for a certain chitinozoan zone were found in samples from 31.00–29.50 m and this interval is dealt as an Interzone here (Fig. 4). The only noteworthy event in these strata is the replacement of the dominant *Con. proboscifera* by *Con. claviformis*. *Conochitina proboscifera* dominates upper Llandovery–lower Wenlock faunas in all studied East Baltic sections (Nestor 1994).

The Conochitina mamilla *CtZ*

The appearance of *Con. mamilla* in sample 28.80–28.92 m indicates that the lower boundary of the *Con. mamilla* CtZ lies below this level. *Conochitina mamilla*, although well represented in Baltoscandia and recognized in most of the sections studied here (Nestor 1994), has not yet been identified outside this region.

The Conochitina tuba *CtZ*

The co-appearance of *Con. tuba* and *Calpichitina acollaris* in sample 25.61–25.80 m marks the lower boundary of the *Con. tuba* CtZ. The uppermost chitinozoans in the

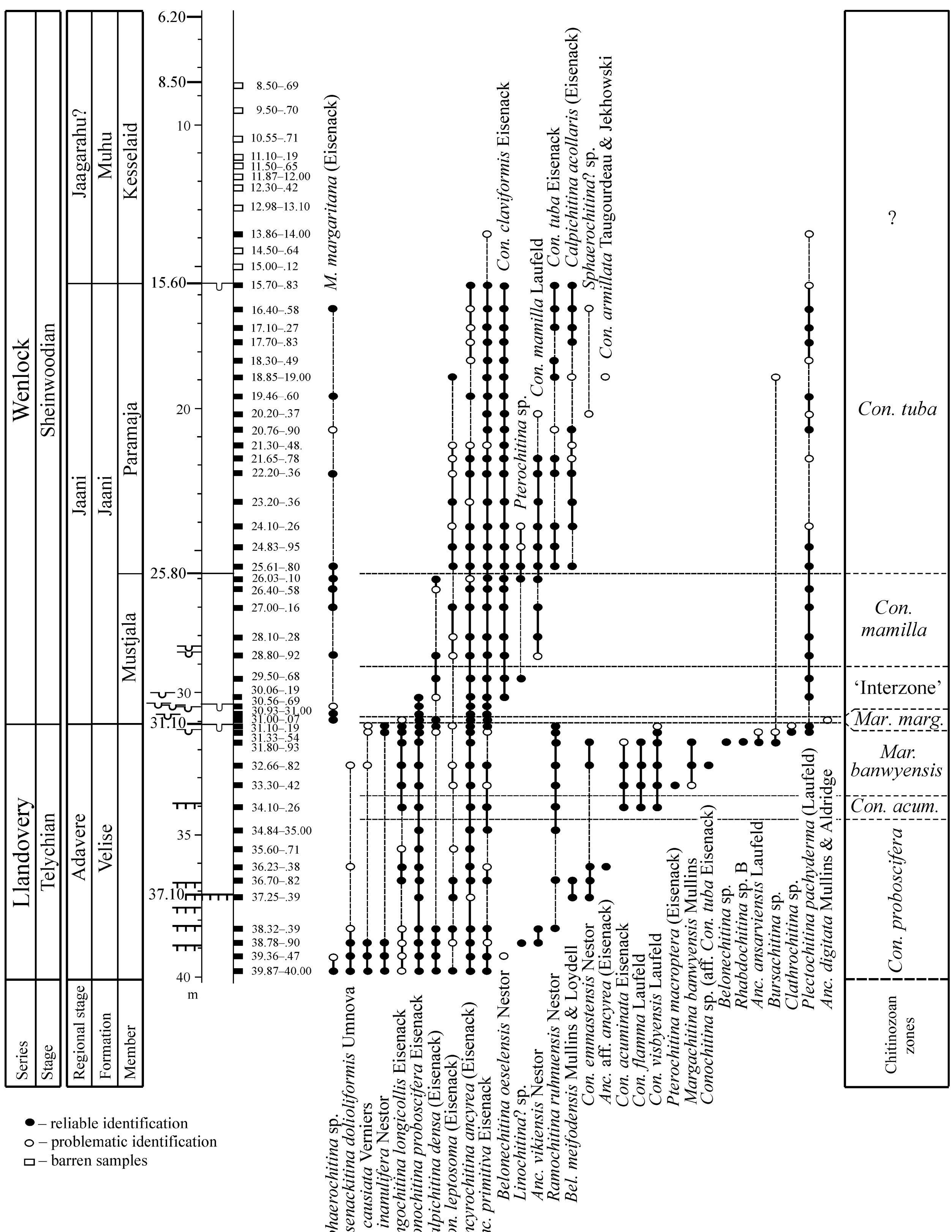

Fig. 4. Distribution of chitinozoans in the Suigu (S-3) core section. *Con. acum.*, *Conochitina acuminata*; *Mar. marg.*, *Margachitina margaritana*. For legend see Fig. 2.

Suigu (S-3) core section come from sample 13.86–14.00 m, still from the *Con. tuba* CtZ. Samples above this level did not yield chitinozoans.

Conodonts

In total, more than 24 000 identifiable conodont specimens were found and four conodont biozones (CZ) were distinguished. The number of specimens in the section varies largely, from 57 (sample 24.83–24.95 m) to 1513 (sample 28.10–28.28 m) specimens per kg. Preservation of conodonts is good, CAI = 1.

The Pterospathodus amorphognathoides lithuanicus *CZ*

The lowermost 3 m of the section correspond to the upper? part of this zone (Fig. 5). In this interval the fauna is dominated by *Pt. a. lithuanicus*, but also *Panderodus unicostatus*, *Pand. greenlandensis* and *Pand. serratus* are common. At the upper boundary of the zone *Pt. a. lithuanicus* is replaced by *Pt. a. amorphognathoides*.

The Pterospathodus amorphognathoides amorphognathoides *CZ*

The strata corresponding to this zone are about 5 m thick. The lower boundary of the zone is marked by the appearance of *Pt. a. amorphognathoides* in sample 36.70–36.82 m. In the next sample (36.23–36.38 m) *Ozarkodina polinclinata polinclinata* and *Apsidognathus walmsleyi*, characteristic of the *Pt. a. amorphognathoides* CZ, appear. The conodont fauna in this interval is also dominated by *Pterospathodus*. Other common taxa are *Pand. unicostatus*, *Pand. greenlandensis* and *O. p. polinclinata*. *Panderodus serratus* is missing. *Panderodus unicostatus* starts to dominate and the relative amount of *Pterospathodus* decreases considerably in the upper part of the zone. The uppermost three samples (31.80–31.93, 31.40–31.54 and 31.10–31.19 m) from this zone contain dark greyish redeposited specimens (e.g. *Panderodus*, *Pterospathodus*, *Pseudooneotodus*). The sample just below the upper boundary of the zone (sample 31.10–31.19 m) yielded mixed faunas: taxa of the *Pt. a. amorphognathoides* CZ (e.g. *Pt. a. amorphognathoides*, *O. p. polinclinata*, *Nudibelodina sensitiva*, *Walliserodus* sp. n. B) together with *Pand. equicostatus*, *Wurmiella excavata* and *Walliserodus* sp. n. C which are characteristic of younger strata. *Walliserodus* sp. n. C is known to appear in the upper part of the Lower *Kockelella ranuliformis* CZ in other sections (Männik 2010). The sample 31.10–31.19 m comes from an interval just below the discontinuity surface at 31.10 m. This could explain the origin of mixed faunas: most probably, several burrows related to this surface and yielding younger material which deposited after a break in sedimentation extend into this sample (Fig. 3: 8).

The Upper Kockelella ranuliformis *CZ*

The overlying, about 1.4 m thick strata (samples 31.00–31.07 m to 30.06–30.19 m) correspond to this zone. However, it cannot be excluded that the lowermost sample from this interval (sample 31.00–31.07 m) comes from the Lower *K. ranuliformis* CZ (see Discussion below). The fauna in the Upper *K. ranuliformis* CZ is strongly dominated by *Pand. equicostatus* in the studied section. *Wurmiella excavata*, *Pseudooneotodus bicornis* and *Walliserodus* sp. n. C (only in the lower part of the zone) are also quite common.

The Ozarkodina sagitta rhenan*a CZ*

Main part of the section, from sample 29.50–29.68 m to the contact with overlying strata of Quaternary age at 6.20 m, corresponds to the *O. sagitta rhenana* CZ. Based on the composition of conodont faunas, two distinct intervals can be recognized in the zone: lower half of the zone is strongly dominated by *Pand. equicostatus*, the upper one by *Wurmiella excavata*. The boundary between these intervals of the *O. s. rhenana* CZ can be tentatively drawn between samples 18.85–19.00 and 18.30–18.49 m, in the upper part of the Paramaja Member. In the lower interval of the *O. s. rhenana* CZ *Walliserodus* sp. n. C is still quite common and *Wurmiella excavata* relatively rare, whereas in the upper interval the situation is reversed.

GEOCHEMISTRY

Carbon isotopes

Carbon isotope ($\delta^{13}C$) values were measured in 55 samples, 52 of them coming from the same intervals as microfossil samples (Table 2, Fig. 6). The curve constructed from the measured $\delta^{13}C$ values demonstrates four characteristic intervals: (1) almost continuous decrease in values in the lower part of the section (from 1.58‰ in the lowermost *Pt. a. lithuanicus* CZ to 0.30‰ in the middle *Pt. a. amorphognathoides* CZ); (2) an interval of continuous increase in values from 0.30‰ in the middle *Pt. a. amorphognathoides* CZ to 3.68‰ in the lowermost *O. s. rhenana* CZ; (3) slow continuous increase in values up to 4.23‰ in the upper Paramaja Member, followed (4) by an interval of variable but in general decreasing values.

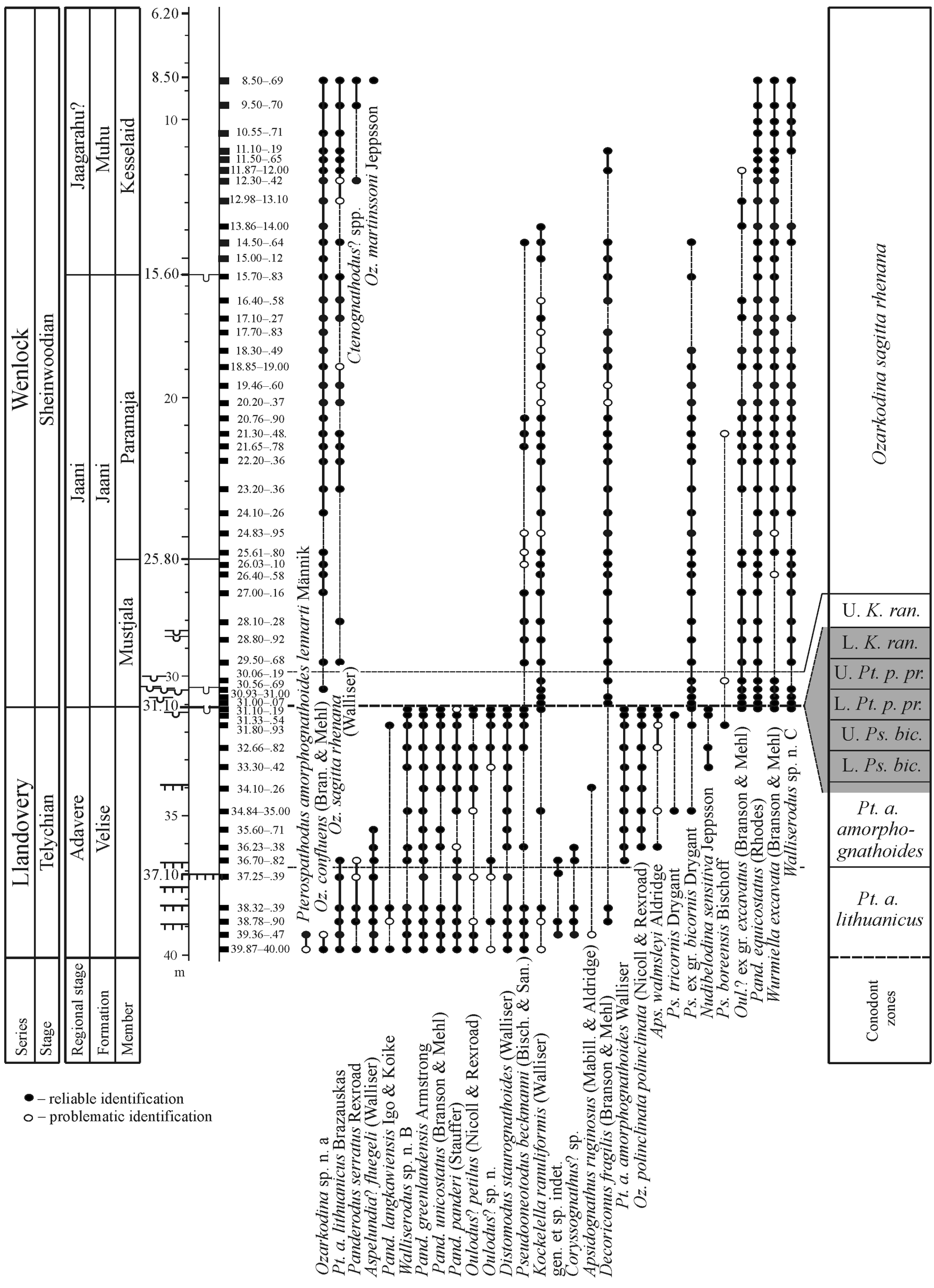

Fig. 5. Distribution of conodonts in the Suigu (S-3) core section. U., Upper; L., Lower; *K. ran.*, *Kockelella ranuliformis*; *Pt. p. pr.*, *Pterospathodus pennatus procerus*; *Ps. bic.*, *Pseudooneotodus bicornis*; *a.*, *amorphognathoides*. For legend see Fig. 2.

Table 2. Carbon isotope data from the Suigu (S-3) core section

Depth, m	δ^{13}C, ‰	Depth, m	δ^{13}C, ‰	Depth, m	δ^{13}C, ‰	Depth, m	δ^{13}C, ‰	Depth, m	δ^{13}C, ‰
8.69	3.55	15.82	4.20	22.36	3.83	28.92	3.68	34.23	0.45
9.50	3.68	16.58	4.23	23.36	3.83	29.57	2.87	35.00	0.45
10.55	2.97	17.27	4.15	24.26	3.87	30.06	2.23	35.71	0.83
11.19	2.79	17.83	4.15	24.94	3.99	30.68	2.08	36.38	1.05
11.50	3.75	18.48	3.99	25.61	3.96	30.96	1.66	36.83	0.98
11.97	3.78	19.00	4.23	26.10	3.68	31.06	1.60	37.38	1.17
12.42	3.86	19.60	4.18	26.58	3.89	31.19	1.49	37.55	1.03
13.10	4.08	20.37	4.13	27.00	3.86	31.45	1.08	38.39	1.16
14.00	3.41	20.90	3.59	27.35	3.75	31.93	0.78	38.86	1.29
14.63	3.85	21.48	3.52	28.13	3.59	32.82	0.46	39.45	1.58
15.12	3.89	21.78	3.82	28.68	3.58	33.42	0.30	39.92	1.49

K-bentonites

Two K-bentonites were recognized visually: (1) a 0.3 cm thick yellowish layer consisting of authigenic feldspar at 38.30 m and (2) a 5–7 cm thick K-bentonite, with authigenic K-feldspar and illite-smectite as main minerals, about a metre higher (lower boundary at 37.20 m). The composition of sanidine measured in the latter bed revealed 45.2 mol% of the Na + Ca component (Table 1), indicating possible correlation of the bed with the Viki K-bentonite (ID 475) *sensu* Kiipli et al. (2010).

Additionally, four potential beds of volcanic origin (distinct argillaceous interbeds at 38.90, 37.55, 36.70 and 33.90 m) were sampled and analysed. All of these beds contain main minerals typical of terrigenous material (quartz, dolomite, illite and chlorite) but yield also some pyroclastic minerals. Based on the composition of sanidine, K-bentonite at 38.90 m correlates with ID 494 and that at 37.55 m with ID 480 (Kiipli et al. 2010; Table 1). Both beds, and also the bed with ID 475, are known to occur in the upper *Pt. a. lithuanicus* CZ. The K-bentonite at 36.70 m correlates with ID 457 known from the lowermost part of the *Pt. a. amorphognathoides* CZ. The sanidine XRD reflection in the bed at 33.90 m is too weak for reliable determination of its composition and therefore no correlation with any bed in earlier studied sections (e.g. Kiipli et al. 2010) can be proved geochemically (see also Discussion below).

DISCUSSION

Dating of the strata

The strata below sample 37.25–37.39 m (included) correspond to the *Pt. a. lithuanicus* CZ and those above that level, up to the discontinuity surface at 31.10 m, to the *Pt. a. amorphognathoides* CZ. Lack of *Aspelundia*? *fluegeli* ssp. n. *sensu* Männik (2007a) in the studied section may indicate that only the Lower Subzone (CSZ) of the *Pt. a. amorphognathoides* CZ is represented and that its Upper Subzone corresponds to a gap. However, the occurrence of *Margachitina* in the upper part of the zone suggests that both subzones of the *Pt. a. amorphognathoides* CZ are represented. The appearance of *Margachitina* marks the upper boundary of the *Con. acuminata* CtZ lying close to (just above?, Kiipli et al. 2010) the boundary between the Lower and Upper *Pt. a. amorphognathoides* CSZs. Also, a K-bentonite with distinct composition (ID 311) is known to occur in the lowermost part of the Upper *Pt. a. amorphognathoides* CSZ in several sections. In the Suigu (S-3) core section a K-bentonite has been found at 33.90 m, just above the only sample (34.10–34.26 m) corresponding to the *Con. acuminata* CtZ (Fig. 4). Although the sanidine reflection is too weak to allow reliable identification of this K-bentonite, its position in the section suggests that it might be the one with ID 311.

Results of δ^{13}C studies provide some other indications that both subzones of the *Pt. a. amorphognathoides* CZ may be represented in the studied section. It appeared that the δ^{13}C curve in the Suigu (S-3) core section is very similar to that from the Viki core section (Kaljo et al. 2003). In both sections the strata corresponding to the main part of the Adavere Stage (in the Suigu core section the lower part of the stage is not represented) are characterized by general gradual decrease in the δ^{13}C values with their minimum in the uppermost part of the stage (in the lower part of the Upper *Pt. a. amorphognathoides* CSZ in the Viki core section, Cramer et al. 2010, fig. 8; Fig. 6). Starting from this level, the δ^{13}C values increase almost continuously in both sections up to their maximums in the Sheinwoodian, in the lower *Oz. s. rhenana* CZ.

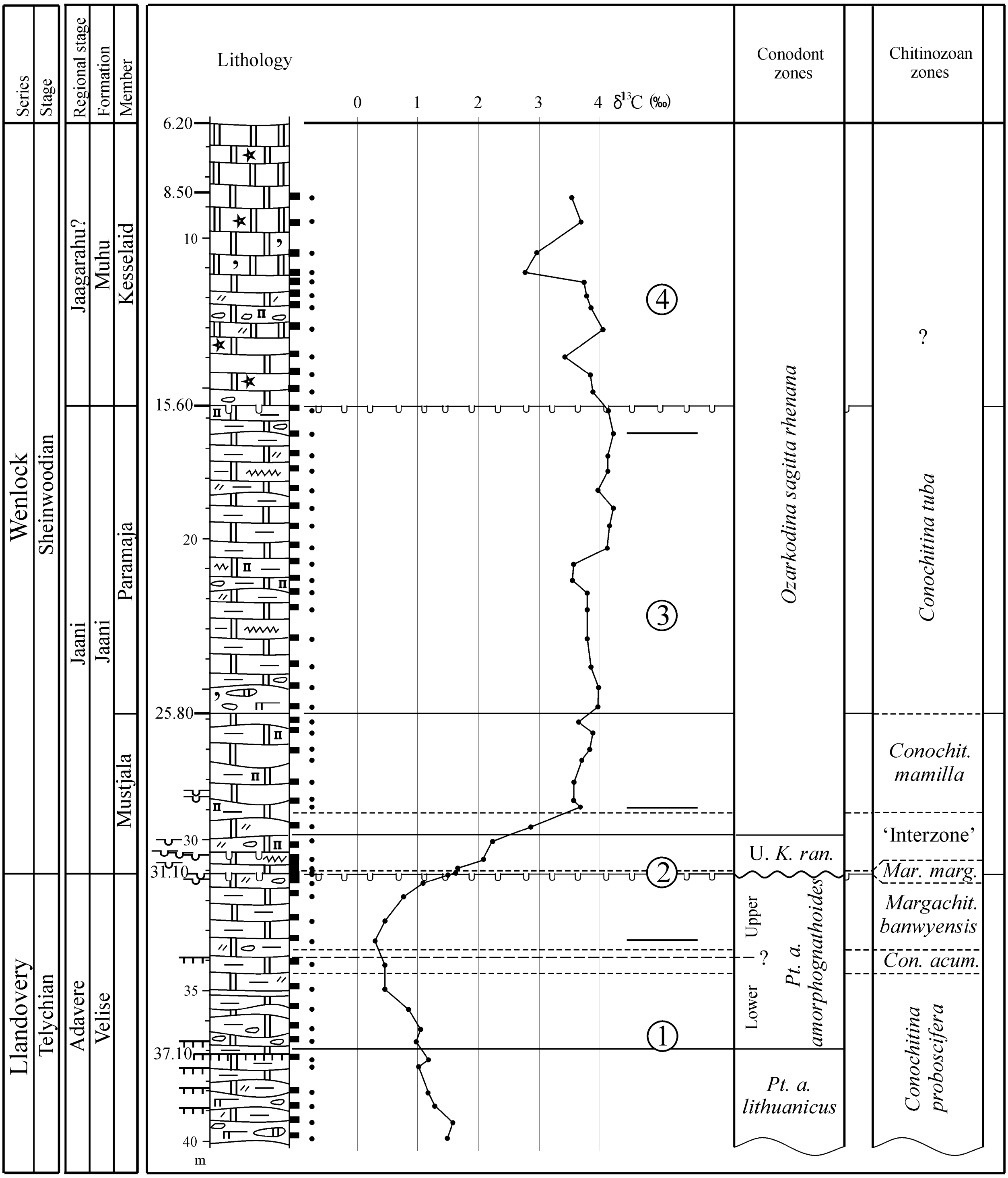

Fig. 6. Carbon isotopes and integrated biostratigraphy in the Suigu (S-3) core section. Dots just right of the micropalaeontological samples indicate the levels of $\delta^{13}C$ analyses; numbers in circles right of the $\delta^{13}C$ curve indicate characteristic intervals of the curve discussed in the text. U. *K. ran.*, Upper *Kockelella ranuliformis*; *Pt. a.*, *Pterospathodus amorphognathoides*; *Mar. marg.*, *Margachitina margaritana*; *Con. acum.*, *Conochitina acuminata*. For legend see Fig. 2.

As known from the Viki core section, the *Con. acuminata* CtZ and the boundary between the Lower and Upper *Pt. a. amorphognathoides* CSZs lie in the upper part of the falling limb of the $\delta^{13}C$ curve in the Adavere Stage. The *Con. acuminata* CtZ has a similar position also in the Suigu (S-3) core section: it occurs just below the level with minimum values in the $\delta^{13}C$ curve, in the middle part of the *Pt. a. amorphognathoides* CZ as recognized here (Fig. 6). Minimum $\delta^{13}C$ values are measured from the sample with the lowermost specimens of *Margachitina*. The $\delta^{13}C$ values increase gradually above this level (with small variations in the interval with discontinuity surfaces in the section: in the Upper *K. ranuliformis* CZ, in the 'Interzone' in sense of chitinozoan stratigraphy) up to their first maximum in the lowermost *O. s. rhenana* CZ (in the lowermost *Con. mamilla* CtZ). Similar features (i.e. general gradual increase in values; variations in the Upper *K. ranuliformis* CZ – in the chitinozoan 'Interzone'; first maximum in the lowermost *O. s. rhenana* CZ – in the *Con. mamilla* CtZ) characterize the $\delta^{13}C$ curve also in the Viki core section.

Hence, although *A.*? *fluegeli* ssp. n. was not found in the Suigu (S-3) section, the data above seem to indicate that also the Upper *Pt. a. amorphognathoides* CSZ, or at least main part of it, is represented there. Possible reasons for the absence of *A.*? *fluegeli* ssp. n. are as follows: (1) usually, when present in a section, elements of *A.*? *fluegeli* ssp. n. are rare and the samples might have been too small to provide them; (2) as the taxon has, as a rule, a very short range (often recognized in one sample only: Rubel et al. 2007), it is most probable that the strata yielding *A.*? *fluegeli* ssp. n. were not sampled in the Suigu (S-3) section.

The strata above the discontinuity surface at 31.10 m, between samples 31.00–31.07 m below and 30.06–30.19 m above (both included), correspond to the *K. ranuliformis* conodont Superzone, probably to the Upper *K. ranuliformis* CZ. The latter zone is favoured by lack of *Distomodus staurognathoides* in this interval. However, in sense of chitinozoan biostratigraphy, the lowermost sample in this interval (31.00–31.07 m) might come from the *M. margaritana* CtZ and the strata above it correspond to the 'Interzone' (Fig. 4). As the upper boundary of the *M. margaritana* CtZ is known to correspond to a level in the Lower *K. ranuliformis* CZ (Rubel et al. 2007), the occurrence of the *M. margaritana* CtZ assemblage in sample 31.00–31.07 m suggests that this sample comes from the Lower *K. ranuliformis* CZ. There are two possible explanations to this seeming disagreement between the dating of sample 31.00–31.07 m based on conodonts and chitinozoans: (1) the level may correspond to the Lower *K. ranuliformis* CZ; *D. staurognathoides* might be missing due to its rare occurrence in the upper part of its range (e.g. Jeppsson & Männik 1993); (2) the occurrence of *A. longicollis* (whose disappearance defines the upper boundary of the *M. margaritana* CtZ; Nestor 1994) in the Upper *K. ranuliformis* CZ in the studied section may result from reworking of its specimens from older strata. As sample 31.00–31.07 m yielded only few poorly preserved specimens of *A. longicollis*, the second explanation seems more probable.

Age and distribution of the gap

Based on the biostratigraphical data discussed above, it is evident that a gap corresponding to at least four conodont zones (from below: Lower and Upper *Ps. bicornis*, Lower and Upper *Pt. pennatus procerus*), but probably also to the upper(most) Upper *Pt. a. amorphognathoides* CSZ and the Lower *K. ranuliformis* CZ (or to part of it) exists in the Suigu (S-3) core section (Figs 5–7). In sense of chitinozoan biostratigraphy, the gap lies between the *M. banwyensis* and *M. margaritana* CtZs. Only the topmost part of the *M. margaritana* CtZ (represented by a single sample just above the gap) might be preserved in the Suigu (S-3) core section. A gap in this section is also supported by the absence of the Ohesaare (ID 210), Lusklint (ID 150) and Ireviken (ID 127) K-bentonites known in several other sections in Baltoscandia (Kiipli et al. 2010, 2012). As the first two of them occur in the upper part of the Upper *Pt. a. amorphognathoides* CSZ, their absence suggests that also this interval is missing in the Suigu (S-3) core section. Surprisingly, the $\delta^{13}C$ curve in that section does not bear any indication of a gap. Although the Ireviken Event (corresponds to the interval from the top of the *Pt. a. amorphognathoides* CZ to the base of the Upper *K. ranuliformis* CZ; Fig. 7) is characterized by rapid increase in $\delta^{13}C$ values (in the Viki core section from 1.9‰ to 3.9‰; Cramer et al. 2010), the curve in the Suigu (S-3) core section does not demonstrate any jump (which might be expected) but the values increase almost gradually also across the gap. Causes of this controversy between the biostratigraphical and $\delta^{13}C$ data are still waiting to be revealed. One possibility might be that almost gradual changes in $\delta^{13}C$ values are caused by mixing of sediment below and above the gap by bioturbation (mixed conodont faunas; see above). However, further studies of other sections are needed to resolve the problem.

A gap in the Llandovery–Wenlock boundary interval has been identified also in some other sections from west-central continental Estonia and from islands located to the west. In the coastal region, break in sedimentation probably started somewhat earlier than in the Suigu region. In the Paatsalu core section, the strata just below

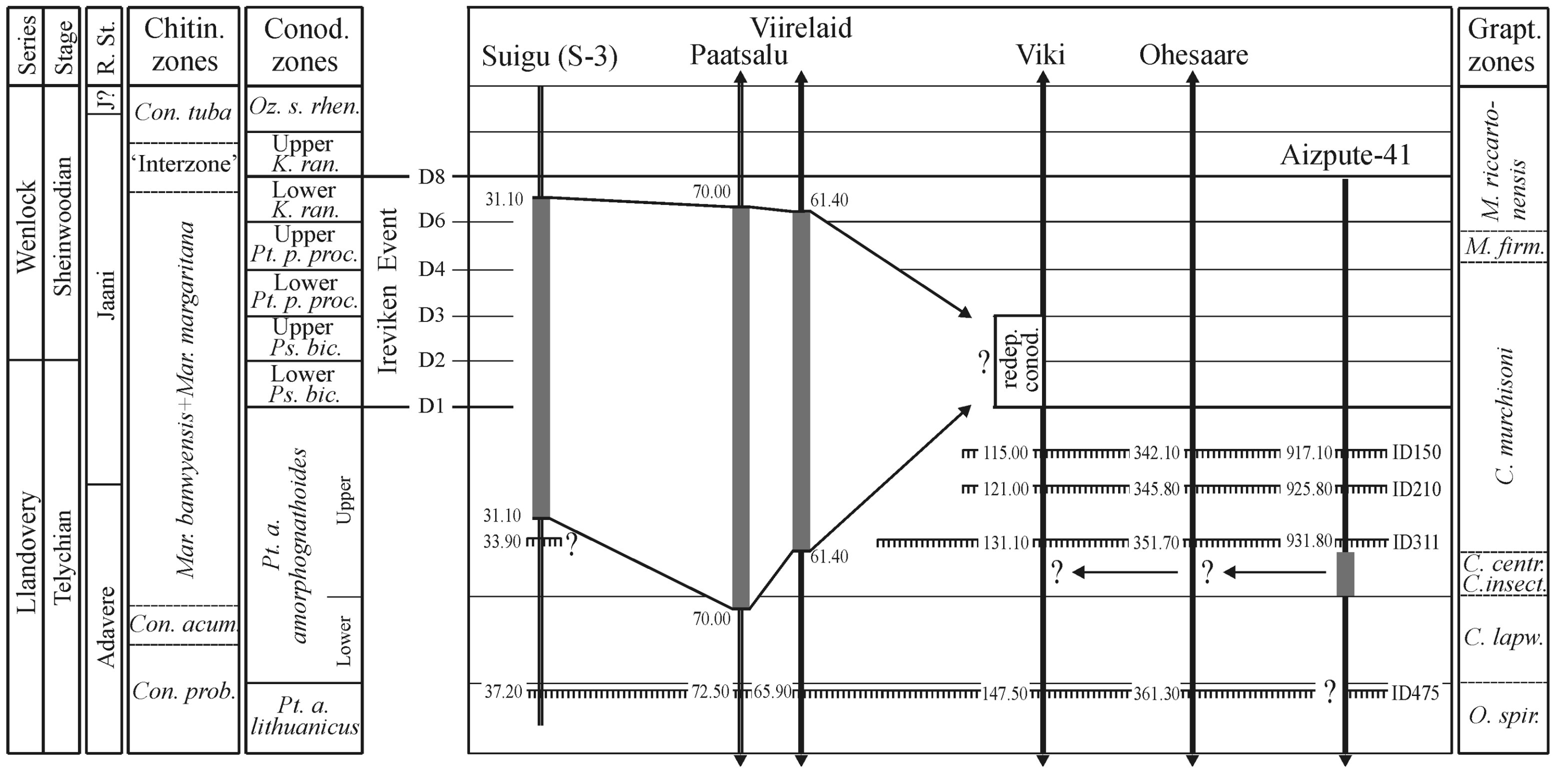

Fig. 7. Distribution of the gap and correlation of sections discussed in this paper. From left to right: general stratigraphy, regional stratigraphy, chitinozoan zones, conodont zones, datums of the Ireviken Event, correlation of sections (grey vertical bars indicate gaps), graptolite zones. Abbreviations: R. St., regional stage; J?, Jaagarahu? Stage; Chitin., Chitinozoan; *Con.*, *Conochitina*; *acum.*, *acuminata*; *prob.*, *proboscifera*; *Mar.*, *Margachitina*; Conod., Conodont; *Oz. s. rhen.*, *Ozarkodina sagitta rhenana*; *K. ran.*, *Kockelella ranuliformis*; *Pt.*, *Pterospathodus*; *p. proc.*, *pennatus procerus*; *Ps. bic.*, *Pseudooneotodus bicornis*; *a.*, *amorphognathoides*; redep. conod., redeposited conodonts; Grapt., Graptolite; *M.*, *Monograptus*; *firm.*, *firmus*; *C.*, *Cyrtograptus*; *centr.*, *centrifugus*; *insect.*, *insectus*; *lapw.*, *lapworthi*; *O. spir.*, *Oktavites spiralis*. Dented horizontal lines – K-bentonites with their identification numbers (ID) according to Kiipli et al. (2010). Arrows at the end(s) of the sections indicate that they continue above and/or below the studied interval. The numbers at boreholes denote depth in metres. For further discussion of the data presented see text.

the gap at 70.00 m correspond to the *Con. acuminata* CtZ (Hints et al. 2006). This dating agrees with conodont data suggesting that the Upper *Pt. a. amorphognathoides* CSZ is missing in that section. Bentonites as well suggest a longer gap in the Paatsalu core section: in addition to the Ohesaare (ID 210), Lusklint (ID 150) and Ireviken (ID 127) bentonites, also the Aizpute (ID 311) bentonite, known to occur in the lowermost Upper *Pt. a. amorphognathoides* CSZ (Kiipli et al. 2010), is missing. Further west, in the Viirelaid core section, the gap seems to be already smaller and corresponds to the Lower and Upper *Ps. bicornis* and to the Lower and Upper *Pt. pennatus procerus* CZs, to an interval in the *M. margaritana* CtZ (Rubel et al. 2007). In all three sections sedimentation restarted in Early *K. ranuliformis* time, probably somewhat later in the Suigu (S-3) section than in the Paatsalu and Viirelaid sections. However, as noted above, additional more detailed sampling of the Paatsalu and Viirelaid core sections is needed to prove the dating of the gap there.

The gap evidently becomes shorter in the western and southwestern direction. It has not been recognized in the Viki and Ohesaare core sections from the western and southern parts of Saaremaa and in the Aizpute-41 core section from western Latvia (Loydell et al. 1998, 2003; Põldvere & Nestor 2010).

Changes in depositional environments

In Estonia, the Llandovery–Wenlock boundary interval is mainly represented by a package of mid- to outer shelf sediments, mostly by bluish-grey, grey or dark brownish-grey more or less calcareous, often dolomitized marlstones and claystones. Three different types of sections across the boundary are known: (1) sections with a gap of various duration in the boundary interval (Paatsalu, Viirelaid and Suigu (S-3) core sections: Hints et al. 2006; Rubel et al. 2007; this paper), (2) continuous sections in non-graptolitic open shelf facies (Viki core section: Jeppsson & Männik 1993; Männik 2007a; Põldvere & Nestor 2010) and (3) continuous sections in graptolitic distal shelf facies (Ohesaare core section: Loydell et al. 1998). All known sections with a gap in the Llandovery–Wenlock boundary interval come from the NE part of the modern distribution area of Telychian–Sheinwoodian strata in Estonia. The Suigu (S-3) core section is the easternmost of them, Paatsalu is located close to the western coast of continental Estonia and the Viirelaid core comes from a small island (Viirelaid) just SE of Muhu Island (Fig. 1).

The latest Llandovery time in the eastern Baltic was characterized by general shallowing of the basin (Nestor & Einasto 1997). In modern west-central continental Estonia, deposition in the late Llandovery, in Adavere time, took place in open shelf environment, below the storm wave base. Gradual decrease in the clay and increase in the calcareous content of the sediment in the Suigu (S-3) core section (see above) evidently resulted from the decrease in water depth. A distinct shallowing event in the region in the earliest Wenlock (early Mustjala) time resulted in frequent periods of non-deposition (marked in the Suigu (S-3) core section by at least nine impregnated and bioturbated discontinuity surfaces in the interval 30.36–31.30 m), increase in carbonate production and in input of bioclastic material. Most probably, this event resulted from the formation of the SE–NW-trending Pärnu Uplift in modern SW continental Estonia at that time (Perens 1995). In the Paatsalu and Viirelaid core sections, which are located closer to the uplift, the gap at the Llandovery–Wenlock boundary interval had longer duration and the strata that formed during the event are thinner (less than 1 m in both sections). Only one discontinuity surface occurs in the Viirelaid (at 61.4 m) and two discontinuity surfaces (at 70.0 and 70.2 m) are found in the Paatsalu core section. Additionally, in both sections, the strata just below the interval with discontinuity surfaces are rich in randomly distributed tangential ooids suggesting a close proximity of these sections to a very shallow active water region (Flügel 2004). Ooids were not found in the Suigu (S-3) core section.

The strata above the discontinuity surfaces in the Paatsalu and Viirelaid core sections are represented by an up to 30 m thick interval of marlstone, suggesting that open shelf quiet water environments were re-established after the shallowing event. The formation of argillaceous deposits (now medium- to thick-bedded argillaceous dolostone) continued in the Suigu (S-3) core section and only in early Paramaja time a brief period of deepening of the basin is represented by an up to 1.5 m thick interval of bioturbated marlstone (Fig. 2). However, very soon the shallowing of the basin continued in the Suigu area and resulted in a distinct environmental change at the Jaani–Jaagarahu? boundary (marked by a discontinuity surface). The appearance of light-coloured dolostones, of conglomeratic, micro-laminated and cross-bedded interbeds, and increased input of silt- and sand-size quarts above this level suggest that the environment became well ventilated and deposition continued in relatively shallow-water conditions.

No distinct change in lithology was observed in the Llandovery–Wenlock boundary interval in the Viki core section from western Saaremaa (Fig. 1; Põldvere & Nestor 2010): marlstones in this interval are just becoming gradually more calcareous (more dolomitic) and the content of bioclastic material in the rock is increasing. Here, at least 21 m of strata formed during a break in sedimentation in the Paatsalu core where the gap had longest duration (Fig. 7). All datums of the Ireviken Event (zonal boundaries *sensu* Jeppsson 1997) described from Gotland are recognized in the Viki core section (Jeppsson & Männik 1993; Männik 2007a, 2010). The only hint to some change in sedimentation close to the Llandovery–Wenlock boundary is the appearance of rare dark redeposited conodont specimens in the Lower and Upper *Ps. bicornis* CZs (in the interval between 113.05 and 113.75 m). Most probably the appearance of redeposited material in the Viki core section is related to the gap recognized in west-central continental Estonia, to the formation of the Pärnu uplift in that region. Hence, the gap identified in west-central continental Estonia evidently had its widest areal distribution at the time of the formation of strata between datums 1 and 3 of the Ireviken Event (Fig. 7).

A distinct change in lithology occurs at 345.8 m in the Ohesaare core section from SW Saaremaa, at the boundary between the Adavere and Jaani stages (Nestor 1990) where greenish-grey marlstones of the Velise Formation are replaced by dark brownish-grey marlstones and mudstones of the Riga Formation. The occurrence of a robust poorly preserved fragment of *Cyrtograptus* at 345.11–345.14 m indicates the *C. centrifugus* or the *C. murchisoni* Graptolite Zone (GZ) (Loydell et al. 1998). The lowermost identifiable *Cyrtograptus* (= *C. murchisoni*) was found higher in that section (at 343.04–343.06 m). The uppermost level below, 352.80–352.88 m, reliably dated by graptolites, lies in the upper Telychian *C. lapworthi* GZ. No precise graptolite biostratigraphical data are available from the interval between this level and that of the occurrence of the lowermost identifiable *C. murchisoni.* Based on the distribution of conodonts in combination with the results of K-bentonite studies, the Llandovery–Wenlock boundary (Datum 2 of the Ireviken Event) in the section lies in the upper part of the *C. murchisoni* GZ (Fig. 7; Männik 2007b). No evidence of a gap in the Llandovery–Wenlock boundary interval was observed in the Ohesaare section.

The Aizpute-41 core section from western Latvia yielded no evidence of a gap in the Llandovery–Wenlock boundary interval, in the upper *C. murchisoni* GZ, either (Fig. 7; Männik 2007b). However, a gap corresponding to the upper *C. lapworthi*, *C. insectus* and *C. centrifugus* GZs has been recognized here (Loydell et al. 2003). In sense of conodont biostratigraphy, the gap occurs in the lowermost Upper *Pt. a. amorphognathoides* CSZ (Männik 2007b; Fig. 7). The dating of the gap identified in west-central continental Estonia (see above; Fig. 7) shows that the gap here is younger than that in the Aizpute-41 core section. No direct indication of a gap possibly of similar age as that in the Aizpute-41 core section was found in any other of the sections discussed in this paper. However, hidden gap(s) cannot be excluded. In the Paatsalu core section the gap marked by a discontinuity surface at 70.00 m seems to include also the interval corresponding to the *C. lapworthi–C. centrifugus* GZs, to the gap recognized in the Aizpute-41 core section.

The data above indicate that the sedimentological history of the Silurian Baltic Palaeobasin was complicated in late Telychian–early Sheinwoodian time. Data from the Aizpute-41 core section suggest that the level of maximum sea level low stand (gap in the section) lies close to (just above?) the boundary between the Lower and Upper *Pt. a. amorphognathoides* CSZs, below the *C. murchisoni* GZ. The lithological change at 345.8 m in the Ohesaare core section, the appearance of dark brownish-grey marlstones rich in graptolites, shows that transgression in that region started in *C. centrifugus* or early *C. murchisoni* time. However, data from the Viirelaid, Paatsalu and Suigu (S-3) core sections suggest that the gap, and accordingly the maximum shallowing of the sea, is younger and lies in the Ireviken Event interval, in the upper *C. murchisoni* GZ (Fig. 7). This gap is probably related to the occurrence of dark redeposited conodonts in the Lower and Upper *Ps. bicornis* CZs in the Viki core section. As noted above, no evidence of lithological changes was found at this level in the Ohesaare and Aizpute-41 core sections. Hence, it seems that in different parts of the basin changes in sedimentation occurred at different times: earlier in the distal graptolite-bearing (Aizpute-41 and Ohesaare core sections) and later in proximal environments (Viki, Suigu (S-3), Paatsalu and Viirelaid core sections).

Causes of the discrepancy in the timing of the sedimentary events in different parts of the basin are not clear yet. Earlier, the gap recognized in the easternmost sections of Estonia was related to the boundary between sequences S4 and S5 described in the Silurian succession in Estonia (Harris et al. 2005). According to these authors, the boundary was characterized by a regional gap in the eastern (proximal) part of the basin and by a lithological change (appearance of transgressive deposits above the boundary) in its distal part. The boundary was considered to be of eustatic origin and coeval all over the basin. However, as the above data revealed, the gap in the easternmost sections of Estonia is younger than the transgressive event (i.e. appearance of sediments with *Cyrtograptus*) in the Ohesaare core section. Accordingly, these two events cannot be caused by the same eustatic event. They, or at least one of them, most probably reflect specific features of tectonic evolution of the Balto-scandian foreland basin (e.g. Lazauskienė et al. 2002). To understand the evolutionary history of the Silurian Baltic Palaeobasin in the interval discussed in this paper, additional detailed studies of several other sections are in progress.

CONCLUSIONS

Strata from the *Pterospathodus amorphognathoides lithuanicus* CZ below to the *Ozarkodina sagitta rhenana* CZ above are exposed in the Suigu (S-3) core section. In sense of chitinozoan biostratigraphy the section corresponds to an interval from the *Conochitina proboscifera* CtZ below up to the *Con. tuba* CtZ above. Samples above 13.86 m did not yield chitinozoans. In the studied section a gap corresponding to at least four conodont zones (from below: Lower and Upper *Pseudooneotodus bicornis*, Lower and Upper *Pterospathodus pennatus procerus*), but probably also to the upper(most) Upper *Pt. a. amorphognathoides* conodont Subzone and to the Lower *Kockelella ranuliformis* CZ (or part of it), are missing. In sense of chitinozoan stratigraphy, the gap correlates with most of the *Margachitina margaritana* CtZ. Only the uppermost part of the last zone is represented in the section. Our data indicate that changes in sedimentation in the Llandovery–Wenlock boundary interval occurred in different parts of the basin at different times: earlier in the distal graptolite-bearing environments (Aizpute-41 and Ohesaare core sections) and later in the proximal regions (Viki, Suigu, Paatsalu and Viirelaid core sections). Sedimentation in the Baltic Palaeobasin in the late Telychian and early Sheinwoodian was most probably strongly affected by tectonic evolution of the Baltoscandian foreland basin. To understand the evolutionary history of the basin in the studied interval, additional detailed investigation of sections in the region is needed.

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Llandovery–Wenlocki piiri intervall Mandri-Eesti lääneosas Suigu (S-3) puurläbilõike näitel

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Suigu (S-3) läbilõikes on esindatud Siluri kihid *Pterospathodus amorphognathoides lithuanicus*'e tsoonist (Adavere lade, Telychi ülemine pool) kuni *Ozarkodina sagitta rhenana* tsoonini (Jaagarahu lade, Sheinwoodi ülemine pool). Kitiinikute tsonaalses skeemis vastavad kitiinikutega kihid intervallile *Conochitina proboscifera* tsoonist kuni *C. tuba* tsoonini. Proovid tasemest 13,86 m kõrgemale jäävast läbilõikeosast kitiinikuid ei sisaldanud. Uuritud läbilõikes Llandovery–Wenlocki piiri intervallis fikseeritud lünga maht vastab vähemalt neljale konodonditsoonile (alt: Alumine ja Ülemine *Pseudooneotodus bicornis*'e, Alumine ning Ülemine *Pt. pennatus procerus*'e tsoon), kuid tõenäoliselt puuduvad ka Ülemise *Pt. a. amorphognathoides*'e alamtsooni ülemine osa ja Alumine *Kockelella ranuliformis*'e tsoon (või osa sellest). Kitiinikute tsonaalses skeemis vastab nimetatud lünk valdavale osale *Margachitina margaritana* tsoonist, ainult viimase kõige ülemine osa on Suigu läbilõikes olemas. Ligilähedase ulatusega lünk Llandovery–Wenlocki piiri intervallis on varasemate uuringute käigus fikseeritud ka mitmes teises läbilõikes Mandri-Eesti lääneosas ja Muhu saarel. Meie tulemuste võrdlus teiste läbilõigete andmetega näitas, et muutused settekeskkonnas toimusid varem basseini sügavamas ja hiljem madalamas osas. Tõenäoliselt olid settetingimused basseinis olulisel määral mõjutatud regiooni tektoonilistest protsessidest.