Geol. Mag. **142** (4), 2005, pp. 369–376. © 2005 Cambridge University Press
doi:10.1017/S0016756805000531 Printed in the United Kingdom

Integrated graptolite and chitinozoan biostratigraphy of the upper Telychian (Llandovery, Silurian) of the Ventspils D-3 core, Latvia

D. K. LOYDELL* & V. NESTOR†

*School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Road, Portsmouth PO1 3QL, UK
†Institute of Geology at Tallinn University of Technology, 7 Estonia Avenue, 10143 Tallinn, Estonia

(*Received* 13 July 2004; *accepted* 14 February 2005)

Abstract – Integrated graptolite and chitinozoan biostratigraphical data are presented from the upper Telychian (*Oktavites spiralis* and *Cyrtograptus lapworthi* graptolite biozones) of the Ventspils D-3 core, Latvia. The base of the *Angochitina longicollis* chitinozoan Biozone is approximately coincident with that of the *spiralis* graptolite Biozone, as it is elsewhere in the East Baltic, although in Wales it lies within the upper *spiralis* graptolite Biozone. *Conochitina proboscifera* appears in the upper *spiralis* graptolite Biozone in the Ventspils D-3 core, but at lower and higher horizons elsewhere, presumably reflecting its patchy distribution during the lower part of its stratigraphical range. *Ramochitina ruhnuensis* appears to be a stratigraphically useful, although geographically restricted, species, appearing at a level close to the base of the *lapworthi* graptolite Biozone. The most remarkable feature of the Ventspils D-3 chitinozoan record is the very early occurrence, in the upper *spiralis* graptolite Biozone, of two chitinozoan biozonal index species: *Margachitina banwyensis* and *M. margaritana*. Previously, these two taxa were considered unequivocal indicators of the uppermost Telychian to Sheinwoodian or Homerian, respectively.

Keywords: graptolites, Chitinozoa, Llandovery, Silurian, biostratigraphy.

1. Introduction

A number of integrated biostratigraphical studies has been undertaken in recent years on the Silurian of Estonia and Latvia: Loydell, Kaljo & Männik (1998) on the Ohesaare core, Saaremaa, Estonia; Nestor *et al.* (2003) on the Rhuddanian–Aeronian of central and southern Estonia; Loydell, Männik & Nestor (2003) on the Aizpute-41 core, Latvia; and Kaljo (*in* Põldvere, 2003), Männik (*in* Põldvere, 2003) and Nestor (*in* Põldvere, 2003) on the Ruhnu (500) core, Estonia (for locations see Fig. 1). Combining the results of these studies with those of integrated biostratigraphical work undertaken elsewhere (see Loydell, Kaljo & Mannik, 1998, p. 205) has been revealing some consistent correlations between the biozonations. The ultimate aim is to present a correlation chart indicating the stratigraphical relationships of all lower Silurian graptolite, conodont and chitinozoan biozones, thus enabling correlation between different marine facies.

The present paper is the result of examination of palynological residues from the upper Telychian of the Ventspils D-3 core, Latvia, which contained both chitinozoans and graptolites. The Ventspils chitinozoans have been previously discussed by Nestor (1994); the material has been revised for the present study. Systematic description of the diverse asssemblages of isolated graptolites will be published elsewhere (Loydell & Nestor, in press). We concern ourself here with the rather significant biostratigraphical implications of the material; all of this is housed in the Institute of Geology at Tallinn University of Technology, Estonia. All graptolite biozones discussed herein are defined by the first appearance of the 'index' species or other species characterizing the biozone. Chitinozoan biozones are assemblage biozones.

2. The Ventspils D-3 core

Ventspils is situated in northwestern Latvia. The D-3 borehole was cored during the 1970s and its stratigraphy, sedimentology and palaeontology were described by Gailite, Ulst & Yakovleva (1987), with the chitinozoans being examined in more detail by Nestor (1994). The palaeoenvironmental setting of Ventspils is similar to that of Aizpute-41, being located further offshore than either Ohesaare or Ruhnu (Fig. 1), within a deep-shelf depression.

Our study is confined to the upper part of the Jūrmala Formation (the upper Degole Beds and Irlava Beds; the boundary between these is at the top of the reddish brown/greenish grey marlstone at 827 m), as it was only from depths between 803.2 m and 834.6 m that identifiable isolated Telychian graptolites were extracted.

3. Graptolites

As indicated above, diverse graptolite assemblages were recovered from the palynological residues.

---

* Author for correspondence: david.loydell@port.ac.uk

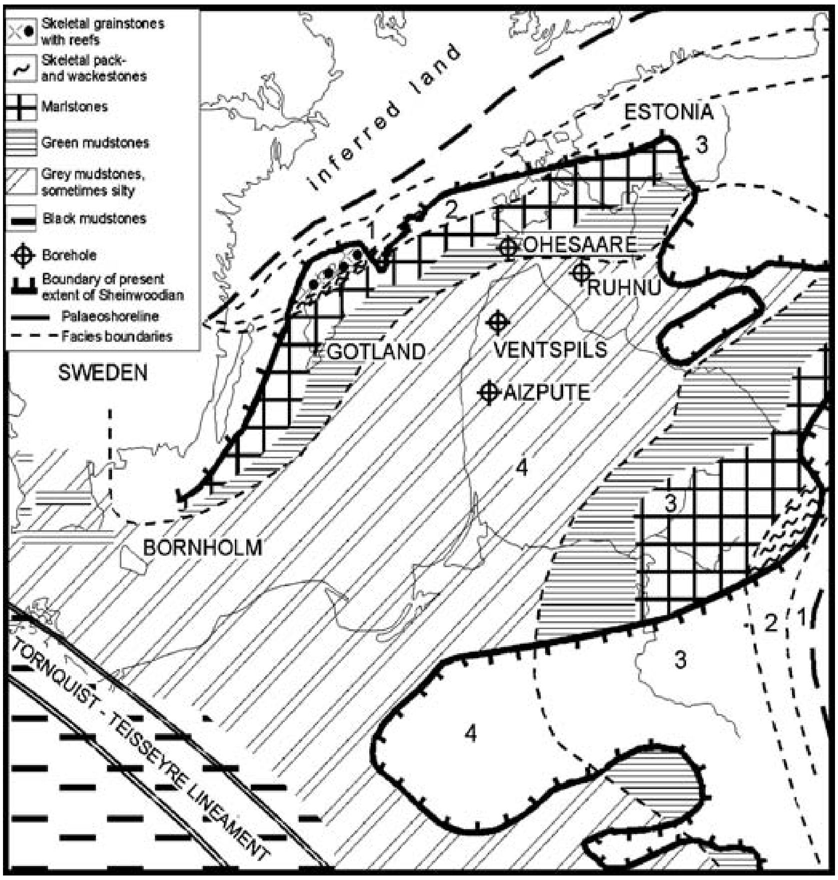

Figure 1. Location of Ventspils, Latvia on a map showing distribution of early Wenlock (approximately *riccartonensis* Zone) sedimentary rock types and facies belts in the northern Baltic region (modified from Bassett, Kaljo & Teller, 1989). The locations of Ohesaare, Aizpute and Ruhnu are also indicated. Key to facies belts: 1 – nearshore, high energy shoals; 2 – shallow mid-shelf; 3 – deeper, outer shelf; 4 – deep-shelf depression.

Mention is made here only of those taxa providing significant biostratigraphical information.

Below 827.6 m, biozonally diagnostic graptolite taxa do not occur. At 826.7 m, *Oktavites spiralis* (Geinitz), '*Monograptus*' *cultellus* Törnquist (Fig. 2f) and *Streptograptus kaljoi* Loydell, Männik & Nestor (Fig. 2c) are present, indicating the lower *Oktavites spiralis* Biozone. *Streptograptus nodifer* (Törnquist) (Fig. 2a), a species confined to the middle and upper *spiralis* Biozone, appears at 821.4 m and occurs in samples up to 814.0 m. '*Monograptus*' *vesiculosus* Perner (Fig. 2e), indicating the upper *spiralis* Biozone, occurs at 814.0 m. The highest sample (803.2 m) belongs to the lower *Cyrtograptus lapworthi* Biozone based upon the occurrence of *Streptograptus wimani* (Bouček) (Fig. 2d) and *Monoclimacis sublinnarssoni* Přibyl (Fig. 2b).

4. Chitinozoans

Chitinozoan yields from the argillaceous dolomitic marlstones of the upper Jŭrmala Formation were very variable, some samples yielding abundant specimens, others few or none at all. Those samples yielding only graptolites or scolecodonts are indicated on Figure 3. Samples from the red beds were devoid of both chitinozoans and graptolites.

The studied core interval represents the uppermost *Eisenackitina dolioliformis* Biozone, the *Angochitina longicollis* Biozone and most of the *Conochitina proboscifera* Biozone. Stratigraphical ranges are provided in Figure 3; the chitinozoans are illustrated in Figure 4.

4.a. The *Eisenackitina dolioliformis* Biozone

The 830–834.6 m interval represents the upper part of the *E. dolioliformis* Biozone. The index species was not found, but does occur lower in the biozone in the Ventspils D-3 core (Nestor, 1994, fig. 2). *Conochitina* sp. 1 of Mullins & Loydell (2001) (Fig. 4b) and *Belonechitina cavei* Mullins & Loydell (Fig. 4e) are both known from the Banwy River section, Wales (Mullins & Loydell, 2001), where they occur in the lower part of the *spiralis* graptolite Biozone and from Buttington Brick Pit, Wales, from the middle of the *spiralis* Biozone (Mullins & Loydell, 2002). In the Aizpute-41 core, *Conochitina visbyensis* Laufeld

Figure 2. Biostratigraphically important graptolites from the upper Telychian of the Ventspils D-3 core, Latvia. (a) *Streptograptus nodifer* (Törnquist); 419-1; 819.0 m. (b) *Monoclimacis sublinnarssoni* Přibyl; 419-2; 803.2 m. (c) *Streptograptus kaljoi* Loydell, Männik & Nestor; 419-3; 826.7 m. (d) *Streptograptus wimani* (Bouček); 419-4; 803.2 m. (e) '*Monograptus*' *vesiculosus* Perner; 419-5; 814.0 m. (f) '*Monograptus*' *cultellus* Törnquist; 419-6; 826.7 m. Scale bars represent 100 μm for all.

(Fig. 4c) first appears within the *dolioliformis* Biozone (Loydell, Männik & Nestor, 2003), whereas in more calcareous strata in Estonia, *C. visbyensis* usually occurs in the uppermost Telychian, above the *A. longicollis* Biozone. *Bursachitina* sp. (Fig. 4h) and *Conochitina* sp. 6 (of Nestor, 1994) (Fig. 4f) were recorded from the Aizpute-41 core in the *dolioliformis* and *longicollis* biozones and the latter species also from the *proboscifera* and lowermost part of the *margaritana* biozones (Loydell, Männik & Nestor, 2003).

4.b. The *Angochitina longicollis* Biozone

All but the lowest sample from the *A. longicollis* Biozone correspond to the lower–middle *O. spiralis* graptolite Biozone. The base of the *longicollis* Biozone is defined by the first appearance of the eponymous species (Fig. 4d) at 827.6 m. The biozonal assemblage includes also *Eisenackitina causiata* Verniers (Fig. 4j) and *E. dolioliformis* Umnova (Fig. 4m). *Belonechitina* cf. *cavei*, *B.* aff. *meifodensis* Mullins & Loydell (Fig. 4g), *Bursachitina nestorae* Mullins & Loydell (Fig. 4l), *Conochitina* cf. *praeproboscifera* Nestor and *Rhabdochitina* sp. (Fig. 4a) are characteristic of the lower part of the biozone and *Conochitina leptosoma* Laufeld (Fig. 4k) and *Calpichitina densa* (Eisenack) of the upper part.

In the Ruhnu core the *A. longicollis* Biozone is highly condensed (see Nestor *in* Põldvere, 2003) and characterized mostly by the same species as occur in the lower part of this biozone in the Ventspils D-3 core. At Buttington Brick Pit, Wales, a diverse chitinozoan assemblage from the middle *spiralis* Biozone includes *E. causiata, B. cavei, C. mathrafalensis*, *C. praeproboscifera*, *Rhabdochitina magna* Eisenack and *C. densa* (Mullins & Loydell, 2002). In the Banwy River section, Wales, the lower and middle *spiralis* Biozone have yielded *E. causiata, C. mathrafalensis, B. cavei, B. nestorae* and *C. densa* (Mullins & Loydell, 2001).

4.c. The *Conochitina proboscifera* Biozone

The base of this biozone is marked by the appearance of the eponymous species (Fig. 4s) at 815 m, 1 m below the occurrence of '*Monograptus*' *vesiculosus* Perner, indicative of the upper *spiralis* graptolite Biozone. The very low appearance of abundant *Margachitina margaritana* (Eisenack) (Fig. 4n) in a single sample at the base of the *proboscifera* Biozone is extremely unusual; this is stratigraphically much lower than anywhere else in the East Baltic (Nestor, 1994). The same (815 m) sample contains also *Plectochitina pachyderma* Laufeld (Fig. 4i), *Conochitina emmastensis* Nestor (Fig. 4r), *Ancyrochitina ansarviensis* Laufeld (Fig. 4o), *Bursachitina* sp. 1 (of Mullins & Loydell, 2001) (Fig. 4p) and *Margachitina banwyensis* Mullins (Fig. 4t). The last is also at an unusually low stratigraphical level, having its lowest occurrence in the Banwy River section in the upper *lapworthi* graptolite Biozone. *Ramochitina ruhnuensis* (Nestor) (Fig. 4u) appears in the Ventspils D-3 core at 808 m, in the

https://doi.org/10.1017/S0016756805000531

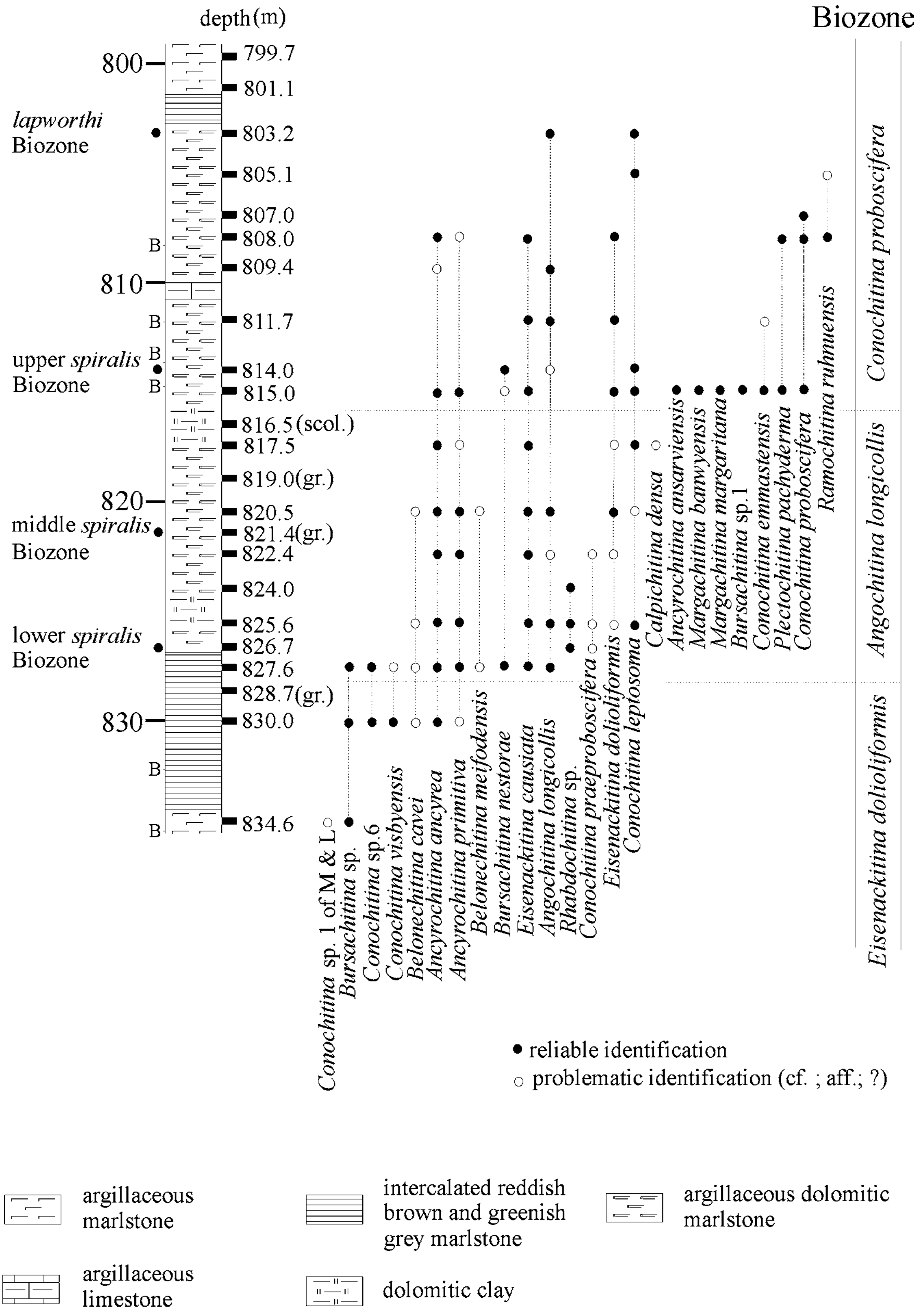

Figure 3. Stratigraphical ranges of upper Telychian chitinozoans in the Ventspils D-3 core, Latvia. Samples yielding only graptolites (gr.) or scolecodonts (scol.) are indicated, as are, in the left hand column, the levels of samples yielding biostratigraphically diagnostic graptolites. B – level of metabentonite layer. M & L – Mullins & Loydell (2001).

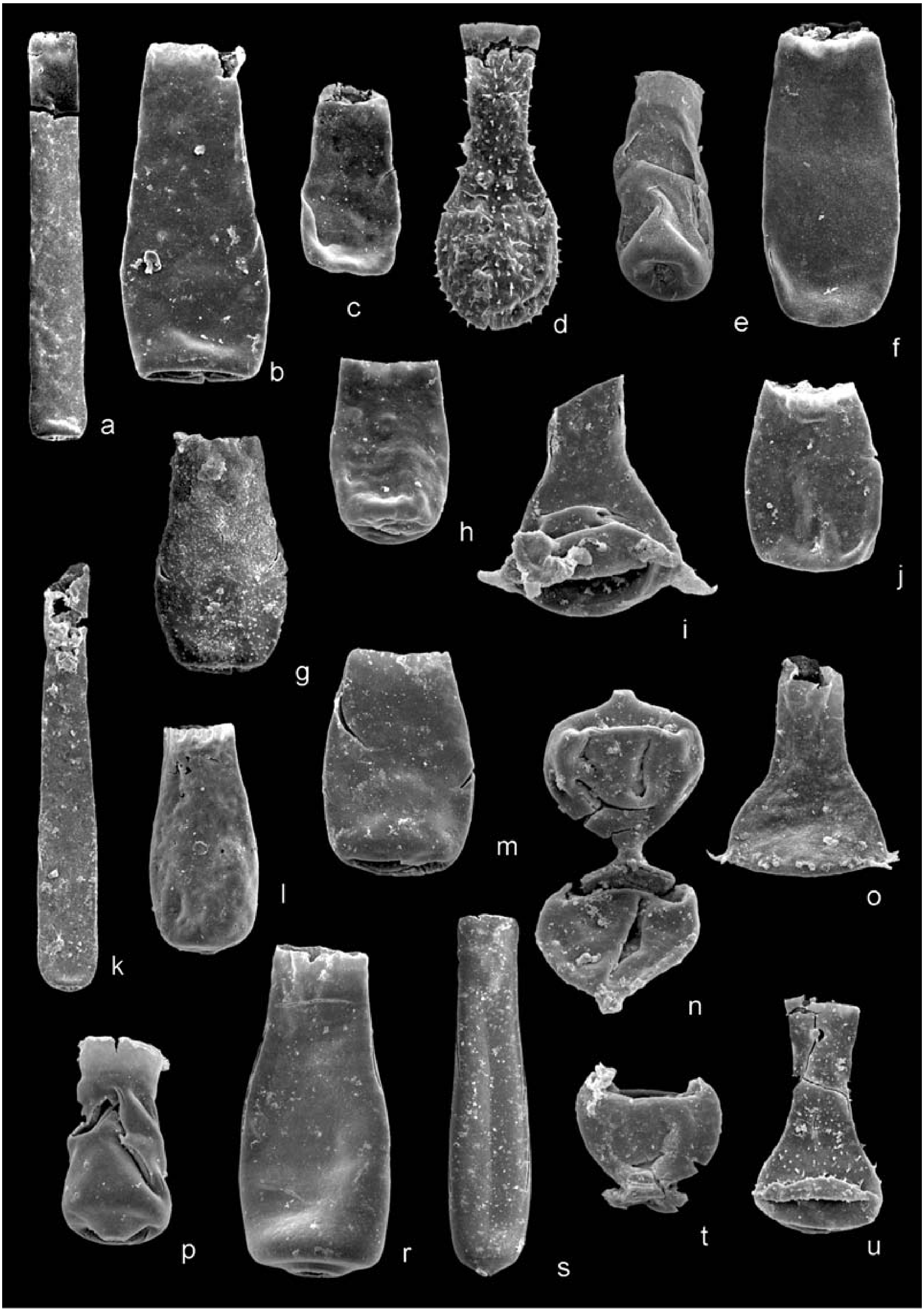

Figure 4. For caption see next page.

middle of the *C. proboscifera* Biozone, just as it does in the Aizpute-41 core (Loydell, Männik & Nestor, 2003) and Ruhnu core (Nestor *in* Põldvere, 2003).

The uppermost part of the biozone (803.2–805.1 m) in the Ventspils D-3 core, below the red beds, contains only scarce chitinozoans, with no new appearances.

5. Discussion

A key feature of a biostratigraphically useful fossil is that its first appearance in different areas is synchronous. The usefulness of the graptolite taxa discussed above (Section 3) is that in all areas in which they have been encountered their stratigraphical ranges are consistent. In some areas a particular species will not occur throughout its entire known stratigraphical range, but nowhere does it occur beyond the limits of this range.

We extend this discussion now to the biostratigraphically important chitinozoan taxa encountered in the upper Telychian of the Ventspils D-3 core.

5.a. *Eisenackitina dolioliformis*

E. dolioliformis occurs in East Baltic sections from the lowermost Telychian Rumba Formation. After description of the new species of *Eisenackitina* from the Wenlock Builth Wells district by Verniers (1999), the material of this genus in the Estonian cores was re-examined. Two species, *E. causiata* (= *E.* sp.1 in Nestor, 1994) and *E.* cf. *anulifera* (= some of the *E. dolioliformis* in Nestor, 1994) were identified, but the overall stratigraphical range of *E. dolioliformis* has not been affected. The species occurs numerously and continuously in the lower part of Telychian in East Baltic cores (Nestor, 1994 and unpub. data). In the upper part of Telychian and lowermost Wenlock it is scarce and occurs patchily. In the Prague Basin, Bohemia (Dufka, Kříž & Štorch, 1995) and the Girvan area, Scotland (Vandenbroucke, Verniers & Clarkson, 2003) *E. dolioliformis* has been recorded up to the *spiralis* Biozone. In the Banwy River and Buttington Brick Pit sections (Mullins & Loydell, 2001, 2002) this species was not recovered above at highest the lower *griestoniensis* Biozone. So the question is: did the *E. dolioliformis*-producing organism survive for a longer interval in the East Baltic than elsewhere, or is its apparent absence elsewhere simply the result of collection failure because of the species' rarity and patchy occurrence in the latter part of its stratigraphical range? From a biozonation viewpoint, the answer is not that critical, because other biostratigraphically important taxa appear in the upper Telychian–lower Sheinwoodian and biozones are erected on the basis of the presence of these, rather than the absence of *E. dolioliformis*.

5.b. *Angochitina longicollis*

In the East Baltic cores with graptolite data, the appearance of *A. longicollis* Eisenack is approximately coincident with the lower boundary of the *spiralis* Biozone (Loydell, Männik & Nestor, 2003; Kaljo *in* Põldvere, 2003; Nestor *in* Põldvere, 2003). Likewise, in the Prague Basin, Bohemia (Dufka, Kříž & Štorch, 1995) and Girvan area of Scotland (Vandenbroucke, Verniers & Clarkson, 2003), the bases of the *spiralis* and *longicollis* biozones are coincident, with data from the Yangtze Platform of China being consistent with this correlation (Mullins & Loydell, 2001, p. 773). However, in Wales (Banwy River and Buttington Brick Pit sections; Mullins & Loydell, 2001, 2002), the lowest *A. longicollis* are from the upper part of the *spiralis* Biozone, with *A. longicollis* occurring with *C. proboscifera*. Reports of *A. longicollis* from lower in the Llandovery (Swedish mainland: Grahn, 1998; Oslo region, Norway: Nestor, 1999) require further investigation (see Mullins & Loydell, 2001, pp. 771–4).

5.c. *Conochitina proboscifera*

The base of the *C. proboscifera* Biozone occurs at a level in the middle *spiralis* Biozone in the Aizpute-41 core (Loydell, Männik & Nestor, 2003) and Ruhnu core (Kaljo *in* Põldvere, 2003), in the upper *spiralis* Biozone in the Ventspils D-3 core and in the Banwy River section (Mullins & Loydell, 2001). In the Ohesaare core, *C. proboscifera* Eisenack appears at a somewhat higher level, close to the base of the *lapworthi* Biozone (Loydell, Kaljo & Männik, 1998). In some places, such

Figure 4. Telychian chitinozoans from the Ventspils D-3 core, Latvia. (a) *Rhabdochitina* sp.; 423-1; 826.7 m; × 170. (b) *Conochitina* sp. 1 (of Mullins & Loydell, 2001); 423-2; 834.6 m; × 295. (c) *Conochitina visbyensis* Laufeld; 423-3; 830 m; × 415. (d) *Angochitina longicollis* Eisenack; 423-4; 827.6 m; × 400. (e) *Belonechitina* cf. *cavei* Mullins & Loydell; 423-5; 830 m; × 305. (f) *Conochitina* sp. 6 (of Nestor, 1994); 423-6; 827.6 m; × 300. (g) *Belonechitina* aff. *meifodensis* Mullins & Loydell; 423-7; 827.6 m; × 295. (h) *Bursachitina* sp.; 423-8; 827.6 m; × 415. (i) *Plectochitina pachyderma* (Laufeld); 423-9; 815 m; × 500. (j) *Eisenackitina causiata* Verniers; 423-10; 827.6 m; × 405. (k) *Conochitina leptosoma* Laufeld; 423-11; 825.6 m; × 165. (l) *Bursachitina nestorae* Mullins & Loydell; 423-12; 827.6 m; × 370. (m) *Eisenackitina dolioliformis* Umnova; slightly flattened vesicle; 423-13; 815 m; × 300. (n) *Margachitina margaritana* Eisenack; 423-14; 815 m; × 500. (o) *Ancyrochitina ansarviensis* Laufeld; 423-15; 815 m; × 370. (p) *Bursachitina* sp. 1 (of Mullins & Loydell); 423-16; 815 m; × 380. (r) *Conochitina emmastensis* Nestor; 423-17; 815 m; × 250. (s) *Conochitina proboscifera* Eisenack; 423-18; 807 m; × 160. (t) *Margachitina banwyensis* Mullins; 423-19; 815 m; × 460. (u) *Ramochitina ruhnuensis* (Nestor); 423-20; 808 m; × 365.

as Buttington Brick Pit, Wales (Mullins & Loydell, 2002), and in the Prague Basin, Bohemia (Dufka, 1992), *C. proboscifera* first appears in the lower Wenlock *murchisoni* Biozone, however, at Buttington no samples were processed for chitinozoans between the *spiralis* and *murchisoni* biozones and Dufka (1992) examined material from only four samples from this interval, so *C. proboscifera* may occur at lower horizons than the *murchisoni* Biozone. In the Girvan area of Scotland the species was not found (Vandenbroucke, Verniers & Clarkson, 2003). Thus, this species shows differences in its first occurrence in relation to the graptolite biozonation, possibly because it had a patchy distribution in the lower part of its range, although in East Baltic core sections *C. proboscifera* is usually a dominant species in uppermost Telychian and lowermost Wenlock samples.

5.d. *Ramochitina ruhnuensis*

Although not a biozonal index species, *R. ruhnuensis* shows a consistent level of first appearance approximately at the base of the *Cyrtograptus lapworthi* Biozone in the Ventspils D-3 and Aizpute-41 cores (Loydell, Männik & Nestor, 2003). In the Ruhnu core it appears at 472 m (Nestor *in* Põldvere, 2003), a little above '*Monograptus vesiculosus*' Perner (indicative of the upper *spiralis* Biozone) at 475.40 m. Unfortunately the species is not widely distributed, but in the East Baltic it appears to be stratigraphically useful.

5.e. *Margachitina banwyensis*

This species was erected only recently (Mullins, 2000). It was considered by Mullins (2000) to form part of a stratigraphically significant chitinozoan morphological lineage: *Calpichitina densa–Margachitina banwyensis–Margachitina margaritana*. In the Banwy River section, it appears in the upper *lapworthi* graptolite Biozone and ranges into the lower Sheinwoodian (Mullins, 2000; Mullins & Loydell, 2001). The species is known elsewhere only from a single illustrated specimen, from Bohemia (see Mullins & Loydell, 2001, p. 774). The occurrence in the Ventspils D-3 core at 815.0 m (Fig. 3) in the upper *spiralis* graptolite Biozone is approximately one graptolite biozone lower than its lowest occurrence in the Banwy River section.

5.f. *Margachitina margaritana*

The most remarkable occurrence in the Ventspils D-3 core is that of *M. margaritana* in the upper *spiralis* Biozone at 815.0 m (Fig. 3). *M. margaritana* is one of the most distinctive of chitinozoan species, is geographically very widespread, and has been considered to be of considerable biostratigraphical importance. In the 'global Chitinozoa biozonation' (Verniers *et al.* 1995, fig. 2) the base of the *margaritana* Biozone was suggested to be coincident with the base of the Wenlock, although it was noted (p. 659) that the species 'occurs slightly below the Llandovery–Wenlock boundary' in some Baltic sections. This slightly lower level was confirmed by Mullins (2000; see also Mullins & Loydell, 2001), who showed that the base of the *margaritana* Biozone was coincident with that of the upper Telychian *Cyrtograptus insectus* graptolite Biozone in the Banwy River section, Wales. *M. margaritana* occurs in probable *insectus* Biozone strata also in the Prague Basin, Bohemia (Dufka, Kříž & Štorch, 1995; see also Mullins & Loydell, 2001, p. 774).

It must be assumed that some unknown environmental factors controlled the distribution of *Margachitina* and that in the pre-*insectus* Biozone part of its stratigraphical range, the genus was generally rare and highly limited in its distribution, either palaeogeographically or palaeoenvironmentally. Similar palaeoenvironmental controls have been recognized in the stratigraphical distribution of some other chitinozoan taxa. For example, Wood (1974) noted that in the Devonian of the American Midwest, *Angochitina* 'had an atypical sensitivity to facies and could not tolerate a change in its favored environment.' Similarly, Nestor (1998) recognized four lateral chitinozoan biofacies, characterized by different *Cyathochitina* species, in the upper Rhuddanian in the East Baltic. Most chitinozoan species, however, are present across a wide range of palaeoenvironments.

The biostratigraphical implications of these early *Margachitina* occurrences are very significant: no longer can the presence of *Margachitina* in an assemblage be taken to indicate unequivocally an age of latest Telychian (late *lapworthi* Zone) or younger. The assemblage as a whole must be considered.

Considering Mullins' (2000) proposed morphological lineage, these early *Margachitina* occurrences suggest that the species transitions must have occurred earlier in the Telychian than Mullins envisaged. The earliest *Calpichitina densa* are recorded from the *crispus* Biozone, more than three graptolite biozones below the Ventspils D-3 *Margachitina* records herein, so presumably the transition took place some time during the middle Telychian.

Acknowledgements. V. Nestor's studies were supported by the Estonian Science Foundation (Grant Nos 5088 and 5920). We thank V. Mikli for the SEM images of the chitinozoans and Gary Mullins (Leicester) and Petr Štorch (Prague) for their constructive comments.

References

Bassett, M. G., Kaljo, D. & Teller, L. 1989. The Baltic region. In *A Global Standard for the Silurian System* (eds C. H. Holland and M. G. Bassett), pp. 158–70. National Museum of Wales, Geological Series no. 9.

DUFKA, P. 1992. Lower Silurian chitinozoans of the Prague Basin (Barrandian, Czechoslovakia). Preliminary results. *Revue de Micropaléontologie* **35**, 117–26.

DUFKA, P., KŘÍŽ, J. & ŠTORCH, P. 1995. Silurian graptolites and chitinozoans from the Uranium Industry boreholes drilled in 1968–1971 (Prague Basin, Bohemia). *Věstník Českého geologického ústavu* **70**, 5–13.

GAILITE, L. K., ULST, R. Z. & YAKOVLEVA, V. I. 1987. *Stratotipicheskie i tipovie razrezi silura Latvii*. Riga: Zinatne, 184 pp.

GRAHN, Y. 1998. Lower Silurian (Llandovery-Middle Wenlock) Chitinozoa and biostratigraphy of the mainland of Sweden. *GFF* **120**, 273–83.

LOYDELL, D. K., KALJO, D. & MÄNNIK, P. 1998. Integrated biostratigraphy of the lower Silurian of the Ohesaare core, Saaremaa, Estonia. *Geological Magazine* **135**, 769–83.

LOYDELL, D. K. & NESTOR, V. In press. Isolated graptolites from the Telychian (Upper Llandovery, Silurian) of Latvia and Estonia. *Palaeontology*.

LOYDELL, D. K., MÄNNIK, P. & NESTOR, V. 2003. Integrated biostratigraphy of the lower Silurian of the Aizpute-41 core, Latvia. *Geological Magazine* **140**, 205–29.

MULLINS, G. L. 2000. A chitinozoan morphological lineage and its importance in lower Silurian stratigraphy. *Palaeontology* **43**, 359–73.

MULLINS, G. L. & LOYDELL, D. K. 2001. Integrated Silurian chitinozoan and graptolite biostratigraphy of the Banwy River section, Wales. *Palaeontology* **44**, 731–81.

MULLINS, G. L. & LOYDELL, D. K. 2002. Integrated lower Silurian chitinozoan and graptolite biostratigraphy of Buttington Brick Pit, Wales. *Geological Magazine* **139**, 89–96.

NESTOR, H., EINASTO, R., MÄNNIK, P. & NESTOR, V. 2003. Correlation of lower–middle Llandovery sections in central and southern Estonia and sedimentation cycles of lime muds. *Proceedings of the Estonian Academy of Sciences, Geology* **52**, 3–27.

NESTOR, V. 1994. Early Silurian chitinozoans of Estonia and north Latvia. *Academia* **4**, 1–163.

NESTOR, V. 1998. Chitinozoan biofacies of late early Llandovery (*Coronograptus cyphus*) age in the East Baltic. *Proceedings of the Estonian Academy of Sciences, Geology* **4**, 219–28.

NESTOR, V. 1999. Distribution of chitinozoans in the Llandovery of the Oslo region. *Bolletino della Società Paleontologica Italiana* **38**, 227–38.

PÕLDVERE, A. (ed.) 2003. Ruhnu (500) drill core. *Estonian Geological Sections, Bulletin* **5**, 1–76, pls 1–3, 30 appendices on CD-ROM.

VANDENBROUCKE, T., VERNIERS, J. & CLARKSON, E. N. K. 2003. A chitinozoan biostratigraphy of the Upper Ordovician and lower Silurian strata of the Girvan area, Midland Valley, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences* **93**, 111–34.

VERNIERS, J. 1999. Calibration of Chitinozoa *versus* graptolite biozonation in the Wenlock of the Builth Wells district (Wales, U.K.), compared with other areas in Avalonia and Baltica. *Bollettino della Società Paleontologica Italiana* **38**, 359–80.

VERNIERS, J., NESTOR, V., PARIS, F., DUFKA, P., SUTHERLAND, S. & VAN GROOTEL, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine* **132**, 651–66.

WOOD, G. D. 1974. Chitinozoa of the Silica Formation (Middle Devonian, Ohio): vesicle ornamentation and palaeoecology. *Publications of the Museum, Michingan State University, Paleontological Series* **1**, 127–62.