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Chitinozoan biostratigraphy of the Přídolí Series of the East Baltic

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Abstract. The succession of chitinozoans in the East Baltic Přídolí Series was studied in the Ohesaare, Ventspils D-3, Pavilosta and Dubovskoye (Northern-Gusevskaya 2) drill cores. Some differences in biozonal characteristics were observed between the shallower and deeper facies sections. The lower Přídoli *Eisenackitina kerria–Ancyrochitina tomentosa* regional Biozone is described from the Ohesaare (Estonia) and Ventspils and Pavilosta (Latvia) cores and the *Fungochitina kosovensis* global Biozone from the Dubovskoye (Kaliningrad district) core. The middle Přídolí *Salopochitina filifera* regional Biozone is represented in all studied sections. The upper Přídolí *Anthochitina superba* global Biozone is described from the Ventspils core, correlating with the range interval of *Margachitina* sp. in the Dubovskoye core. In the uppermost Přídolí the *Ancyrochitina lemniscata* regional Biozone is distinguished for the first time in the Ventspils and Dubovskoye cores. All biozones were correlated with regional stratigraphical units, as well as with conodont and vertebrate biozones in the Ventspils core.

Key words: Silurian, Přídolí, East Baltic, chitinozoans.

INTRODUCTION

The most important results of palaeontological and lithostratigraphical investigations of the Silurian in Estonia are summarized in the monograph *The Silurian of Estonia*, edited by Kaljo (1970). This book was followed by studies on different faunal groups including those from the Ventspils, Pavilosta and Dubovskoye cores (Kaljo & Sarv 1976; Viira 1982, 1999; Märss 1986, 1997; Gailite et al. 1987). Much palaeontological, mineralogical and facies information on the Ohesaare, Ventspils and Pavilosta cores may be found in the volume edited by Kaljo and Klaamann (1982). The currently used stratigraphical scheme, which is followed in the present paper, was published in the comprehensive overview *Geology and Mineral Resources of Estonia* (see H. Nestor 1997).

Graptolites are missing in the carbonate sediments of the studied Přídolí sections. The lithological logs in this paper were composed after Gailite et al. (1987) and using unpublished descriptions by R. Einasto and H. Nestor. The Dubovskoye core section is divided into formations according to Koren et al. (2009). The boundary between the Kaugatuma and Ohesaare stages in the Ventspils and Dubovskoye cores has been distinguished by the appearance of the fossil fish *Nostolepis alta* (Märss 1986).

The first records of Přídoli chitinozoans in Estonia, in the Ohesaare core, were presented by Männil (1970) and Eisenack (1970), who studied some samples from the Kaugatuma and Ohesaare cliffs on Saaremaa Island. Both authors identified *Eisenackitina lagenomorpha* and *E. filifera* and noted a good correspondence of higher strata on Saaremaa (Ösel) with the Beyrichia Limestone in the erratics of the South Baltic coast. The first attempt to divide the upper Silurian of the Ohesaare core section on the basis of chitinozoan assemblages was made by Nestor (1976). The successions of chitinozoan species in the Silurian of the Ventspils and Pavilosta cores were published more than two decades ago (Nestor in Gailite et al. 1987). Later also the successions of Přídoli species in the Ohesaare (Nestor 1990) and Ruhnu (Nestor 2003) cores were published. Two specimens of *Urochitina* were identified (Nestor 1990) in the samples from the Ohesaare cliff, but later these identifications appeared to be mistakes resulting from deformation of specimens.

The biostratigraphy of the Ludlow chitinozoans in the East Baltic drill cores has been treated earlier by Nestor (2009). The present paper is sequential to that work, as here the chitinozoan biostratigraphy of the Přídolí Series is examined from the same Ohesaare, Ventspils D-3, Pavilosta and Dubovskoye (Northern-Gusevskaya 2) cores, situated from north to south in Estonia, Latvia and Kaliningrad district, Russia.

Most of the studied samples were collected with colleagues in the Skrunda, Riga and Gussev depositories between 1980 and 1986. The best studied drill core is still Ohesaare, with a large volume of published data concerning all fossil groups.

The distribution of Přídolí chitinozoans in different localities worldwide is discussed in numerous publications, for example Eisenack (1955, 1972), Wrona (1980), Paris (1981), Paris et al. (1981), Paris & Kříž (1984), Jaglin (1986), Kříž et al. (1986), Verniers et al. (1995), Paris & Grahn (1996), Miller et al. (1997), Boumendjel (2002), Jaglin & Paris (2002), and Grahn (2005, 2006). Part of the species described in the above-named papers have been established also in the East Baltic cores, studied for this paper.

The diversity of Silurian chitinozoans is very high. In total more than one hundred chitinozoan species have been identified globally from the Přídolí Series (see Grahn & Paris 2011). Knowledge of the distribution of Přídolí chitinozoans in the East Baltic sections is still quite incomplete. The aim of the present paper is to fill this gap and to correlate more precisely the East Baltic chitinozoan biozones with global biozones (Verniers et al. 1995) and find the stratigraphically most useful taxa for inter-regional correlation.

A total of 242 samples (with a weight of 100–300 g) were processed; all but six yielded chitinozoans. The studied material is deposited in the Institute of Geology at Tallinn University of Technology (collection GIT 607).

GEOLOGICAL SETTING

During the regression of the Palaeobaltic sea in the Přídolí Epoch the facies belts in the East Baltic area migrated southwestwards. The studied drill cores represent mostly carbonate deposits of the open shelf, except from the Dubovskoye core which contains mostly argillaceous sedimentary rocks of the deeper-water transitional facies belt (Fig. 1). In the East Baltic area the Přídolí Series is represented by the Kaugatuma and Ohesaare regional stages and is subdivided into several lithostratigraphical units, changing laterally from region to region (Fig. 2). The Äigu Beds, forming the lower part of the Kaugatuma Formation in Estonia, are

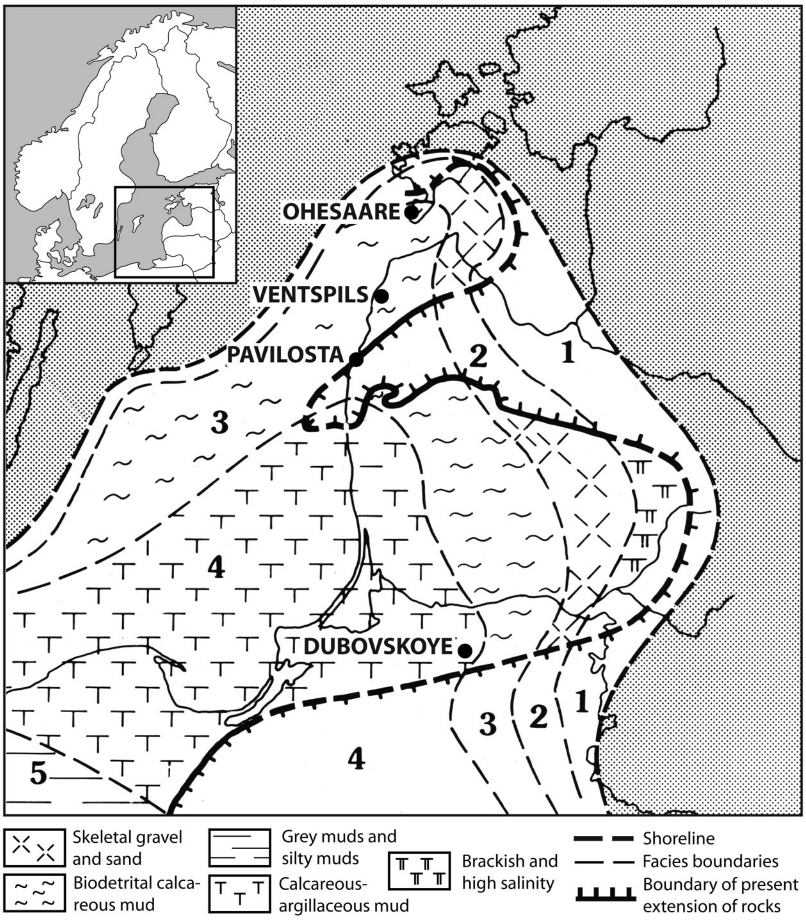


Fig. 1. Location of the studied drill cores (black dots). Distribution of early Přídolí sedimentary rock and facies belts of the Baltic Gulf (modified from Bassett et al. 1989). 1, tidal flat/lagoon; 2, shoal; 3, open shelf; 4, transition from open to deep shelf; 5, shelf depression.

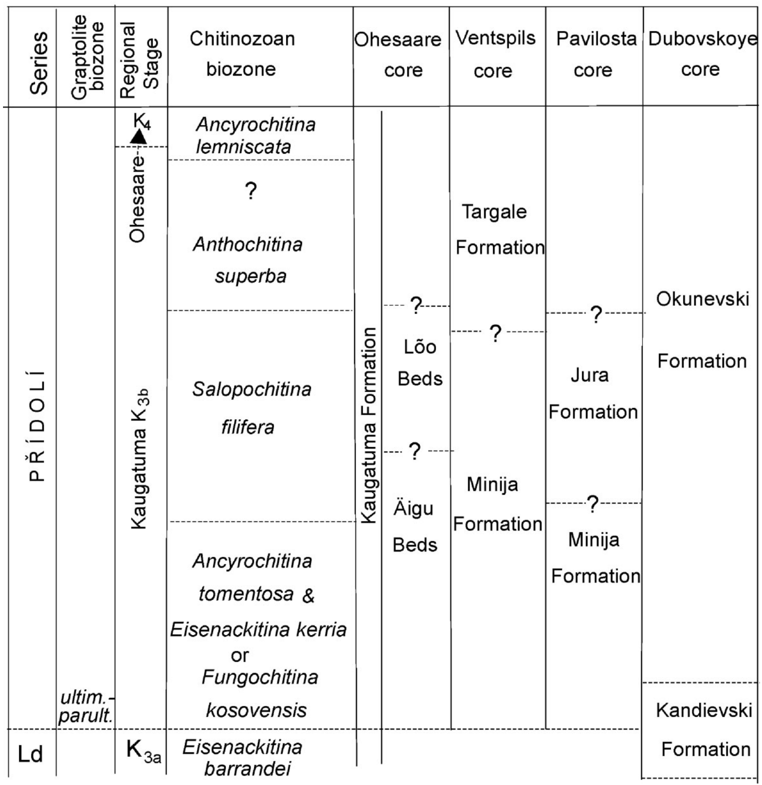


Fig. 2. Chitinozoan biozones and correlation of lithostratigraphical units in the Přídolí of the Ohesaare, Ventspils D-3, Pavilosta and Dubovskoye drill cores. Formations after H. Nestor (1997), Gailite et al. (1987) and Koren et al. (2009). K_{3a}, Kuressaare Stage.

characterized by alternating argillaceous and micritic limestones and argillaceous dolomitic marlstones with numerous hardgrounds. The upper, Lõo Beds consist of argillaceous dolomitic marlstones intercalated with argillaceous limestones (Figs 2, 3). The Ohesaare Formation of the regional stage with the same name consists of bioclastic limestones and marlstones. More information about the lithology and facies of the upper Silurian sequence of Estonia is available in H. Nestor (1997). The Minija Formation in Latvia is characterized mostly by argillaceous marlstones in the Ventspils core (Fig. 4) and argillaceous dolomitic marlstones in the Pavilosta core (Fig. 5). The lower part of the Targale Formation in the Ventspils core is represented by intercalations of calcareous and argillaceous marlstone with limestone interbeds. The upper part of the formation contains dolomitic marlstones with dolomite interbeds. The Jūra Formation is represented only by its lower part in the Pavilosta core, consisting mostly of argillaceous dolomitic marlstones with limestone interbeds in the lower half and with argillaceous dolomite interbeds in the upper half.

The Kandievski and Okunevski formations of the Dubovskoye core are characterized by dolomitic mudstones (Fig. 6). These formations overlying the Uljanov Formation (Koren & Suyarkova 2007) were recently described by Koren et al. (2009) (see Fig. 2). It is worth mentioning that earlier Kaljo & Sarv (1976) described this section and identified the Kaugatuma Stage, composed of the Äigu and Lõo beds, with the boundary between them at 1050 m, on the basis of the succession of ostracode species.

THE LUDLOW–PŘÍDOLÍ BOUNDARY

In graptolitic sections the lower boundary of the Přídolí Series is placed at the base of the *ultimus–parultimus* Biozone. In the East Baltic drill cores, however, graptolites are absent, except in some Lithuanian sections, where characteristic species of the lowermost graptolite biozone have been identified (Paškevičius 1979).

Besides graptolites, the disappearance of the conodont *Ozarkodina crispa* (Walliser) is one of the most reliable indicators of the base of the Přídolí Series in the Přídolí type area in Bohemia (Kříž et al. 1986). In the East Baltic cores this species disappears at the beginning (Ohesaare core) or in the middle part (Kolka core) of the underlying Kuressaare Formation. It ranges up to 407.6 m in the Minija Formation in the Ventspils core, but has not been found in the Pavilosta core (Viira 1999). *Ozarkodina remscheidensis eosteinhornensis* (Walliser) appears just above the boundary of the Kaugatuma Formation in the Ohesaare core, about 20 m higher than the Přídolí boundary in the Ventspils core and deep in the Ludlow

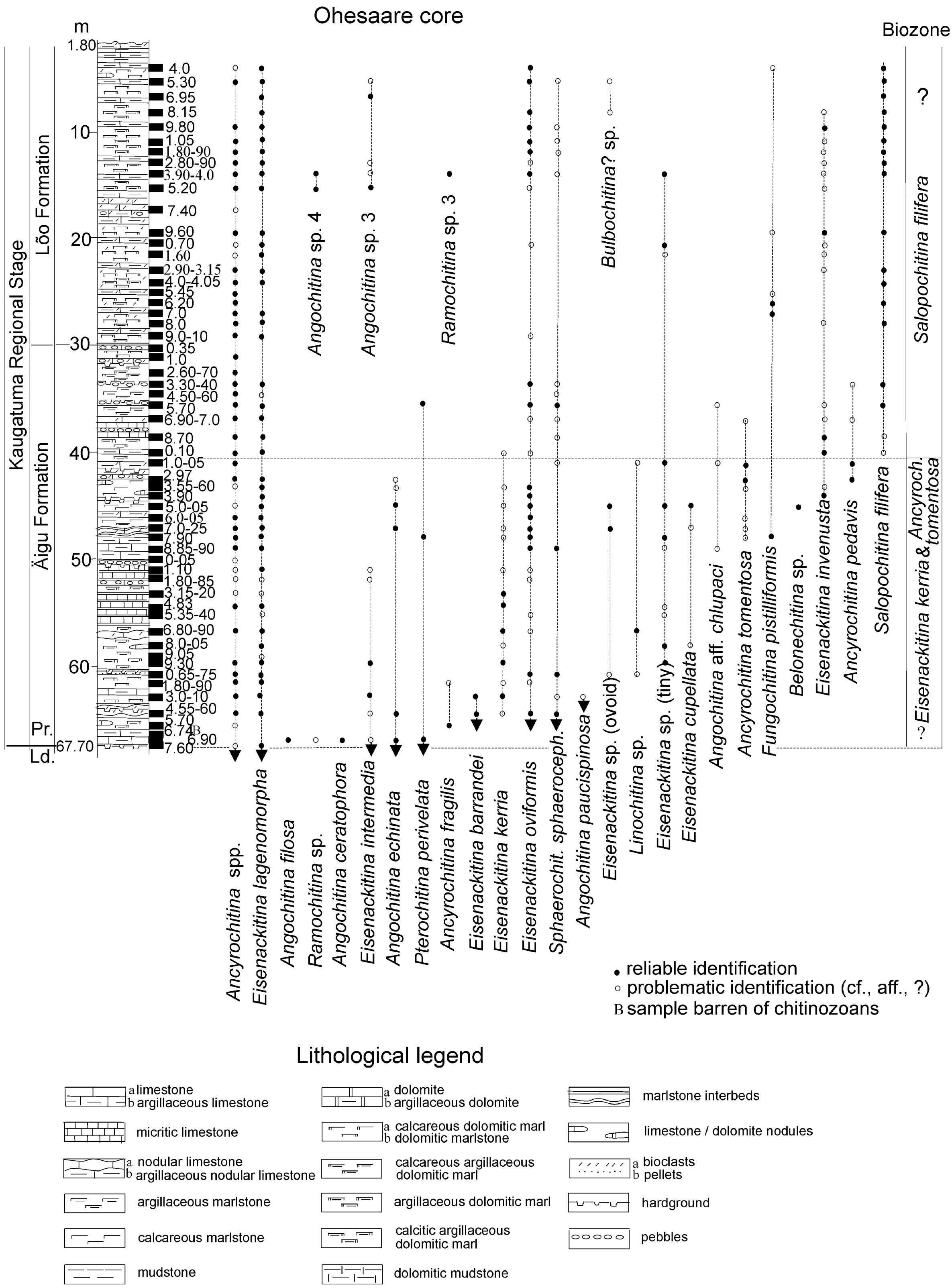


Fig. 3. Lithological log, legend and ranges of chitinozoan species in the Přídolí of the Ohesaare core. The legend follows H. Nestor (1990).

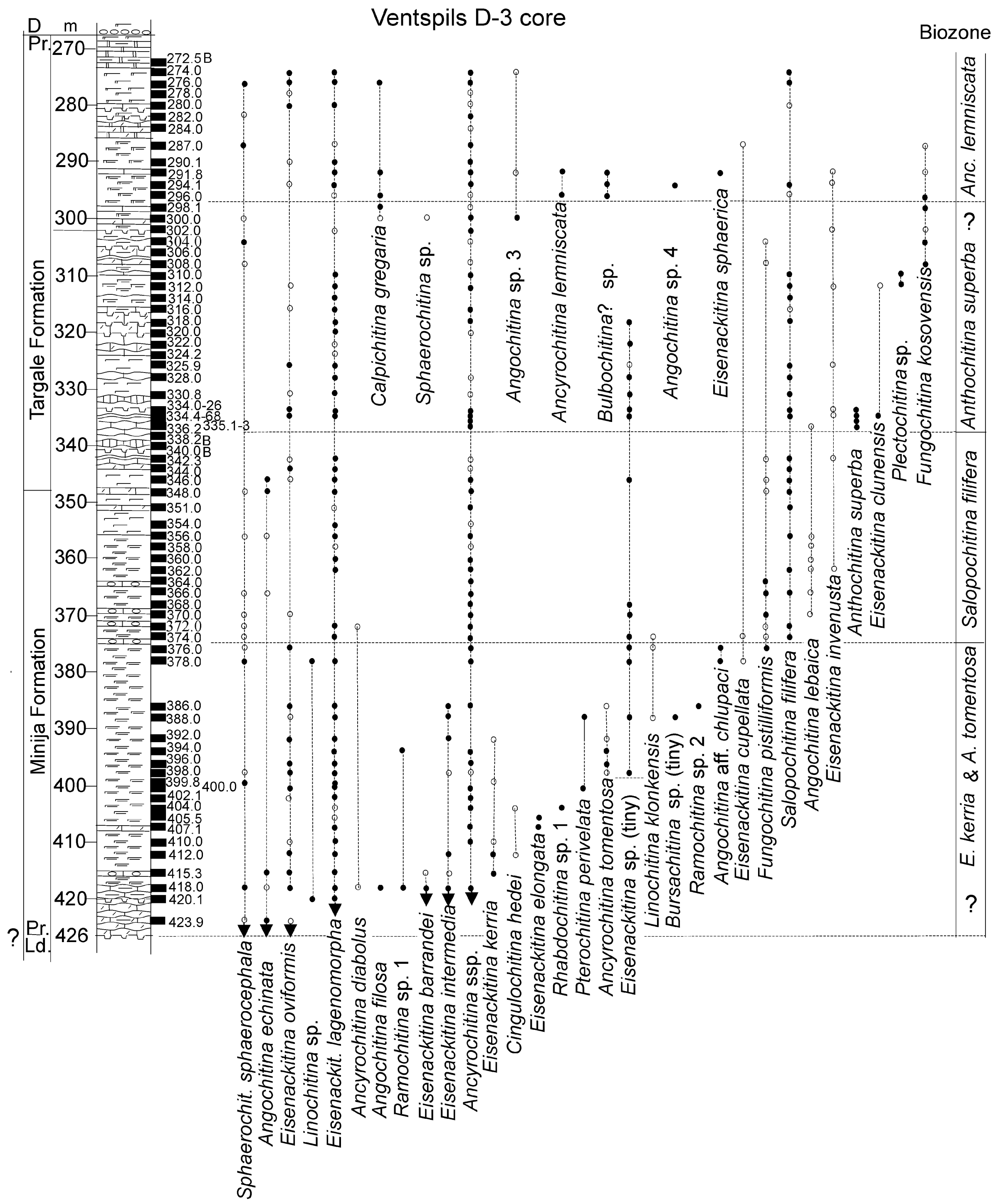


Fig. 4. Lithological log (compiled after Gailite et al. 1987 and unpublished description of R. Einasto) and ranges of chitinozoan species in the Přídolí of the Ventspils D-3 drill core. For legend see Fig. 3.

in the Pavilosta core (Viira 1999). Thus, according to the conodont distribution in the East Baltic drill cores, it is difficult to find reliable criteria for identification of the exact level of the Ludlow–Přídolí boundary.

Vertebrates have been studied from the same sections (Märss 1986, 1997). *Thelodus sculptilis* Gross disappears below or close to the Ludlow–Přídolí boundary, except in the Dubovskoye core, where vertebrate

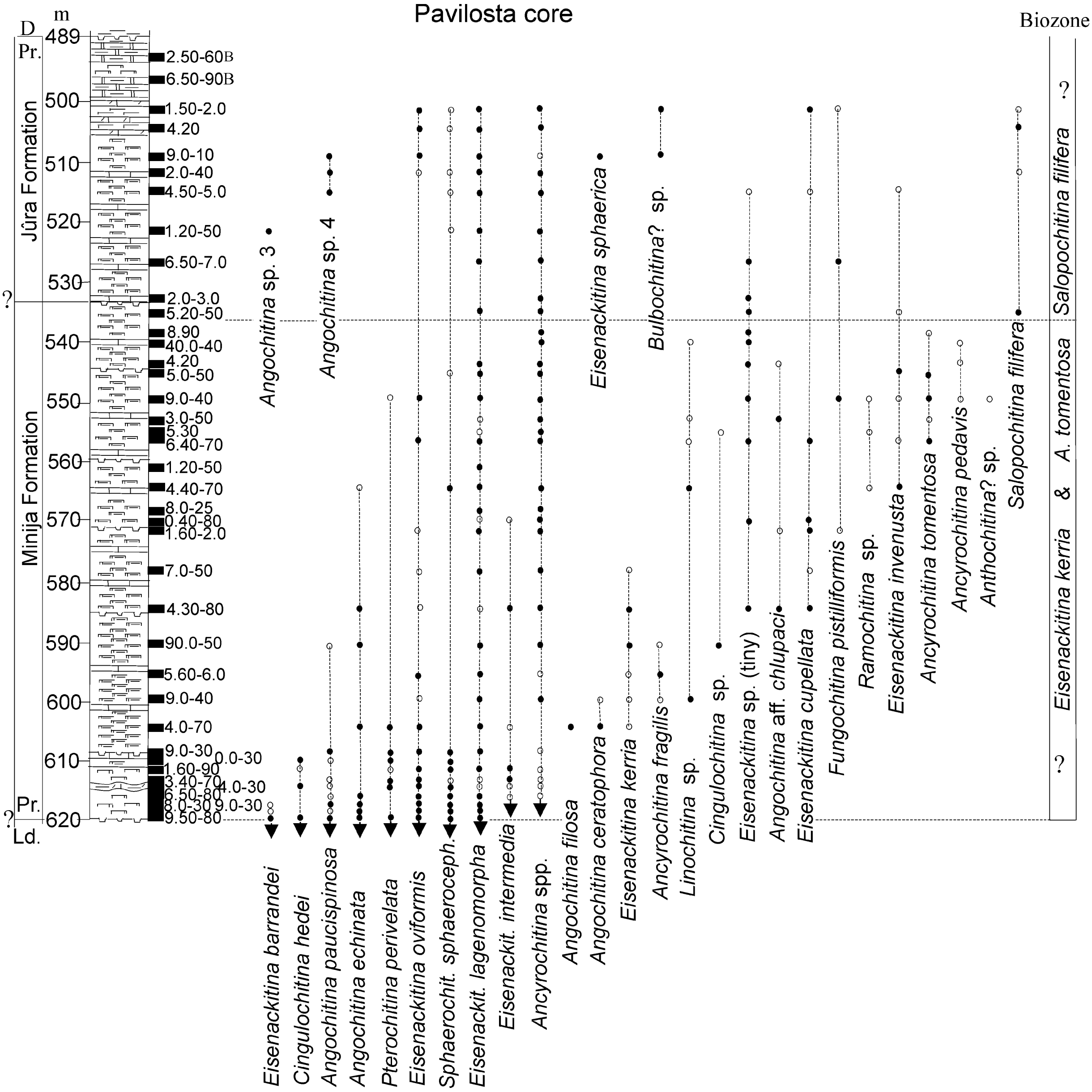


Fig. 5. Lithological log (compiled after Gailite et al. 1987 and unpublished description of H. Nestor) and ranges of chitinozoan species in the Přídolí of the Pavilosta drill core. For legend see Fig. 3.

remains have not been found from the boundary interval (1131.8–1257 m).

The Ludlow ostracodes and graptolites and Přídolí ostracodes of the Dubovskoye core have been studied by Kaljo & Sarv (1976). They determined the boundary of the Kuressaare and Kaugatuma stages at a depth of 1230 m, which has also been followed by Nestor (2009). In comparison with the Dubovskoye core, the Přídolí stratotype sections of Bohemia (Kříž et al. 1986) contain a different ostracode assemblage at the Ludlow–Přídolí boundary.

Recently, Koren et al. (2009) distinguished, on the grounds of the appearance of the brachiopod *Isorthis ovalis* Paškevičius in the uppermost Silurian of the Severo-Gusevskaya 2 (= Dubovskoye) core, the Kandievski and Okunevski formations, with the Ludlow–Přídolí boundary between them, at a depth of 1168 m. From the Okunevski Formation *Oulodus elegans* Walliser was found, which was treated as the Přídolí index species, but in the Ohesaare, Ventspils and Pavilosta cores this species appears stratigraphically much lower, in the middle Ludlow (Viira 1999).

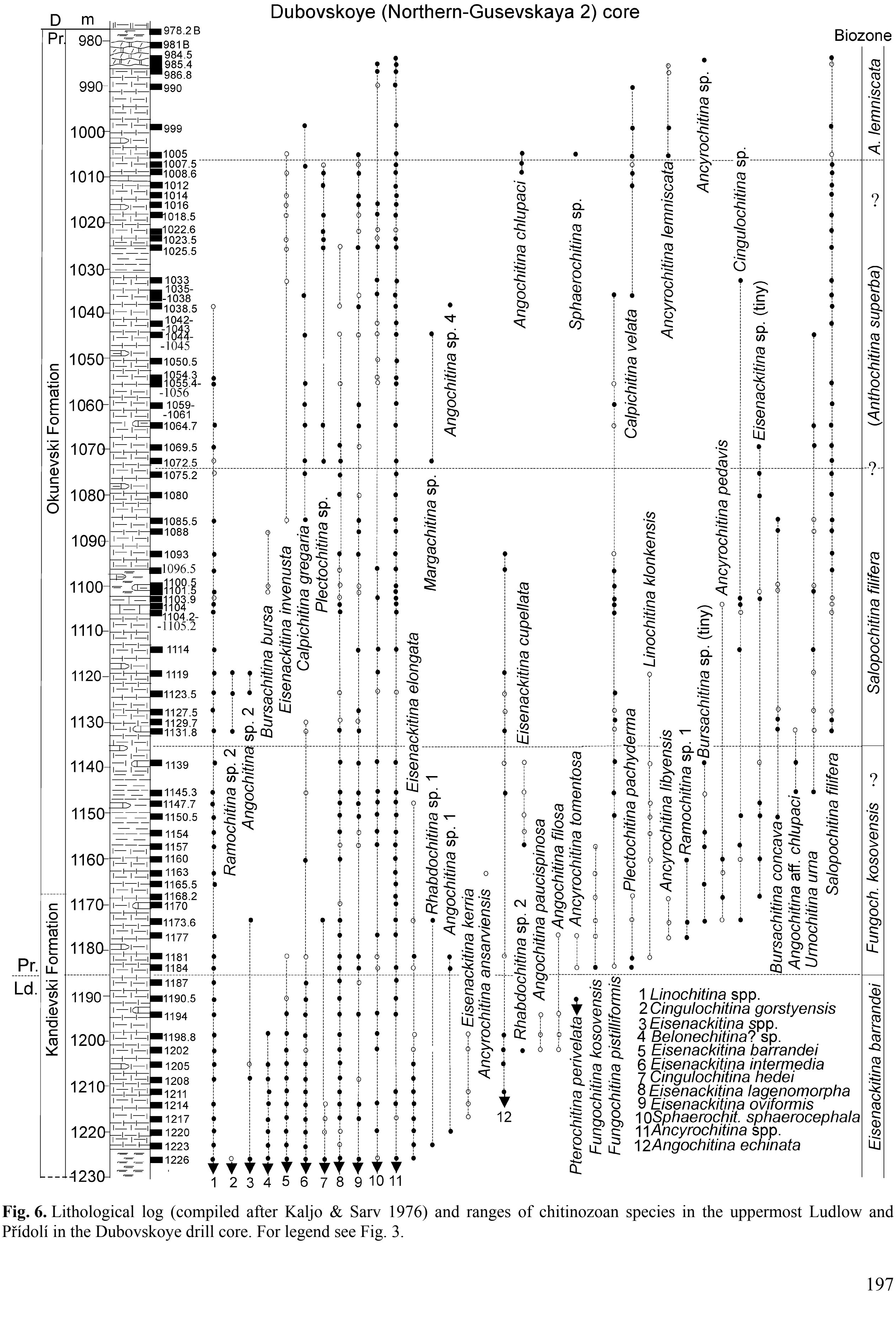


Fig. 6. Lithological log (compiled after Kaljo & Sarv 1976) and ranges of chitinozoan species in the uppermost Ludlow and Přídolí in the Dubovskoye drill core. For legend see Fig. 3.

Chitinozoans belong to a fossil group with a planktic mode of life and are thus less dependent on facies conditions than the benthic or nekto-benthic groups. Nevertheless, lateral variation in assemblages can be pronounced. In the stratotype area of Bohemia, at the base of the Přídolí, dated by the first appearance of *Monograptus parultimus*, there appear also chitinozoans *Fungochitina kosovensis* Paris & Kříž, *Linochitina* cf. *klonkensis* Paris & Laufeld and *Urnochitina urna* (Eisenack) (Paris in Kříž et al. 1986). In the Dubovskoye core the first two chitinozoan species make their appearance respectively at depths of 1184 and 1181 m, in the upper part of the Kandievski Formation. In addition, in both sections at about the same level the characteristic species of the upper Ludlow, *Eisenackitina barrandei* Paris (see Kříž et al. 1986), disappears. Thus, the middle part of the Kandievski Formation, in the interval 1187–1226 m in the Dubovskoye core (Fig. 6) belongs to the Ludlow Series, the uppermost part in the interval 1184–1168 m to the Přídolí Series.

CHITINOZOAN BIOSTRATIGRAPHY

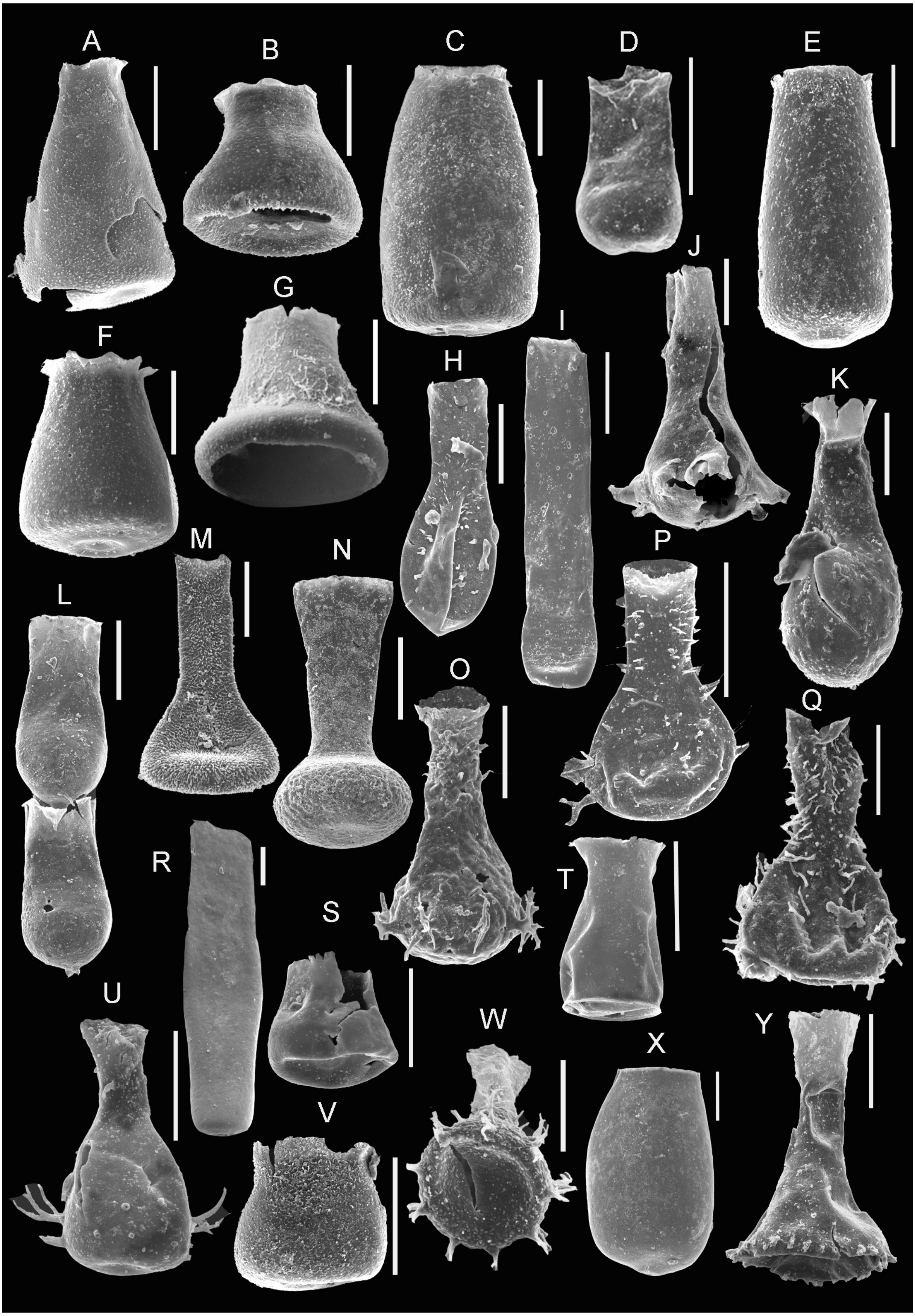
Attempts to subdivide the Přídolí Series using chitinozoans have been made by different authors in several regions: Taugourdeau & de Jekhowsky (1960), Sahara; Cramer & Diez (1978), Iberian Peninsula; Paris (1981), southwestern Europe; Schweineberg (1987), Palencia; Nestor (1990), Estonia and Latvia; Paris & Grahn (1996), Podolia; Geng et al. (1997), Yangtze region, China; Jaglin & Paris (2002), Libya; Grahn (2005), Amazonas Basin, Brazil.

Verniers et al. (1995) compiled a global chitinozoan biozonation scheme. According to this scheme three biozones are distinguished in the Přídolí Series: *Fungochitina kosovensis*, *Margachitina elegans* and *Anthochitina superba*. This 'model' works only partly in the East Baltic drill cores. *Fungochitina kosovensis* Paris & Kříž occurs in the lowermost Přídolí only in the Dubovskoye core, *Margachitina elegans* (Taugourdeau & de Jekhowsky) is completely lacking in the East Baltic cores and *Anthochitina superba* Eisenack has been found only in the Ventspils core and only in the middle part of the Přídolí. The most important and widely distributed species for identification of the lower Přídolí boundary, *Urnochitina urna* (Eisenack), has been identified only in the Dubovskoye core, but about 40 m above the base of the series. Thus, the northern East Baltic chitinozoan biozonal succession is rather different from those of the other regions. Differences exist also between the Dubovskoye section and the more northern sections.

Similar to the global chitinozoan biozones (Verniers et al. 1995) we define the East Baltic Přídolí biozones as interval zones. Their bases are defined by the first occurrence of the index species.

The uppermost Ludlow chitinozoan assemblage in the Dubovskoye core (Fig. 6) corresponds well with the assemblage in the Ohesaare and Pavilosta cores, treated as the *Eisenackitina barrandei* Biozone (Nestor 2009). It includes *Eisenackitina intermedia* (Eisenack) (Fig. 7A),

Fig. 7. Selected chitinozoan species. Scale 50 µm. **A**, *Eisenackitina intermedia* (Eisenack, 1955), GIT 607-1, Dubovskoye (Northern-Gusevskaya 2) core, depth 1226 m, Kandievski Formation. **B**, *Eisenackitina* cf. *kerria* Miller, Sutherland & Dorning, 1997, GIT 607-2, Dubovskoye core, depth 1202 m, Kandievski Formation. **C**, *Eisenackitina barrandei* Paris & Kříž, 1984, GIT 607-3, Dubovskoye core, depth 1226 m, Kandievski Formation. **D**, *Linochitina* sp., GIT 607-4, Dubovskoye core, depth 1226 m, Kandievski Formation. **E**, *Belonechitina*? sp., GIT 607-5, Dubovskoye core, depth 1220 m, Kandievski Formation. **F**, *Eisenackitina lagenomorpha* (Eisenack, 1931), GIT 607-6, Dubovskoye core, depth 1202 m, Kandievski Formation. **G**, *Eisenackitina kerria* Miller, Sutherland & Dorning, 1997, GIT 607-7, Ohesaare core, depth 63.0–63.10 m, Kaugatuma Formation, Äigu Beds. **H**, *Angochitina* cf. *paucispinosa* Miller, Sutherland & Dorning 1997, GIT 607-8, Dubovskoye core, depth 1202 m, Kandievski Formation. **I**, *Rhabdochitina* sp. 2, GIT 607-9, Dubovskoye core, depth 1202 m, Kandievski Formation. **J**, *Plectochitina pachyderma* (Laufeld, 1974), GIT 607-10, Dubovskoye core, depth 1184 m, Kandievski Formation. **K**, *Angochitina* sp. 1, GIT 607-11, Dubovskoye core, depth 1220 m, Kandievski Formation. **L**, *Linochitina klonkensis* Paris, Laufeld & Chlupáč, 1981, GIT 607-12, Dubovskoye core, depth 1181 m, Kandievski Formation. **M**, *Fungochitina kosovensis* Paris & Kříž, 1984, GIT 607-13 Dubovskoye core, depth 1184 m, Kandievski Formation. **N**, *Fungochitina pistilliformis* (Eisenack, 1931), GIT 607-14, Dubovskoye core, depth 1059 m, Okunevski Formation. **O**, *Ancyrochitina* cf. *libyensis* Jaglin, 1986, GIT 607-15, Dubovskoye core, depth 1177 m, Kandievski Formation. **P**, *Ancyrochitina* cf. *tomentosa* Taugourdeau & de Jekhowsky, 1960, GIT 607-16, Dubovskoye core, depth 1177 m, Kandievski Formation. **Q**, *Ramochitina* sp. 1, GIT 607-17, Dubovskoye core, depth 1177 m, Kandievski Formation. **R**, *Rhabdochitina* sp. 1, GIT 607-18, Ventspils core, depth 404 m, Minija Formation. **S**, *Bursachitina* sp. (tiny), GIT 607-19, Dubovskoye core, depth 1173.6 m, Kandievski Formation. **T**, *Cingulochitina hedei* Laufeld, 1974, GIT 607-20, Dubovskoye core, depth 1173.6 m, Kandievski Formation. **U**, *Ancyrochitina pedavis* Laufeld, 1974, GIT 607-21, Dubovskoye core, depth 1173.6 m, Kandievski Formation. **V**, *Eisenackitina* sp. (tiny), GIT 607-22, Dubovskoye core, depth 1165.5 m, Okunevski Formation. **W**, *Ancyrochitina tomentosa* Taugourdeau & de Jekhowsky, 1960, GIT 607-23, Dubovskoye core, depth 1160 m, Okunevski Formation. **X**, *Eisenackitina cupellata* Wrona, 1980, GIT 607-24, Dubovskoye core, depth 1157 m, Okunevski Formation. **Y**, *Ancyrochitina* aff. *ansarviensis* Laufeld, 1974, GIT 607-25, Dubovskoye core, depth 1163 m, Okunevski Formation.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Eisenackitina cf. *kerria* Miller, Sutherland & Dorning (Fig. 7B), *Eisenackitina barrandei* Paris & Kříž (Fig. 7C), *Linochitina* sp. (Fig. 7D), *Belonechitina*? sp. (Fig. 7E), *Eisenackitina lagenomorpha* (Eisenack) (Fig. 7F), *Angochitina* cf. *paucispinosa* Miller, Sutherland & Dorning (Fig. 7H), *Rhabdochitina* sp. 2 (Fig. 7I), *Angochitina* sp. 1 (Fig. 7K), *Rhabdochitina* sp. 1 (Fig. 7R), *Cingulochitina hedei* Laufeld (Figs 7T, 8I), *Pterochitina perivelata* (Eisenack) (Fig. 8A), *Eisenackitina oviformis* Eisenack (Fig. 8B), *Angochitina echinata* Eisenack (Fig. 8G, H), *Eisenackitina elongata* Eisenack (Fig. 8F) and *Sphaerochitina sphaerocephala* (Eisenack) (Fig. 8P). Most of these species occur also in the Přídolí.

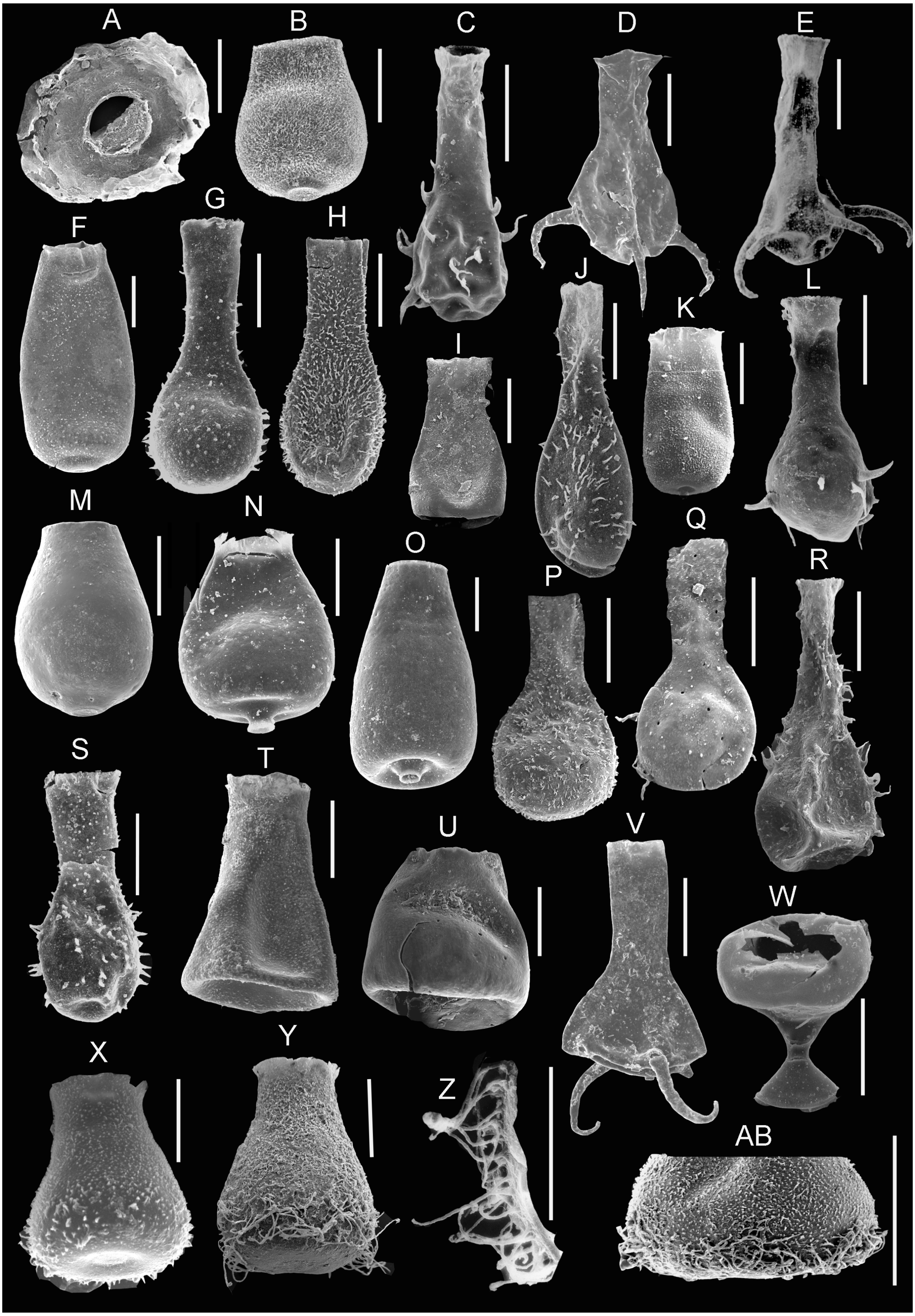
The *Fungochitina kosovensis* global and *Eisenackitina kerria–Ancyrochitina tomentosa* regional biozones

Fungochitina kosovensis is widely distributed in the Přídolí sections of the Gondwana palaeoplate, but is also found on the Baltica palaeoplate, in Podolia (Paris & Grahn 1996) and now in the Dubovskoye core in the Kaliningrad district (Fig. 6). It is the index species of the lowermost global biozone of the Přídolí Series (Verniers et al. 1995).

In addition to *Fungochitina kosovensis* (Fig. 7M), *Linochitina klonkensis* (Fig. 7L), *Bursachitina concava* Eisenack (Fig. 8M), *Urnochitina urna* (Fig. 8N, O), *Plectochitina pachyderma* (Laufeld) (Fig. 7J), *Ancyrochitina* cf. *libyensis* Jaglin (Fig. 7O), *Ramochitina* sp. 1 (Fig. 7Q) and *Ancyrochitina* aff. *ansarviensis* Laufeld (Fig. 7Y) appear in the Dubovskoye core in the lower part of the Přídolí. These species are unknown in the other studied Přídolí sections. Thus, the assemblage of the lower Přídolí chitinozoans in the Dubovskoye core contains several Gondwana-type faunal elements (*Fungochitina kosovensis*, *Linochitina klonkensis*, *Bursachitina concava* Eisenack, *Urnochitina urna*), which are totally lacking in the northern East Baltic drill cores. They allow us to place this part of the section in the global *Fungochitina kosovensis* Biozone.

However, in the northern drill cores (Ohesaare, Ventspils, Pavilosta, Figs 3–5), *F. kosovensis* has not been found in the lowermost Přídolí. Its position has been taken by *Eisenackitina kerria* Miller, Sutherland & Dorning (Fig. 7G) and *Ancyrochitina tomentosa* Taugourdeau & de Jekhowsky (Fig. 7W), which have partly overlapping ranges in the interval that probably corresponds to the *F. kosovensis* Biozone in the Dubovskoye core. Both biozones are characterized by the disappearance of *Eisenackitina barrandei* in all studied sections, within some metres above the base of the Přídolí (Figs 3–6), as in the Požary and Hviždalka sections of the Přídolí stratotype area (Kříž et al. 1986). *Angochitina filosa* Eisenack (Fig. 8C), *Angochitina ceratophora* Eisenack (Fig. 8L) and *Ancyrochitina fragilis* Eisenack (Fig. 8D, E) occur in a short interval just above the base of the *E. kerria–A. tomentosa* Biozone, whereas *Ancyrochitina pedavis* Laufeld (Fig. 7U), tiny (<70 μm) *Bursachitina* sp. (Fig. 7S), *Eisenackitina* sp.

Fig. 8. Selected chitinozoan species. Scale 50 μm. **A**, *Pterochitina perivelata* (Eisenack, 1937), GIT 607-26, Ohesaare core, depth 66.9 m, Kaugatuma Formation, Äigu Beds. **B**, *Eisenackitina oviformis* Eisenack, 1972, GIT 607-27, Pavilosta core, depth 614–614.30 m, Minija Formation. **C**, *Angochitina filosa* Eisenack, 1955, GIT 607-28, Ohesaare core, depth 66.9 m, Kaugatuma Formation, Äigu Beds. **D**, **E**, *Ancyrochitina fragilis* Eisenack, 1955: D, GIT 607-29, Pavilosta core, depth 595.50–596 m, Minija Formation; E, GIT 607-30, Ohesaare core, depth 65.70 m, Kaugatuma Formation, Äigu Beds. **F**, *Eisenackitina elongata* Eisenack, 1972, GIT 607-31, Ventspils core, depth 407.10 m, Minija Formation. **G**, **H**, *Angochitina echinata* Eisenack, 1931: G, GIT 607-32, Dubovskoye core, depth 1145.30 m, Okunevski Formation; H, GIT 607-33, Pavilosta core, depth 584.30–584.80 m, Minija Formation. **I**, *Cingulochitina hedei* Laufeld, 1974, GIT 607-34, Pavilosta core, depth 610–610.30 m, Minija Formation. **J**, *Angochitina* aff. *chlupaci* Paris & Laufeld, 1981, GIT 607-35, Dubovskoye core, depth 1145.30 m, Okunevski Formation. **K**, *Eisenackitina* sp. (ovoid), GIT 607-36, Ohesaare core, depth 45–45.05 m, Kaugatuma Formation, Äigu Beds. **L**, *Angochitina ceratophora* Eisenack, 1964, GIT 607-37, Ohesaare core, depth 66.90 m, Kaugatuma Formation, Äigu Beds. **M**, *Bursachitina concava* Eisenack, 1972, GIT 607-38, Dubovskoye core, depth 1131.8 m, Okunevski Formation. **N**, **O**, *Urnochitina urna* (Eisenack, 1934), Kandievski Formation: N, GIT 607-39, Dubovskoye core, depth 1145.30 m; O, GIT 607-40, Dubovskoye core, depth 1101.50 m. **P**, *Sphaerochitina sphaerocephala* (Eisenack, 1932), GIT 607-41, Pavilosta core, depth 619.50–619.80 m, Minija Formation. **Q**, *Angochitina* cf. *lebaica* Eisenack, 1972, GIT 607-42, Ventspils core, depth 386 m, Minija Formation. **R**, *Ramochitina* sp. 2, GIT 607-43, Dubovskoye core, depth 1123.50 m, Okunevski Formation. **S**, *Angochitina* sp. 2, GIT 607-44, Dubovskoye core, depth 1131.80 m, Okunevski Formation. **T**, *Eisenackitina* cf. *invenusta* (Wrona, 1980), GIT 607-45, Dubovskoye core, depth 1033 m, Okunevski Formation. **U**, *Bursachitina bursa* (Taugourdeau & de Jekhowsky, 1960), GIT 607-46, Dubovskoye core, depth 1101.50 m, Okunevski Formation. **V**, *Plectochitina* sp., GIT 607-47, Dubovskoye core, depth 1023.50 m, Okunevski Formation. **W**, *Margachitina* sp., GIT 607-48, Dubovskoye core, depth 1072.50 m, Okunevski Formation. **X**–**AB**, *Salopochitina filifera* (Eisenack, 1931): X, GIT 607-49, Ohesaare core, depth 19.60 m, Kaugatuma Formation, Lõo Beds; Y, GIT 607-50, Dubovskoye core, depth 1008 m, Okunevski Formation; Z, detail of basal ornament of GIT 607-51, Dubovskoye core, depth 1014 m, Okunevski Formation; AB, detail of GIT 607-52, Dubovskoye core, depth 1093 m, Okunevski Formation.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(ovoid) (Fig. 8K) and *Ramochitina* sp. 2 (Fig. 8R) have been found only in some sections. Rare finds of *Fungochitina pistilliformis* Eisenack (Fig. 7N), *Eisenackitina cupellata* Wrona (Fig. 7X), tiny (<70 µm) *Eisenackitina* sp. (Fig. 7V) and *Angochitina* aff. *chlupaci* Paris & Laufeld (Fig. 8J) come from the middle or upper parts of the biozone.

The *Salopochitina filifera* regional Biozone

This biozone is represented in all studied drill cores. According to Eisenack (1968), *Salopochitina filifera* (Eisenack 1931, Fig. 8X–AB) was previously found only in a few locations, in the Beyrichia Limestone of the south Baltic erratics, Klinta (Sweden) and Ohesaare cliff (Estonia). In the studied East Baltic drill cores this species is represented abundantly in the upper part of the Äigu and in the Lõo beds, as well as in the Targale, Jūra and Okunevski formations (Figs 3–6), respectively in the Ohesaare, Ventspils, Pavilosta and Dubovskoye cores. *Eisenackitina* cf. *invenusta* (Wrona) (Fig. 8T) is one of the common species, appearing somewhat lower than the biozonal boundary. More newcomers occur in the Dubovskoye core, where *Ramochitina* sp. 2 (Fig. 8R), *Angochitina* sp. 2 (Fig. 8S) and *Bursachitina bursa* (Taugourdeau & de Jekhowsky) (Fig. 8U) appear in the lower part and *Calpichitina gregaria* Paris & Kříž (Fig. 9E, F) in the uppermost part of the biozone. Besides the index species, *Angochitina* cf. *lebaica* Eisenack (Fig. 8Q) has been found in the Ventspils core.

Some new species appear in the middle part of the Lõo Beds (Ohesaare core) and in the Jūra Formation (Pavilosta core) (Figs 3, 5). *Angochitina* sp. 3 (Fig. 9S), *Angochitina* sp. 4 (Fig. 9U) and *Bulbochitina*? sp. (Fig. 9O, P) occur in both drill cores. *Ramochitina* sp. 3 (Fig. 9Q) is found in the Ohesaare and *Eisenackitina sphaerica* (Eisenack) (Fig. 9N) in the Pavilosta core.

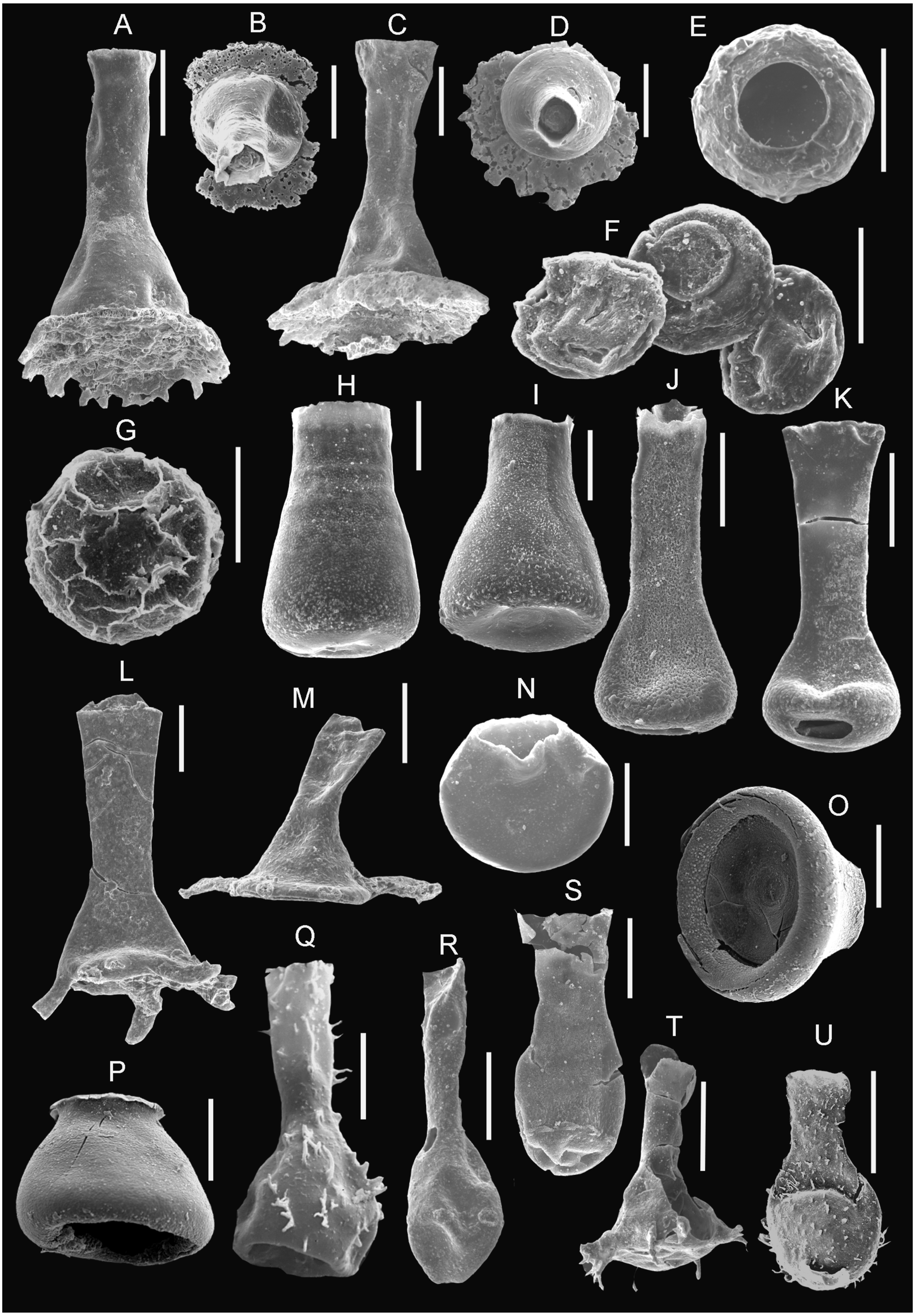
In the global Silurian chitinozoan range chart of index and characteristic species the appearance level of *Salopochitina filifera* (Eisenack) coincides with that of *Margachitina elegans* Taugourdeau & de Jekhowsky (Verniers et al. 1995). The latter species is known in several Gondwana sections and is also found in the Přídolí of Podolia (Paris & Grahn 1996), but does not occur in the East Baltic.

The *Anthochitina superba* regional Biozone

The index species was described by Eisenack (1971) from the Beyrichia Limestone of South Baltic erratics. According to Verniers et al. (1995), the *A. superba* Biozone is the highest chitinozoan biozone in the Silurian, established in Algeria, Sweden, Poland and Ukraine. In the East Baltic sections *Anthochitina superba* (Fig. 9A–D) has been identified only in a short interval (334–336.20 m) of the Ventspils drill core (Fig. 4). The interval 298–330.80 m in the middle of the Targale Formation, lacking the biozonal species, but below the first appearance of *Ancyrochitina lemniscata* is also provisionally included into the biozone. Besides *A. superba*, a few other species appear in this zone in the Ventspils core: *Eisenackitina clunensis* Miller, Sutherland & Dorning (Fig. 9H, I) in the lower part and *Fungochitina kosovensis* (Fig. 9J, K) in its upper part. The occurrence of the latter species so high in the Ventspils section is quite surprising as commonly this species has been treated as indicative of the base of the lower Přídolí.

In the Ohesaare and Pavilosta drill cores *A. superba* is lacking, probably due to pre-Devonian erosion of the corresponding strata. This species has not been found in the Dubovskoye core either, where its position is seemingly occupied by *Margachitina* sp. (Fig. 8W) and *Plectochitina* sp. (Fig. 8V), appearing at a depth of 1075.2 m (Fig. 6). The latter species occurs in the

Fig. 9. Selected chitinozoan species. Scale 50 µm. **A–D**, *Anthochitina superba* Eisenack, 1971, Targale Formation: A, B, Ventspils core, depth 335.10 m: A, GIT 607-53; B, GIT 607-54; C, GIT 607-55, Ventspils core, depth 334.52–334.68 m; D, GIT 607-56, Ventspils core, depth 335.21–335.36 m. **E**, **F**, *Calpichitina gregaria* Paris & Křiž, 1984: E, GIT 607-57, Dubovskoye core, depth 1007.50 m, Okunevski Formation; F, GIT 607-58, Ventspils core, depth 298.10 m, Targale Formation. **G**, *Calpichitina velata* (Wrona, 1980), GIT 607-59, Dubovskoye core, depth 1008.60 m, Okunevski Formation. **H**, **I**, *Eisenackitina clunensis* Miller, Sutherland & Dorning, 1997, Targale Formation: H, GIT 607-60, Ventspils core, depth 334.40–334.50 m; I, GIT 607-61, Ventspils core, depth 312 m. **J**, **K**, *Fungochitina kosovensis* Paris & Křiž, 1984, Targale Formation: J, GIT 607-62, Ventspils core, depth 308 m; K, GIT 607-63, Ventspils core, depth 298.10 m. **L**, **M**, *Ancyrochitina lemniscata* Wrona, 1980, Ventspils core, depth 296 m, Targale Formation: L, GIT 607-64; M, GIT 607-65. **N**, *Eisenackitina sphaerica* (Eisenack, 1972), GIT 607-66, Pavilosta core, depth 509–509.10 m, Jūra Formation. **O**, **P**, *Bulbochitina*? sp., Ventspils core, depth 290.10 m, Targale Formation: O, GIT 607-67; P, GIT 607-68. **Q**, *Ramochitina* sp. 3, GIT 607-69, Ohesaare core, depth 13.95–14 m, Kaugatuma Formation, Lõo Beds. **R**, *Angochitina chlupaci* Paris & Laufeld, 1981, GIT 607-70, Dubovskoye core, depth 1005 m, Okunevski Formation. **S**, *Angochitina* sp. 3, GIT 607-71, Ventspils core, depth 300 m, Targale Formation. **T**, *Ancyrochitina* sp., GIT 607-72, Dubovskoye core, depth 984 m, Okunevski Formation. **U**, *Angochitina* sp. 4, GIT 607-73, Dubovskoye core, depth 1038.50 m, Okunevski Formation.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Ventspils core in the *A. superba* Biozone. The correspondence of the beds with *Plectochitina* sp. in the Dubovskoye core to the *A. superba* Biozone in the Ventspils section is also supported by the disappearance of *Fungochitina pistilliformis* in both sections, as well as by a similar position of these strata between the under- and overlying biozones. However, these are all indirect evidences, so really we do not know where the exact boundary level might be. Due to the absence of the index species in the Dubovskoye section, the name of the biozone has been put in brackets (see Fig. 6). In the middle and upper parts of this subdivision in the Dubovskoye core *Calpichitina velata* (Wrona) (Fig. 9G) occurs. *Angochitina chlupaci* Paris & Laufeld (Fig. 9R), known as a characteristic species of the Silurian–Devonian boundary in the stratotype sections of Bohemia (Paris et al. 1981), appears at a depth of 1008.60 m.

The *Ancyrochitina lemniscata* regional Biozone

Ancyrochitina lemniscata Wrona (Fig. 9L, M) has previously been described from the uppermost Přídolí in drill cores from Poland (Wrona 1980); its biozone is erected herein. Besides the index species, occurring in the Dubovskoye and Ventspils cores (Figs 4, 6), *Angochitina* sp. 3 (Fig. 9S), *Angochitina* sp. 4 (Fig. 9U), *Bulbochitina*? sp. (Fig. 9O, P) and *Eisenackitina sphaerica* (Fig. 9N) have also been identified in the Ventspils core. These species were found in the Ohesaare and Pavilosta cores in lower layers (see Figs 3, 5). In the Dubovskoye core *Ancyrochitina* sp. (Fig. 9T) is additionally present.

Přídolí conodonts (Viira 1999) and vertebrates (Märss 1997) have also been studied from the Ventspils core, allowing correlation of different biozones, best represented in deep shelf facies (Fig. 10). A good correspondence exists between the bases of the *Salopochitina filifera*, *Ozarkodina remscheidensis canadensis* and *Nostolepis gracilis* biozones in the middle of the Minija Formation.

CONCLUSIONS

1. The studied East Baltic sections contain an abundant association of the typical Přídolí chitinozoan species, including some species described previously from the Lower Devonian: *Calpichitina velata* (Wrona), *Eisenackitina cupellata* Wrona and *E. invenusta* (Wrona) from Poland and *Angochitina chlupaci* Paris & Laufeld from Bohemia. This indicates the completeness of the Přídolí succession in the East Baltic drill cores.
2. The new regional *Eisenackitina kerria–Ancyrochitina tomentosa* Biozone, corresponding to the *Fungochitina kosovensis* Biozone in the Dubovskoye drill core, is

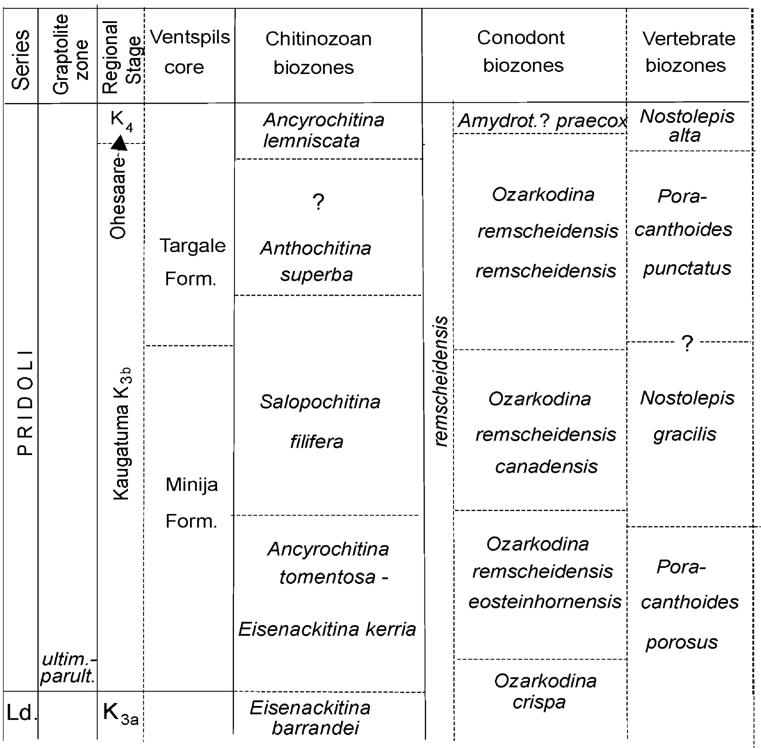

Fig. 10. Correlation chart of the chitinozoan, conodont (Viira 1999) and vertebrate (Märss 1997) biozones in the Přídolí of the Ventspils D-3 drill core. K_{3a}, Kuressaare Stage.

distinguished in the northern East Baltic Ohesaare, Ventspils and Pavilosta sections in the lower part of the Přídolí Series.
3. The Přídolí chitinozoan assemblage of the East Baltic shows an increasing presence of Gondwana elements (*Fungochitina kosovensis*, *Linochitina klonkensis*, *Urnochitina urna*, *Bursachitina concava*), particularly in the southern, deeper-water areas (Dubovskoye section). This may result from the approaching of palaeoplates in Přídolí time.
4. The *Anthochitina superba* Biozone is lacking in the Ohesaare and Pavilosta cores probably due to pre-Devonian erosion of the corresponding strata.
5. The *Ancyrochitina lemniscata* Biozone is erected above the *Anthochitina superba* Biozone in the East Baltic uppermost Silurian.
6. Correlation of the chitinozoan, conodont and vertebrate biozones in the Ventspils core demonstrates a good correspondence of some biozonal boundaries.

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Pridoli kitiinikute biostratigraafia Ida-Balti puuraukudes

Viiu Nestor

Kitiinikuliikide levik ja biotsoonid on kindlaks tehtud neljas Ida-Balti puuraugu Pridoli vanusega kivimites. On kirjeldatud *Eisenackitina kerria–Ancyrochitina tomentosa* ja *Fungochitina kosovensis*'e biotsoonid Pridoli allosast, *Salopochitina filifera* Pridoli keskosast ning *Anthochitina superba* ja *Ancyrochitina lemniscata* tsoonid Pridoli ülaosast.

On korreleeritud kitiinikute, konodontide ja vertebraatide biotsoonid Ventspilsi puuraugus.