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Age of the Kalana *Lagerstätte*, early Silurian, Estonia

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Abstract. The Kalana quarry in central Estonia is known for its exceptionally well-preserved non-calcified algal and other fossils. The interval with the fossil *Konservat Lagerstätte* in the Kalana section has previously been tentatively dated as early Aeronian. Recent findings of graptolites now enable more precise dating of these beds. The strata yielding the *Lagerstätte* are not older than the mid-Aeronian and correspond to the *Pribylograptus leptotheca* graptolite Biozone. In terms of conodont biostratigraphy they correlate with the middle of the *Pranognathus tenuis* conodont Biozone. It has also become evident that the uppermost Jõgeva Beds of the Nurmekund Formation, and probably also the uppermost Ikla Member of the Saarde Formation, are younger than previously thought and correlate with the *Pribylograptus leptotheca* graptolite Biozone. Our data additionally indicate that the conodont genus *Aulacognathus* had appeared by the mid-Aeronian.

Key words: Kalana *Lagerstätte*, conodonts, graptolites, biostratigraphy, early Silurian, Estonia.

INTRODUCTION

A fossil *Konservat Lagerstätte*, containing a rich and abundant exceptionally well-preserved algal flora (Tinn et al. 2009, 2015; Mastik & Tinn 2015) and also invertebrate and vertebrate fossils, was discovered in the Kalana (also known as Otissaare) quarry, central Estonia in 2006. In this working quarry an interval of shallow-water shelf carbonates of the Raikküla Regional Stage, Llandovery, is exposed. Cyclostratigraphical correlation of these strata with nearby core sections indicates that they correspond to the middle part of the stage (Perens 1992). The interval with the exceptionally preserved fossils is restricted to the lowermost part of the section. Based on tentative biostratigraphical correlation of the sections from east-central Estonia with those in western Estonia, the middle part of the Raikküla Stage (the Jõgeva Beds) and, hence, the interval with the *Lagerstätte* in the Kalana quarry were dated as early Aeronian by Ainsaar et al. (2014). Recent findings of identifiable graptolites in this interval now allow more precise dating of the *Lagerstätte*.

All illustrated conodont specimens and isolated graptolite fragments are housed in the Institute of Geology at Tallinn University of Technology (collection GIT 738); rock slabs with graptolites are stored at the Natural History Museum of the University of Tartu (collection TUG 1720).

GENERAL GEOLOGICAL BACKGROUND

The Raikküla Regional Stage consists of various calcareous rocks in a succession of shallowing-upward sedimentary cycles. Five major cycles have been recognized in central Estonia, named (from base to top) the Järva-Jaani, Vändra, Jõgeva, Imavere and Mõhküla beds (Perens 1992). The cycles begin with a layer of marlstone or argillaceous limestone, followed by wavy-bedded micritic limestone, and are terminated by bioclastic limestone with numerous discontinuity surfaces (Nestor H. 1997). Lateral facies changes in the Raikküla succession from shallow- to deeper-shelf carbonates have resulted in the erection of different lithostratigraphical units, the Raikküla, Nurmerkund and Saarde formations replacing each other from north to south. In western Estonia the uppermost part of the Raikküla Stage is missing; the stratigraphical interval represented by this hiatus increases in extent in a northwestward direction (Nestor V. 1976; Männik et al. 2015).

The Kalana quarry is located in central Estonia, in the northeastern part of the outcrop of the Nurmekund Formation (Fig. 1). In the quarry, the upper part of the Jõgeva Beds and the lower part of the Imavere Beds are exposed (Ainsaar et al. 2014). The Jõgeva Beds in the studied section (thickness up to 8 m, Fig. 2) are dominated by limestone (wackestone and/or packstone) which is strongly dolomitized in the upper half of the interval.

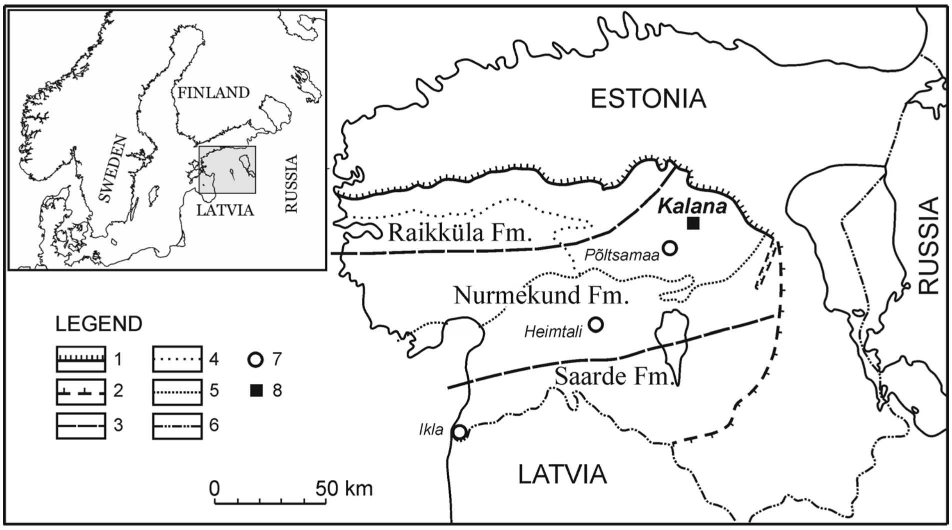


Fig. 1. Distribution of the Raikküla Regional Stage in Estonia and location of the sections discussed in the text (modified from Nestor H. et al. 2003). Legend: 1, limit of the Raikküla Stage in the outcrop area; 2, limit of the stage in the subsurface area; 3, geographical boundaries between formations in the Raikküla Stage; 4, limit of the overlying Adavere Stage in the outcrop area; 5, northern limit of overlying Middle Devonian strata; 6, state boundaries; 7, core sections; 8, Kalana quarry.

Numerous 1–20 mm thick lenses and irregular interbeds of light to dark brown organic-rich microlaminated dolomitized argillaceous limestone occur in these strata. The upper part of the Jõgeva Beds is represented by a series of beds of pure hard light grey cross-bedded fine-grained grainstone with a thickness of 1–4 m. Historically, this rock has been known as the 'Kalana Marble', a highly valued building limestone (Perens 2006). Interbeds of micritic limestone occurring in grainstone often contain lenses of lithoclastic tempestites in which the lithoclasts were formed from the same micritic limestone. The Imavere Beds consist of partly dolomitized greenish-grey argillaceous micritic limestone, which becomes less argillaceous upwards in the succession.

Unusually for Estonian bedrock, the strata in the Kalana region are slightly deformed and dip westwards (Fig. 3). Thus, the oldest part of the succession that yields the *Lagerstätte* is exposed at the eastern end of the quarry.

BIOTA IN THE KALANA QUARRY

It is mainly the light to dark brown organic-rich interbeds in the lower part of the succession exposed at the eastern end of the quarry that have become known for their exceptionally well-preserved non-calcified algal fossils (Tinn et al. 2009). Although the rich and abundant algal flora is currently under study, it has already been revealed that the majority of the species are dasyclads (division Chlorophyta), i.e. *Palaeocymopolia silurica* Mastik & Tinn and *Kalania pusilla* Tinn, Mastik, Ainsaar & Meidla (Mastik & Tinn 2015; Tinn et al. 2015). Dasycladales is an order of macroscopic unicellular, usually heavily calcified algae, whose earliest fossils are from the Lower Cambrian (Korde 1961, 1973; Peel 2014) and which also thrive in modern tropical seas (Berger & Kaever 1992). However, the most common algal fossil in the Kalana quarry is *Leveilleites hartnageli* Foerste, assigned to the division Rhodophyta (Tinn et al. 2009).

The faunal fossils reveal a rich biota, within which benthic, nektic and planktic faunas are all well represented. However, the preservation of the different groups, depending upon their lifestyle and skeletal mineralogy, is rather variable. The excellent preservation of some fossils, e.g. complete specimens of crinoids, with the finest pinnules preserved on the brachials, suggests that they were buried in situ. However, a considerable proportion of shelly fossils, including rhynchonelliformean [e.g. *Eostropheodonta delicata* (Baarli), *Koigia extenuata* (Rubel), *Clintonella aprinis* (Verneuil), *Hindella crassa* (J. de C. Sowerby), *Coolinia applanata* (Salter)] and craniiformean (e.g. Trimerellidae spp.) brachiopods (Madis Rubel, pers. comm. 2011), and gastropods (e.g. *Murchisonia* sp.; Mare Isakar, pers. comm. 2011), are common in storm accumulated coquina lenses. Gastropods, as a rule, are preserved as internal moulds only.

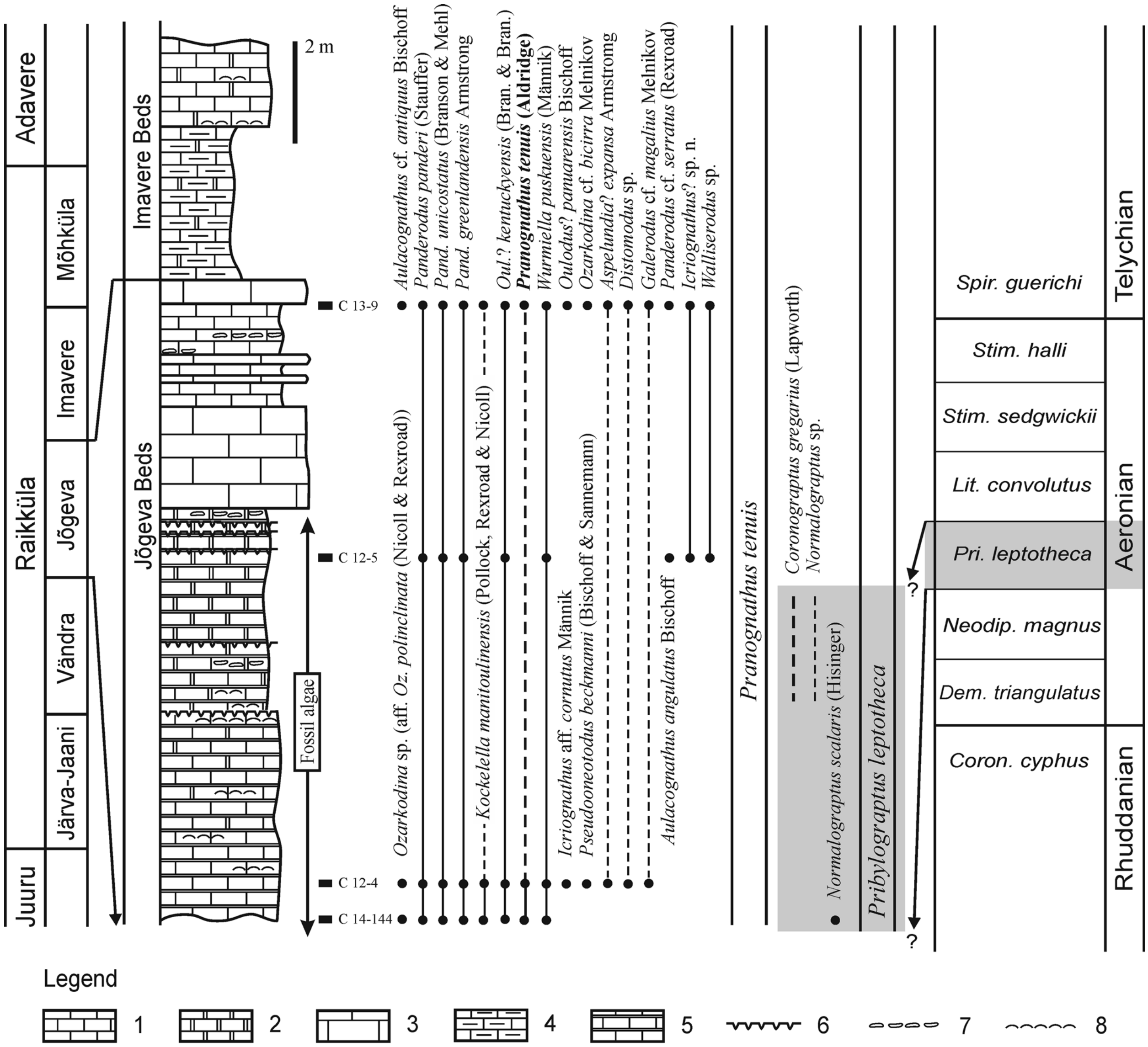


Fig. 2. The studied Kalana quarry section. From left to right: regional stages; beds in the Nurmekund Formation; lithology (modified from Ainsaar et al. 2014); conodont samples; distribution of conodonts; conodont biozone recognized; distribution of graptolites; graptolite biozone recognized; Aeronian graptolite biozonation (after Loydell 2012). Grey interval marks the identified graptolite biozone. Legend: 1, limestone (wackestone and packstone); 2, dolomitized wackestone and packstone; 3, limestone (grainstone); 4, argillaceous limestone (wackestone); 5, intercalation of different limestones and dolomitized limestones (mainly wackestone and packstone) with kerogenous laminae and thin interbeds; 6, pyritized discontinuity surfaces; 7, lithoclastic tempestites; 8, coquinal interbeds. Abbreviations: *Coron*., *Coronograptus*; *Dem*., *Demirastrites*; *Lit*., *Lituigraptus*; *Neodip*., *Neodiplograptus*; *Pri*., *Pribylograptus*; *Spir*., *Spirograptus*; *Stim*., *Stimulograptus*.

So far, ten taxa of ostracods have been identified at Kalana; however, due to the poor preservation, only one – aff. *Craspedobolbina* (*Mitrobeyrichia*) *permira* Sarv – has been identified to species level. Other ostracod taxa recognized include the palaeocopids *Beyrichia* sp., *Macrypsilon* sp., aff. *Bingeria* sp., *Craspedobolbina* sp. and the metacopids *Hemeaschmidtella* sp., *Microcheilinella* sp., aff. *Silenis* sp., aff. *Pullvillites* sp. and unspecified metacopes (Tinn 2015). Other arthropods are represented by cuticle remains of the eurypterid *Eurypterus tetragonophthalmus* (Fischer) and, at some levels, accumulations of leperditiid shells.

Among the scolecodonts (class Polychaeta) identified are *Oenonites* aff. *latus* (Kielan-Jaworowska), *Kettnerites sisyphi* Bergman, *K. sisyphi klasaardensis* (Bergman), *K. bankvaetensis* (Bergman), *Koslowskiprion*

Fig. 3. A, southern wall of the quarry where the west tilted strata are well exposed. **B**, southeastern wall of the quarry. The lower part of the succession exposed here (below the person in the middle of the photo) contains numerous interbeds rich in algae and many other exceptionally well-preserved fossils. Photos by O. Tinn.

longicavernosus Kielan-Jaworowska, *Polychaetaspis wyszogrodensis* (Kozłowski), *Vistulella koslowskii* Kielan-Jaworowska, *Atraktoprion cornutus* Kielan-Jaworowska, *Mochtyella cristata* Kielan-Jaworowska and *Ramphoprion* sp. (Truuver 2009).

Additionally, rare trilobites representing the families Lichiidae, Odontopleuriidae, Encrinuridae and Illaenidae have been found at Kalana. Tabulates, small rugose corals and conulariids are also quite common here, trepostomate bryozoans and 'lithistid' demosponges occur at some levels and both orthoconic and coiled nautiloid cephalopods have been found. Recently, an agnathan, the oldest ostracoderm in the world, has been discovered (description in prep.).

Most of the fauna and flora that has been identified from the Kalana quarry has either a long temporal range, or the species/specimens described from here are unique and thus they cannot be used in the dating of the strata.

AGE OF THE STRATA

Previous dating of the section

The Jõgeva and Imavere beds have been considered to be of early to middle Aeronian age [lower-middle and upper '*gregarius–triangulatus*' graptolite Biozone (GZ), respectively] (Nestor H. 1997). However, as graptolites are very rare and occur only sporadically in the Nurmekund Formation [graptolites characteristic of the *Coronograptus cyphus* GZ have been recorded from the Järva-Jaani Beds at the base of the formation and *Cor.* aff. *gregarius* (Lapworth) from the Jõgeva Beds (Nestor H. 1994 and references therein)], the dating of the beds in the formation has largely resulted from chitinozoan-based correlation of the units within the Nurmekund Formation with successions in SW Estonia and western Latvia.

In SW Estonia, in the Ikla core section, graptolites are common in the lower part of the Raikküla Stage. In this region the stage is represented by the Saarde Formation consisting of six members (Fig. 4). According to Kaljo & Vingisaar (1969), the interval 460–500 m (Heinaste, Slitere and Kolka members: Nestor H. et al. 2003) in the Ikla section yields an assemblage of graptolites characteristic of the upper Rhuddanian *Cor. cyphus* GZ comprising *Pribylograptus sandersoni* (Lapworth), *Prib. incommodus* (Törnquist), *Pseudoclimacograptus* [now *Metaclimacograptus*] *hughesi* (Nicholson), *Glyptograptus tamariscus* (Nicholson), *Pernerograptus revolutus* (Kurck), *Rhapidograptus toernquisti* (Elles & Wood), '*Climacograptus*' cf. *minutus* Carruthers, etc. As graptolites are not present below

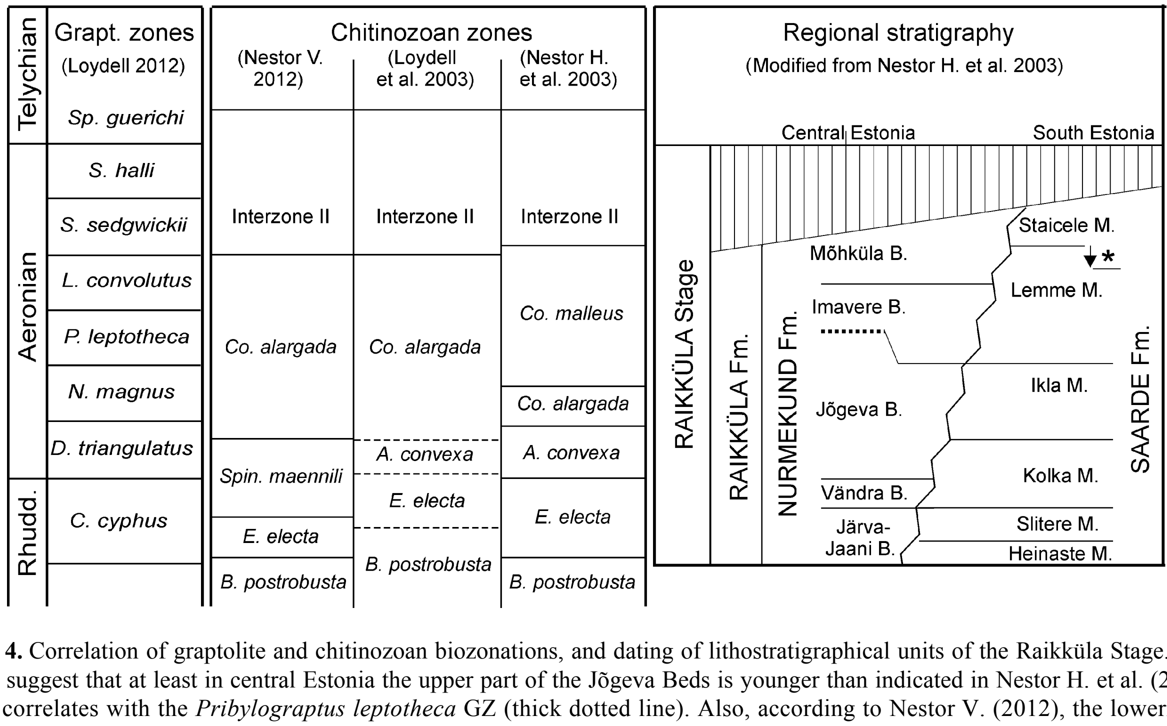


Fig. 4. Correlation of graptolite and chitinozoan biozonations, and dating of lithostratigraphical units of the Raikküla Stage. Our data suggest that at least in central Estonia the upper part of the Jõgeva Beds is younger than indicated in Nestor H. et al. (2003) and correlates with the *Pribylograptus leptotheca* GZ (thick dotted line). Also, according to Nestor V. (2012), the lowermost Staicele Member might be older than suggested by Nestor H. et al. (2003) and corresponds to the *Lituigraptus convolutus* GZ (indicated by the arrow with *). Abbreviations: *A.*, *Ancyrochitina*; *B.*, *Belonechitina*; *C.*, *Coronograptus*; *Co.*, *Conochitina*; *D.*, *Demirastrites*; *E.*, *Euconochitina*; *L.*, *Lituigraptus*; *N.*, *Neodiplograptus*; *P.*, *Pribylograptus*; *S.*, *Stimulograptus*; *Sp.*, *Spirograptus*; *Spin.*, *Spinachitina*.

500 m, the level of the lower boundary of the *Cor. cyphus* Biozone in the Ikla core section is not known.

Higher in the section, above 460 m, in the Ikla Member, there appears an assemblage indicating the *Demirastrites triangulatus* GZ. *Demirastrites triangulatus* (Harkness) is common up to 420 m, in the lower and middle parts of the member. Together with this taxon the most common species recorded are *Ps.* [now *Metaclimacograptus*] *hughesi* and *Rh. toernquisti*. Other species recorded include *Prib.* [now *Atavograptus*] *atavus* (Jones), *Pristiograptus* cf. *concinnus* (Lapworth), *Campograptus elongatus* (Törnquist), *Climacograptus* [now *Normalograptus*] *scalaris*, *Glyptograptus tamariscus*, *Prist.* [now *Coronograptus*] *gregarius* (Lapworth) and '*Monograptus*' *intermedius* (Carruthers). Higher in the section, above 420 m, graptolites are rare and it was not possible to recognize specific graptolite biozones.

The chitinozoan biozonation of the Raikküla Regional Stage has been revised repeatedly (e.g. Nestor V. 1994; Loydell et al. 2003; Nestor H. et al. 2003; Nestor V. 2012). According to the latest version of the chitinozoan biozonation (Nestor V. 2012), the Saarde Formation includes the *Euconochitina electa* (= lower and middle parts of the Slitere Member), *Spinachitina maennili* (= upper Slitere and Kolka members) and *Conochitina alargada* (= Ikla, Lemme and lowermost Staicele members) chitinozoan biozones, and an unzoned (Interzone) interval (= most of the Staicele Member) (Fig. 4). The co-occurrences of chitinozoans and graptolites in the Aizpute-41 core section in Latvia enable precise correlation between the chitinozoan and graptolite biozonations (Loydell et al. 2003; Nestor V. 2012).

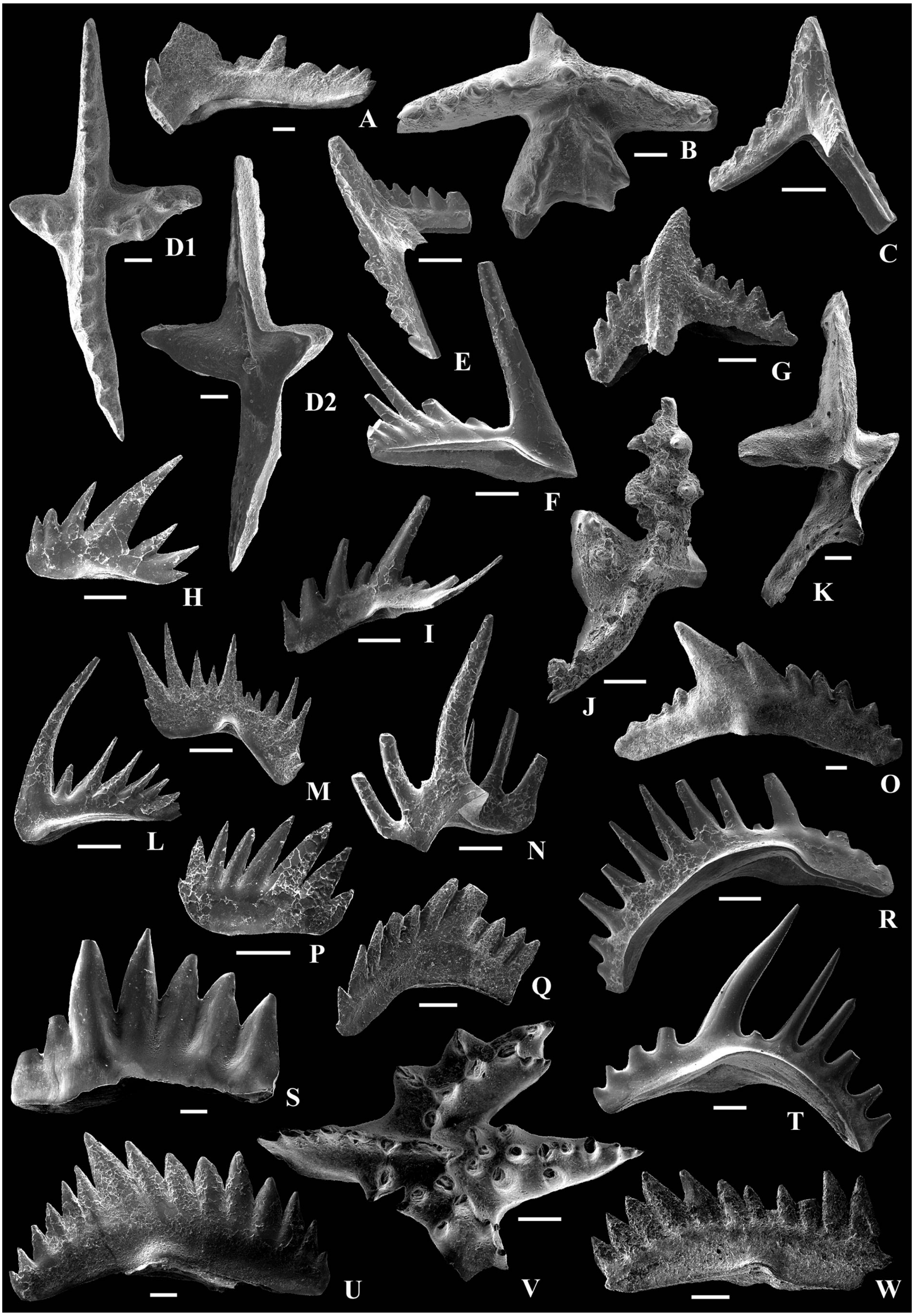
Detailed sedimentological and biostratigraphical studies of the Ikla, Heimtali and Põltsamaa core sections have resulted in reliable correlation between the Saarde and Nurmekund formations of south and central Estonia (Nestor H. et al. 2003). According to these data, the interval represented by the Jõgeva and Imavere beds of the Nurmekund Formation and the upper Kolka, Ikla and lower Lemme members of the Saarde Formation is of the same age. The upper, more argillaceous part of the Kolka Member in the Ikla section corresponds to the *Ancyrochitina convexa* chitinozoan Biozone (CtZ), correlates with the lower(most) Jõgeva Beds in the e.g. Põltsamaa section and is of early Aeronian age (*Anc. convexa* CtZ = lower *D. triangulatus* GZ: Loydell et al. 2003).

The lower and middle parts of the Ikla Member in the Ikla core section yield numerous graptolites of the *Dem. triangulatus* GZ, and correspond to the *Con. alargada* CtZ as also does most of the Jõgeva Beds (Nestor V. et al. 2003; Fig. 4). The upper part of the Ikla Member correlates with the lower *Con. malleus* CtZ (= upper part of the *Con. alargada* CtZ in Nestor V. 2012). The *Con. alargada* CtZ *sensu* Nestor V. (2012) corresponds to the upper *Dem. triangulatus*–topmost *Lituigraptus convolutus* GZs (Loydell et al. 2003; Fig. 4). Chitinozoans are almost absent in the uppermost part of the Jõgeva Beds but, by its stratigraphical position, this interval was tentatively correlated with the lower part of the *Con. malleus* CtZ corresponding to the uppermost Ikla Member (Nestor H. et al. 2003). Data from the Heimtali section suggest that the Imavere Beds correspond to the main part of the *Con. malleus* CtZ (to the upper *Con. alargada* CtZ *sensu* Nestor V. 2012) and correlate with the lower part of the Lemme Member of the Saarde Formation which yields a similar chitinozoan fauna (Nestor H. et al. 2003). This lithostratigraphical interval has been correlated with the *Monograptus argenteus*/*Prib. leptotheca* and lower *Lit. convolutus* GZs (Nestor V. 2012).

New data

Four samples were processed for conodonts from the Jõgeva Beds in the lower part of the succession exposed in the Kalana quarry with the aim of dating the section more precisely (Fig. 2). Samples were dissolved in buffered acetic and formic acids. All samples were productive, yielding relatively rich and varied conodont faunas. The occurrence of *Pranognathus tenuis* (Aldridge) (Fig. 5: B, C, E, G) in three samples indicates the *Pr. tenuis* conodont Biozone (CZ) for the studied interval.

Fig. 5. Selected conodonts from the Kalana section. As positional homology of elements in an apparatus has been determined only for few taxa, the traditional Pa, Pb, Pc, M, Sa, Sb, Sc notation introduced by Sweet & Schönlaub (1975) is followed here. Scale bar represents 100 µm. **A**, **D**, **O**, *Aulacognathus* cf. *antiquus* Bischoff: A, Sc element, GIT 738-1; D, Pa element (D1 – from above, D2 – from below), GIT 738-2; O, Pb element, GIT 738-3. **B**, **C**, **E**, **G**, *Pranognathus tenuis* (Aldridge): B, Pa element, GIT 738-4; C, Pc element, GIT 738-5; E, M element, GIT 738-6; G, Pb element, GIT 738-7. **F**, **I**, **N**, *Aspelundia*? *expansa* Armstrong: F, M element, GIT 738-8; I, Pb element, GIT 738-9; N, Sb element, GIT 738-10. **H**, **L**, **M**, **P**, *Ozarkodina* sp. (aff. *Oz. polinclinata*) (Nicoll & Rexroad): H, Pb element, GIT 738-11; L, M element, GIT 738-12; M, Sb element, GIT 738-13; P, Pa element, GIT 738-14. **J**, *Icriognathus* aff. *cornutus* Männik, Pa element, GIT 738-15. **K**, *Aulacognathus angulatus* Bischoff, Pa element, GIT 738-16. **Q**, **W**, *Ozarkodina* cf. *bicirra* Melnikov: Q, Pb? element, GIT 738-17; W, Pa element, GIT 738-18. **R**, **T**, *Oulodus*? *kentuckyensis* (Branson & Branson): R, Pa element, GIT 738-19; T, Pb? element, GIT 738-20. **S**, *Galerodus* cf. *magalius* Melnikov, Pa element, GIT 738-21. **U**, *Wurmiella puskuensis* (Männik), Pa element, GIT 738-22. **V**, *Icriognathus*? sp., Pa element, GIT 738-23. All specimens from sample C12-4.



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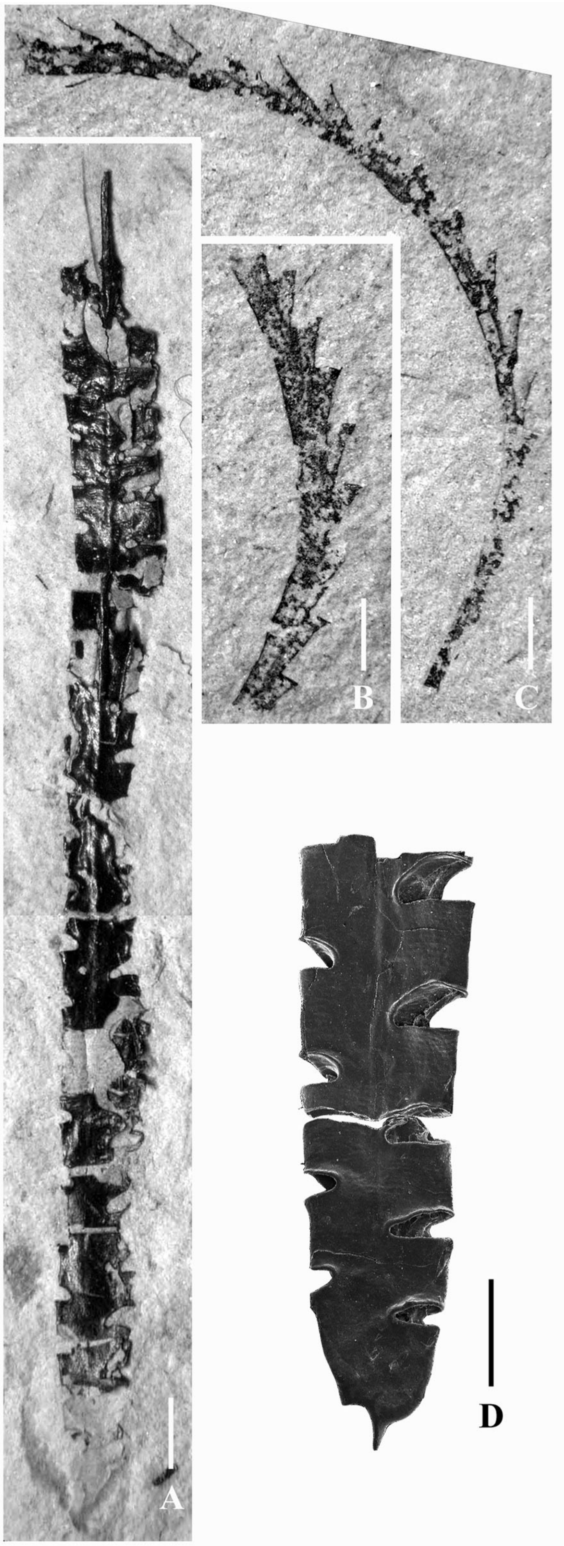

Fig. 6. Graptolites from the Kalana section. Scale bar represents 1 mm. **A**, *Normalograptus* sp. apparently showing regeneration after damages, TUG 1720-1. **B**, **C**, *Coronograptus gregarius* (Lapworth). TUG 1720-2 and TUG 1720-3. **D**, *Normalograptus scalaris* (Hisinger). GIT 738-24, sample C14-144.

The boundaries of the *Pr. tenuis* CZ are defined by the first and last appearance levels of this species (Cramer et al. 2011 and references therein). According to Aldridge (1972) and Aldridge et al. (1993), *Pr. tenuis* appears in the *Lit. convolutus* GZ and reaches the *Stimulograptus sedgwickii* GZ, although in Estonia (Nestor H. 1997) the base of the biozone has been shown as coincident with the base of the *Dem. triangulatus* GZ (and thus with the base of the Aeronian Stage) and its top questionably correlating with a level low in the *Lit. convolutus* GZ. As *Pr. tenuis* is not common in sections around the world, its overall stratigraphical range is still problematic. In addition to records from Great Britain and Estonia, *Pr. tenuis* has been found in Norway (see below) and Arctic Russia [from Severnaya Zemlya (Männik & Aldridge 1989; Männik 2002) and the Subpolar Urals (Mel′nikov 1999, = *Pterospathodus tenuis*)].

In Norway *Pr. tenuis* (identified as '*Amorphognathus*' *tenuis*) has been found widely throughout the Oslo Region where it occurs in the uppermost Solvik–lowermost Rytteråker formations (in the Asker and Malmøya areas) and in the uppermost Sælabonn–lowermost Rytteråker formations (in the Ringerike area) (Aldridge & Idris 1982). In the Asker and Malmøya successions this interval has been correlated with the *Stim. sedgwickii* GZ (but with no diagnostic graptolites recorded). However, it is probably older in the Ringerike area where it has been stated to correspond to the *Neodiplograptus magnus* and *Mon. argenteus* GZs (Baarli & Johnson 1988), although this dating was based upon brachiopods rather than graptolites and a rather different (younger) age, with the Solvik/Rytteråker formational boundary shown at the base of the *Lit. convolutus* GZ, was given by Worsley et al. (1983). Baarli & Johnson's (1988) dating suggests an earlier, early Aeronian, appearance for *Pr. tenuis* and agrees with data from Estonia: the conodont has been found in the lowermost Jõgeva Beds, in strata corresponding to the *Anc. convexa* CtZ in the Põltsamaa core section in central Estonia (Nestor H. et al. 2003). The *Anc. convexa* CtZ correlates with the lower Aeronian *Dem. triangulatus–Dem. pectinatus* GZ (Loydell et al. 2003; Nestor V. 2012). Hence, the conodont data available at the moment only confirm the general Aeronian age of the *Lagerstätte* in the Kalana quarry but do not allow more precise dating of the interval. The Estonian occurrences of *Pr. tenuis* strongly suggest, however, that the species' FAD is significantly lower than shown by Cramer et al. (2011).

The lowermost of the four samples processed for conodonts, sample C14-144 (Fig. 2), yielded besides conodonts two well-preserved fragments of the same specimen of *Normalograptus scalaris* (Hisinger) (Fig. 6: D). This species is known to appear in the *Prib. leptotheca* GZ and ranges up to the lowermost

Spirograptus turriculatus GZ (Štorch 1998; Loydell & Maletz 2009; Zalasiewicz et al. 2009). Hence, sample C14-144 comes from a level not older than the middle Aeronian *Prib. leptotheca* GZ. Graptolites of poor preservation have been discovered also on several surfaces higher in the *Lagerstätte*. According to preliminary identifications, they belong either to *Cor. cyphus* (Lapworth) or *Cor. gregarius* (Sigitas Radzevičius, pers. comm. 2014). New, better-preserved specimens from bedding planes are available now. Most common among them is *Cor. gregarius* (Fig. 6: B, C), but a few poorly preserved specimens of *Normalograptus* (Fig. 6: A) were also found, the illustrated specimen apparently showing regeneration after damage during life. These cannot be identified to species level.

Both of the identifiable species of graptolites, *Norm. scalaris* and *Cor. gregarius*, are long-ranging: *Cor. gregarius* appears in the uppermost Rhuddanian and reaches the *Prib. leptotheca* GZ, *Norm. scalaris* ranges from the *Prib. leptotheca* GZ to the lowermost *Spir. turriculatus* GZ. The ranges of these two taxa overlap in the *Prib. leptotheca* GZ. Hence, it is evident that the *Lagerstätte*, and the interval of the Jõgeva Beds exposed in the Kalana quarry cannot be older than the middle Aeronian *Prib. leptotheca* GZ and that at least part of the *Lagerstätte* corresponds to this biozone.

A conodont sample from the middle part of the Jõgeva Beds in the Kalana section (sample C12-5) shows the appearance of *Aulacognathus angulatus* Bischoff (Figs 2, 5: K) and the sample from the uppermost part of the bed yielded *Aul.* cf. *antiquus* Bischoff (Figs 2, 5: A, D, O). Both taxa are stated to occur in the upper Aeronian *Stim. sedgwickii* or lower Telychian *Spir. turriculatus* GZ in New South Wales, Australia (Bischoff 1986), although graptolites from these biozones have not been recorded from the Quarry Creek Limestone which yielded the conodonts (Packham & Stevens 1954) and thus there is no evidence to support this biostratigraphical assignment. These occurrences might indicate the *Stim. sedgwickii* GZ or younger for the upper half of the Jõgeva Beds in the Kalana quarry. However, as conodonts are not known from the strata between the *Mon. argenteus* GZ and the highly questionable *Stim. sedgwickii* GZ in New South Wales, it is possible that in reality both taxa appeared in this unstudied interval, and that the uppermost Jõgeva Beds are older than the *Stim. sedgwickii* GZ.

CONCLUSIONS

1. The lowermost strata exposed in the Kalana quarry containing the fossil *Konservat Lagerstätte* are not older than mid-Aeronian and can be dated to the *Pribylograptus leptotheca* GZ.
2. In terms of conodont biostratigraphy the *Lagerstätte* is within the middle *Pranognathus tenuis* CZ.
3. The FAD of *Pranognathus tenuis* is significantly lower stratigraphically in Estonia than indicated in Cramer et al. (2011). In that paper the lower boundary of the *Pr. tenuis* CZ (FAD of *Pr. tenuis*) is indicated in the lower *Lituigraptus convolutus* GZ but data from Estonia suggest that this conodont appears already in the lower Aeronian *Demirastrites triangulatus–Dem. pectinatus* GZ.
4. The uppermost Jõgeva Beds of the Nurmekund Formation, but most probably also the uppermost Ikla Member of the Saarde Formation, are younger than previously thought and correlate with the *Pribylograptus leptotheca* GZ.
5. The conodont genus *Aulacognathus* evidently had appeared already in the mid-Aeronian.

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Kalana *Lagerstätte* vanus, Vara-Silur, Eesti

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Kalana karjäär Kesk-Eestis on saanud tuntuks erakordselt hästi säilinud Siluri-aegsete fossiilide, sealhulgas vetikate poolest. Fossiiliderikast intervalli (*Lagerstätte*) korreleeriti tinglikult Alam-Aeroniga. Hiljutised määratavate graptoliitide leiud näitavad aga, et eelmainitud kihid on veidi nooremad, Kesk-Aeroni vanusega, ja vastavad graptoliidi *Pribylograptus leptotheca* biotsoonile.