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Latest Sandbian brachiopods and chitinozoan biostratigraphy in North Estonia

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ABSTRACT

The latest Sandbian brachiopods and chitinozoans were studied in the Kõrgessaare and Haapsalu drill cores of Estonia. The brachiopod fauna shows a gradual renewal through the Keila Regional Stage (RS), differently from the rather persistent association of chitinozoans. An exception is the uppermost part of the stage, which differs in two sections in the taxonomic composition of chitinozoans and the occurrence of two species-level taxa of the *Dalmanella kegelensis* brachiopod group. *D. kegelensis sensu lato* has been considered an index taxon of the biozone in the Keila RS. It links the brachiopod faunas of North Estonia to those in NW Russia. In the latter region, the dolomitic and siliciclastic lagoonal and peritidal deposits overlying the strata with brachiopods of the *D. kegelensis* group are considered the youngest part of the Keila RS.

Introduction

In the East Baltic, the Keila Regional Stage (RS) corresponds to the latest Sandbian and the Sandbian–Katian transition. It has been the subject of special studies on faunas, facies, environments and stratigraphy (Põlma et al. 1988; Ainsaar et al. 1996; Hints and Nõlvak 1999; Ainsaar and Meidla 2001; Kröger et al. 2014). The occurrence of reefs in a narrow belt (Kröger et al. 2014) and the greatest thicknesses over 30 m, instead of 12–15 m in NE Estonia, characterise the Keila RS in NW Estonia. In several sections in West Estonia, the globally identified Guttenberg Carbon Isotope Excursion (GICE) interval falls into a gap at the boundary between the Keila and Oandu RSs (Fig. 1; Ainsaar et al. 2010). However, the GICE is identified in the reefs and related facies (Kröger et al. 2014), as well as in South Estonian sections (Ainsaar et al. 2010).

Alichova (1953, 1960) identified a regional biozone with nominal species *Dalmanella kegelensis* in the Keila RS. This brachiopod has a wide distribution in shallow shelf environments from West Estonia to the western periphery of the Moscow syneclise. In Estonia, *D. kegelensis* Alichova, 1953 occurs in the upper part of the Keila RS and is represented by two subspecies (Hints 1975) with different distribution areas. In this study, the subspecies of the *Dalmanella kegelensis* brachiopod group are interpreted as separate species of different genera, marked here tentatively as '*D.*' *kegelensis* and '*D.*' *oanduensis*.

The aim of this report is to document the distribution of brachiopods and chitinozoans in NW Estonia, to characterise the latest Sandbian biotic turnover and find new regional correlation criteria with NW Russia. In the latter region, the Keila RS is represented by the lithologically variable Jelizavetino Formation (Fm).

Materials and methods

The latest Sandbian rhynchonelliformean brachiopods, chitinozoans and selected other fossils were studied in two sections of NW Estonia (Figs 1–2). The Kõrgessaare and Haapsalu GS3 sections are located on the island of Hiiumaa and on the western mainland of Estonia, ca 60 km apart from each other (Fig. 1). Chitinozoans were studied in 57 samples (ca 150 to 300 grams) using standard processing techniques and hand-picking (Nõlvak et al. 2019). The lithological description of the Kõrgessaare and Haapsalu cores is represented by Rõõmusoks (1970) and Vingisaar (1971), respectively. The collection of brachiopods (GIT 207) and preparates of microfossils are housed at the Department of Geology, Tallinn University of Technology.

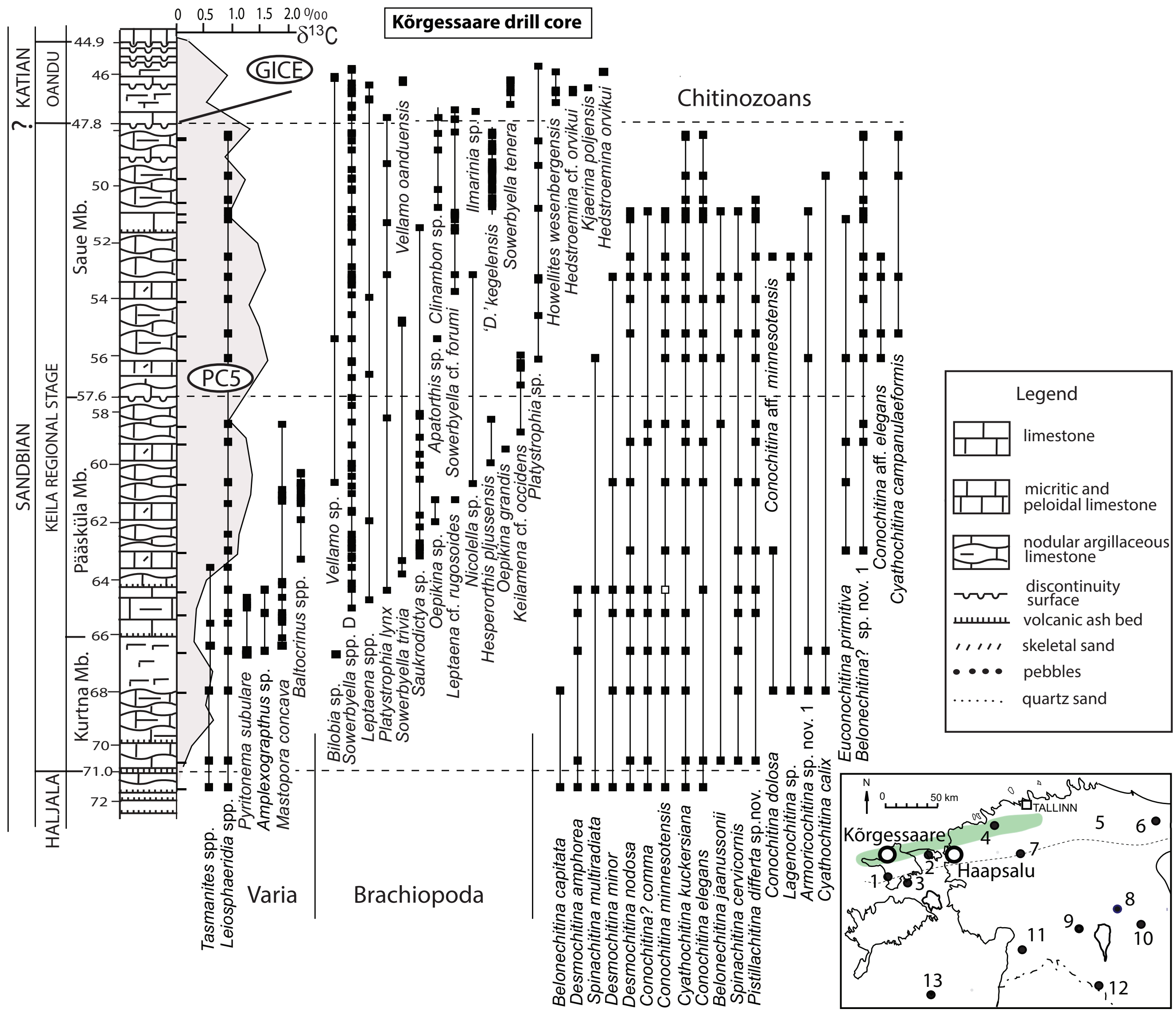

Fig. 1. Distribution of brachiopods, chitinozoans and selected associated fossils in the Kõrgessaare core section. The empty markers denote doubtful identification (cf.). The carbon isotope curve is marked after Kaljo et al. (2004). GICE corresponds to a gap, the PC5 isotopic zone is presented after Ainsaar et al. (2001). The map (bottom right) shows the sections mentioned in the text: 1 – Männamaa, 2 – Söderby, 3 – Orjaku, 4 – Vasalemma district, 5 – Kerguta, 6 – Oandu, 7 – Rapla, 8 – Laeva, 9 –Viljandi, 10 – Tartu, 11 – Ristiküla, 12 – Valga, 13 – Ruhnu. The green belt marks the distribution area of *'D.' kegelensis*, the dotted line marks the supposed southern boundary of the distribution of *'D.' oanduensis*.

Results and discussion

The earliest benthic faunas of the Keila age were stressed by a volcanic ash fall forming the Kinnekulle K-bentonite Bed at the base of the stage (Hints and Nõlvak 1999). Several new brachiopod and trilobite taxa appear somewhat above that level. In the Kõrgessaare and Haapsalu sections, spicules of *Pyritonema*, fragments of *Mastopora concava* and the trace fossil *Conichnus* are transitional from the underlying strata. The brachiopod *Sowerbyella* is represented by *S. trivia* in the lower part and *S. forumi* in the upper part of the stage. The columnals of *Baltocrinus* sp. occur in several succeeding samples in the Kurtna and Pääsküla members. The upper part of the Pääsküla Member (Mb) is characterised by the strophomenid *Keilamena occidens.* The upper part of the Keila RS corresponds to the Saue Mb and is characterised by *S. forumi* and *Clinambon anomalus* (Figs 1–2). Notable is the occurrence of '*D.*' *kegelensis* and '*D.*' *oanduensis* in the Kõrgessaare and Haapsalu sections of the Saue Mb, respectively. '*D.*' *oanduensis* was previously known mainly from NE Estonia, and its stratigraphic position in comparison with '*D.*' *kegelensis* was unclear. In the Kõrgessaare section, '*D.*' *kegelensis* also occurs in the upper part of the Saue Mb (Fig. 2), disappearing together with *S. forumi* and *Clinambon* sp. below a discontinuity surface at 47.8 m core depth. Above that level, the Katian species *Sowerbyella tenera*, *Kjaerina poljensis* and *Howellites wesenbergensis* first appear.

A rich and well-preserved assemblage of chitinozoans in both sections (Figs 1–2) corresponds to the middle part of the *Spinachitina cervicornis* Biozone (Nõlvak et al. 2006). Furthermore, the distribution and diversity of chitinozoans and rare graptolites (such as *Amplexograptus maxwelli*) are generally in good accordance with previous data from Estonia and Latvia (e.g., Goldman et al. 2015).

In the Haapsalu core, *Angochitina multiplex* and *Hercochitina spinetum* appear immediately above the Kinnekulle K-bentonite, providing additional criteria for the stage bound-

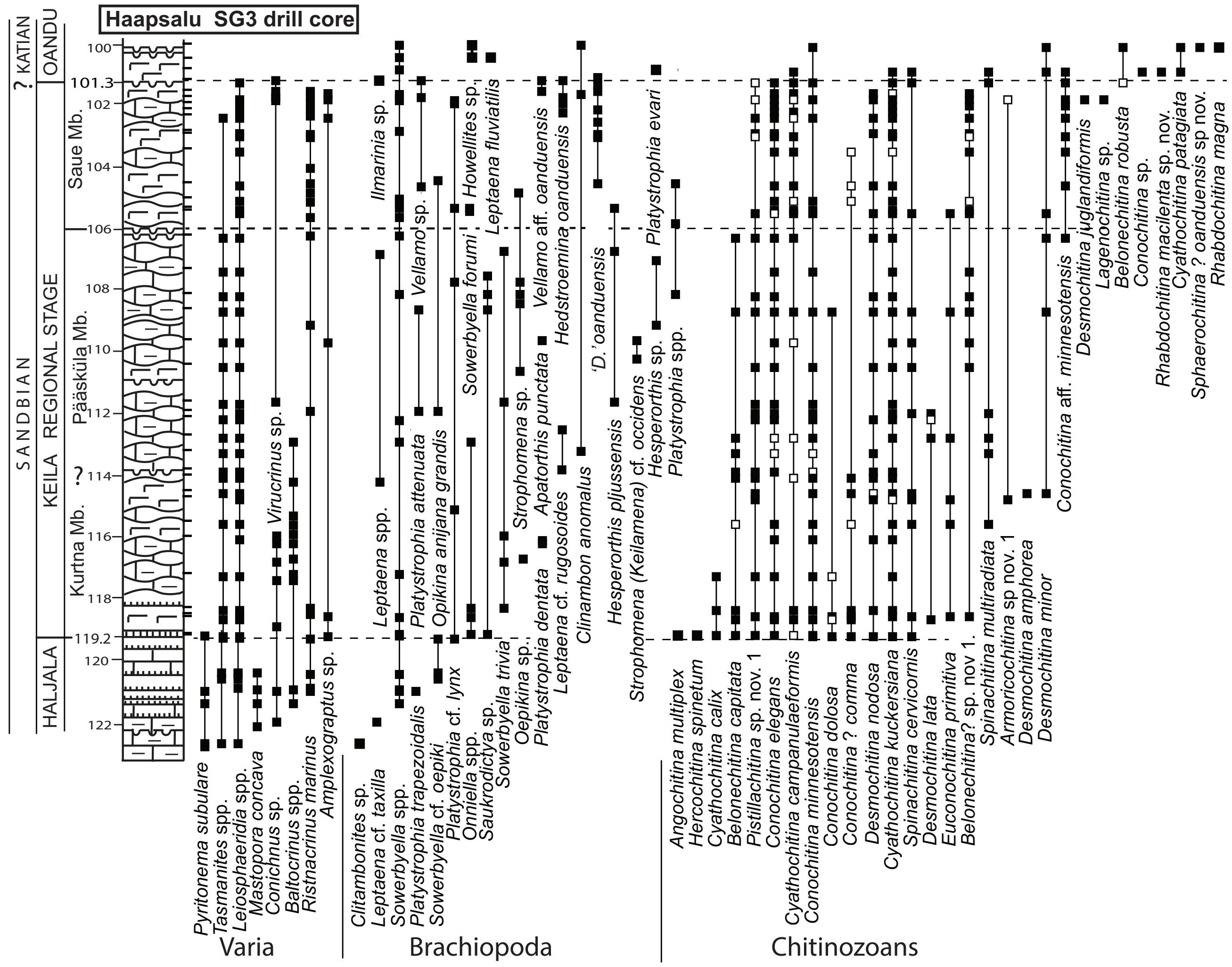

Fig. 2. Distribution of the latest Sandbian brachiopods, chitinozoans and selected other fossils in the Haapsalu GS3 core. For the legend, see Fig. 1.

ary (Hints and Nõlvak 1999). In the Kõrgessaare section, the lowermost part of the Keila RS is sparsely sampled, and the two marker species were probably overlooked. In both sections, the taxonomic composition of the chitinozoan fauna is very similar to that of the underlying Haljala RS; however, *Belonechitina?* sp. n. 1, *Conochitina* aff. *minnesotensis*, *C.* aff. *elegans* are only characteristic of the Keila RS. A notable change in the chitinozoan assemblage occurred in the Kõrgessaare section within the upper part of the Saue Mb, on the level of ca 51 m (Fig. 1), where several species disappeared. The impoverished chitinozoan fauna may represent the youngest part of the Keila RS, corresponding to the weakly falling limb of the carbon isotope curve (Fig. 1) and the occurrence of '*D.*' *kegelensis*. In the Haapsalu core, a similar low-diversity fauna was not recovered from the uppermost Keila RS. This suggests a more significant gap at the Keila–Oandu boundary in this section (Fig. 2), marked by a hardground and the disappearance of many chitinozoans (*Pistillachitina* sp. nov. 1, *Conochitina elegans*, *Desmochitina nodosa*) and prasinophyceans (*Leiosphaeridia* spp.) characteristic of the Keila RS. However, the overlying Oandu RS contains several new chitinozoan species (*Cyathochitina patagiata*, *Sphaerochitina*? *oanduensis* sp. nov.) (Fig. 2).

Based on these new data, the Saue Mb seems to have a somewhat different age in the two sections studied. The interval with low diversity of chitinozoans and the occurrence of '*D.*' *kegelensis* may be missing in the Haapsalu section.

The combined study of chitinozoans and brachiopods in association with selected other fossils in the Kõrgessaare and Haapsalu sections revealed continuous renewal of the shelly fauna. At the same time, a relatively invariable composition of the chitinozoan fauna is helpful for correlation across facies boundaries. An exception is the uppermost part of the Keila RS, represented by the Saue Mb. In NW Estonia, the Saue Mb follows the period of deposition of nearshore peloidal limestones of the Pääsküla Mb, grades into the grainstones of the Vasalemma Fm with reefs, and marks a new cycle in sedimentation. The stratigraphic extent of the Saue Mb possibly differs to some degree in different localities. Moreover, the brachiopods conspecific with the holotype of 'D.' *kegelensis*, defined by Alichova from the Saue locality, occur mainly in the north-western part, including in the reef-related settings. The other group of shells ('*D.*' *oanduensis*) was adapted in offsore more muddy-bottom environments. Its distribution area possibly extends from NW Estonia to NW Russia. Due to the inappropriate choice of holotype among the specimens with restricted distribution in westernmost Estonia, the biostratigraphic significance of *Dalmanella kegelensis* sensu Alichova should be reconsidered.The uppermost Keila RS with '*D.*' *kegelensis* brachiopod group in

Estonia differs notably from those in NW Russia, where the stage is represented by a variety of lithologies of the Jelizavetino Fm, including lagoonal, peritidal dolomitic carbonates and sandstones (Dronov 2005). The occurrence of kukersite-rich beds in the upper half of the Keila RS is unusual for Estonian sections, where only a few kukersite interlayers are known. The relatively high content of siliciclastic material in carbonates of the uppermost Keila RS in NW Russia makes this interval similar to the Variku Fm in Estonia, which forms a belt in the transitional facies zone in the Baltic Basin (Ainsaar and Meidla 2001). Based on ostracod biostratigraphy, the Variku Fm is of Keila–Rakvere age (Ainsaar et al. 1999). The main positive shift on the carbon isotope curve belongs to the lowermost part of the silty deposits of the Variku Fm (Bauert et al. 2017), which should correspond to the youngest part of the Keila RS. Based on chemostratigraphic data, this part of the Keila RS is missing in the studied Kõrgessaare and Haapsalu sections. However, the positive isotope shift (GICE) characterises the reefs in northern Estonia (Kaljo et al. 2001; Kröger et al. 2014). The exact age of the siliciclastic deposits in NW Russia is unknown; however, this region could be the source area of siliciclastic material in the Estonian sections. The siliciclastic deposits in the basin supposedly represent the terminal episode of the deposition during the Keila age.

Conclusions

The combined study of shelly faunas and microfossils ensures more reliable correlations and a better understanding of facies patterns during rapid environmental changes. New data showed that biostratigraphic usage of *Dalmanella kegelensis* s. l. should be disregarded due to the existence of two separate species. However, both '*D.*' *kegelensis* and '*D.*' *oanduensis* occur in the uppermost Sandbian below the GICE. They are associated with somewhat different chitinozoan assemblages, possibly indicating different stratigraphic ranges. The latest Keila sequences in Estonia and NW Russia deserve further high-resolution studies in order to decipher the sequence of events, climate shifts, sedimentation patterns and stratigraphic gaps across the Keila–Oandu transition in Baltoscandia.

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