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Boundary between the Porkuni and Juuru regional stages in the Neitla section, Estonia

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ABSTRACT

Conodonts and chitinozoans were studied from the Neitla section, which exposes the boundary between the Porkuni and Juuru regional stages. This level, although not proved biostratigraphically, has been traditionally considered to correspond to the Ordovician–Silurian boundary. However, stable carbon isotope data indicate that the system boundary lies higher in the succession, in the lower part of the Juuru Regional Stage. Rare conodonts and chitinozoans discovered in the section do not provide any criteria for locating the boundary. Although conodonts are represented by taxa characteristic of the Silurian, all of them are known to have already appeared elsewhere in the Upper Ordovician.

Introduction

The boundary interval between the Porkuni and Juuru regional stages (RSs) is poorly exposed in Estonia. For about two decades, only one small outcrop section, Neitla, was known. Recently, boundary strata were also exposed in the active Reinu quarry in west-central Estonia, but this has not been studied in detail yet. Biostratigraphical location of the RSs boundary in a section is often complicated and, traditionally, it is identified based on lithological criteria. In the outcrop area, a lithologically distinct contact between the Ärina and Varbola formations (Fms) has been treated historically as the stage boundary. The Ärina Fm is represented by a succession of shallow-water sediments (Hints L. and Meidla 1997). The dolostone with interbeds rich in fragments of crinoid ossicles at the base of the formation (Röa Member (Mb)) is overlain by stromatoporoid-tabulate reefs (Tõrevere Mb) and their surrounding facies, skeletal limestone and kerogenous dolostone, traditionally treated as the Vohilaid and Siuge Mbs, respectively. The uppermost Ärina Fm consists of quartz-sand-rich dolostone of the Kamariku Mb. The Ärina Fm is overlain by an intercalation of marlstones and calcareous wackestones of the lower Varbola Fm. In some sections, a thin interval of micro- to cryptocrystalline limestone (calcareous mudstone) of the Koigi Mb occurs at the base of the Varbola Fm.

Conodonts are rare in both the Porkuni and Juuru RSs and nearly absent in the boundary beds of these units in northern Estonia. Until recently, the boundary has been studied in the core sections only. Due to the limited size of samples and the generally rare occurrence of conodonts in this interval, most of the samples processed so far were barren. In 2006, a small exposure of bedrock exposing the contact between the Kamariku and probable Koigi Mbs was discovered in the Neitla gravel-pit (Einasto 2007; Fig. 1). The discovery of this section provided the first opportunity to collect and process conodont samples of larger size in the hope of obtaining better information about these microfossils in the regional stage boundary interval and to search for new regional biostratigraphic criteria for this boundary. The results of these investigations are summarised in this paper.

Materials and methods

Two sections (Neitla-I and Neitla-II, see Fig. 1A) on the bottom of the gravel pit, with a distance of about 10 m between them, were described and sampled in 2009, 2010 and 2015. Both expose the uppermost Ärina Fm (Kamariku Mb) and the lowermost Varbola Fm (Koigi? Mb) underlain by reef limestone of the Tõrevere Mb.

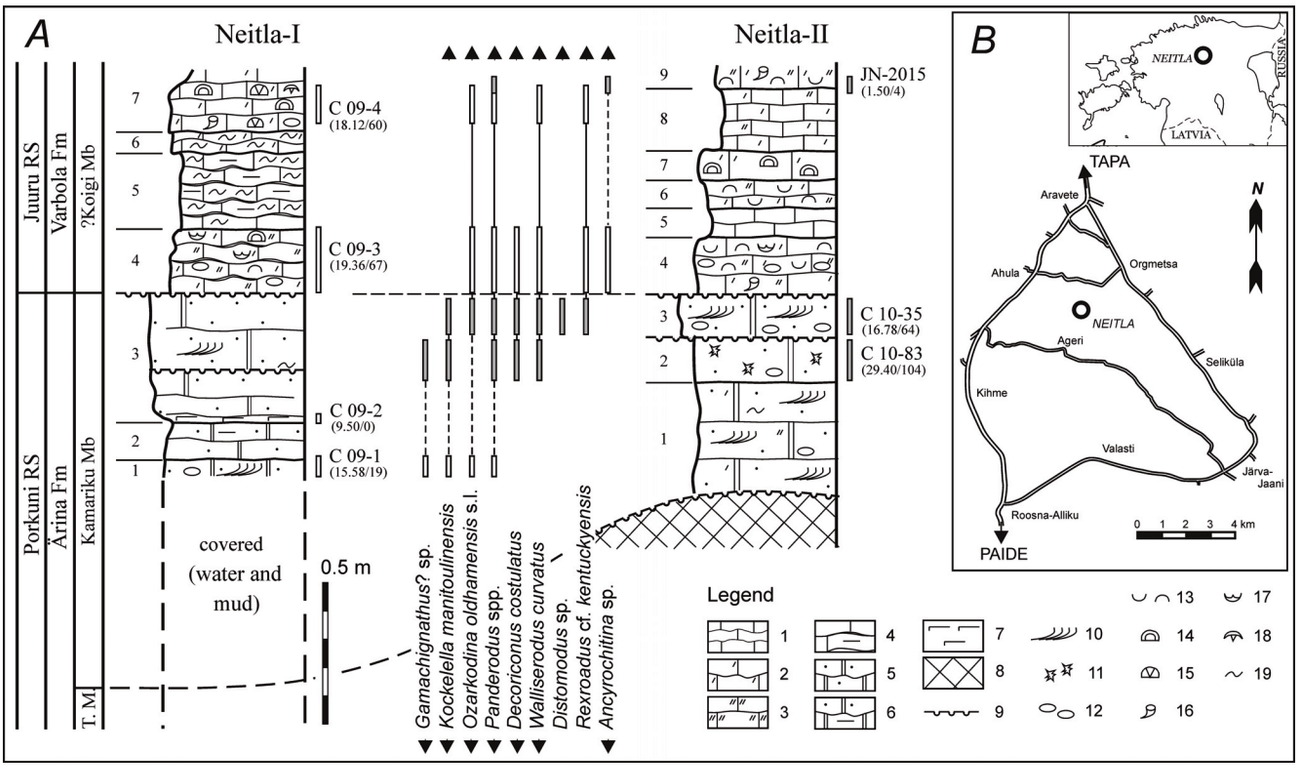

Fig. 1. Studied sections (A) and the location of the Neitla gravel pit (B). **A** (from left to right) – regional stratigraphy; lithological log of the profile Neitla-I with bed numbers on the left; samples with their numbers, below the sample numbers in brackets are the weight of the sample (in kg) and the number of conodont specimens discovered in it; distribution of taxa; log of the profile Neitla-II with bed numbers on the left and the location of samples, their numbers, weights and numbers of conodont specimens. Arrowheads above and below the ranges of the taxa indicate their longer ranges in the Estonian succession. Legend: 1 – cryptocrystalline limestone (lmst), 2 – detrital lmst, 3 – bioclastic lmst, 4 – argillaceous lmst, 5 – dolostone rich in quartz sand, 6 – argillaceous dolostone rich in quartz sand, 7 – marlstone, 8 – reef lmst, 9 – discontinuity surface, 10 – cross-bedding, 11 – vugs, 12 – pebbles, 13 – various shell fragments, 14 – stromatoporate, 15 – tabulate coral, 16 – rugose coral, 17 – brachiopod, 18 – trilobite, 19 – bioturbation. Abbreviations: T. M. – Tõrevere Member, RS – Regional Stage, Fm – Formation, Mb – Member. **B** – location of the studied section (indicated by a circle).

The contact between the reef and the overlying Kamariku Mb is marked by a strongly undulating erosional surface. Due to this, the thickness of the Kamariku Mb varies considerably.

The samples weighing between 9.50 and 29.40 kg were processed using standard methods (Jeppsson and Anehus 1995; Jeppsson et al. 1999). Additionally, a loose piece of limestone (wackestone-packstone rich in small silicified rugose corals, 1.50 kg) from the uppermost part of the Neitla-II section was dissolved. All samples, except for C 09-2, yielded conodonts. Preservation of the specimens is variable; many elements are broken, and the surface of most specimens is covered with a secondary coating of apatite, complicating the identification of simple-cone elements. The colour of the specimens is pale yellow (CAI = 1). A few poorly preserved chitinozoans were found in only two samples from the Varbola Fm. All illustrated specimens are housed at the Department of Geology, Tallinn University of Technology (collections GIT254, 889, 890).

Results and discussion

Conodonts are rare in the studied samples, only few specimens per kilogram of rock (Fig. 1A). All productive samples (excluding C09-1) are strongly dominated by *Panderodus* (up to 75% of specimens). Poor preservation does not allow their reliable identification, but based on rare, better preserved specimens, at least two taxa are represented, likely *P. serratus* (Rexroad) and a species of the *P. equicostatus* (Rhodes) group (Fig. 1A). The most common conodont in sample C09-1 is *Kockelella manitoulinensis* (Pollock, Rexroad and Nicoll) (Fig. 2W), which in the Neitla section is restricted to the Kamariku Mb. So far, *K. manitoulinensis* was mainly known from the Raikküla RS (upper Rhuddanian and Aeronian; Männik 1994) in Estonia. Below this level, only few probable elements (including a single Pa) of this species were found in the Porkuni RS, in the back-reef facies (‘Siuge Mb’) of the Ärina Fm in the Porkuni quarry (Hints, L. and Männik 2014; identified as *Kockelella*? sp. (aff. *K. manitoulinensis*); Fig. 2V). In the Neitla section, *K. manitoulinensis* ranges into the upper part of the Kamariku Mb (samples C 10-83 and C 10-35; Figs 1A, 2X) but is missing in the overlying Varbola Fm. Morphologically, the Pa elements of *K. manitoulinensis* in the Neitla section are identical to those from the Raikküla RS (Fig. 2U; Männik 1994, pl. 4, figs 2, 4, 7). The specimen from the Porkuni quarry is shorter and taller, but has a posterior process turned outwards and bears considerably lower denticles than those on the anterior process of the element. Both features are characteristic of the Pa element of *K. manitoulinensis*.

In the upper Kamariku Mb, *K. manitoulinensis* occurs together with *Walliserodus curvatus* (Branson and Branson) (Fig. 2O, S), *Decoriconus costulatus* (Rexroad) (Fig. 2R),

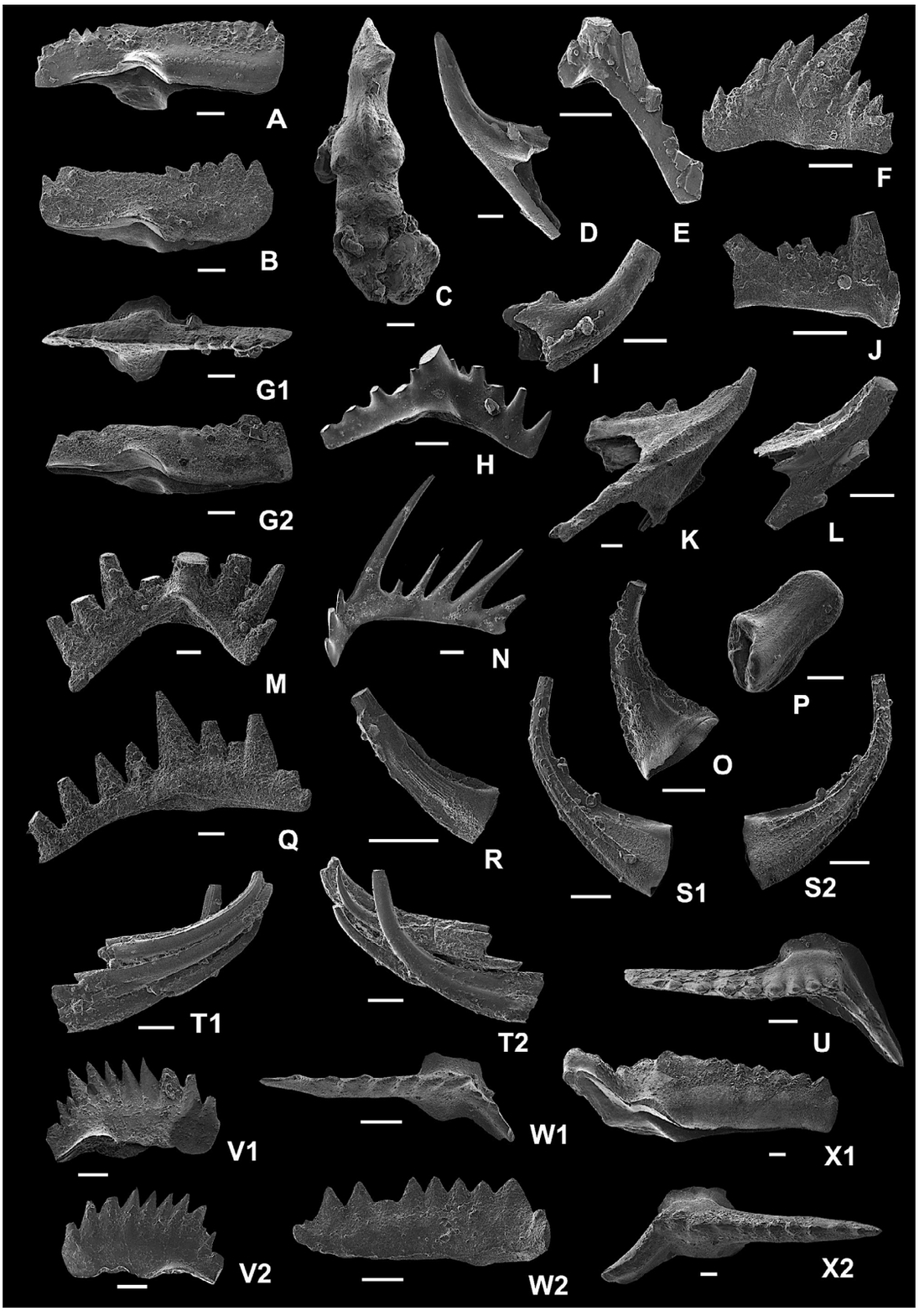

Fig. 2. Selected conodonts from the Neitla, Porkuni and Pusku sections. Scale bar represents 100 µm. All samples come from the Neitla section unless stated otherwise. **A**, **B**, **E**–**G**, **J** – *Ozarkodina oldhamensis* s.l. (Pollock, Rexroad and Nicoll): A, B, G – Pa elements, GIT889-1, 2, 3; E – M element, GIT889-4; F – Pb element, GIT889-5; J – Sc element, GIT889-6. A, E – from sample C10-35; B, G – from sample C09-4; F, J – from sample C09-1. **C**, **D**, **I** – *Distomodus* sp.: C – Pa element (fragment), GIT889-7; D – Sb element, GIT889-8; I – Sa? element, GIT889-9. All from sample C10-35. **H**, **M**, **N**, **Q** – *Rexroadus* cf. *kentuckyensis* (Branson and Branson): H – Pb element, GIT889-10; M – Sb element, GIT889-11; N – Sc element, GIT889-12; Q – Pa element, GIT889-13. All from sample C09-4. **K**, **L**, **P**? – *Gamachignathus* sp.: K – Pc? element, GIT889-14; L – Sb element, GIT889-15; P? – M element, GIT889-16. K and L – from sample C10-83, P? – from sample C09-1. **R** – *Decoriconus costulatus* (Rexroad), paltodontiform element, GIT889-17, sample C09-3. **O**, **S** – *Walliserodus curvatus* (Branson and Branson): O – curvatiform element, GIT889-18, sample C09-3; S – multicostatiform element, GIT889-19, sample C10-83. **T** – *Panderodus* sp., cluster of elements, GIT889-20, sample C09-4. **U**, **W**, **X** – *Kockelella manitoulinensis* (Pollock, Rexroad and Nicoll): Pa elements, W – GIT889-21, sample C09-1; X – GIT889-22, sample C10-35; U – GIT254-52, Pusku quarry, sample M-226. **V** – *Kockelella* cf. *manitoulinensis* (Pollock, Rexroad and Nicoll), Pa element, GIT890-1, Porkuni quarry, sample M-334.

Rexroadus cf. *kentuckyensis* (Branson and Branson) (Fig. 2H, M, N, Q), *Distomodus* sp. (Fig. 2C, D, I) and *Ozarkodina oldhamensis* s.l. (Rexroad) (Fig. 2A, B, E–G, J). All these taxa are present also in the Varbola Fm in the Neitla-I section and are known from the strata of Rhuddanian and Aeronian age from other sections in Estonia and elsewhere. Also, in the Porkuni quarry the probable specimens of *K. manitoulinensis* occur together with *Decoriconus* sp., *P. equicostatus* s.l. and *Walliserodus* sp. (Hints, L. and Männik 2014). The uppermost sample, JN-2015 from Neitla-II yielded only four unidentifiable specimens of *Panderodus* sp.

Chitinozoans were found in two samples from the Varbola Fm: 2 specimens from Neitla-I (sample C 09-3) and 30 specimens from Neitla-II (sample JN-2015). The specimens are very poorly preserved, but all seem to belong to the same taxon, *Ancyrochitina* spp., which appears in Estonia in the lower Katian (Oandu RS) and is widely distributed in the Silurian.

Although the conodont assemblage in the Neitla section is mainly represented by taxa characteristic of the Rhuddanian, all of them are known to have already appeared in the (upper) Hirnantian elsewhere (e.g., Armstrong 1996). Considering the distribution of conodonts in the Estonian succession, most of the taxa found in the Neitla section so far were previously known to have appeared in the lower(most) Juuru RS. Only *D. costulatus* is also common in the Upper Ordovician and rare specimens of *Oz. oldhamensis* s.l. were recorded from the Porkuni RS. The only 'typical' Ordovician conodont, i.e., so far not identified from the strata of the Silurian age, found in the Neitla section is *Gamachignathus*? sp. (Fig. 2K, L, P).

Traditionally, the boundary between the Porkuni and Juuru RSs has been considered to correspond to the Ordovician–Silurian boundary. This conclusion was based on the occurrence of Hirnantian trilobites and brachiopods in the Porkuni RS in western Latvia and Lithuania, and on the records of *Stricklandia lens prima* Williams from the lower part of the Juuru RS in (northern) Estonia (Kaljo et al. 1988). In all known sections, a gap and a sharp change in lithology mark this stage boundary, but because of the lack of diagnostic taxa, its correlation with the Ordovician–Silurian boundary is highly problematic. Moreover, the results of $\delta^{13}C$ studies suggest that the lowermost Juuru RS might be of late Hirnantian age (Meidla et al. 2023). The $\delta^{13}C$ data from the Porkuni quarry indicate that the Ärina Fm exposed in that section corresponds to the rising limb of the Hirnantian Carbon Isotope Excursion (HICE) and correlates with the lower Hirnantian, whereas the strata exposed in Neitla (the Kamariku Mb and the lowermost Varbola Fm) correspond to its falling limb and correlate with the upper Hirnantian (Hints, L. and Männik 2014; Gul et al. 2021). The conodont assemblage from the Neitla section does not contradict or support this conclusion.

Conclusions

Conodonts and chitinozoans are rare in the Neitla section. The low-diversity conodont assemblage discovered in this section is not age-diagnostic. Although it is represented by taxa that were formerly considered to be characteristic of the Silurian in the Baltic region, all of them are known to have already appeared elsewhere in the Upper Ordovician. The assemblages in the Ärina and Varbola Fms are almost identical and do not provide any criteria for the identification of the boundary between the Porkuni and Juuru RSs. The only possibility to locate the level in a succession might be the disappearance of *Gamachignathus*, but further studies are needed to prove this. The study also confirmed that *K. manitoulinensis* appears in the Estonian succession already in the Porkunis RS, as previously assumed, based on the occurrence of a few probable specimens of this species in the Porkuni quarry.

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