ISOS-14 Field Guide
The Ordovician of Estonia

Edited by Olle Hints and Ursula Toom

14th International Symposium on the Ordovician System, Estonia, July 19-21, 2023
Pre-conference Field Excursion: The Ordovician of Estonia, July 15-18, 2023

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Tallinn, 2023

Excursion Day 2

Stop 5: Harku quarry

Ursula Toom and Olle Hints

Location: Latitude 59.39837°N, longitude 24.56378°E; Harju County, northern Estonia.
Stratigraphy: Dapingian to Sandbian, Volkhov to Kukruse regional stages.
Status: Active quarry – follow safety instructions; sampling and fossil collecting welcome!
More information: https://geoloogia.info/en/locality/14672

The Harku quarry is an active limestone quarry located on the northwest edge of Tallinn, Hüüru Village, Harjumaa County. Investigations of Ordovician limestones as a building material near Tallinn intensified in 1933. Orviku (1940) gave the first description of the old Harku quarry, and since 1953, the Harku area has been continuously subject to mineral exploration. The company “Kombinaat No. 469” started quarrying limestone in 1984. Since 1994, the quarry has been operating under the company “Harku Karjäär AS”. The limestone from the Harku quarry is mainly used to produce crushed stone for the construction industry. Today, the Harku quarry extends about 1.8 km in the N–S and 0.8 km in the W–E direction, being one of the largest limestone quarries in Estonia (Fig. 5.1).

The Ordovician rocks are exposed in a thickness of ca 14 m, constituting the entire Darriwilian succession and the lowermost beds of the Sandbian. The oldest strata are observable only in drainage ditches and occasional deeper excavations below the main quarry floor (Fig. 5.2). They include the topmost Toila Formation, Volkhov Regional Stage, Dapingian, and the complete Kunda Stage, Darriwilian. The main quarry walls (Fig. 5.3) constitute the Lasnamägi and Uhaku regional stages (Darriwilian), and the lowermost Kukruse Regional Stage (basal Sandbian).

Fig. 5.1. Overview of the southern part of the Harku limestone quarry. Photo: Gennadi Baranov, 2023.

The Middle Ordovician limestones are famous building stones around the Baltic Sea (Knaust 2021). They have been classically named ‘Orthoceratite Limestones’ due to their characteristic fossils, the orthocone cephalopods. The lower parts of the ‘Orthoceratite Limestone’ (corresponding to the Kunda Regional Stage, lower Darriwilian) are strongly dominated by endocerids (Kröger 2012). However, orthocerids are the dominant group in the Lasnamägi and Uhaku stages (upper Darriwilian). This is expressed in historical local stratigraphical terms such as the ‘Endoceras Limestone’ in the Oslo area, ‘Vaginatumkalk’ or ‘Vaginatum limestone’ in Sweden, ‘Vaginatenkalk’ in the East Baltic region and the southern coast of the Baltic Sea where the rocks are found as erratic boulders. These informal terms are occasionally still in use.

The ‘Orthoceratite Limestone’ lithofacies is widely interpreted as being deposited on a wide flat-bottomed, near-shore carbonate shelf. Water depth fluctuated but rarely fell below the photic zone (Jaanusson 1973; Chen & Lindström 1991). The concentration and distribution of cephalopod conchs in some beds indicate that these were deposited extremely rapidly. However, numerous significant breaks within the sequence are believed to represent periods of subaerial emergence. The average deposition rate of the 'Orthoceratite Limestone' was very low, perhaps 1–3 millimetres per thousand years (Jaanusson 1973).

Formations exposed in the Harku quarry

The Toila Formation (ca 0.4 m, Volkhov Regional Stage, Dapinginan) is composed of grey glauconitic limestones in the upper boundary, partly sandy or conglomeratic (Fig. 5.4D), which is assumed to represent the youngest part of the Toila Formation. The upper boundary of the formation (contact with the Pakri Formation) shows variable lithology in the Harku quarry, similar to what has been described from the Pakri Peninsula and Pakri islands, and, in particular, the Osmussaar Island (Alwmark et al. 2010).

The Pakri Formation (up to 0.2 m, Kunda Regional Stage, Darriwilian) comprises bioturbated limy sandstone to sandy limestone. The infill of burrows is brownish due to the admixture of kukersite (Fig. 5.4C, E). Calcareous sandstones of the Pakri Formation occur in a limited area in NW Estonia. Eastwards, the limestones of the Sillaoru and Loobu formations fully replace the Pakri Formation laterally. The Pakri formation is thin and irregular, partly occurring as bored sandstone pebbles with pyritic impregnation. The upper boundary of the formation is marked by bored pyritic hardground (Fig. 5.4B).

Fig. 5.2. The Volkhov and Kunda regional stages (Dapingian to lower Darriwilian) are cropping out only in ditches and few deeper excavations. Photo: Olle Hints, 2023.

The Pakri Formation contains numerous soft-sediment deformations, sedimentary dykes, and breccias. An earthquake (Põldsaar & Ainsaar 2014) or meteorite shower (Alwmark et al. 2010; Ainsaar et al. 2007) are discussed as possible causes for the liquefaction and fluidisation of the unconsolidated and water-saturated sediments.

The Loobu Formation (ca 0.2 m, Kunda Regional Stage, Darriwilian) consists of limestone with fine pyritic skeletal sand with rare glauconite grains. Numerous

Fig. 5.3. The main wall in the southern part of the Harku limestone quarry is exposing the succession from the Aseri Regional Stage to the basal part of the Kukruse Regional Stage (correlated with the base of the Sandbian), including complete Lasnamägi and Uhaku regional stages (Väo and Kõrgekallas formations). Photo: Gennadi Baranov, 2023.

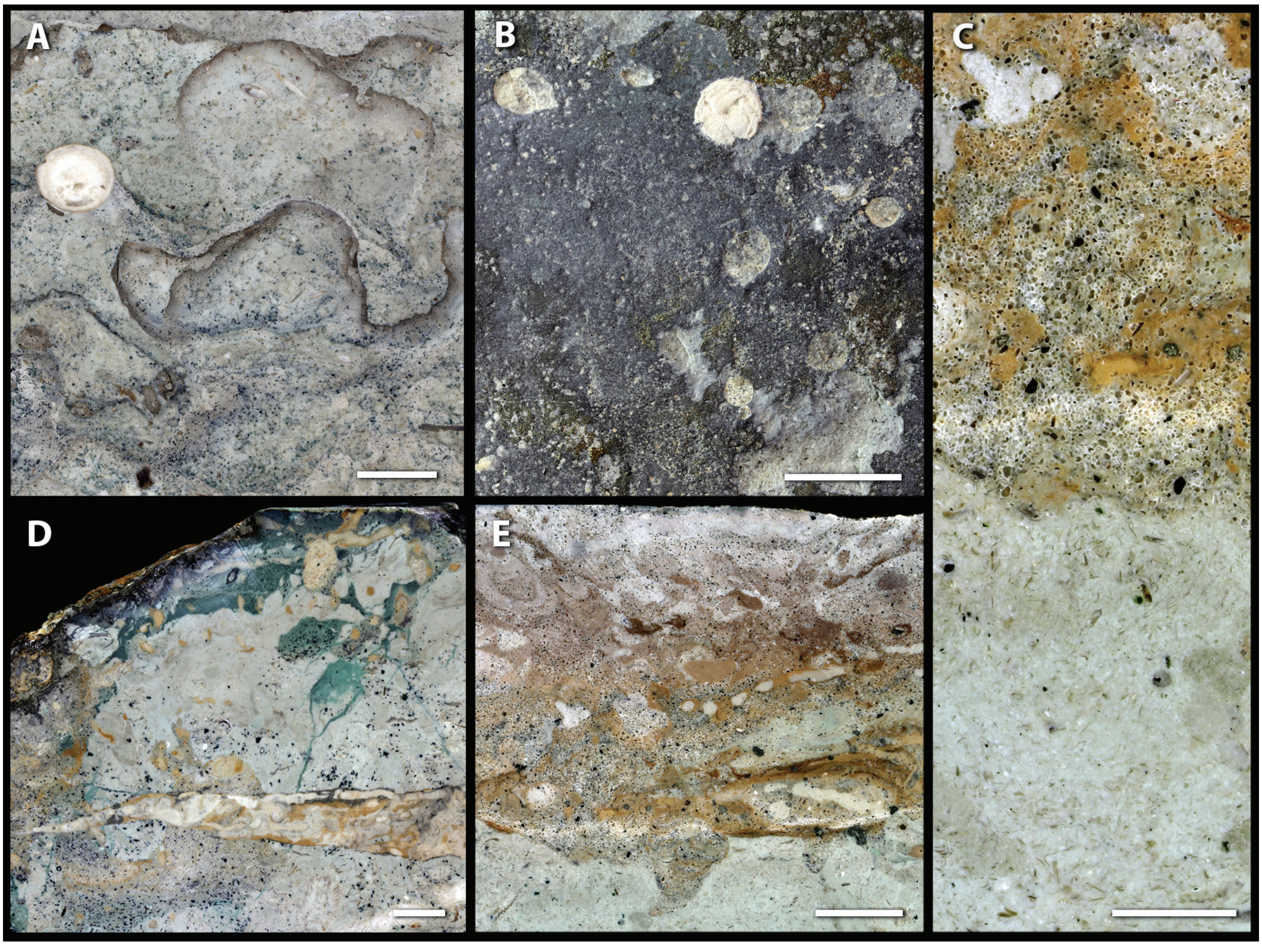

Fig. 5.4. Selected samples of Darriwilian limestones from the Harku quarry. Scale bars: A, D, E – 1 cm, B, C – 5 mm. **A** – rough discontinuity surfaces with phosphatic impregnation characteristic for the Loobu Formation, GIT 695-58-1; **B** – hardground with strong pyritic impregnation on the top of the Pakri Formation, demonstrating *Trypanites* borings and small bryozoan holdfast, GIT 362-925; **C** – detail from the Toila and Pakri formations boundary bed marked by wavy surface, GIT 362-717; **D** – vertical section from the top of the Toila Formation demonstrates partly sandy and conglomeratic glauconitic limestones with strong pyritic hardground, detail from GIT 362-922; **E** – bioturbated limy sandstone of the Pakri Formation in total thickness, GIT 362-922.

rough discontinuity surfaces with phosphatic impregnation can be observed (Fig. 5.4A). The boundary between the Loobu and Kandle formations in the Harku quarry is marked by an even phosphatic hardground surface with deep burrows (Fig. 5.5D).

The Kandle Formation (ca 0.3–0.4 m, Aseri Regional Stage, Darriwilian) consists of bioclastic limestones with unevenly distributed brown iron ooids. The upper boundary of the formation is marked by an uneven discontinuity surface and is overlain by hard and unsorted skeletal limestone with numerous small light phosphatic ooids (cf. Sturesson and Bauert 1994) in the basal portion (Fig. 5.5H).

The Väo Formation (ca 5 m, Lasnamägi and Uhaku regional stages, Darriwilian) consist of medium to thick-bedded light grey limestones (wacke- to packstones) with occasional interbeds of brownish dolostones with a large number of burrowed discontinuity surfaces and bored and burrowed hardgrounds (Fig. 5.5B). The Väo Formation is subdivided into three members; the middle and upper members represent the 'Lasnamägi Building Limestone'. The most remarkable complex of discontinuity surfaces and hardgrounds marks the upper boundary of the Väo formation (Fig. 5.5C). The boundary between the Lasnamägi and Uhaku stages can be identified biostratigraphically using the FAD of *Gymnograptus linnarssoni* or FAD of the conodont *Baltoplacognathus robustus*. It falls into the Väo Formation and is marked by a discontinuity surface within the bed named 'Raudsüda'.

The Kõrgekallas Formation (ca 6.5 m, Uhaku Regional Stage, Darriwilian) is represented by wavy-bedded to seminodular argillaceous limestone. Impregnated and bored discontinuity surfaces and hardgrounds are characteristic, but less common than in the Väo Formation. In the upper part of the formation, kukersite kerogen occurs as infill of borings (Fig. 5.5A) and thin layers.

The Viivikonna Formation (1.5 m?, Kukruse Regional Stage, Sandbian) is represented in the Harku area by marly limestones with thin beds and dispersed kukersite kerogen. It is tentatively identified in the southern part of the quarry, but the beds are weathered and not easily accessible due to the high quarry walls. Moreover, the whole succession still awaits biostratigraphic study.

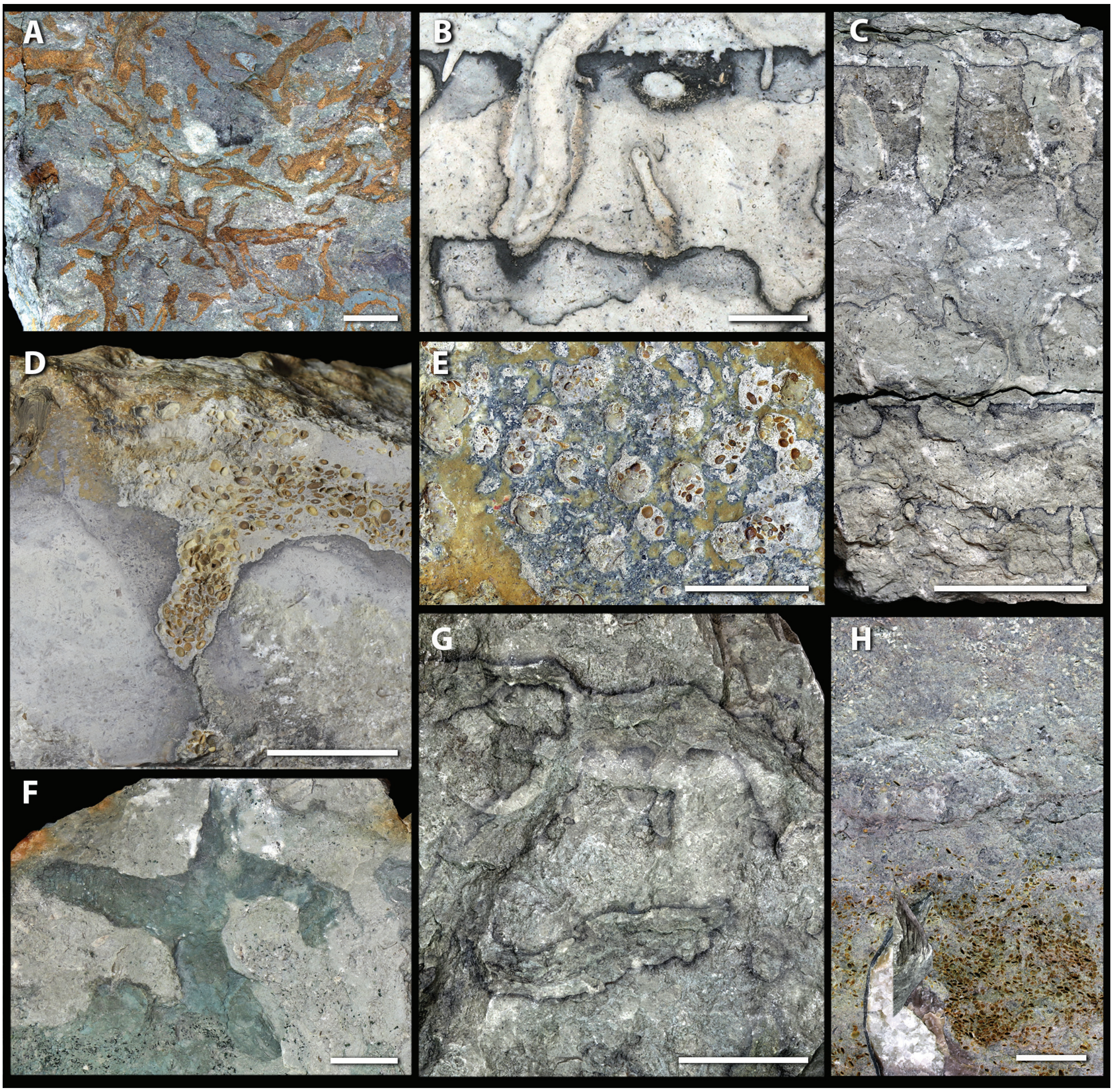

Fig. 5.5. Selected samples of Darriwilian limestones from the Harku quarry. All scale bars are 1 cm, and only B is 5 cm. **A** – *Chondrites* borings filled with kukersite, Kõrgekallas Formation, Pärtilioru Member, GIT 362-972-1; **B** – detail of burrowed and bored pyrite-stained hardgrounds, Väo Formation, GIT 362-720; **C** – complex of discontinuity surfaces and hardgrounds with *Balanoglossites triadicus* burrows and *Trypanites sozialis* borings, from the boundary beds of Väo and Kõrgekallas formations, GIT 362-915; **D** – *Balanoglossites triadicus* burrow from Loobu and Kandle formations boundary bed, filled with brown iron ooids, GIT 362-920; **E** – bedding-plane view of Loobu and Kandle formations boundary bed. Dense accumulation of *Trypanites sozialis* borings on top of the surface, borings are filled with iron ooids, GIT 362-917; **F** – bedding-plane view of *Balanoglossites triadicus* filled with glauconite, Toila Formation, GIT 362-920; **G** – bedding-plane view of *Balanoglossites triadicus*, Loobu Formation, GIT 362-921; **H** – upper boundary of the Kandle Formation, demonstrating brown iron ooids of the Kandle Formation and light phosphatic ooids of the Väo Formation, sample GIT UT23-1.

Ichnofabrics with *Balanoglossites* and *Trypanites*

Ichnofabrics with *Balanoglossites* and T*rypanites* are typical of the Darriwilian limestones in Estonia (Knaust et al. 2023). *Balanoglossites triadicus* show U- and Y-shaped components in cross-section, irregular outline, highly variable tube diameter, and net-like appearance on the bedding planes (Fig. 5.5B, C, D, F, G). The trace maker could simultaneously bioerode and burrow (Knaust & Dronov 2013). Short and straight *Trypanites sozialis* borings (Fig. 5.5B, E; 5.4B) are common on the hardgrounds. Usually, the borings are densely placed on positive features of the surface topography.

Macrofauna

In the outcrop area, large nautiloids are characteristic of the Loobu Formation. The trench in the Harku quarry is well-known for yielding excellent phosphatised cephalopod remains of the Kunda Regional Stage (e.g., Mutvei

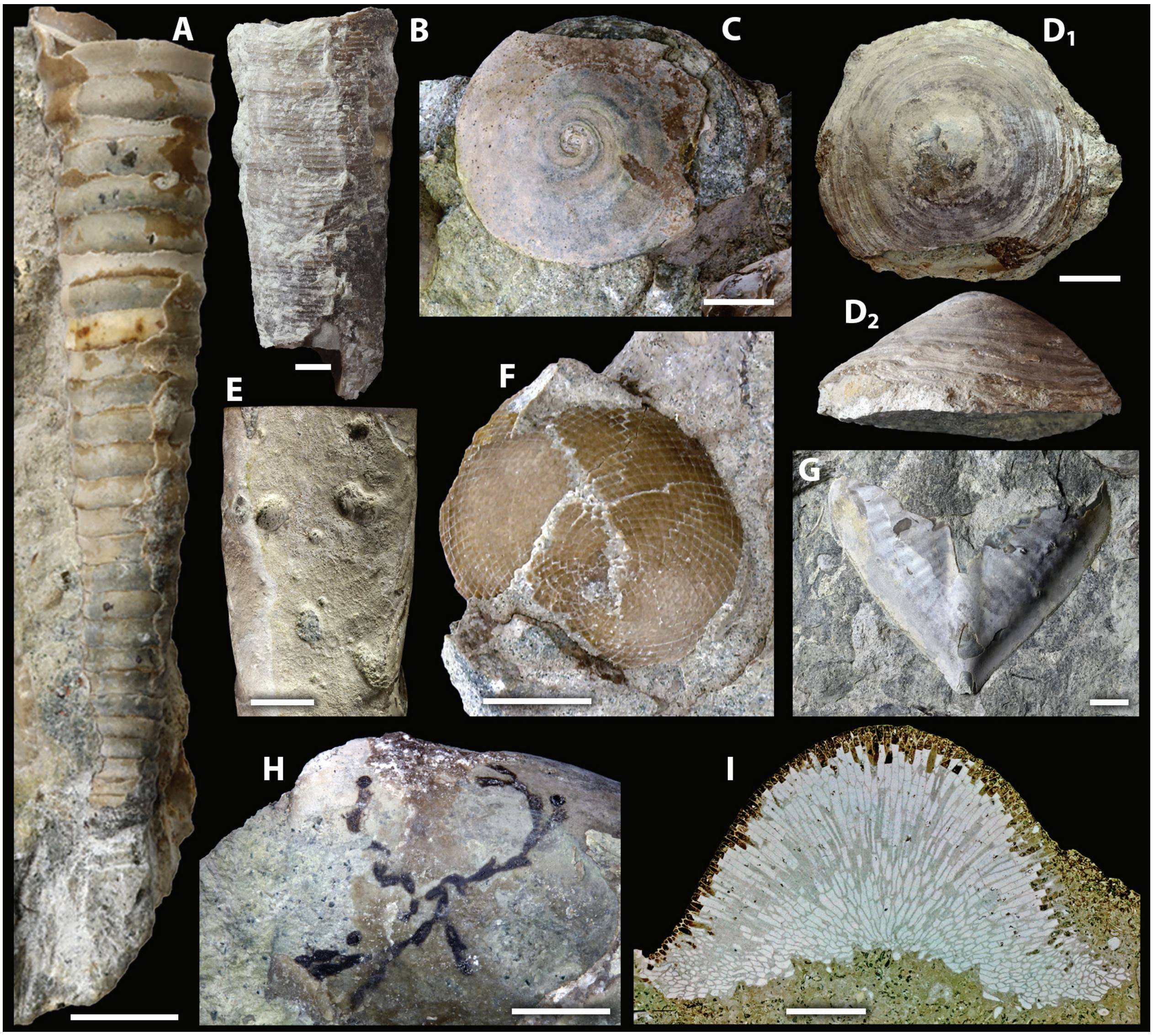

Fig. 5.6. Selected fossils from the Harku quarry, Loobu Formation (Darriwilian). Scale bars: A, C, D, F, G – 1 cm; B, E, H, I – 1 mm. **A–B** – cephalopods; **A** – *Proterovaginoceras incognitum*, TUG 1612-32; **B** – *Anthoceras vaginatum*, GIT 695-53. **C** – gastropod *Pararaphistoma qualteriata*, TUG 1585-71. **D** – monoplacophorian *Metoptoma siluricum*, GIT 815-2. **E** – steinkern of *Proterovaginoceras incognitum* with *Trypanites sozialis* borings, GIT 858-7. **F** – retceptaculitid *Fisherites orbis*, TUG 1644-8. **G** – trilobite *Megistaspis* (*Heraspis*) *heroica*, 398-950-1. **H** – graptolite *Hormograptus*? attached to the internal surface of a nautiloid conch, GIT 494-41-1. **I** – bryozoan *Dianulites collucatus*, GIT 494-41-1.

1996, 1997, 2002; Kröger 2012; King 2014; Pohle et al. 2019). Endocerids *Anthocerąs vaginatum*, *Dideroceras wahlenbergi* and *Suecocerąs barrandei*; bisonoceratid *Proterovaginoceras incognitum*; ormocerid *Adamsoceras holmi* and tarphycerids *Tragoceras falcatum* and *Estonioceras* are reported from the Loobu Formation. Lithified steinkerns exposed on the seafloor were colonised by boring organisms or filled with small faecal pellets of *Coprulus oblongus*. Large shells of Ordovician cephalopods host cryptic faunas, mainly represented by bryozoans and cornulitids. From the Harku quarry a rare crustoid graptolite *Hormograptus*? lithoimmured inside a nautiloid conch was described (Vinn et al. 2019). Bryozoans are not common, but recent study by Ernst (2022) brought out five genera (*Dianulites collucatus, Revalotrypa gibbosa, Mesotrypa bystrowi, Orbipora acanthophora, Orbipora* aff. *distinca* and *Sonninopora*). Due to phosphatisation, not only nautiloid shells, but also gastropods (e.g., *Pararaphistoma qualteriata* and *Salpingostoma locator*, retseptaculitids (*Fischerites orbis*), and rare tergomyans (e.g., *Metoptoma siluricum*) are exceptionally well preserved. Trilobites are abundant in the upper part of the Loobu Formation. Helje Pärnaste has identified *Megistaspis (Heraspis) heroica* and *Pterygometopus sclerops.*

Rõõmusoks (1970) listed various macrofossils from the Lasnamägi and Uhaku regional stages from the Harku area. The faunas were dominated by sedentary forms, particularly articulate brachiopods e.g., *Christiania oblonga, Clitambonites schmidti septatus, Clitambonites squamatus*, *Porambonites* (*Equirostra*) *deformatus*, *Estlandia marginata marginata*, *Leptestia musculosa, Orthisocrania planissima*, Sowerbyella (*Sowerbyella*) *orvikui*, *Sowerbyella* (*Sowerbyella*) *uhakuana*. In addition, bryozoans, orthocerid cephalopods, and blastozoan *Echinosphaerites* occur.

References

Ainsaar, L., Tinn, O. and Suuroja, K. 2007. Darriwilian high energy sedimentary facies in Baltoscandia - possible responses to meteorite shower? In: WOGOGOB 2007. Field guide and Abstracts (Ebbestad, J. O. R., Wickström, L. M., Högström, A. E. S., eds.), SGU, 79–80.

Alwmark, C., Schmitz, B. and Kirsimäe, K. 2010. The mid-Ordovician Osmussaar breccia in Estonia linked to the disruption of the L-chondrite parent body in the asteroid belt. Geological Society of America Bulletin, 122, 1039–1046.

Chen, J. and Lindström, M. 1991. Cephalopod Septal Strength Indices (SSI) and the depositional depth of Swedish Orthoceratite limestone. Geologica et Palaeontologica, 25, 5–18.

Ernst, A. 2022. Bryozoan fauna from the Kunda Stage (Darriwilian, Middle Ordovician) of Estonia and NW Russia. Bulletin of Geosciences, 97(1), 33–68.

Jaanusson, V. 1973. Aspects of carbonate sedimentation in the Ordovician of Baltoscandia. Lethaia, 6(1), 11–34.

King, A. H. 2014. Taxonomic review of early Darriwilian estonioceratids (Tarphycerida, Nautiloidea) from Sweden, Estonia, and the 'Diluvium-Geschiebe' of northern Germany and Poland. – Kataloge des Oberösterreichischen Landesmuseums, Neue Serie, 157, 47–57.

Knaust, D. 2021. *Balanoglossites*-burrowed firmgrounds – The most common ichnofabric on earth? Earth-Science Reviews, 220, 103747.

Knaust, D. and Dronov, A. 2013. *Balanoglossites* ichnofabrics from the Middle Ordovician Volkhov formation (St. Petersburg Region, Russia). Stratigraphy and Geological Correlation 21(3), 265–279.

Knaust, D., Dronov, A. V. and Toom, U. 2023. Two almost-forgotten *Trypanites* ichnospecies names for the most common Palaeozoic macroboring. Papers in Palaeontology, 9(3), e1491.

Kröger, B. 2012. The "Vaginaten": the dominant cephalopods of the Baltoscandian Mid Ordovician endocerid limestone. GFF, 134(2). 115–132

Mutvei, H. 1996. Characterisation of actinoceratoid cephalopods by their siphuncular structure. Lethaia, 29(4) 339–348.

Mutvei, H. 1997. Siphuncular structure in Ordovician endocerid cephalopods. Acta Palaeontologica Polonica, 42(3), 375–390.

Mutvei, H. 2002. Connecting ring structure and its significance for classification of the orthoceratid cephalopods. Acta Palaeontologica Polonica 47(1), 157–168.

Pohle, A., Klug, C., Toom, U. and Kröger, B. 2019. Conch structures, soft-tissue imprints and taphonomy of the Middle Ordovician cephalopod *Tragoceras falcatum* from Estonia. Fossil Imprint 75(1), 70–78.

Põldsaar, K. and Ainsaar, L. 2014. Extensive soft-sediment deformation structures in the early Darriwilian (Middle Ordovician) shallow marine siliciclastic sediments formed on the Baltoscandian carbonate ramp, northwestern Estonia. Marine Geology, 356, 111–127.

Rõõmusoks, A. 1970. Stratigraphy of the Viruan Series (Middle Ordovician) in Northern Estonia, I. Valgus, Tallinn. pp. 1–346.

Sturesson, U. and Bauert, H. 1994. Origin and palaeogeographical distribution of the Viruan iron and phosphate ooids in Estonia: evidence from mineralogical and chemical compositions. Sedimentary Geology, 93, 51–72.

Vinn, O., Wilson, M. A., Toom, U. 2019. A crustoid graptolite lithoimmured inside a Middle Ordovician nautiloid conch from northern Estonia. Annales Societatis Geologorum Poloniae, 89, 285–290.