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A review of ichnofossils from Estonian palaeontological collections

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Trace fossils (ichnofossils) record biological activity and are effective tools for the reconstruction of sedimentary environments. The purpose of this study was to summarize the existing data and provide an overview of ichnofossils from carbonate facies reposited in Estonian palaeontological collections.

In the last decade investigations of Ordovician and Silurian trace fossils of the Baltic region have been reinitiated and diverse associations of trace fossils have been described in detail (Knaust *et al*., 2012; Knaust and Dronov 2013; Hanken *et al*. 2016). In Estonia ichnofossils of this age have not been systematically studied and collected in the past. There is only a single paper (Männil *et al*. 1984), where the authors report that trace fossils are abundant and distributed all over the palaeobasin, but their diversity is lower than in the Cambrian and Devonian of the region. Recently, many soft sediment trace fossils such as *Arachnostega*, *Skolithos*, *Conichnus*, *Amphorichnus* and *Zoophycos* have been described from the Ordovician and Silurian of Estonia. Several bioerosional trace fossils, such as *Trypanites* and *Osprioneides*, have also received much attention.

The first step of this study was to collect data and get an overview of previously collected trace fossils. The preliminary results indicate that more than 30 different ichnogenera have been identified from the Ordovician and Silurian exposures in Estonia. They are largely confined to shallow-marine environments. In general, the number of well-preserved ichnofossils is small and their distribution is irregular. However, some weak patterns are observable and need to be studied and discussed furthering the future.

The most numerous ichofossil group was the domichnia (dwelling structures), represented by hundreds of specimens of *Amphorichnus papillatus* and *Conichnus conicus* from the Upper Ordovician and Silurian strata. *Skolithos*, *Paleophycos* and *Planolites* are identified only from a few levels. In the Haljala Regional Stage, well–preserved, thin-walled *Paleophycus tubularis* is very common. Thick-walled *Paleophycus herberti* is identified from the Silurian Juuru and Ohesaare Regional Stages. From the upper part of the Ohesaare cliff (Ohesaare Regional Stage), a corkscrew-shaped *Helicodromites*-like horizontal burrow occurs, probably representing dwelling structures as described by Poschmann (2015).

Feeding-dwelling traces are represented by a number of genera including *Trypanites*, *Gastrochaenolites*, *Balanoglossites*, *Sanctum*, *Palaeosabella*, *Planolites*, *Thalassinoides*, *Oikobesalon* and *Rosselia*. The most common macroborer is *Trypanites*, which occurs widely within Ordovician and Silurian hardgrounds, as well as on brachiopods, bryozoans, stromatoporoids, and rugose corals. The distribution of *Palaeosabella* is known from the Silurian (Vinn and Wilson 2010); it is attributed only to stromatoporoids as the representative *Maeanderopolydora*? isp. From the Lower Ordovician (Volkhov Regional Stage) of the Sankt Petersburg area, numerous asaphid trilobites bearing thin networks of "bryozoan borings" have been reported (Dronov and Mikulaš 2010). This type of network is missing in Estonian collections. The collected samples are often too small for a reliable assessment of branching in the case of large burrows, but nevertheless the material suggests a rather wide distribution of *Thalassinoides* with several ichnospecies in the Ordovician. Knaust and Dronov (2013) have described very abundant *Balanoglossites* ichnofabrics from the Middle Ordovician of the Sankt Petersburg area. The Middle Ordovician limestone with *Balanoglossites* is used in buildings in Tallinn. It is possible that *Balanoglossites* occurs also in the strata of the Silurian Jaagarahu Regional Stage.

Various feeding structures (fodichnia) are less common, represented by *Arachnostega*, *Zoophycos*, *Phycodes*, *Chondrites*, *Teichichnus*, *Taenidium*, *Rhizocorallium* and *Halopoa*. *Arachnostega gastrochaenae* is surprisingly widely distributed, associated with different groups of Ordovician shallow-water molluscs. *Phycodes* is also rather common, especially in the lower Silurian, but the oldest representatives are identified from the Keila Regional Stage. Noteworthy is the presence of rare *Phycodes reniforme*, previously described

only from the Ordovician of Laurentia (Hofmann 1979). *Teichichnus rectus,* a softground ichnotaxon*,* is determined from the Kukruse Regional Stage.

The ichnofamily Coprulidae *sensu* Knaust (2008) is represented by two genera. Small cylindrical pellets associated with gastropods from the Haljala Regional Stage may represent the genus *Tomaculum* and the isolated oval pellets from the Väo Formation (Middle Ordovician) belong to *Coprulus oblongus*.

Cubichnia and repichnia are represented by a few finds only. *Rusophycus*, *Cruziana* and *Lockeia*, all poorly preserved, cannot be identified at species level. *Protovirgularia*, which may be related to *Lockeia*, has not been recorded in the existing collections. Impedichnia and praedichnia are likewise not very common. *Helicosalpinx*, *Tremnichnus* and *Oichnus* are quite rare, *Anoigmaichnus*, first described in trepostome bryozoan colonies from the Uhaku Regional Stage, occurs also in the Haljala and Oandu stages.

In conclusion, many samples with burrows on bedding plains have been collected, but the identification of traces is often quite difficult. Important diagnostic characteristics, such as the presence of lining, type of striae or the presence of finer structures, have often been poorly preserved making identification complicated or even impossible. Nevertheless, the studied trace fossils are characteristic of shallow-marine environments. The association contains a large proportion of horizontally oriented traces and burrows, accompanied by vertical structures representing dwelling and feeding structures. Bioturbation is mostly moderate to high. The ichnodiversity seems to be not very high, in contrast to what has been suggested by Männil *et al.* (1984). This may be due to insufficient sampling resolution, and/or the not very good preservation conditions of carbonates generated during early diagenesis as described by Knaust *et al.* (2012). However, given the fact that some ichnogenera are represented by several species and there are well-preserved trace fossils in the collections, it is possible to study them in full detail and gain a more thorough picture of different trace fossil assemblages in the Baltic shallow-marine carbonates.

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