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MICRO-COPROLITES INSIDE ORDOVOCIAN BODY FOSSILS FROM ESTONIA

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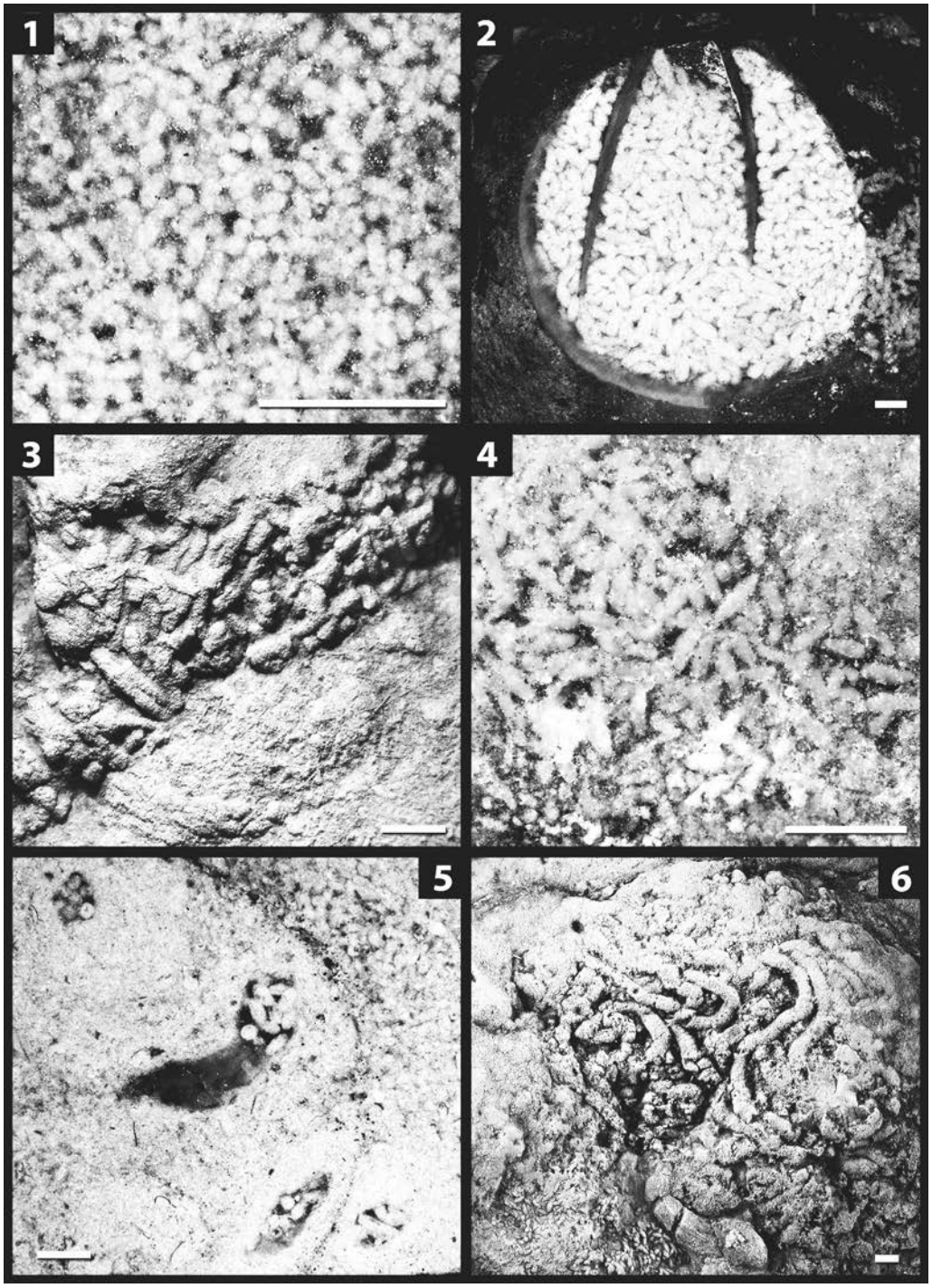
Trace fossils are important environmental indicators, providing valuable knowledge on animal behavior in geological past. Coprolites and faecal pellets are distinct category of trace fossils. Faeces, like all soft-sediment fossils, have generally low fossilization potential and their finds from non-carbonate sediments are related to deeper water environments, higher sedimentation rates and different exceptional preservation conditions characteristic of Lagerstätten. The preservation of micro-coprolites in carbonate sediments is usually related to tropical shallow-marine environments and is common in the Mesozoic and Cenozoic. The majority of pellets in these environments are produced by crustaceans; they have characteristic internal structure and belong to the ichnofamily Favreinidae. Very elongated coprolites are representing the ichnofamily Lumbricariidae. Small cylindrical bodies with outer ornamentation are described from several different ichnogenera. Isolated rounded pellets without characteristic internal structure and smooth surface are representing the ichnofamily Coprulidae. They are described as infill in different trace fossils and shells. The size, shape and number of produced faecal pellets is, in general, a combination of structure and function of digestive organs and the nature of the diet of the producers.

Small faecal pellets are particularly typical for the Ordovician of Europe. Usually they are identified as *Tomaculum* Groom, 1902 and in rare cases as *Cilindrotomaculum* Gutiérrez Marco, 1984. Bruthansová & Kraft (2003) reported small pellets inside different Darriwillian to Katian shelly fossils from offshore environments of Bohemia, preserved via silicification. From the Ordovician shallow-marine carbonate succession of Estonia, the occurrence of pellets was noted by Põlma (1982). The latter author suggested that the pellets have been trapped inside shells and may have faecal origin.

Our studies on large Estonian paleontological collections housed at the Department of Geology, Tallinn University of Technology (GIT) and the Natural History Museum, University of Tartu (TUG), brought up new data on the occurrence of small pellets in Ordovician shallow-marine carbonates. Stratigraphically such finds range from the Kunda (Lower Darriwillian) to Pirgu (Upper Katian) regional stages with higher number of better preserved pellets at two levels: Haljala (Sandbian) and Rakvere (Katian) regional stages. All pellets recovered are devoid of internal structure, without wall and lining, and with smooth outer surface. They are elongated, varying from oval to rod-shaped, with circular cross section, almost constant in their dimensions within an individual accumulation. The size of pellets between accumulations is, however, very variable, ranging from 0.1 to 1.8 mm in length, and from 0.08 to 0.5 mm in diameter. An important diagnostic feature, the length/width ratio ranges from 2 to 6. The number of pellets in individual accumulations depends on the size of pellets; for the larger ones a few dozen may be observed and for the smallest pellets a single accumulation may contain up to a thousand pieces. The host shells derive from gastropods, bivalves, cephalopods, brachiopods, echinoderms and trilobites. Pellets inside the shells are preserved in two different modes: the majority of cases are massive accumulations and fewer finds are related to small burrows within shells.

The shelly fossils with pellets inside derive from temperate to tropical carbonates in Baltoscandia. Rapid lithification and small size of pellets have played an important role for the preservation of pellets in carbonates. EDS chemical analyses have shown that the composition of pellets is similar to the rock matrix; however, specimens from the Haljala Regional Stage suggest that silicification may have supported the preservation of pellets. We have identified the following ichnospecies: *Coprulus oblongus* Mayer, 1952 (Pl., Fig. 1) and *C.* cf. *oblongus* (Pl., Fig. 2) *sensu* Knaust 2008, *C. bacilliformis* Mayer, 1955 (Pl., Fig. 3) and *C.* cf. *bacilliformis* (Pl., Fig. 4). In addition, *C. oblongus* was found to be as a constituent of a compound trace fossil *Tubularina* Gaillard et al., 1994 (Pl., Fig. 5). According to Bruthansová & Kraft (2003), only a limited number of taxa could have been the producers of pellets inside empty shells, mostly scavengers and filter feeders looking for a shelter. Our study supports this idea, but the large variation

Micro-coprolites inside Ordovician shelly fossils



Scale bar is 1 mm. Fig. 1. *Coprulus oblongus,* Värska 6 borehole, 381.8 m, Haljala Regional Stage, GIT 156-1066-1. Fig. 2. *Coprulus* cf. *oblongus*, Oandu River outcrops, Rakvere Regional Stage, GIT 619-85-5. Fig. 3. *Coprulus bacilliformi*s, Rakvere, Rakvere Regional Stage, TUG 1779-477-1. Fig. 4. *Coprulus* cf. *bacilliformis*, Kullaaru ditch, Oandu Regional Stage, GIT 694-93-3. Fig. 5. *C. oblongus* as constituent of compound trace fossil *Tubularina*, Aluvere Quarry, Haljala *oprulus*. Fig. 6. *Lumbricaria intestinum*, Rägavere quarry, Rakvere Regional Stage, TUG 73-148-2.

in size, shape and in the number of pellets in accumulations suggest even a wider spectrum of potential tracemakers.

Besides the pellets, a single examined steinkern of large gastropod contained a very elongated (the length far exceeds the width), convolute, cylindrical coprolite, without internal structure, showing an overlapping pattern and exhibiting constrictions. This specimen comes from the Rakvere Regional Stage (Katian) and is assigned to the rare

ichnogenus *Lumbricaria* Münster in Goldfuss, 1831 (emended by Kietzmann & Bressan, 2019) (Pl., Fig. 6). This ichnogenus was previously described from Jurassic shallow subtropical carbonates. Different origins have been proposed for *Lumbricaria*, more recently holoturians (Kietzmann & Bressan, 2019). Holothurians use the shelters for hiding and are known from the Upper Ordovician of Estonia. The specimen from the Rakvere Regional Stage is small (the diameter is about 0.7-0.8 mm, and the length of loops is more than 10 mm) and is probably representing a juvenile tracemaker.

In summary, our study showed that the fauna inhabiting different empty shells was diverse through the Middle and Late Ordovician in Estonia; and consisted of different mobile tracemakers. Data on individual specimens and related micro-coprolites (including images and localities) is deposited in the Estonian geocollections database SARV, which is accessible online at https://geocollections.info.

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