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Trace fossils accompanying possible "Ediacaran organisms" in the Middle Cambrian sediments of the St. Petersburg Region, Russia

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ABSTRACT:

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Shallow-marine Middle Cambrian sandy sediments of the St. Petersburg Region (i.e., sedimentary cover of the Baltic Shield) bear non-shelly, cup-like fossils, interpreted tentatively as descendants of Ediacaran organisms. The ichnoassemblage accompanying this occurrence consists of *Skolithos, Diplocraterion* and indeterminate biogenic sedimentary structures. The ichnofabric index is low (1-2). The probable body fossils are crosscut by the trace fossils. Though simple, the ichnoassemblage recorded here yields valuable information on the environment that could have hosted Ediacaran organisms during the earliest Phanerozoic.

Key words: Skolithos ichnofacies; Ediacaran-like organisms; Middle Cambrian; shallow-marine; Baltic Shield; Russia.

INTRODUCTION

Ediacaran organisms represent one of the important palaeontologic topics of the past few decades. Discovered independently at several places (Newfoundland, 1872; Namibia, 1929; Ediacara in Australia, 1947; Russia; cf. Fedonkin and Vickers-Rich 2007), finds have been made on all continents but Antarctica. The late Proterozoic (Ediacaran) age of the fossils was unrecognized before the 1950s; previously, the fossils were placed in the Cambrian. Numerous theories have been published on the character of the assemblage of Ediacaran organisms. Initially, ediacarans were understood as representatives of extant phyla, especially cnidarians and annelids (e.g., Glaessner and Wade 1966). Later, the peculiar characters of some forms led to the erection of a separate phylum (Petalonamae Pflug 1970; Pflug 1972) or even kingdom (Vendobionta Seilacher 1992). At present, most authors tend to combine both views, or to return to the original views of Glaessner and coauthors (e.g., Runnegar and Fedonkin 1992; Gehling and Rigby 1996; Waggoner 1998; Gehling 2001), but the "vendobiont" attitude still has its arguments and promoters (e.g., McMenamin 1996, 1998). Current accounts of the opinions can be found, e.g., in papers by Narbonne (2005) and Xiao and Laflamme (2008).

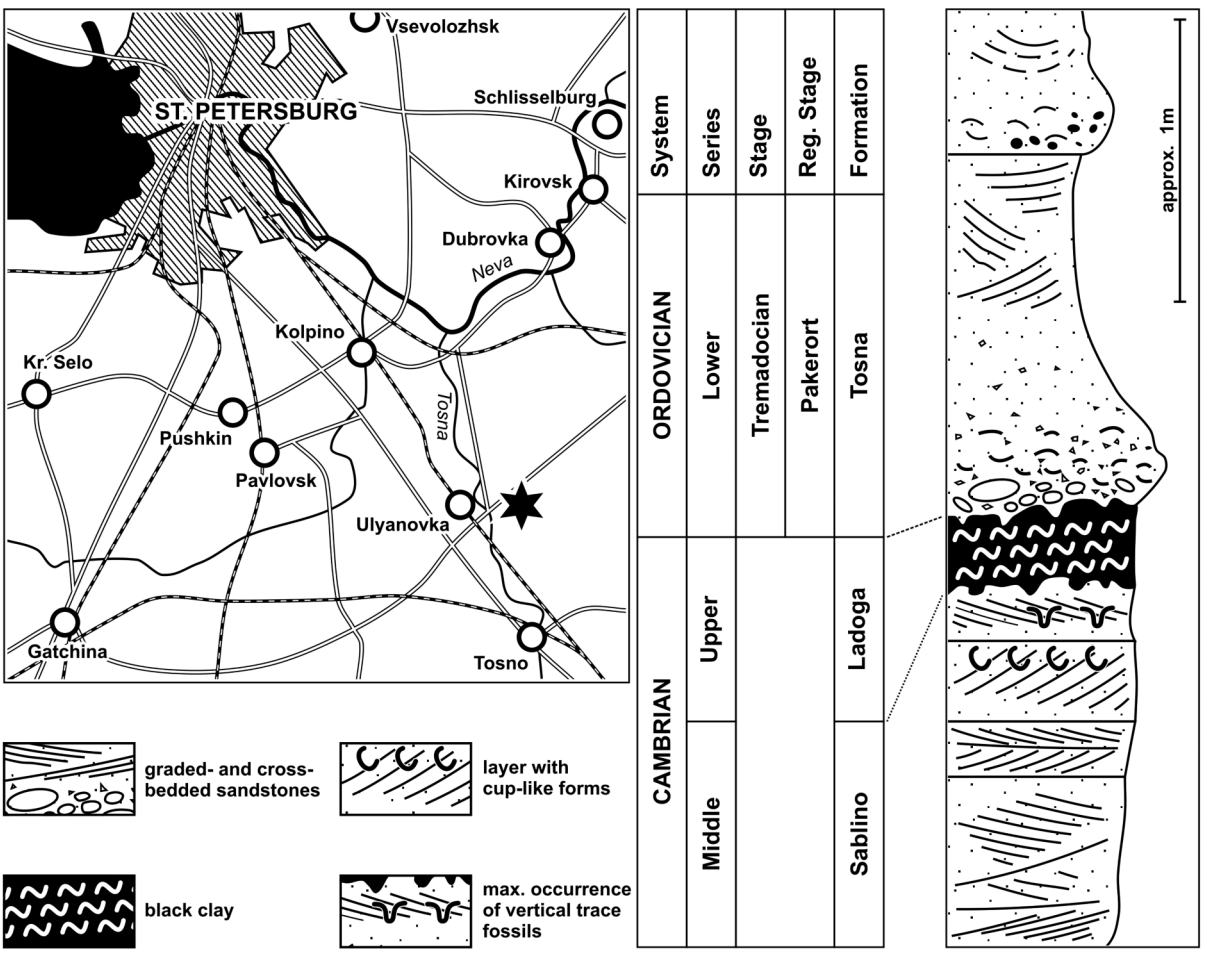
From the 1950s to early 1990s, the consensus held that the ediacarans are restricted to what is now

called the Ediacaran Period of the Proterozoic. The 1990s brought, among numerous attempts to explain Ediacaran life coherently, an effort to find direct descendants of the ediacarans in Early Palaeozoic rocks or in the Proterozoic/Palaeozoic boundary interval, hence to demonstrate that the ediacaran organisms did not disappear completely before the onset of the Palaeozoic (e.g., Horodyski 1991; Conway Morris 1998, 2000; Crimes and McIlroy 1999; Hagadorn *et al*. 2000). These finds are not all equally convincing as possible continuations of Ediacaran organisms. Some may be only roughly interpreted in terms of original morphology, or may yet be pseudofossils as radial and concentric shapes can both be produced by numerous inorganic processes. In conclusion, Cambrian Ediacara-like fossils probably exist, but each find has to be considered critically, and future finds have to be well documented and adequately published.

A new occurrence of possible Ediacaran-like organisms in the Middle Cambrian was briefly reported by Natalin *et al*. (2006). From the ichnologic point of view, this occurrence is interesting for its clear and understandable ichnologic context. It gives the opportunity to characterize, through accompanying trace fossils, some parameters of the environment suitable for the post-Proterozoic "ediacarans". Therefore, the aim of the present paper is to describe the co-occurrence of trace fossils and morphological analogues of Ediacaran organisms in the Middle Cambrian shallow marine sands of the St. Petersburg Region.

GEOLOGICAL SETTING

The Palaeozoic sedimentary cover of the Baltic Shield (mostly of Cambrian, Ordovician and Devonian age) is unique in certain aspects. Horizontal strata result from the tectonic stability of the region. Because of the small accommodation space and low average sedimentation rate, the sediments have never been exposed to high pressures and temperatures; consequently, clas-



Text-fig. 1. Location map; stratigraphic section in the Sablino Caves

tic rocks of different grain size are often unlithified or only weakly cemented (clays/claystones; sands/poorly lithified sandstones). Therefore, the fossil record, only slightly influenced by diagenesis, could include components that were usually destroyed in other regions. In addition, the shallow epeiric sea was extremely extensive over the Baltic Shield, and its duration in the geologic time-scale was also uniquely long.

In the St. Petersburg region, the Middle Cambrian, represented by the Sablino Formation, is best exposed in the vicinity of the village Sablino. Fine-grained quartzose sands are accessible for study in the so-called "Sablino Caves" (tunnels for glass sand extraction; Text-fig. 1), ca. 50 km ESE of the city centre of St. Petersburg (see, e.g. Ershova *et al*. 2006 for a geologic sketch map of the area). Only the uppermost 50–60 cm of the Sablino Formation shows trace fossils and bioturbate structures; the same layer also yields structures morphologically resembling Ediacaran-like body fossils. These are limited to the lower to middle part of the bioturbated layer; the maximum bioturbation has been ascertained to be at a few decimetres above the layer bearing the presumed body fossils (Text-fig. 1).

The Sablino Formation is overlain by the Ladoga Formation, several centimetres thick (locally missing) and composed of black clay. The following succession of strata is represented by the Upper Cambrian sands of the Tosna Formation (cf. Dronov *et al*. 2005 for stratigraphic details).

ICHNOFOSSILS AND BODY FOSSILS

The palaeontological content of the Sablino Formation can usually be studied only from vertical, oblique and horizontal cross-sections in consolidated sand on the walls and roofs of the mine tunnels. Collection of samples is very problematic both technically (the rock tends to disintegrate to individual grains) and legally (the tunnels are a technical monument accessible to the public). However, a few structures were ground serially both *in situ* and in the laboratory; the series of cross-sections was drawn and/or photographed. This enables us to describe the biogenic structures three-dimensionally.

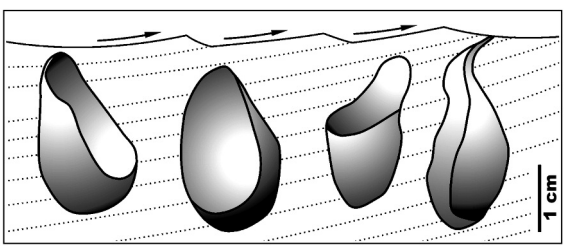
The ichnologic content of the uppermost 60 cm of the Sablino Formation consists both of indeterminate bioturbation structures (spots, disturbed laminae) and of identifiable trace fossils. The ichnofabric index ranges from 1 (= no bioturbation) to 2 (= few percent of the bioturbated substrate); the index usually increases upwards. Individual colonisation horizons can be seen in only a few places (Pl. 1, Fig. 2), showing, however, very limited lateral extent.

Among identifiable trace fossils, the ichnogenera *Diplocraterion* Torell, 1870 and *Skolithos* Haldeman, 1840 were recognized (Pl. 1, Figs 3–5).

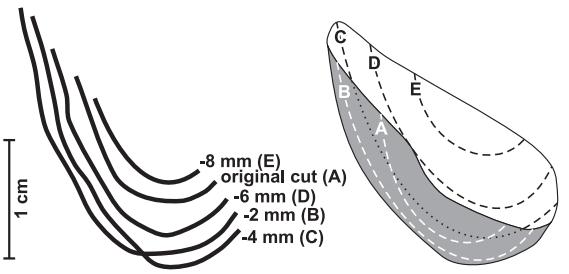
Diplocraterion (Pl. 1, Figs 4, 5) is represented by vertical U-shaped tubes showing a reworked lamina (spreite) between the limbs of the U. The spreite is in some cases deflected, ladle-like. The tube is up to 10 mm in diameter, smooth, unlined, with maximum depth of the structure 50 mm. Crosscutting relationships show that *Diplocraterion* can disturb the cup-like bodies as described below. For description, relations and figures of the ichnogenus and its particular ichnospecies see Fürsich (1974), Häntzschel (1975), Fillion and Pickerill (1990). According to these authors, *Diplocraterion* is the dwelling burrow of a suspension feeder, characteristic of settings with relatively strong wave and current energy. The specimens from Sablino cannot be, according to the section observed, identified at the ichnospecific level.

The ichnogenus *Skolithos* (Pl. 1, Fig. 3) displays vertical and steeply oblique shafts, 2–8 mm in diameter, up to 60 mm in depth. The shafts are solitary or in widely spaced groups (usual spacing 1–5 cm). Walls of the shafts are probably always smooth, probably unlined but made visible by dark (? manganiferous) precipitates. For systematic ichnology of *Skolithos* and its ichnospecies see, e.g., Alpert (1974, 1975), Fillion and Pickerill (1990). *Skolithos* is typically a dwelling burrow; in the described material, some vertical shafts might also represent escape structures, as chevron-like patterns can be observed on their top parts.

Another kind of biogenic structure is represented by shallow, relatively wide shafts with "flame-like" structures in their upper parts (Pl. 1, Fig. 2). These structures, purely on a morphological basis, resemble body fossils of sea anemones. They can be explained by the collapse of hollow dwelling burrows; the "flames" possibly originated from the collapse



Text-fig. 2. A three-dimensional reconstruction of the "cup-like" body fossils from the top of the Middle Cambrian at Sablino and their presumed position in the substrate. Presumed mechanism of shifting the substrate (i.e. current ripples) is also marked



Text-fig. 3. A three-dimensional reconstruction of a cup-like body based on serial cutting by a knife *in situ;* cross-sections normal to bedding. Distance between the cuts = 2 mm. The model was made from cardboard at 1:10 scale and then photographed and drawn

of a thin mud drape (? algal mat) covering the sea bottom.

The morphological analogues of Ediacaran-like fossils display thin (up to 0.5 mm) cross-sections in the form of a regular to slightly irregular C, U or J. Circular cross-sections are rare; exceptionally, the cross-section is an asymmetrical S (Pl. 1, Figs 5–6). Cross-sections resembling broad Us or Cs are typically observed in vertical cross sections up to 20 mm deep and 10–15 mm of horizontal extent. The resulting shapes, reconstructed on the basis of the cross sections, are irregular, minute cups (Text-figs 2, 3). Walls of the cups are smooth, with no preserved inner structure. Only a division crack filled with clay substance and poor ferruginous/manganiferous cement is observed. These structures resemble "cup-shaped" Ediacaran animals, among which the genus *Ernietta* is closest by its general body-plan (cf. Dzik 1999); some similarities can be found also to *Ediacaria, Cyclomedusa* and *Nemiana* (cf. Runnegar and Fedonkin 1992; Natalin *et al*. 2006; M. Fedonkin, personal communication, 2007).

Crosscuttings between trace fossils and the cup-like forms are rare, but in all observed cases burrows of the ichnogenus *Diplocraterion* crosscut the cup-like structures. The cup-like bodies do not crosscut mutually, but may touch; usually they are arranged in weakly bordered clusters, where the average distance of the individuals reaches 5–10 mm; outside the clusters, the distance may be 20 or more cm.

CONCLUSIONS

The cup-like bodies found in the Sablino Formation may represent remnants of soft-bodied body fossils that lived partly or completely buried in sand substrates in dynamic (but not extremely dynamic) settings, as shown by the colonisation of producers of *Skolithos* and *Diplocraterion*. This simple ichnoassemblage corresponds to the classical *Skolithos* ichnofacies (e.g., Seilacher 1967).

The cup-like forms were probably not capable of movement as they left no corresponding bioturbation structures. The influx of nutrition may have been mediated by the whole body surface (with the help of symbiotic autotrophic organisms?) or through thin pores and connected canals inside the body (as in sponges).

The environment's high current and wave energy was evidently unsuitable for the development of typical Cambrian fauna, e.g., trilobites, as their body and trace fossils are absent and the bioturbation index is low. Ediacaran organisms as understood, e.g., by Seilacher (1992) and Crimes and McIlroy (1999), might have occupied a similar habitat. Thus, the survival of Ediacaran forms to the earliest Phanerozoic is possible across the extremely extensive epeiric sea of the Baltic region.

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PLATE 1

1 – A view of the gallery at the Sablino Caves showing rocks of the Sablino, Ladoga and Tosna formations

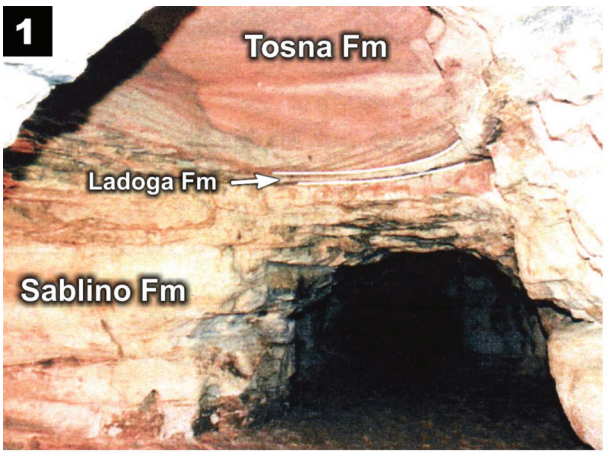
2 – Shafts of undetermined trace fossils with "flame-like" structures in their upper parts, top of the Middle Cambrian, Sablino Caves

3 – *Skolithos* isp., top of the Middle Cambrian, Sablino Caves

4 – *Diplocraterion* isp. (horizontal cross section), top of the Middle Cambrian, Sablino Caves

5-6 – Horizontal and oblique cross sections of body fossils, top of the Middle Cambrian, Sablino Caves

Scale bars = 5 cm for all figures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Tosna Fm
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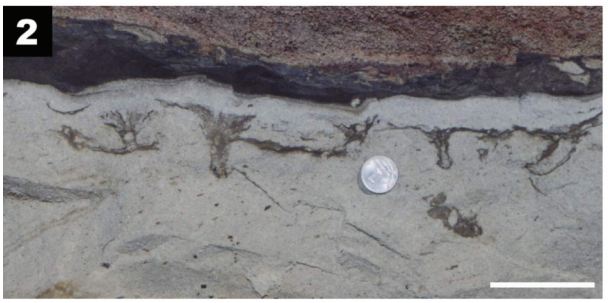
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