ISSN 0031-0301, Paleontological Journal, 2010, Vol. 44, No. 12, pp. 1552–1559. © Pleiades Publishing, Ltd., 2010

Paleontological Evidence for the Supposed Precambrian Occurrence of Mollusks

A. Yu. Ivantsov

Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya ul. 123, Moscow, 117997 Russia
e-mail: ivancov@paleo.ru

Received March 3, 2010

Abstarct—The paper discusses a group of the Late Vendian fossils supposedly related to mollusks. The fossils include imprints with some anatomical characteristics of mollusks, traces resembling scratch marks left by radula, and structures resembling soft shells. *Kimberella quadrata*, which is represented by all the above kinds of fossils was most likely a trochophore animal of a pre-molluscan evolutionary stage. Remains of *Armillifera parva* and *Solza margarita* only slightly resemble shells, and in the absence of the knowledge on the soft body of these animals there are no enongh evidences affiliate them with mollusks.

Keywords: Precambrian, Vendian, mollusks, *Radulichnus*, *Kimberella*, *Armillifera*, *Solza*.

DOI: 10.1134/S0031030110120105

INTRODUCTION

One of the most interesting questions in Precambrian paleozoology is the origin and early evolution of the phyla of Metazoan animals, especially those (like arthropods and mollusks) that are successful in the modern biosphere. Judging from the "SSF", the remains of true mollusks, at least gastropods, monoplacophorans, and polyplacophorans, appear seemingly suddenly in the fossil record near the base of the Cambrian (Parkhaev, 2008). The phylum had probably appeared earlier, in the Vendian, but mineral shells and sclerites are absent among the Vendian fossils represented by imprints of soft bodies and trace fossils. It is possible that the early mollusks lacked a shell, or had a soft, weakly mineralized shell. Examination of the collection of Vendian fossils at the Paleontological Institute, Russian Academy of Sciences allowed the recognition of a group of fossils provisionally assigned to mollusks and resembling soft saucerlike shells, trace fossils resembling the scratch marks left by radula, and imprints with anatomical characteristics resembling those of mollusks. It has recently been shown that most of these fossils represent variously preserved remains of the metazoan animal *Kimberella* (Fedonkin et al., 2007).

MATERIAL

All specimens are housed in the Paleontological Institute, Russian Academy of Sciences (PIN), collection nos. 3993 and 4853.

SOFT BODY IMPRINTS

Kimberella (*Kimberella quadrata* (Glaessner and Wade, 1966)) is a relatively common fossil from the Upper Vendian of the Arkhangelsk Region. Remains of *Kimberella* come from the Verkhovka, Zimnegory, and Yorga formations (as interpreted by Grazhdankin, 2003), which together constitute about half of the section containing Vendian macrofauna. However, they are only found in one type of deposits, i.e., at the bases of lenses and strata resulting from short episodes of turbulence and redeposition of sandy sediments. The assemblages with *Kimberella* in the same localities contain typical Vendian fossils, e.g., *Tribrachidium*, various species of *Dickinsonia* and *Parvancorina*. All fossils are represented by low relief imprints of the upper surface of the dead organisms (Ivantsov, 2009).

Kimberella has frequently been studied by Vendian paleontologists. However, reconstructions of animals based on different material at different times are significantly different. In the mid-20th century, when *Kimberella* was known only from a few poorly preserved imprints of compressed bodies from the Ediacaran beds of South Australia, it was assigned to siphonophores, or chirodropid cubozoans (Glaessner and Daily, 1959; Wade, 1972; Jenkins, 1992). Only by the end of the 1990s, after the first excavations in the Arkhangelsk Region (Zimnegory locality), resulting in several dozen excellently preserved specimens, it became possible to establish that this was a complex benthic organism, similar in its organization to triploblastic animals, possibly to shelled mollusks (Fedonkin and Waggoner, 1997). As a result of further large-scale excavations in Zimnegory and on the Solza River, several hundred imprints were collected, and at

least three types of body preservation were discovered (Pl. 2, figs. 1–7). *Kimberella* showed the presence of dense, possibly mineralized covers, muscles, and intestines, traces of its movement were discovered, and specific feeding traces were confirmed as belonging to these animals (Ivantsov and Fedonkin, 2001a; 2001b; Seilacher et al., 2003; Fedonkin and Vickers-Rich, 2007). Thus, the hypothesis of the molluscan affinity of *Kimberella* has been fixed in the literature (Fedonkin, 2003; Fedonkin et al., 2007; Seilacher, 2007; Trusler et al., 2007). The discovery at the beginning of the 21st century of strongly elongated specimens of *Kimberella* allowed the reinterpretation of previously collected material (Pl. 1, figs. 1–3). According to new interpretations, this animal had a worm-like body and head, and a compressible, possibly retractable ante-head region (Ivantsov, 2009).

TRACE FOSSILS

Kimberella was one of few metazoan animals that produced trace fossils. The fact that the trace fossil trails belonged to this particular organism was established based on aggregate imprints (a combined imprint of a trace fossil trail and that of a soft body). Two kinds of traces are recognized: (1) flat bands, weakly raised over the edge of the trail and (2) fan-shaped groups of thin grooves (the description of the relief is based on a latex cast; on the rock matrix the former kind of traces appear as elongated depressions, and the latter as narrow ridges (Pl. 1, figs. 6, 7)). It is suggested that these traces were left by *Kimberella* on the substrate it inhabited (Ivantsov and Fedonkin, 2001a; 2001b). What kind of substrate was that? Judging from the lithology of the host rock, the mineral component of the bottom sediment was composed mainly of clayey or silty particles. However, the texture of the base of the sandstone overlying the fossiliferous surface suggests that the upper layer of the substrate was of biogenic origin and was probably a microbial mat. The substance of the mat decayed as the mat was buried in the siliciclastic sediment, and the only cast of its upper surface can be preserved. Fossil trails of *Kimberella*, and Proarticulata (other Vendian actively moving animals) were found on this very surface (Ivantsov, 2008; Ivantsov and Malakhovskaya, 2002).

The first type of traces found in association with the soft body imprints of *Kimberella* was found by the present author together with Ya.E. Malakhovskaya in the Verkhovka beds on the Solza River (Ivantsov and Fedonkin, 2001a; 2001b). Band-trails usually form aggregates with soft body imprints and bunches of grooves. One end of such a band is in contact with the head side of the soft body imprint, as if continuing or "flowing" from the body; while the other end levels and becomes obsolete above the narrow side of the bunch of grooves (Pl. 1, fig. 6). We had previously suggested that the trail was originally a burrow in a sandy sediment that the animal made before it was dead (Ivantsov and Fedonkin 2001a; 2001b; Fedonkin et al., 2007). Moving along the boundary between the mat and overlying sediment, *Kimberella* moved the sediment and inevitably should have disturbed the texture of the surface of the mat. However, it can be observed in places where the height of the band was at minimum that the surface of the mat was not deformed. The "burrow" hypothesis is not consistent with the generally sharp and irregular changes in the width of the band. It is more likely that the mucous sheath was preserved, as a large amount of mucous was apparently secreted by a distressed animal, i.e., suddenly surrounded by a cloud of perturbed, oxygen-deprived sediment. The mucous could be made denser (which increased its volume on the imprint) by the sediment particles from the cloud stuck to it and engulfed by it. The length of the band is definitive, similar to the length of the stretched out body of *Kimberella*. It is suggested that the animal was covered by the sediment while stretched out, and became compressed and secreted mucous after it was covered (Ivantsov, 2009).

The second type of trace fossil has been long known from Australia, where it was interpreted as spicules of sponges (see references in Fedonkin and Vickers-Rich, 2007) or casts of scratch marks left by claws of an unknown arthropod (Gehling, 1991; Jenkins, 1992; 1995). Seilacher (1999; 2007) and Seilacher et al. (2003) interpreted them as resembling scratch marks left by radulae and assigned them to *Kimberella*, whose imprints are occasionally found on the same bedding planes (Seilacher, 1999; 2007; Seilacher et al., 2003). The first aggregate imprint consisting of a fan of grooves and a body imprint of *Kimberella* was discovered by M.A. Fedonkin in university museum in Western Europe. That specimen, originally from the Winter Coast of the White Sea, was illegally excavated and exported out of Russia by private collectors and was returned to Russia due to the gracious decision of the director of that museum (Fedonkin, 2001; Fedonkin and Vickers-Rich, 2007). When analyzing the trace fossil, Fedonkin interpreted it as having been left by a single articulated pair of teeth located at the end of a long protracted proboscis (Fedonkin, 2003; Fedonkin et al., 2007). Massive collections of aggregates of both types of trace fossils were collected by the present author and Yana Malakhovskaya on the Solza in 2000–2006.

Traces, fanlike grooves, are always found in large accumulations, sometimes covering the entire visible surface of the bed. Each fan consists of several indistinctly separated and convergent bunches of grooves rather than an isolated groove or pairs of grooves. Grooves in a bunch are almost parallel or clearly converge to one of the ends (Pl. 1, fig. 7b). The fans often overlie each other to form series, in which they are all directed, with the narrow end of each overlain and smoothened by the wide end of the next bunch. In case of aggregates, the imprint of *Kimberella* lies in the