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PALEONTOLOGY

Chuariomorphs from the Upper Vendian Chernyi Kamen Formation of the Central Urals (Perm Krai)

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Abstract—The complex body-trace fossils of Vendian soft-bodied biota have been found for the first time in the Central Urals during the study of the Vilukha and Sinii Kamen members of the Chernyi Kamen Formation of the Upper Vendian Sylvitsa Group (Kos'va River area, Perm Krai of Russia). These sedimentary sequences were exposed along the valley of the Shirokovskii Reservoir. Among the fossils, the chuariomorpha-like species *Beltanelliformis konovalovi*, previously described from the Konovalovka Member of the Chernyi Kamen Formation, was identified. However, the morphological analysis of the new fossil material revealed a number of principal differences from representatives of the genus *Beltanelliformi*s Menner, 1974. It was shown that the taxon *B. konovalovi*, most likely, does not belong to this genus and probably needs further revision, and, in turn, the fossil locality at the Shirokovskii Reservoir allows us to establish a new area with fossils of the Precambrian mobile organisms.

Keywords: chuariomorpha, mobile organisms, Ediacara-type biota, Chernyi Kamen Formation, Vendian, Ediacaran, Sylvitsa Group, Central Urals

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The discovery of signs of mobility and the ability to locomotion in the fossil record is important for decoding and understanding the evolutionary features of the oldest living systems. Up to now, such very old features have been identified from the finds of complex body-trace fossils of the Ediacara-type organisms *Kimberella, Tribrachidium, Dickinsonia*, and *Yorgia* from the Vendian of southeastern White Sea area and the Ediacaran of southern Australia [1–3]. In addition, indirect signs of locomotion were established as a result of a spatial analysis of intravitally buried populations of *Dickinsonia* and "*Beltanelliformis*" in the Vendian of the Central Urals on the Sylvitsa River; however, we found no combined body-trace fossils in the latter two populations [4, 5].

In the Central Urals (Fig. 1a), the Vendian soft-bodied biota was discovered by Yu.R. Becker in 1972 in the Chernyi Kamen Formation on the right bank of the Shirokovskii Reservoir (Fig. 1b), approximately 3.5 km southeast of the mouth of the Nyar (Nyur) River in the Krasnaya Gorka site [6]. At that time, the paleontological remains, discovered by Yu.R. Becker, were characterized by low taxonomic diversity, represented generally by disc-shaped structures with concentric grooves and folds, described as impressions of medusoids *Tirasiana,* as well as by numerous arumberiamorph structures (*Arumberia*). Since then, nothing has been known about new finds from the Shirokovskii Reservoir; the main vector of the search for Vendian soft-bodied fossils was directed to the southeast—to the valleys of the Chusovaya, Sylvitsa, Mezhevaya Utka, Us'va, and other rivers in Sverdlovsk oblast [7]. However, reconnaissance studies of the type locality, which we undertook in 2021, allowed us to discover new Vendian macrofossils with a high degree of preservation in the Chernyi Kamen Formation—numerous fossils of the palaeopascichnid group represented by the species *Palaeopascichnus delicatus, P. gracilis*, and *P. linearis* [8, 9].

This paper reports on the first finds of presumably mobile Vendian soft-bodied organisms similar to the representatives of the chuariomorpha group from the Vilukha and Sinii Kamen members (Fig. 1c) of the Chernyi Kamen Formation at the Shirokovskii Reservoir. Studies of these finds continue to expand the understanding of the paleontological diversity of the Vendian of the Central Urals. The collection consists of 87 specimens preserved in fine-grained sandstones and siltstones of the Vilukha and Sinii Kamen members, which have been revealed on the right and left sides of the middle part of the Shirokovskii Reservoir

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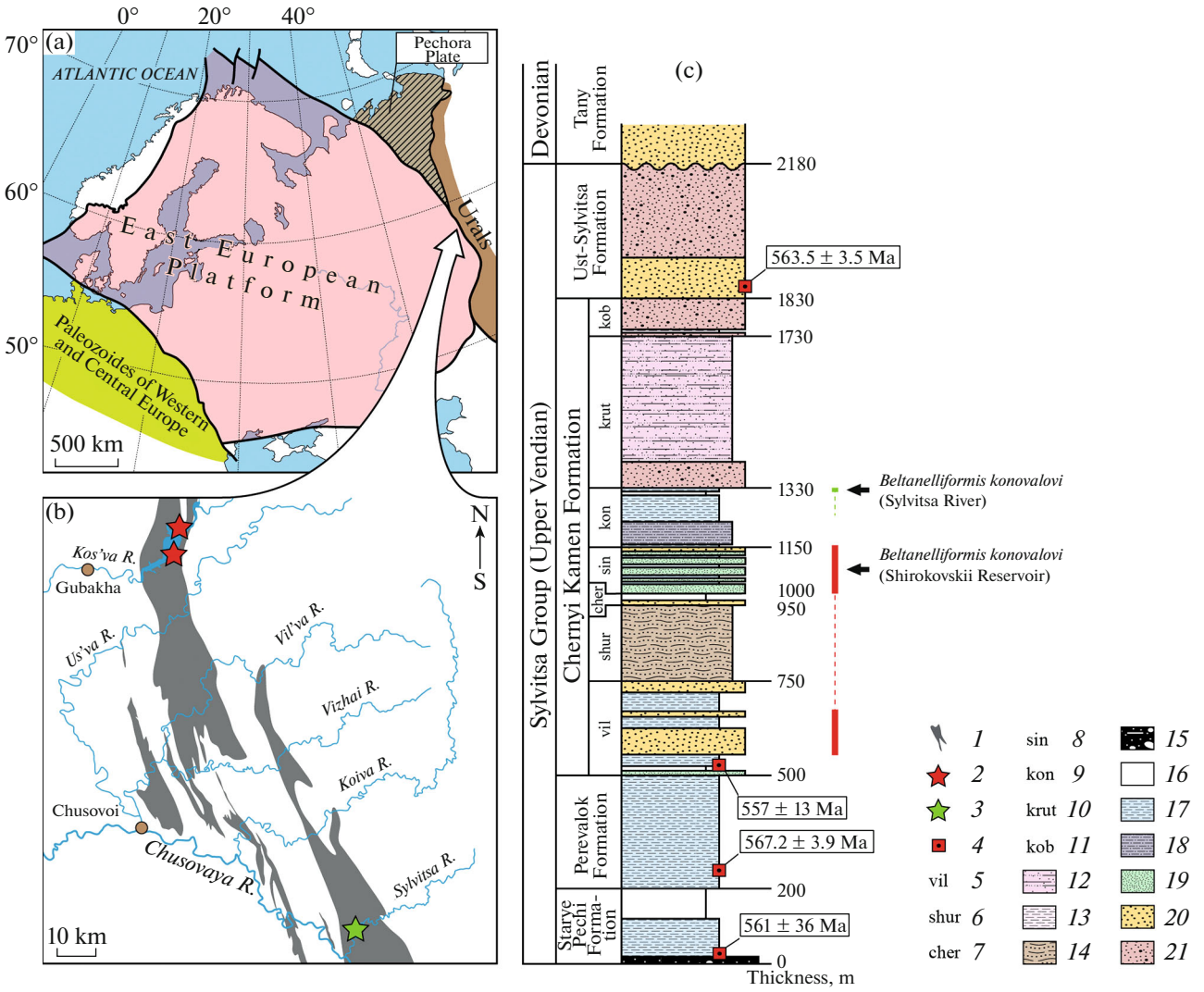

Fig. 1. (a, b) Scheme of a new location of fossils similar to *Beltanelliformis konovalovi* in the Central Urals. (c) Generalized section of the Sylvitsa Group of the Upper Vendian of the Central Urals and stratigraphic occurrence of new fossils. (*1*) Outcrops of the Sylvitsa Group; (*2*) new location of *B. konovalovi* at the Shirokovskii Reservoir (Perm Krai); (*3*) location of *B. konovalovi* on the Sylvitsa River (Sverdlovsk Oblast); (*4*) location of ash tuffs, from which U–Pb dating of zircon was obtained, in the section of the Sylvitsa Group; (*5*) Vilukha Member; (*6*) Shurysh Member; (*7*) Cheryomukha Member; (*8*) Sinii Kamen Member; (*9*) Konovalovka Member; (*10*) Krutikha Member; (*11*) Kobylii Ostrov Member; (*12*) alternating shale, siltstone and sandstone; (*13*) alternating shale and siltstone; (*14*) laminar- and wave-bedded siltstone and sandstone; (*15*) diamictites; (*16*) laminated shale; (*17*) alternating shale and siltstone (low-energy inner shelf); (*18*) alternating shale, siltstone and sandstone (wave- and current agitated shoreface and prodelta); (*19*) interstratified sandstone and shale; (*20*) interstratified sandstone; (*21*) cross-bedded sandstone.

(Krasnaya Gorka site and Cape Galechnik). The fossils show a wide range of preservation: low-relief negative impressions (negative hyporelief) on bedding planes with wave ripple marks (Fig. 2a); partially collapsed (Figs. 2b–2d) and entire (Figs. 2e–2g) pancake-like three-dimensional casts in positive hypo- and epirelief; low-relief weakly visible (taphonomic phantoms) disk-shaped and ring-shaped impressions (Fig. 2h); pancake-like casts with a prominent lumpy or furrowed distinct texture on the surface (Fig. 2k); detailed three-dimensional pancake-like casts and their counter-impressions with numerous small circular and wrinkled structures with variously oriented folds, as well as with lumps and depressions on the surfaces arranged in mosaic form (Figs. 2j–2m).

The fossils may be represented by single or paired (Fig. 2) individuals, and, in some cases, as clusters of numerous and closely adjoining specimens (Fig. 3). The diameters of the specimens range from 5 to 50 mm; the thickness of a three-dimensional cast varies from 0.5 to 5 mm.

The observed set of the specific features, including wrinkling on the surfaces of fossils, marginal rims, pancake-like casts, and body deformations, allows us

Fig. 2. Different variants of preservation of the fossils of individuals of presumably *Beltanelliformis konovalovi* from the Chernyi Kamen Formation at the Shirokovskii Reservoir: (a) sample no. CU21/3-64, Sinii Kamen Member; (b) sample no. CU20/6-1, Vilukha Member; (c) sample no. CU22/9-56, Sinii Kamen Member; (d) sample no. CU22/9-2, Sinii Kamen Member, counter-impression (c); (e) sample no. CU20/6-4, Vilukha Member; (f) sample no. CU21/2-6, Vilukha Member; (g) sample no. CU 22/10-34, Vilukha Member; (h) sample no. CU22/9-101, Sinii Kamen Member, *B. konovalovi* is shown by yellow arrows; (i) sample no. CU21/3-61, Sinii Kamen; (j) sample no. CU21/3-73, Sinii Kamen Member; (k) sample no. CU21/3-15, Sinii Kamen Member; (l) sample no. CU22/9-20, Sinii Kamen Member; (m) sample no. CU22/9-19, Sinii Kamen Member, counter-impression (l).

to define these fossils confidently as different taphonomic variants of representatives of the chuariomorph fossil *Beltanelliformis konovalovi* Kolesnikov, 2022, which have been previously described from the upper part of the Konovalovka Member of the Chernyi Kamen Formation near the mouth of the Sylvitsa River (Sverdlovsk oblast) [4]. However, in contrast to previous finds, the new paleontological material from the Vilukha and Sinii Kamen members demonstrates a higher diversity of preservation forms, which allows us to interpret these fossils unambiguously as intravitally buried pancake-like bodies. These fossils have a wall and an inner cavity, presumably partitioned and partially filled with sediment, which in turn essentially differs from the previously described representatives of the genus *Beltanelliformis* Menner, 1974 [10, 11]. In addition, we have been able to find the most intriguing finds, represented by combined fossils of jointly preserved bodies, and, presumably, traces of their locomotion (Fig. 4), which is also not typical for the representatives of the genus *Beltanelliformis*. In some cases, they consist of a furrow perpendicularly dissected by

Fig. 3. Clusters of *Beltanelliformis konovalovi* fossils from the Sinii Kamen Member at the Shirokovskii Reservoir: (a) sample no. CU22/9-26; (b) sample no. CU 21/3-23; (c) sample no. CU21/3-60; (d) sample no. CU22/9-40; (e) sample no. CU21/3-25.

subparallel rolls and grooves of the same amplitude. The width of the amplitude repeats or is close to the diameter of the body of an organism (Figs. 4a, 4b), at the same time, having no clear boundary within the bedding plane of fine-grained sandstone or siltstone and resembling a trace of feeding (grazing) on the microbial substrate. In other cases, a possible trace of locomotion has distinct boundaries (Figs. 4c, 4d); its width corresponds to the width of the organism's body, but its length is significantly shorter, which may indicate minor movement in the buried (premortem) state within the sediment. The combined fossil remains can also include the specimens represented by both the body impressions with broad marks of grazing and the narrow sinusoidal parallel grooves similar to crawl marks, but with the width several times smaller than the diameter of the presumed organism (Fig. 4e).

To date, chuariomorphs have been classified as clusters of flattened disk-shaped bodies or convex tubercles that include the taxa *Beltanelliformis brun-*

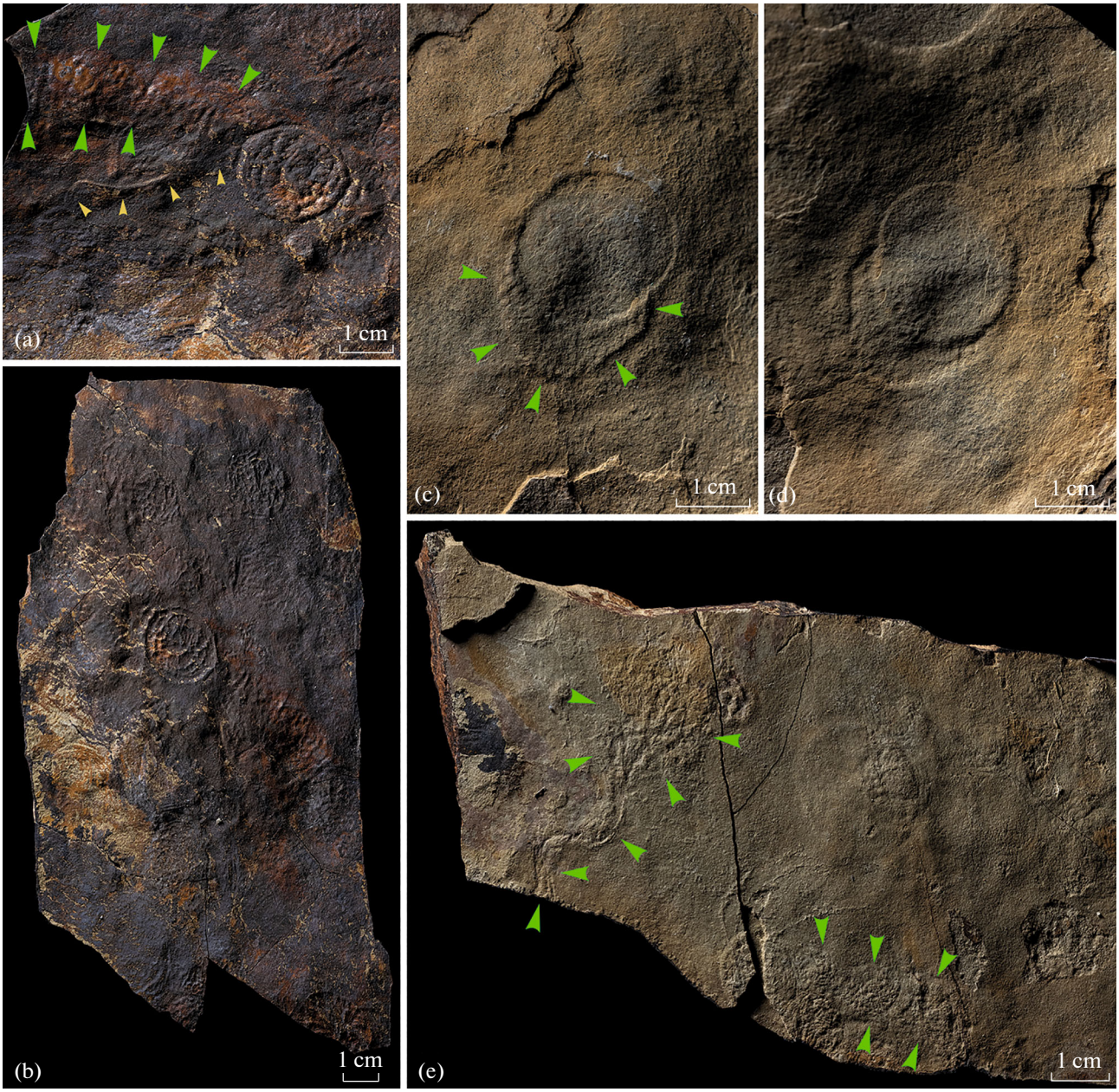

Fig. 4. Complex body-trace fossils of soft-bodied organisms with signs of locomotion found in the Chernyi Kamen Formation at the Shirokovskii Reservoir: (a) sample no. CU22/9-29, grazing traces (green arrows), casts of pancake-like bodies connected by a filament-like structure (yellow arrows), Sinii Kamen Member; (b) sample no. CU22/9-34, Sinii Kamen Member, counter-impression (a); (c) sample no. CU22/10-51, body cast and a likely impression of premortem locomotion (green arrows) within the sediment, Vilukha Member; (d) sample no. CU22/10-50, counter-impression (c), Vilukha Member; (e) sample no. CU21/3-7, taphonomic phantoms of pancake-like bodies and traces of their locomotion/grazing (green arrows), Sinii Kamen Member.

sae, *B. konovalovi,* and *B. minutae* [4, 7, 10, 11]. Previously, they have been interpreted as abiogenic structures or fossils of medusoid organisms, algae, fungal colonies, corals, resting traces, sponges, or primitive colonial prokaryotes [12–17]. Chuariomorphs are known from the Vendian (Ediacaran) sections of southeastern White Sea area, Podolian Trans-Dniesteria, Central and Southern Urals, Southern Timan, Olenek Uplift of Siberia, Patom Highlands, Southern China, Namibia, and Australia [11–19]. Relatively recently, the study of the composition of organic matter biomarkers from flattened carbonized fossils of *Beltanelliformis* from the Valdai Group of the Vendian of southeastern White Sea area showed that they could have a primitive cyanobacterial origin [20]. On the other hand, the analysis of the distribution of the intravital buried population of *B. konovalovi* in the Konovalovka Member of the Chernyi Kamen Forma-

tion of the Upper Vendian of the Central Urals revealed signs of a more complex paleobiology in the organisms that were previously considered primitive [4]. Therefore, taking into consideration the new data, we can conclude that the taxon *B. konovalovi* does not belong to this genus and probably needs further revision. At the same time, the discovery of complex body-trace fossils of the Vendian soft-bodied organisms was the first in the Central Urals. The discovery of new macrofossils with unique preservation in the Chernyi Kamen Formation indicates that the paleontological potential of the Vendian of the Central Urals has not yet been fully realized, and the locality at the Shirokovskii Reservoir, in turn, makes it possible to identify a new area with Precambrian fossils with the ability to locomotion. This implies that the type locality of the Ediacara-type fossils at the Shirokovskii Reservoir may in the future acquire the status of new "lagerstätte" (a locality of fossils with unique preservation), and, accordingly, the continuation of these studies in the foreseeable future may provoke a revision and expansion of our concepts about the evolution and paleoecology of the oldest macroscopic organisms in the Earth's history.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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