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STRATIGRAPHY

Ediacara-Type Biota in the Upper Precambrian of the Timan Range (Dzhezhim–Parma Hill, Komi Republic)

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Abstract—Macroscopic fossils as composite molds and casts of Ediacara-type soft-bodied organisms were found in the Dzhezhim Formation of the Timan Range for the first time. Among them, representatives of palaeopascichnids, arboreomorphs, chuariomorphids, microbial colonies, and trace fossils were identified. This finding of such a large number of various Ediacaran fossils on the Timan Range not only develops our understanding of their paleogeographic range but also clarifies the age limits of the deposition of the Dzhezhim Formation, the stratigraphic position of which in the Upper Precambrian section was controversial.

Keywords: Vendian, South Timan, Timan Range, Dzhezhim–Parma, Ediacara biota, *Palaeopascichnus*, *Arumberia*

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The Timan Range is located in the northeastern part of European Russia. Extending from the northwest to the southeast, it consists of a number of hills from 300 to 450 m high that confine Pechora Lowland from the southwest. In terms of the structural character and completeness of the Upper Precambrian sections, several zones were identified within the Timan Range (from the southwest to the northeast): Obdyr–Nivshera, Chetlas–Dzhezhim–Parma, Tsilma–Ropchin and Vymsk–Volsk [1]. In the Chetlas–Dzhezhim–Parma zone, the Upper Precambrian is integrated into the Chetlas and Bystrin series. Some authors assigned the first zone to the Middle Riphean [2], while the others assigned it to the Upper Riphean–(?)Vendian [1]. The Svetlin, Novobobrov, and Vizinga formations were distinguished in the composite section of the Chetlas series. This series is nonconformably overlapped by the Bystrin series stratified into the Ust'-Palega (An'yug, Dzhezhim), Vorykvin, Pav'yug, and Paun formations.

Dzhezhim–Parma Hill is located in the southeastern part of the Timan Range. Sandstones and siltstones of the Vizinga Formation, sandstones of the Dzhezhim Formation, and limestones (in some places dolomitized) and silty mudstones of the Pav'yug Formation are distributed here, in the margin of the Paleozoic complexes [3]. The relationships between the formations are tectonic, and the character of dislocations is unknown [4]. The age and the stratigraphic position of these formations were controversial over a long period of time. For example, V.G. Olovyanishnikov believed that the dolomites from the Pav'yug Formation represent the oldest part of the section and assigned them to the Late Riphean, comparing the Dzhezhim Formation to the Vendian An'yug Formation [3]. However, in the legend of the second edition of the Timan series of the sheets of State Geological Map SGM-200 RF [5], the Dzhezhim Formation is placed at the base of the section and is assigned to the Late Riphean.

In 2021–2022, we conducted reconnaissance surveys of red silicaclastic rocks in the Dzhezhim Formation in the Asyvvozh deposit of quarry rock (Fig. 1), where numerous Ediacara-type fossils were discovered for the first time (Fig. 2).

The total thickness of the formation exposed by the quarry is ~70 m. The formation is composed of red, primarily cross-bedded sandstones and sandstones with ripple marks and scarce packages of interlayered siltstones and sandstones up to 50 cm thick. The fossils are confined to one of the packages at a height of 12 m from the base of the visible part of the section of the Dzhezhim Formation. Our collection consists of 84 specimens representing palaeopascichnids, arboreomorphs (holdfast structures), chuariomorphids, trace fossils, and microbial colonies.

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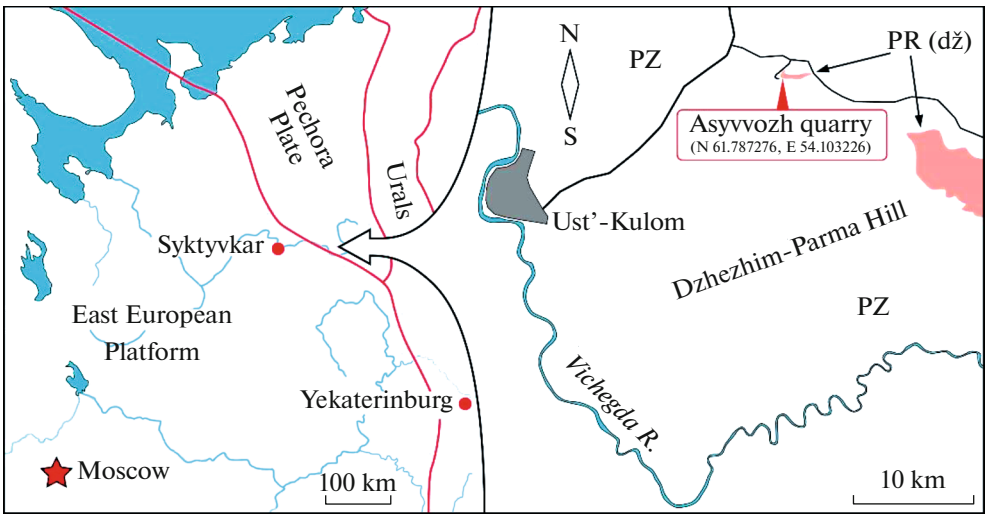

Fig. 1. Newly-discovered location of Ediacara-type fossils in the northeastern margin of the East European Platform.

Taxonomically, the most diverse palaeopascichnids are represented as single-row series of concave molds of the chambers at the bottom surfaces of siltstones and fine-grained sandstones (positive hyporelief), having a globular, elongate, or allantoid (convex) shape and located chain-line one after another (Figs. 2a–2e). In most cases, palaeopascichnids can be identified only using a straight light source located at a low angle to the bedding surface. This is determined by the fact that the fossils are low-relief and demonstrate worse preservation than, e.g., a typical association from the Vilukha Member of the Chernyi Kamen Formation from the Vendian in the Middle Urals [6]. Among the palaeopascichnids, three species were identified: *Palaeopascichnus linearis*, consisting of single-row series of globular or slightly elongate chambers 3 to 6 mm wide (Figs. 2a, 2b); *P. gracilis*, comprising single-row series of strongly elongate chambers up to 1 mm long and up to 25 mm wide (Fig. 2c); and *P. delicatus*, including single-row series of chambers having an allantoid shape with the width increasing progressively (Fig. 2d).

The holdfast structures are represented by positive hyporelief bulb-shaped molds or disk-shaped casts in siltstones and fine-grained sandstones (Figs. 2e, 2f). The diameter of the bulb-shaped bodies and the disks varies from 1 to 3 cm, and the hyporelief height reaches 5 mm. The state of preservation does not allow us to identify the fossil species unanimously; however, such forms are widely distributed in the Sinyi Kamen Member of the Chernyi Kamen Formation from the Vendian in the Middle Urals and were recognized as *Aspidella* Billings [7].

The fossils of chuariomorphids are the most numerous in the Dzhezhim Formation. They are represented by assemblages of small round or elliptical molds without any visible concentric or radial folds in the positive hyporelief of siltstones and fine-grained sandstones (Fig. 2g). The diameter of individual specimens rarely exceeds 7–10 mm, and the hyporelief height is usually shorter than 1 mm. Despite a passing resemblance to the textures of microbial mats, the character of the areal distribution of individual specimens is identical to *Beltanelliformis konovalovi* chuariomorphids from the Chernyi Kamen Formation in the Middle Urals [8], although the latter demonstrate a significant difference in the sizes of the species. Thus, based on the observed features, chuariomorphids from the Dzhezhim Formation are identified as *Beltanelliformis minutae* [9]. These fossils are known from the Longmyndian Ediacaria series in England [10] and the Dal'nyaya Taiga Series of the Patom Highlands (Yakutia) in the Vendian [11].

The trace fossils are represented on the bedding surfaces of fine-grained sandstones and siltstones by common horizontal nonbranching meandering rollers (positive hyporelief) or grooves (negative epirelief) 1–3 mm wide (Figs. 2h, 2i), which we interpreted as the remains of the burrows filled with sediments. The surface of the burrows is smooth, without any visible swells and morphological structures. The observed features are quite convincing for identifying these remains as the ichnogenus *Helminthoidichnites* isp., which are widespread in the fossil record starting from the Late Ediacaran deposits [12].

In addition, problematical and different microbial structures occur in the Dzhezhim Formation, which include arumberiamorph structures, which are well-known in the literature under the generic name "*Arumberia*" (Figs. 2j, 2k). Over a long period of time, they were considered to be erosional structures; however, the results of the latter research convincingly demonstrated their biological origin [13–15]. Two varieties of arumberiamorph structures were encountered in the Dzhezhim Formation: *Arumberia vindhyanensis* (Fig. 2j), the series of subparallel small grooves or short rollers (up to 0.7 mm) located close to each other in a space dissected by finer grooves/roll-

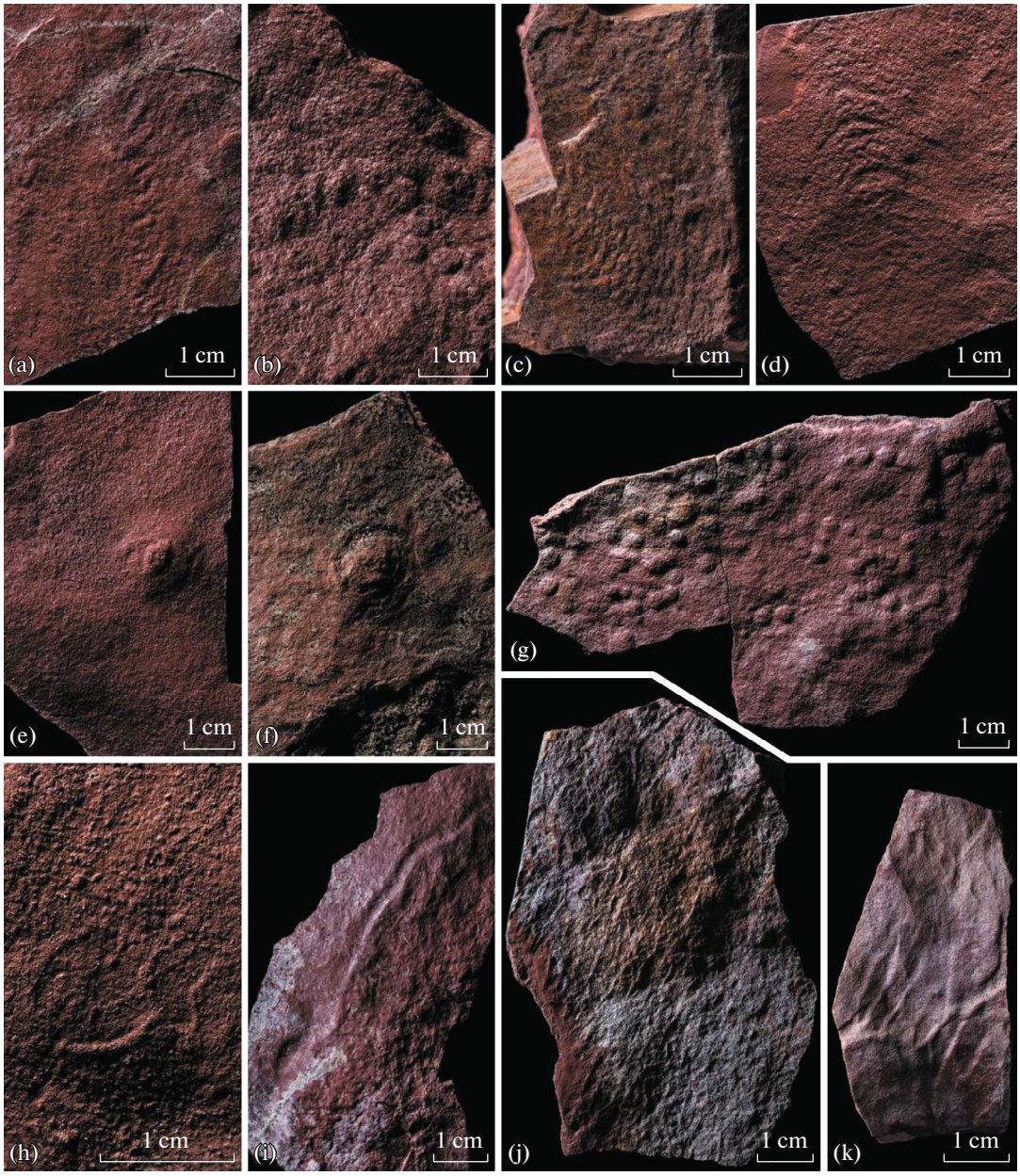

Fig. 2. Representatives of the Ediacara-type biota from the Dzhezhim Formation of South Timan: (a) specimen no. ST22/1-55, *Palaeopascichnus linearis;* (b) ST22/1-67, *P. linearis*; (c) specimen no. ST22/1-62, *P. gracilis*; (d) specimen no. ST22/1-64, *P. delicatus*; (e) specimen no. ST22/1-71, *Aspidella* sp.; (f) specimen no. ST22/1-42, *Aspidella* sp.; (g) specimen no. ST22/1-72, *Beltanelliformis minutae*; (h) specimen no. ST22/1-34, *Helminthoidichnites* isp.; (i) specimen no. ST22/1-68, *H. tenuis* (?); (j) specimen no. ST22/1-73, *Arumberia vindhyanensis*; (k) specimen no. ST22/1-61, *A. banksi*. Collection from the Laboratory of Upper Precambrian Stratigraphy at the Geological Institute, Russian Academy of Sciences (Moscow).

ers; *A. banksi* (Fig. 2k), the series of relatively large subparallel and fan-shaped grooves (negative epirelief) and rollers (positive hyporelief) up to 2 mm wide and up to 2 mm deep/high at the bottom surface and within the sand layers.

Until recently, findings of Ediacara-type fossils in the northeastern margin of the East European Platform have not been known, and the Dzhezhim Formation of South Timan was assigned to the Late Riphean [1, 2, 5]. The discovery of Ediacara-type fossils unambiguously indicates that this formation has the Vendian age. The younger (post-Riphean) age is evidenced by the findings of ichnofossils *Helminthoidichnites* isp., known in the fossil record starting from the age of ~560 Ma [12], as well as by the casts of microbial communities of the *Arumberia banksi* type, the lifetime of which in the fossil record is confined to the interval of 560–520 Ma [16]. The exception is the modern occurrences of arumberiamorphs on the surfaces of halotolerant cyanobacterial mats in the

extremely shallow water reservoirs on the tidal plains [14]. An important finding is palaeopascichnids with the stratigraphic range corresponding to the entire scope of the Vendian System [17]. Moreover, we discovered a palaeopascichnid assemblage comprising *Palaeopascichnus delicatus*, *P. gracilis*, and *P. linearis* species that existed in the interval of 560–550 Ma [18], which conforms in the modern understanding to the Belomorian Stage of the Upper Vendian of the East European Platform [19].

Despite the fact that the state of preservation of macrofossils from the Timan Range is worse than the preservation of similar organisms from the world's largest deposits, the complex of Ediacara-type fossils from the Dzhezhim Formation can be compared to the Vendian biota of the Chernyi Kamen Formation in Middle Urals in terms of the variety of taxa and numerosity [8]. Like the fossil-bearing levels of the Chernyi Kamen Formation in the Middle Urals [6–8, 20], the fossils from the Dzhezhim Formation are confined to the deposits of the extremely shallow water settings of the tidal flats with features of periodic dessication (the occurrence of arumberiamorph structures, wave ripple marks, desiccation cracks, and casts of small salt crystals of cubic shape).

Taxonomically, the material presented is not yet sufficiently rich for detailed study of the morphology, taphonomy, and paleoecology. Nevertheless, the findings of the first macrofossils in the Dzhezhim Formation are promising for the search for new fossils and the discovery of a valuable locality of Ediacaran fossils in the region and indicate that the paleontological potential of the northeastern part of the East European Platform in the Vendian has not yet been realized. Hence, the Upper Precambrian sections of the Timan Range acquire the status of key objects for studying the functional features of paleo-ecosystems at the early stages of Metazoa evolution and making a reconstruction of their natural habitat from the southeastern White Sea area to the Southern Urals.

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