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Kuckaraukia multituberculata: A New Vendian Fossil from the Basa Formation of the Asha Group in the South Urals

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Abstract—A new macrofossil genus and species from the Late Vendian of the Urals is described. Fossils are found on a bedding plane between the sandstone and mudstone and are represented mainly by casts on the sandstone surface. The casts are negative and flat-bottomed, covered with numerous, closely spaced uniform indentations and rimmed by a small, low, narrow, flat flange. This fossil can be reconstructed as a disk consisting of two layers. The top layer was less resistant and probably unstructured. The bottom layer was denser and was structured (either with a tuberculate surface or consisted of loosely packed spherical elements). *Kuckaraukia multituberculata* gen. et sp. nov. could be interpreted as a unitary organism or as a colony of motionless benthic organisms.

Keywords: Urals, Vendian, Ediacaran, Asha Group, macrofossils, *Kuckaraukia multituberculata*

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INTRODUCTION

The discovery of an unusual fauna of soft-bodied organisms in the first half of the last century, referred to as "Ediacaran," was a major contribution to the understanding of the origin and evolution of life on Earth. Many of these Precambrian macrofossils, including the most complex organisms, and some that are, owing to their strikingly unusual morphology, sometimes recognized as a separate group Vendozoa or Vendobionta (Seilacher, 1989, 1992; Seilacher et al., 2003), lack apparent descendants in the Phanerozoic biota. Since then only about 30 localities for these fossil have been discovered, and their age is at present estimated as 575–542 Ma (Fedonkin et al., 2007).

In the Urals, the Ediacaran fauna was described for the first time in the Middle Urals, in the basin of the Chusovaya River, in siliciclastic rocks of the Chernyi Kamen and Ustsylvitsa formations of the upper part of the Sylvitsa Group (Becker, 1977, 1980). Many occurrences for Vendian fossils over a number of years were linked to this region (Grazhdankin et al., 2010, and references in this paper). Ediacaran fossils were reported in the South Urals in 1986 (Becker, 1988; Becker and Kishka, 1989), and later records include a small number of casts of soft-bodied organisms, an assemblage of ichnofossils, and remains of uncertain taxonomic affinity (Becker, 1992, 1996, 2013; Kolesnikov et al., 2012). All these collections come from the siliciclastic deposits of the Asha Series of the western wing of the Bashkirian Anticlinorium. We found a new taxon of soft-bodied macroremains in a locality (53°35.505′ N, 56°44.458′ E; Pulkovo coordinate system, 1942), a roadside quarry near the old road from Sterlitamak to Beloretsk, between Makarovo and Kulgunino, on the right side of Kukkarauk Creek (Fig. 1).

RESULTS AND DISCUSSION

Geological background

The Bashkirian Anticlinorium is located in the south of the Central-Uralian Zone, which is mainly built from Pre-Paleozoic complexes and thrust onto the mainly shelf Ordovician–Carboniferous beds of the Western Uralian Zone. The basal part of the Bashkirian Anticlinorium contains the Archean-early Proterozoic metamorphic Taratash Complex, an immediate continuation of the East European Platform basement (Puchkov, 2010 and references therein). The overlying sedimentary, less commonly volcanic-sedi-

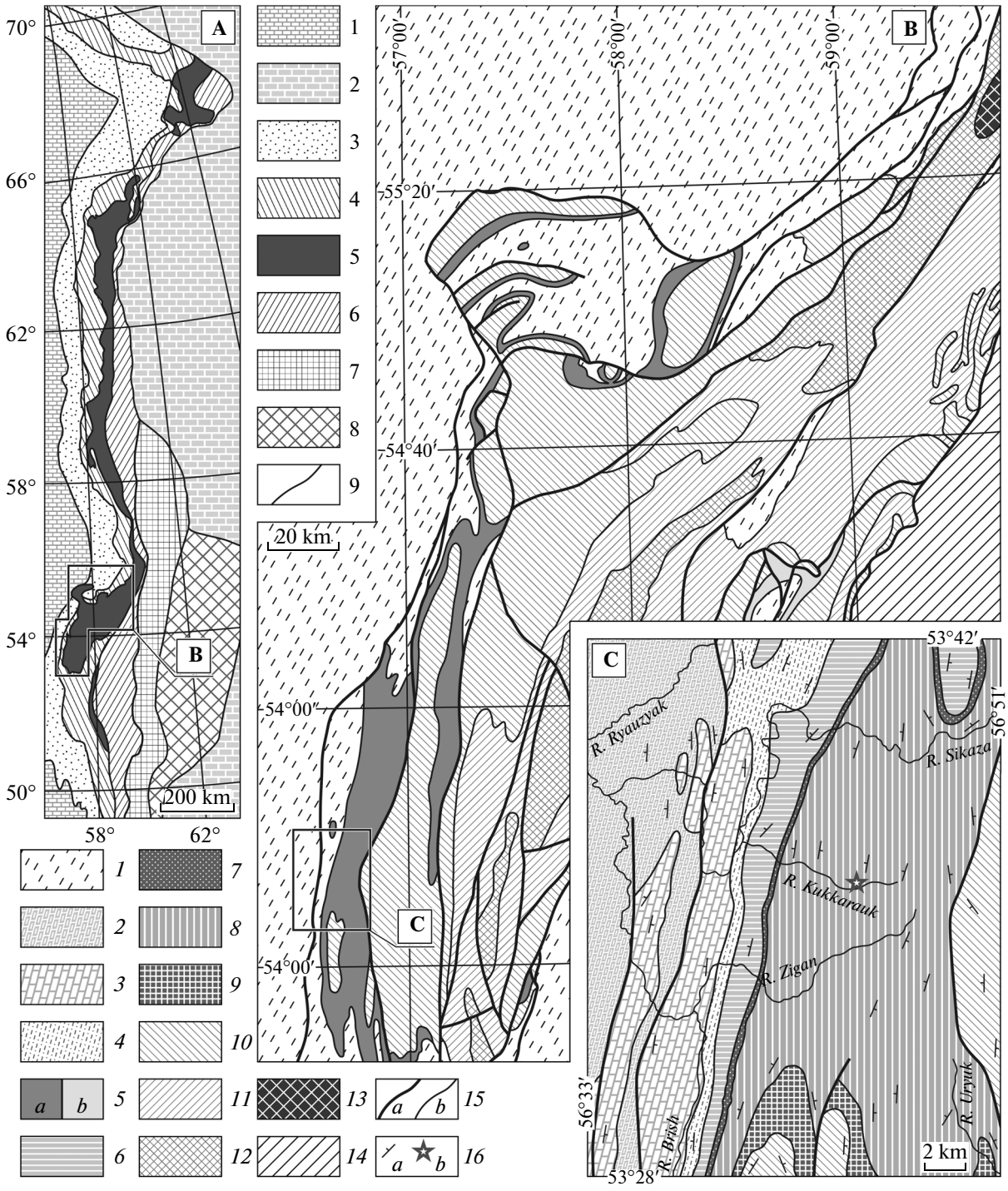


Fig. 1. (**A**) tectonic zones of the Urals (after Puchkov, 2010); (1) sediment cover of the Russian and Timan-Pechora Plates; (2) sediment cover of the Western Siberian Plate; (3) Uralian Foredeep; (4) Western Uralian Zone; (5) Central Uralian Zone; (6) Tagil-Magnitogorsk Zone; (7) Eastern Uralian Zone; (8) Transuralian Zone; (9) boundaries of tectonic zones; (**B**) correlation of the litho-stratigraphic complexes of the Bashkirian Anticlinorium and adjacent areas; (**C**) geology of the Sikaza-Zigan watershed (using data of Kozlova et al. (2002)); (*1–13*) complexes of the Russian Plate, Uralian Foredeep, Western Uralian and Central Uralian zones: (1–4): (*1–4*) Paleozoic–Mesozoic deposits: (*1*) undivided, (*2*) Lower Permian siliciclastics-carbonates, (*3*) Carboniferous carbonates and siliciclastic-carbonates, (*4*) Devonian siliciclastic-carbonates; (*5–9*) Asha and Arsha Group: (*5*) undivided: (*a*) Asha Group; (*b*) Arsha Group; (*6–9*) Asha Group: (6) Zigan Formation, (*7*) Kukkarauk Formation, (*8*) Basa Formation, (*9*) Uryuk Formation; (*10–12*) Riphean stratotypic deposits: (*10*) Upper Riphean (Karatavian), (*11*) Middle Riphean (Yurmatinian), (*12*) Lower Riphean (Burzyanian); (*13*) Archeyan–early Proterozoic Taratash Complex; (*14*) complexes of Magnitogorsk Zone; (*15*) boundaries: (*a*) tectonic; (*b*) geological; (16): (*a*) dipping of the beds, (*b*) location of the Kukkarauk fossil site.

mentary, rocks are in turn subdivided into two unequal parts; the lower, larger part represents the stratotype section of the Riphean (*Stratotip rifieya*, 1983; Semikhatov et al., 1991). The upper part, in the east of the Bashkirian Anticlinorium, previously recognized as the Vendian Arsha Formation (Kozlov, 1982; Stratigraficheskie..., 1993), is now considered as a group terminating the Riphean (Puchkov, 2010). On the west wing of the Bashkirian Anticlinorium, the upper part of the section is recognized as the Asha Formation (Vendian) (Kozlov, 1982; Becker, 1985b; *Stratigraficheskie* ..., 1993).

The Asha Group unconformably overlies the Riphean rocks, and its total thickness is over 2 km (Becker, 1988). In general, deposits of the group are usually interpteted as a molassa (Becker, 1968, 1988), connected with the Timanide orogeny (Puchkov, 2010). The deposits of the Asha Formation with stratigraphic (parallel) unconformity are overlain by the deposits of the Lower Devonian Takata Formation (Emsian), and less commonly by the Middle and Upper Ordovician mainly siliciclastic deposits (Becker, 1988; Puchkov, 2010).

Lithologically, the Asha Group is subdivided into several formations: Tolparovo, Suir, Bakeevo, Uryuk, Basa, Kykkarayk, and Zigan formation, all connected to each other in the section by gradual transition (Becker, 1985b; Puchkov, 2010).

The Tolparovo Formation is formed mainly by sandstones with thin layers and lenses of conglomerates, siltstones and shale, its thickness reaches 600 m. The Suir Formation is composed of poorly sorted sandstones, siltstone with boulders, layers of mudstone, and a thin bed of dolomite terminating this diamictite succession; the total thickness of the formation is 350 m (Maslov et al., 2001; Puchkov, 2010). The Rb–Sr age of the first generation of the autigenic illite (a variety of muscovite) from the mudstone of the Tolparovo Formation is 593 ± 15 Ma (Zaitseva et al., 2012). The siliciclastic series combining the Tolparovo and Suir formations is a thicker equivalent of the Bakeevo Formation and represents deposits filling a glacial trough or fjord in the Karatavian beds (Puchkov, 2010).

The Bakeevo Formation is mainly composed of glauconitic arcose and quartz sandstone, siltstone, and mudstone, often with basal tillite-like conglomerates, conglometratic breccia, gravelite, and hematite ores. The formation is up to 140 m thick (Becker, 1988). The siltstone of the middle and upper parts of the section of the Bakeevo Formation contain occurrences of Ediacaran fossils and ichnofossils (Becker, 1992, 2013). The K-Ar age of the autigenic glauconite from the sandstone of the formationis estimated as 605–615 Ma (Becker, 1985b, 1992), whereas the Rb-Sr dating gives 618 ± 13 Ma (Gorozhanin, 1995).

The Uryuk Formation in its lower part is composed mainly of arkose sandstone with layers of gravelite, conglomerate, and ferruginous concretions. The upper part of the section is composed of siltstone and sandstone with infrequent layers of mudstone. The thickness of the formation is ca. 200 m (Becker, 1988; Maslov et al., 2001). The K-Ar age of the syngenetic glauconite from sandstone of the two sections of the Uryuk Formation is dated 582 and 569 Ma, respectively (*Stratotip rifeya*, 1983).

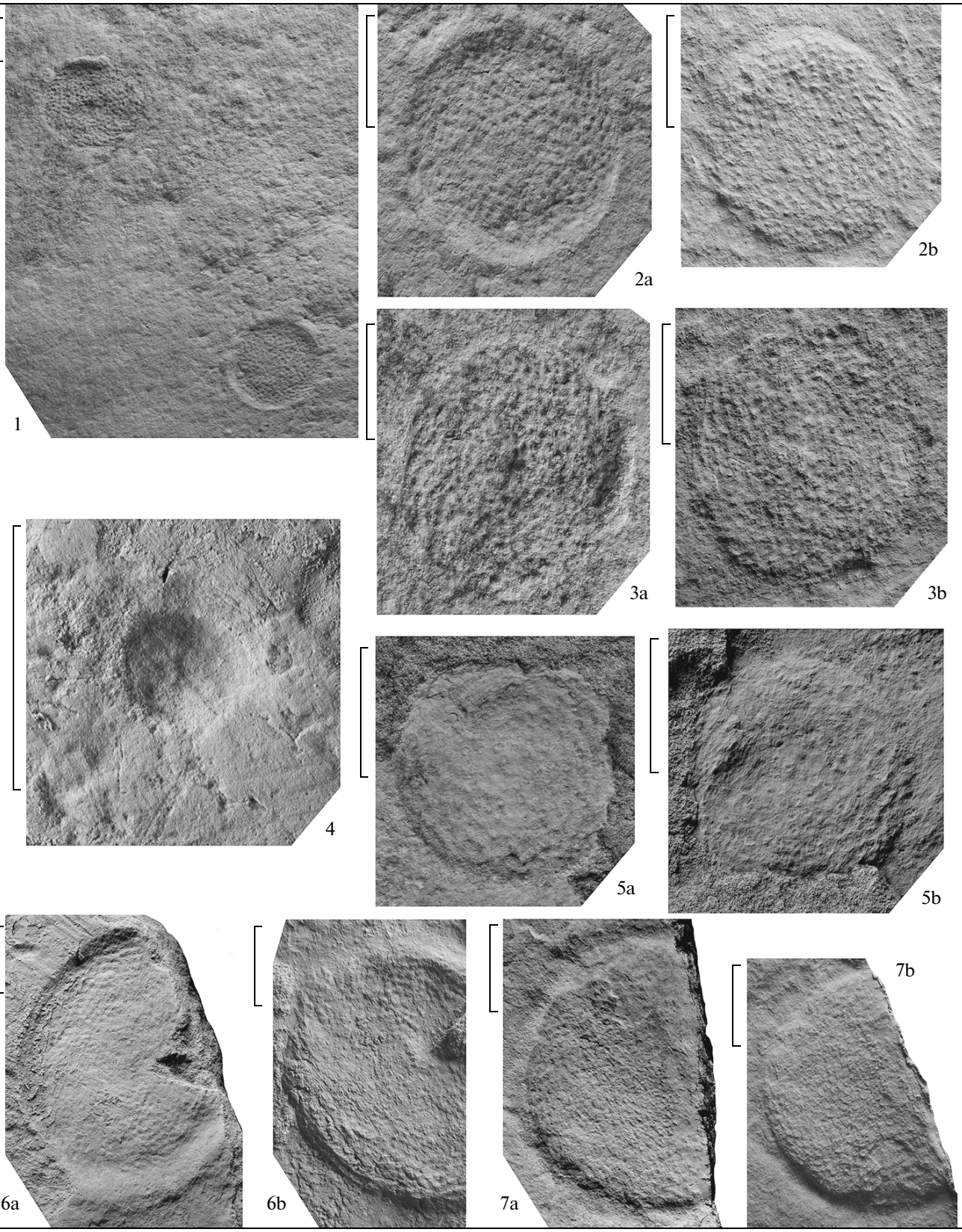
The Basa Formation is composed mainly of subgrauwacke, polymictic, and quartz sandstone and siltstone, less commonly mudstone and shale; the formation is up to 1050 m thick (Becker, 1988). Near the top of the Basa Formation, casts of Ediacara-like fossils were found for the first time in the South Urals (Becker, 1988; Becker and Kishka, 1989) and the richest collection for this region of ichnofossils was assembled (Becker, 2013). The K–Ar age of glauconite in sandstone in the two sections of the Basa Formation showed 557 and 600 Ma (*Stratotip rifeya*, 1983), and the minimal age of the detrital zircons from the sandstones in the Basa Formation was 755 ± 25.2 Ma (Kuznetsov et al., 2012).

The Kukkarauk Formation is observed in the area exposing the Asha Group as a narrow marker horizon formed by pebbled conglomerate and gravelite, with subgrauwacke and polymictic sandstone in the lower and upper parts of the section. The thickness of the formation varies from 50 to 350 m (Becker, 1988). The coarse-grained sandstone of the Kukkarauk Formation contains phosphatic debris interpreted by the authors who were the first to describe it as fragments of Middle Cambrian brachiopods (Kuznetsov and Shazillo, 2011). The Ar-Ar age of the microcline from the pebbles in the Kukkarauk Formation conglomerates is 530–550 Ma (Glasmacher et al., 1999), whereas the minimal age of the detrital zircons from the sandstones of the Kukkarauk Formation is 616.7 ± 9.7 Ma (Kuznetsov et al., 2012).

The Zigan Formation is composed of polymictic, arcose, and quartz sandstone, siltstone, and mudstones, contains carbonate and ferruginous nodules, and the formation is up to 480 m thick (Becker, 1988). The middle and upper part of the succession of the Zigan Formations contained ichnofossils and problematic remains *Arumberia* (Becker, 1996, 2013; Kolesnikov et al., 2012). Orthoclase from the arkose sandstone of the Zigan Formation yielded spectra with ages of ca. 590–630 Ma (Glasmacher et al., 1999), whereas zircons from the ash horizons in the basal part of the Zigan Formation showed a U–Pb age of 547.6 ± 3.8 (Grazhdankin et al., 2011; Levashova et al., 2013).

Largely because of the absence of convincing and potentially repeatable modern samples of Ediacara-like macrofossil, the question of the age range of the Asha Series remains debatable. Some authors correlate the Tolparovo, Suir, and their equivalent Bakeevo forma-

Plate 1



tions, and also overlying Uryuk Formations with the Arsha Group, terminating the Riphean section on the south wing of the Bashkirian Anticlinorium (Puchkov, 2010). At the same time, an Early Paleozoic age is given for at least the two upper formations of the Asha Group (Kukkarauk and Zigan) (Glasmacher et al., 1999; Kuznetsov and Shazillo, 2011). The uniqueness and good preservation of the fossils discovered by the present authors, and the discovery of the new, previously unknown Kukkarauk locality extends knowledge on the Asha Formation of the Bashkirian Anticlinorium and brings us closer to a solution of the problem of correlation of its formations with the subdivisions of the General Stratigraphic scale of Russia.

KUKKARAUK LOCALITY

As mentioned above, this locality is a roadside quarry exposing deposits of the Basa Formation of the Asha Group. The visible thickness of the exposed siliciclastic series is about 6 m, the beds gently dip northwest at about 5°. The lower part of the section is formed by greenish-gray and gray polymictic platy sandstone beds alternating with gray, greenish-gray laminated siltstone and mudstone. The upper part of the section is composed of almost uniform gray thinly laminated mudstone, with rare layers of siltstone. In the middle part of the section 1.5–2 m below the base of the uninterrupted series of thinly plated mudstone, layers of cross-bedded sandstone 1.5–7 cm thick occur within the series of undulating bedded siltstone and mudstone. In this section, bedding joints do not coincide with changes in lithology except in cases where the basal bedding planes in sandstone coincide with thin (1–3 mm) fissures filled with ochreous clay facilitating mechanical separation of sandstones from the underlying siltstone and mudstone along the bedding planes. In these cases, the sandstone is strongly ferruginous, and brown in color. The clay is apparently epigenetic in origin, as its layers cut across the bedding plane and clay also fills in the fissures going across the bedding. Previously rounded and discoid casts were described by Becker (1985a) from the Sylvitsa Formation of the Middle Urals and from the Asha Group of the South Urals (Becker and Kishka, 1989; Becker, 1992, 1996). Most these forms fall in the range of variation established for *Aspidella terranovica* Billings (Gehling et al., 2000). These are mostly positive discs with prominent concentric and linear radial structures. They include no casts with the regular pitted ornamentation characteristic of the new fossil. In one of his papers Becker published a photograph of two oval flat-bottomed negative casts from the Bakeevo Formation of the basin of the Zilim River (Becker, 1992, p. 19, text-fig. 8), which could equally be casts of *Kuckaraukia* (assuming that the ornamentation is poorly preserved) and flat argillaceous pebbles. In the caption of the photograph these fossils were identified as *Beltanelloides* (?) sp., but no description was given in the text of the paper. The specimen was not deposited in a museum collection and was not found among Becker's material. As the examination of these two casts was not possible, no comparison with our material is given in the description below.

Imprints of *Kuckaraukia* are found on the basal surface of brown fine-grained micaceous sandstone, in places cross-bedded, with an undulating top 1.5–2.5 cm thick. The sandstone is underlain and overlain by compact greenish-gray mudstone. The bedding plane with casts is brown, finely hummocky, in places smooth and shiny. One cast apparently had a low circular ring-like flange with a diameter twice as large as that of the cast. Unfortunately, a large portion of the bedding plane is missing in place of this flange. Judging from a small preserved fragment, this flange is composed of the sandstone of the bed with the cast. The surface of the cast preserved is covered by fine folds parallel to the ends of the ring; but these short fragments do not make it clear whether the folds were arranged in a ring-like pattern or ran in one direction. Several other casts possess similar looking wide ring-like structures observed as slightly raised relief or a zone of darker rock matrix. The nature of the ring is not clear. Most likely, it is not part of the organism, but represents a diagenetic structure, which appeared when the sediment was affected by the decomposing organic matter of the organism represented by the fossil.

The fossil is interpreted in accordance with the "post-mortem mask" hypothesis (Gehling, 1999), as impressions of the upper side of the biogenic structure buried under the layer of sand. The presence of consistent and distinct morphological features allows these casts to be regarded as representing a distinct Precambrian organism. As this fossil does not resemble any other synchronous fossil previously described from the South Urals, or anywhere in the world, we describe it

Explanation of Plate 1

Figs. 1–7. *Kuckaraukia multituberculata* sp. nov.: (1) two closely spaced casts, above – specimen PIN, no. 5525/005, below – holotype PIN, no. 5525/004; (2) holotype PIN, no. 5525/004: (2a) natural cast, (2b) latex cast; (3) specimen PIN, no. 5525/005: (3a) natural cast, (3b) latex cast; (4) specimen PIN, no. 5525/008, natural cast; (5) specimen PIN, no. 5525/001: (5a) natural cast, (5b) counter-cast on mudstone surface; (6) specimen PIN, no. 5525/002: (6a) natural cast, (6b) fragment of a latex cast; (7) specimen PIN, no. 5525/003: (7a) natural cast, (7b) latex cast; South Urals, Bashkirian Anticlinorium, right bank of Kukkarauk Creek; Late Vendian, Asha Group, Basa Formation. Scale bar, 1 cm.

as a new species and genus. However, its position in the system of Precambrian fossils cannot be yet determined.

MATERIAL

The material studied is housed in the Paleontological Institute, Russian Academy of Sciences (PIN), coll. no 5525.

SYSTEMATIC PALEONTOLOGY

Genus *Kuckaraukia* Ivantsov, Novikov et Razumovskiy, gen. nov.

Etymology. After Kukkarauk Creek.

Type species. *Kuckaraukia multituberculata* sp. nov.

Diagnosis. Circular, negative, flat-bottomed cast covered by numerous closely spaced uniform pits and surrounded by narrow slightly raised flange.

Species composition. Type species from the Late Vendian of the South Urals.

Comparison. This genus slightly resembles shortened casts of *Kimberella quadrata* (Glaessner et Wade, 1966) assuming that only the hummocky dorsal cover is preserved, and also *Armillifera parva* Fedonkin, 1980 and *Solza margarita* Ivantsov, 2004 (Ivantsov, 2012, text-figs. 16–18). However all the above fossils are elongated in outline, and their lateral margin is flattened, covered by thin closely-spaced subradial grooves, whereas pits are considerably smaller and are more closely spaced.

Kuckaraukia multituberculata Ivantsov, Novikov et Razumovskiy, sp. nov.

Plate 1, figs. 1–7

Etymology. From the Latin *multum* (many) and *tuberculum* (tubercle).

Holotype. PIN, no. 5525/004; South Urals, Bashkirian Anticlinorium, right bank of Kukkarauk Creek; Late Vendian, Asha Group, Basa Formation.

Description. The fossils are represented by small casts formed on a bedding plane separating a bed of sandstone and a bed of mudstone. Most of these casts are preserved on the sandstone basal surface in negative hyporelief, and one is accompanied by a counterpart preserved on the surface bedding plane of a mudstone bed in positive epirelief. The casts are singular, circular or elliptical in outline, shallow, flat-bottomed, surrounded by a low, narrow flange. The surface of the cast is covered by numerous regularly (hexagonally) arranged uniform isolated pits rounded or oval in outline. Oval pits occur near the cast margins and their long axes are oriented across the radius of the cast. The centers of some pits have distinctly raised areas sometimes shifted to one side from the center of the pit. The pit diameter varies from 0.5 to 1.2, on average 0.7–0.9 mm with no apparent correlation with the size of the cast. The number of pits varies from a few in the smaller specimens to hundreds in the largest specimens.

Dimensions. Diameter of the cast or the long axis of an ellipse in the case of an oval cast.

Specimen no.	5525/001	5525/002	5525/003	5525/004	5525/005	5525/006	5525/008
Size (mm)	17.5	>37	>30	21	21.5	≈16	4.5

Remarks. The fossil represents a cast of the upper side of a discoid biogenic structure. The microrelief of the surface of the cast can reflect either the ornamentation of the surface of the organism itself, composed of evenly spaced hemispherical tubercles, or suggest compact spherical elements of its inner structure. Due to the compaction of the sediment and compression of the fossil, the tubercles on the sides of the disc became oval in shape, whereas their apices were pressed through. The character of the folded edges can be explained by their having appeared as a result of a sliding force during their catastrophic burial. The development of a raised flange surrounding a depressed circular area can be explained along the same lines. It could have been formed by pressing through to the sediment of some other (presumably external) part of the organism, which was not preserved.

Thus, *Kuckaraukia multituberculata* can be reconstructed as a bifoliate disk composed of a relatively resistant, structured bottom layer and a less resistant, possibly structureless upper layer. In the absence of any traces of movement, it can be interpreted as a unitary organism, or as a colony of motionless bottom dwellers.

Material. Holotype, four incomplete and three complete casts from the type locality, one of which is accompanied by a counterpart; specimens PIN, nos. 5525/001-3 and 5525/005-8.

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