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New Proarticulata from the Vendian of the Arkhangel'sk Region

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Abstract—The new taxa *Vendia rachiata* sp. nov. and *Cyanorus singularis* gen. et sp. nov. are described from the Upper Vendian of the Onega Peninsula, Arkhangel'sk region. These taxa belong to the invertebrate phylum Proarticulata, which became extinct in the Precambrian. The species *Vendia janae* Ivantsov, 2001 is assigned to the new genus *Paravendia* based on new data and the results of restudying the holotype of the type species of the genus *Vendia* Keller. The axial structure of Proarticulata is interpreted as a digestive–distributive system.

Key words: Proarticulata, Vendian, Arkhangel'sk region, Russia.

INTRODUCTION

This paper continues the description of new Upper Vendian species of the extinct phylum Proarticulata that have been collected in the southeastern White Sea area by the regular expeditions of the Laboratory of Precambrian Animals of the Paleontological Institute of the Russian Academy of Sciences (PIN).

Most of the material under study came from two localities that were recently discovered on the Onega Peninsula near the town of Severodvinsk. They are situated (1) on the Solza River, about 6.5 km from the dam of the water intake structure, and (2) on the Karakhta River, about 2 km upstream from the Severodvinsk–Onega road (Fig. 1). The fossiliferous deposits are referred to the Ust'-Pinega Formation of the Upper Vendian (Grazhdankin and Bronnikov, 1997). In addition to the described species and rare "cyclic" forms, the same bedding planes contain some other species: *Armilifera parva* Fedonkin, 1980; *Dickinsonia costata* Sprigg, 1947; *D. tenuis* Glaessner et Wade, 1966; *Kimberella quadrata* Glaessner et Wade, 1966; and *Tribrachidium heraldicum* Glaessner, 1959 from the Solza River and *Anfesta stankovskii* Fedonkin, 1984; *Archaeaspis fedonkini* Ivantsov, 2001; *D. costata*; *D. tenuis*; and *K. quadrata* from the Karakhta River. *Cyanorus singularis* gen. et sp. nov. has already been reported from the local assemblage of the Kimberella lenses locality, which is located in the Zimnii Bereg (Winter Coast) of the White Sea (Ivantsov, 1999; 2001). All the described fossils are negative prints on the slightly pyritized base of fine-grained sandstone beds. The low, slightly visible prints of *Vendia rachiata* sp. nov. can be seen owing to the admixture of brown (probably organic) substance.

MATERIAL

The material examined in this study is currently housed at the Paleontological Institute of the Russian Academy of Sciences (collection nos. 3993, 4852, 4853, and 4894).

RECONSTRUCTION

The body of *V. rachiata* is completely segmented, being composed of two rows of similar (although

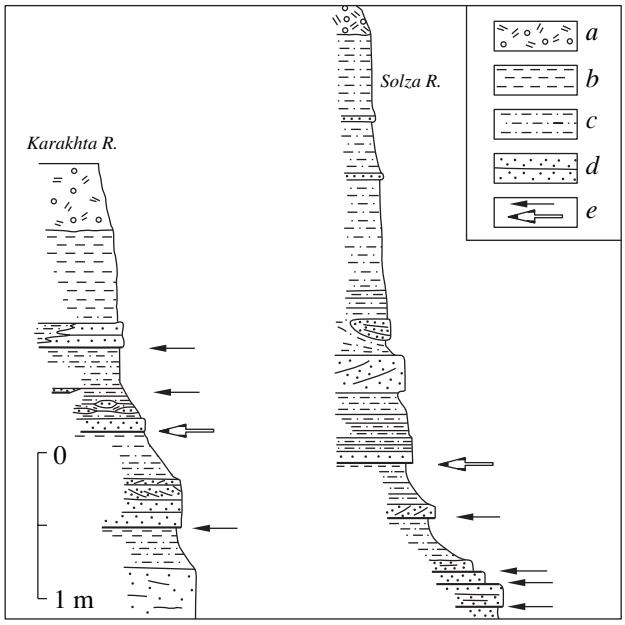


Fig. 1. Schematic section of the outcrops containing most of the material under study. Designations: (*a*) Quaternary loam, (*b*) clay, (*c*) siltstone, (*d*) sandstone, and (*e*) beds with prints (double arrow shows beds with fossils described in this paper).

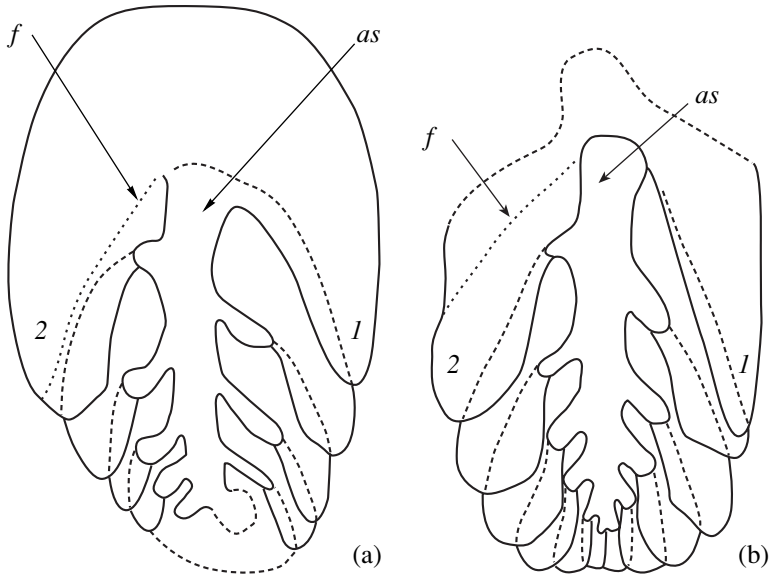


Fig. 2. *Vendia rachiata* sp. nov., sketch based on latex casts: (a) holotype PIN, no. 4853/63; (b) specimen PIN, no. 4853/68. Designations: (*as*) axial structure; (*f*) transverse fold, possible edge of the head region; and (*1*) and (*2*) isomers of the first pair.

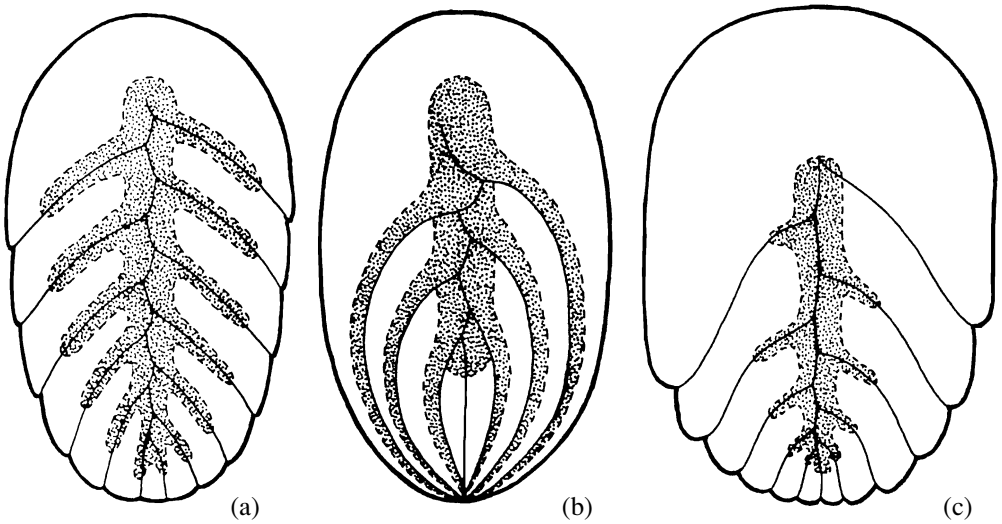


Fig. 3. Schematic reconstruction of the *Vendia*-like Proarticulata, dorsal view (digestive system is dotted): (a) *Vendia sokolovi* Keller, 1969; (b) *Paravendia janae* (Ivantsov, 2001); (c) *Vendia rachiata* sp. nov.

unequal) isomers that alternate along the body axis (Fig. 2). The first element in the row is a right isomer (from the dorsal side). The posterior edge of this isomer has a fold that is analogous to overlapping folds that limit the following isomers but is less pronounced. The left side of the body bears a gently sloping projection that is symmetrical about this fold and a ridge that may be shaped like a thin, small rib (Pl. 1, Fig. 12). Either this is a casual deformation, or the anterior part of the first left isomer was apparently separated from the posterior part. The partial overlapping of the larger isomers onto the smaller isomers that is observed in the prints of *V. rachiata* may be due to compression during fossilization. If this is the case, each isomer was very convex dorsally. *V. rachiata* has a very well-defined axis with short lateral appendages located on the borders between the isomers. This structure is present, in one form or another, in the majority of Proarticulata. A similar structure occurs in members of the family Vendomiidae that are close to *V. rachiata* morphologically

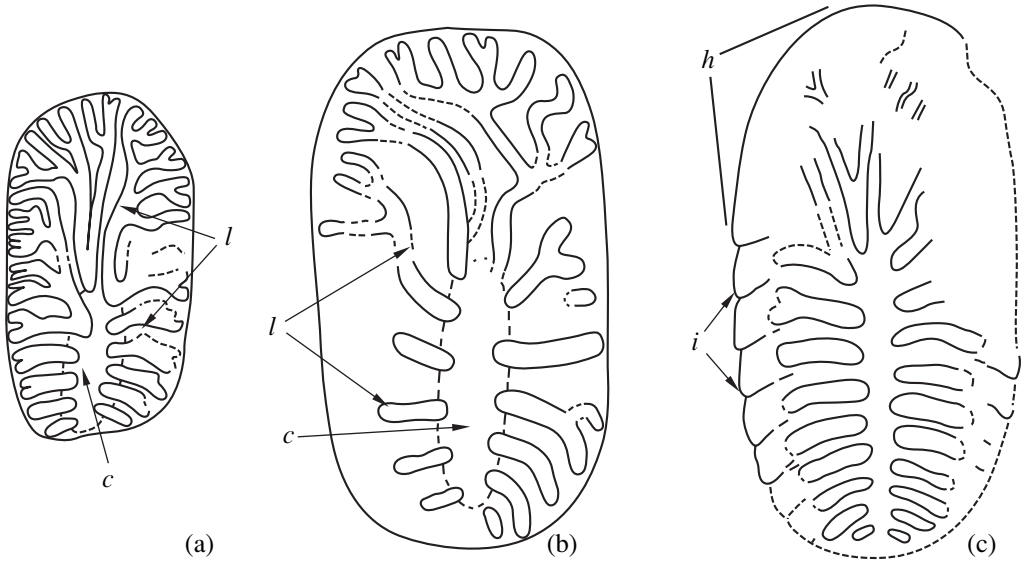


Fig. 4. *Cyanorus singularis* sp. nov., sketch based on latex casts: (a) specimen PIN, no. 4852/139; (b) specimen PIN, no. 3993/5168; and (c) holotype PIN, no. 4853/83. Designations: (*c*) central axis of the axial structure, (*l*) its lateral branches, (*h*) head region, and (*i*) isomers of the trunk region.

but differ from the latter in having longer lateral appendages (Fig. 3).

Cyanorus singularis gen. et sp. nov. was small-sized and had very soft covering tissues. Since these latter are poorly preserved, the borders of the isomers are only slightly visible in the edges of some specimens (Fig. 4). The anterior part of the body probably was not segmented and formed the head region (Fig. 5a). The axial structure is far better (though not completely) preserved in each specimen. The two pairs of its largest appendages, which branch repeatedly, are situated in the anterior part of the body (head) of the fossil and are directed anteriorly from the axis (Figs. 4, 5b). The other appendages branch only occasionally and are directed laterally and posteriorly. There is a one-to-one correspondence between these appendages and the isomers.

Among Proarticulata, the axial structure is better developed in some species of the genus *Dickinsonia* Sprigg. The best specimens of *Dickinsonia* sp. from the Zimnegorsk Locality (Arkhangel'sk region) show that the longitudinal part of the axis consists of two divisions: wide anterior and narrow posterior (Fig. 6; Pl. 1, Fig. 7). The lateral appendages are arranged alternately along the posterior division, with those located anteriorly being branched. The axial structure of the vendomiids is similar in pattern, but its anterior division has appendages, and each lateral appendage corresponds to one isomer, whereas, in greatly segmented *Dickinsonia* species, each lateral appendage corresponds to several tens of isomers. In addition, lateral appendages are directed posteriorly along the border between adjoining isomers in the vendomiids but anteriorly and perpendicularly to the isomers in *Dickinsonia* species. The axial structure of *C. singularis* combines features of *Vendia* species (the anterior division has appendages, and the lateral appendages in the posterior division are directed laterally and posteriorly, each corresponding to only one isomer) and of *Dickinsonia* species (anterior appendages branching and directed anteriorly). The segmentation of the body in comparatively simply organized Proarticulata—vendomiids—is analogous to the axial structure in *Dickinsonia* species. The elements of segmentation (isomers in the former case and lateral appendages in the latter) are arranged alternately in two rows, and their sizes decrease posteriorly; the first element on the right side is the first in the sequence, but the first element on the left is largest in area. This analogy, as applied to *Dickinsonia*

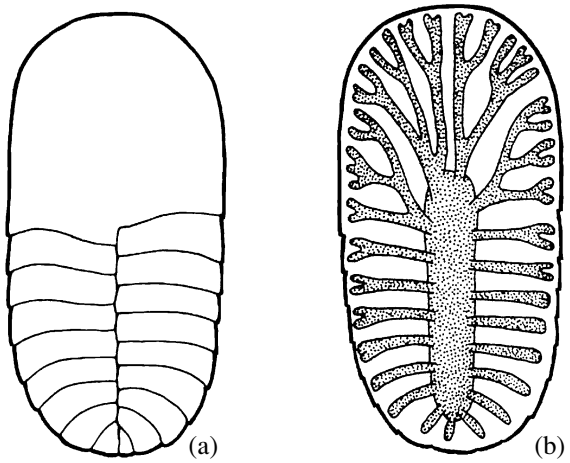


Fig. 5. Schematic reconstructions, dorsal view. *Cyanorus singularis* sp. nov.: (a) external surface, (b) digestive and distributive system.

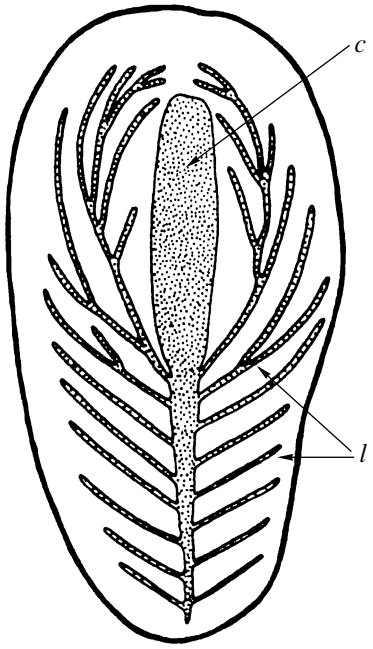


Fig. 6. Axial structure (digestive–distributive system) of *Dickinsonia* reconstructed on the basis of specimen PIN, no. 3993/5173, dorsal view. Designations: (*c*) central axis (gastric intestinal tract) and (*l*) lateral (distributive) appendages.

species, suggests that the uniform subradial segmentation of the external cover of their body is secondary.

Notwithstanding the fact that the axial structure has been preserved as depressions on the print, i.e., as the most compact structure, it has been suggested that this structure was formed by the system of cavities (Jenkins, 1992; Ivantsov, 2001; Dzik and Ivantsov, 2002). The cavities could not be permanently filled completely and uniformly; most likely, they had relatively thick walls. The variations in the degree of preservation of different elements of the axial structure may be explained by variations in the diameter–thickness ratio of cavity walls. Only the thickest and thinnest ends of the lateral appendages have been preserved in the form of elevations, whereas the central parts have been compressed and are obscured by surface folds (Pl. 1, Figs. 2, 3). The thicker central part of the axial structure is usually depressed in the middle and, for the most part, resembles a compressed tube (Pl. 1, Figs. 4–6, 7, 8). The axial structure of Proarticulata has been interpreted as a form of preservation of the digestive system (Wade, 1972; Jenkins, 1992; Fedonkin, 1985; Ivantsov, 2001; Dzik and Ivantsov, 2002). Judging from their length and degree of branching, the lateral appendages may have extended to all parts of the body to serve a distributive function. Thus, the axial structure may have served both digestive and distributive functions.

MATERIAL

The material being studied is housed at the Paleontological Institute of the Russian Academy of Sciences (PIN) (nos. 3993, 4852, 4853, and 4894).

SYSTEMATIC PALEONTOLOGY

Phylum Proarticulata Fedonkin, 1985

CLASS VENDIAMORPHA, 1985

Family Vendomiidae Keller, 1976

Genus *Vendia* Keller, 1969

***Vendia rachiata* Ivantsov, sp. nov.**

Plate 1, figs. 10–13

Etymology. From Latin *rachis* (stem).

Holotype. PIN, no. 4853/63; Arkhangel'sk region, Onega Peninsula, Solza River; Upper Vendian, Ust'-Pinega Formation.

Description (Figs. 2, 3c). The organisms are small and have an elongated oval body that is completely segmented into isomers, which are arranged alternately in two rows. The isomers have rounded posterior edges, with each row containing five or fewer isomers. The larger isomers cover the smaller ones externally and partially overlap them; however, the posterior ends of all the isomers remain free. The size of the isomers quickly decreases posteriorly. The digestive–distributive system consists of a simple axial tube and short non-branching lateral appendages located along

Explanation of Plate 1

Figs. 1–6. *Cyanorus singularis* sp. nov.: (1) holotype PIN, no. 4853/83, ×8; (2) specimen PIN, no. 3993/5168, ×8; (3) specimen PIN, no. 4853/84, ×8; (4) specimen PIN, no. 4852/6, ×10; (5) specimen PIN, no. 3993/5075, ×8; (6) specimen PIN, no. 3993/5055, ×10; (1a), (2), and (3) latex casts of the originals, (1b) and (4)–(6) prints on rocks; Arkhangel'sk region, Upper Vendian: (1) and (3) Solza River, Ust'-Pinega Formation; (4) Karakhta River, Ust'-Pinega Formation; (2), (5), and (6) Zimnii Bereg of the White Sea, Mezen' Formation.

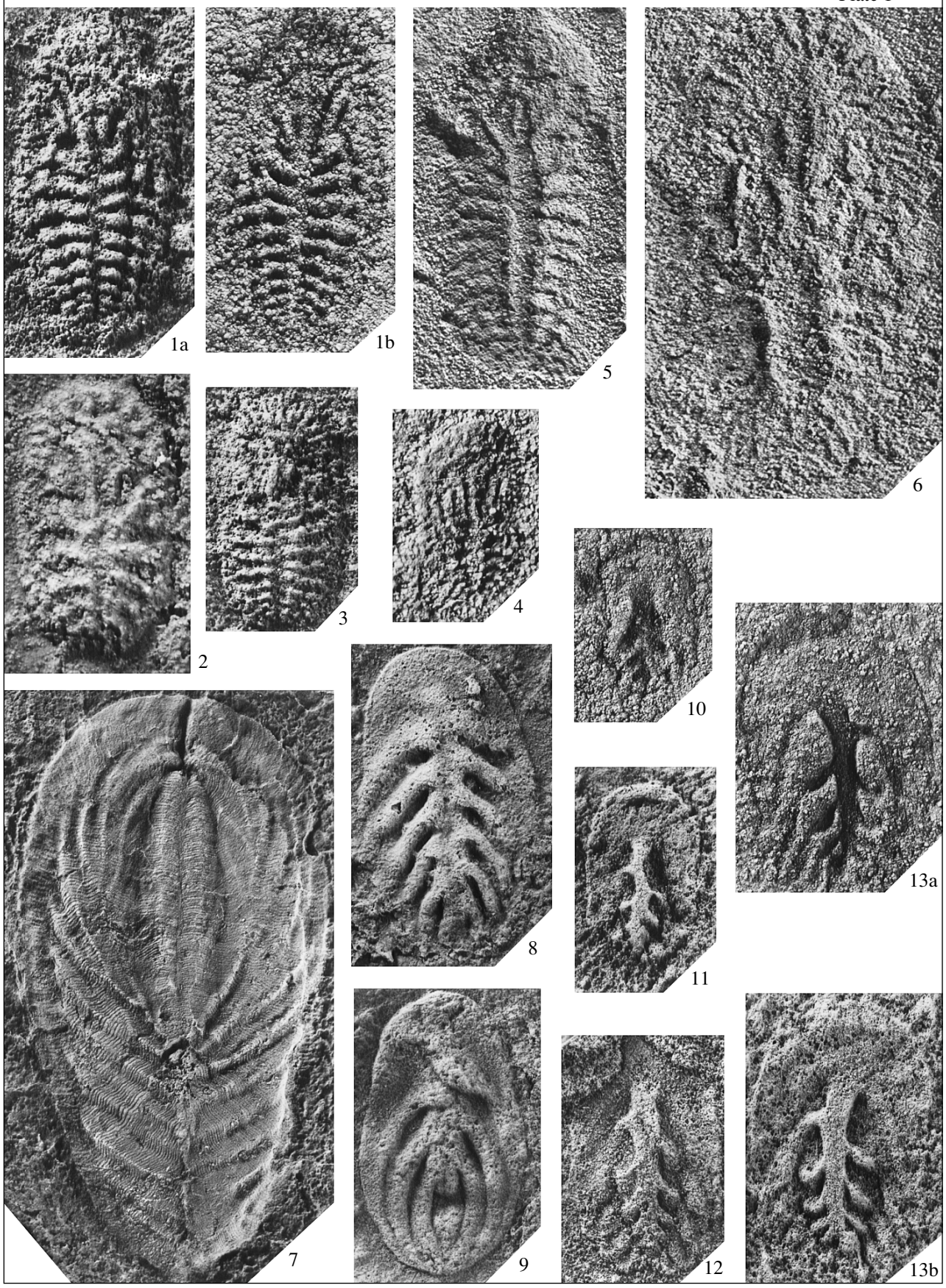
Fig. 7. *Dickinsonia* sp., specimen PIN, no. 3993/5173, specimen with a completely preserved print of the digestive system, latex cast, ×2; Arkhangel'sk region, Zimnii Bereg of the White Sea; Upper Vendian, Mezen' Formation.

Fig. 8. *Vendia sokolovi* Keller, 1969, holotype PIN, no. 4894/1, latex cast, ×4; Arkhangel'sk region, Yarensk Borehole, depth 1552 m; Upper Vendian, Ust'-Pinega Formation.

Fig. 9. *Paravendia janae* (Ivantsov, 2001), holotype PIN, no. 3993/5070, latex cast, ×4; Arkhangel'sk region, Zimnii Bereg of the White Sea; Upper Vendian, Mezen' Formation.

Figs. 10–13. *Vendia rachiata* sp. nov., ×4: (10) specimen PIN, no. 4853/77; (11) specimen PIN, no. 4853/71; (12) specimen PIN, no. 4853/68; (13) holotype PN, no. 4853/63; (10), (11), and (13b) latex casts of the originals; (12) and (13a) prints on rock; Arkhangel'sk region, Solza River; Upper Vendian, Ust'-Pinega Formation.

Plate 1



the borders between isomers. Except for the first isomer, all the isomers have one lateral appendage.

Measurements. The first left isomer of the holotype (in the dorsal view) near the body axis is 6 mm long; the lengths of the second, third, fourth, and fifth isomers are 2.2, 1.7, 0.8, and 0.6 mm, respectively.

Specimen no.	Length	Width
PIN 4853/78	4.5	3.8
PIN 4853/67	7.4	4.3
PIN 4853/71	8	5.2
PIN 4853/79	8.2	5.6
PIN 4853/65	9	5.3
PIN 4853/63, holotype	12.5	8.5

Comparison. The species differs from *V. sokolovi* in the smaller number of isomers (the 11-mm-long holotype of *V. sokolovi* and 12.5-mm-long holotype of *V. rachiata* have seven and five isomers in one row, respectively), in the length of isomers sharply decreasing posteriorly, and in the short lateral appendages of the digestive–distributive system.

Material. Holotype and paratypes, specimen PIN, nos. 4853/65, 4853/67–4853/72, 4853/74, 4853/76–4853/80, 4853/103, and 4853/104 from the type locality.

Genus *Paravendia* Ivantsov, gen. nov.

Vendia: Ivantsov, 2001, p. 8 (part.).

Etymology. From Greek παρα (near) and generic name *Vendia*.

Type species. *Vendia janae* Ivantsov, 2001.

Diagnosis. Bodies of organisms elongated, oval-shaped, and consisting of two rows of scale-shaped (in plan) isomers with pointed posterior ends, inclined posteriorly and converging to common point. Larger isomers cover smaller ones externally. Largest isomers of first pair form lateral edge of body.

Species composition. Type species.

Comparison. This genus differs from the genus *Vendia* Keller, 1969 in the shape and relative position of the isomers, in which larger isomers completely cover smaller ones.

Family incertae sedis

Genus *Cyanorus* Ivantsov, gen. nov.

Etymology. From Greek κυανεος ορος (blue mountain) after the locality of Sinyaya Gora.

Type species. *Cyanorus singularis* sp. nov.

Diagnosis. See Description section for this species.

Species composition. Type species.

Comparison. The genus is similar to the genera *Yorgia* Ivantsov, 1999; *Archaeaspis* Ivantsov, 2001; and *Andiva* Fedonkin, 2000 in the presence of the head region and differs from them in the distinctive structure of the digestive–distributive system.

Cyanorus singularis Ivantsov, sp. nov.

Plate 1, figs. 1–6

Etymology. From Latin *singularis* (singular, peculiar).

Holotype. PIN, no. 4853/81; Arkhangel'sk region, Onega Peninsula, Solza River; Upper Vendian, Ust'-Pinega Formation.

Description (Fig. 5). The organisms have small, elongated, oval-shaped bodies consisting of head and trunk regions. The length of the head region is about one-third of the total body length. The trunk region is segmented into short isomers arranged alternately in two rows. The lateral ends of the isomers are blunt and slightly curved posteriorly. The digestive–distributive system consists of a short, simple axial tube and lateral appendages, some of which are branched. The lateral appendages in the head region are long, branch repeatedly, and are directed anteriorly from the axial tube. The lateral appendages of the trunk are simple or bifurcate at their ends and are aligned along the borders between isomers laterally and posteriorly from the axis. One lateral appendage corresponds to one isomer.

Measurements, mm:

Specimen no.	Length	Width
PIN 4852/6	3.3	1.9
PIN 4852/5	3.8	2
PIN 3993/5168	4.2	2.6
PIN 4853/86	4.6	2.5
PIN 4852/139	4.7	2.6
PIN 4853/28	5	2.6
PIN 4853/84	5	2.8
PIN 3993/5127	5.8	3.4
PIN 4852/7	7.9	3.4
PIN 3993/5075	7.9	4
PIN 4853/81, holotype	8.8	4.2
PIN 3993/5055	11	6

Occurrence. Upper Vendian, Arkhangel'sk region.

Material. Holotype and paratypes, PIN, nos. 4853/28, 4853/84, and 4853/86 from the type locality; specimen PIN, nos. 4852/5-7, 4852/139, and 4852/140; Onega Peninsula, Karakhta River, Ust'-Pinega Formation; specimen PIN, nos. 3993/5055, 3993/5075, 3993/5127, and 3993/5168; Zimnii Bereg of the White Sea, Mezen' Formation, Erga Beds, locality of Kimberella lenses.

DISCUSSION: TAXONOMIC POSITION

Some difficulties in placing *V. rachiata* into the genus *Vendia* are due to incomplete preservation of the

holotype of *V. sokolovi*. The posterolateral edge is nearly absent, and the lateral appendages are visible only in the first two isomers on the right side (in the cast) (Pl. 1, Fig. 8). This is enough, however, to determine that the isomers of *V. sokolovi* were short and that the lateral edge of this organism was formed by the ends of all the isomers rather than by the first pair of isomers, as in *V. janae* (Pl. 1, fig. 9; Fig. 3b). The lateral edge of *V. rachiata* was similar in construction. Since this feature is very important taxonomically, the species *V. janae* is designated here as the separate genus *Paravendia* gen. nov.

C. singularis may be compared with South Australian members of the family Sprigginidae Glaessner: *Spriggina floundersi* Glaessner, 1958 and *Marywadea ovata* (Glaessner et Wade, 1966). All these species have an elongated body, large head region, and segmented trunk region, in which its structural elements are arranged alternately. All these elements, the isomers of *Cyanorus* with elevations above the appendages of the digestive system, and the "segments" of sprigginids with cylinder-shaped crests, are similar. The sprigginids are often considered to be polychaetes or forms transitional between annelids and arthropods (Glaessner, 1976; Birket-Smith, 1981; Fedonkin, 1985; Jenkins, 1996). All the features of *Cyanorus* suggest that it belongs to Proarticulata. It is quite possible that the sprigginids belong to this extinct phylum, and the complicated structure of their transverse elements (Birket-Smith, 1981) may be explained by the mixture of features of the external surface and lateral appendages of the digestive system.

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